COCONUT RESEARCH & DEVELOPMENT

Proceedings of the International Symposium on Coconut Research and Development, held at Central Plantation Crops Research Institute, Kasaragod 670 124, Kerala, December 27-31, 1976

EDITED BY
N. M. NAYAR
On Behalf of
INDIAN SOCIETY FOR PLANTATION CROPS

WILEY EASTERN LIMITED
NEW DELHI BANGALORE BOMBAY CALCUTTA

Copyright © 1983 WILEY EASTERN LIMITED

WILEY EASTERN LIMITED
4835/24 Ansari Road, Daryaganj, New Delhi 110002
4654/21 Daryaganj, New Delhi 110002
6 Shri B.P. Wadia Road, Basavangudi, Bangalore 560004
Abid House, Dr. Bhadkamkar Marg, Bombay 400007
40/8 Ballygunge Circular Road, Calcutta 700019

This book or any part thereof may not be reproduced in any form without the written permission of the publisher

This book is not to be sold outside the country to which it is consigned by Wiley Eastern Limited

ISBN 0 85226 607 3

Published by Mohinder Singh Sejwal for Wiley Eastern Limited, 4835/24 Ansari Road, Daryaganj, New Delhi-110002 and printed at Printex India, E-306, East of Kailash, New Delhi. Printed in India.

Coconut research institutions and the coconut industry of India, are among the oldest and most progressive in the world. The International Symposium on Coconut Research and Development, held to celebrate the Diamond Jubilee of coconut research in India, is not only a fitting tribute to the hundreds of Indian coconut research workers but also a well-earned recognition for the tremendous efforts and valuable contribution of India and the Indian people, to this vital agricultural industry of Asia and the Pacific region.

In publishing for posterity the proceedings of the International Symposium, coconut technicians in the years to come will have a clear, precise and comprehensive overview of the state of coconut technology of this generation. This by itself along is a distinct contribution to furthering coconut research and development. It is contribution adding assurance to the survival of the coconut industry to the next generation.

There is no need for me to comment on the meritous and substantive content of the wide-range of coconut disciplines dealt with in this publication. The contents, as well as the technical qualifications of the various authors, all speak for themselves. This is a valuable record from which future technonuts can build on to fulfill the richness contained in the tree of life.

GODOFREDO P REYES JR
Executive Director
Asian and Pacific Coconut Community
Jakarta—Indonesia

Jakarta
15 October 1982

634.616.5 (100) 1976.

12.27/31 (082.2)

M3

Preface

Of all the cultivated tree species in the tropical world, the majestic, tall growing coconut palm is the most widespread. In the tropics perhaps no other crop has so much to offer to mankind. Because of the usefulness of each and every part of this palm and the vast multitude of people that it supports through ancillary and small scale industries, it is often called '*Kalpa Vriksha*' or the 'Tree of Heaven'. The coconut oil ranks sixth in the world vegetable oil production and fourth in the international trade of edible oils. The production of oil from unit area of this crop is next only to that of oil palm. India accounts for about 12.5 per cent of the total world area of eight million ha under this crop.

Research on coconut was first started in India in 1916 with the establishment of four centres, one each at Kasaragod and Pilicode and two at Nileshwar on the West Coast of the present Kerala State to initiate work on crop improvement and crop management. The Indian Central Coconut Committee was constituted in 1945 to co-ordinate the research and development activities at the national level. In 1947, the Committee took over the Coconut Research Centre at Kasaragod and strengthened the staff and facilities to carry out work on production aspects. The Committee set up a research centre at Kayangulam in 1948 to work on the plant protection aspects, with particular reference to root (wilt) disease. In 1966, the Indian Council of Agricultural Research was entrusted with the research responsibilities on coconut as well as other important plantation crops and in 1970, the Council established the Central Plantation Crops Research Institute (CPCRI) with its headquarters at Kasaragod.

The Diamond Jubilee of Coconut Research in India was celebrated during December, 1976 at CPCRI, Kasaragod with programmes spread over a fortnight. During the celebrations a Philatelic Exhibition with two themes: 'Coconut on Stamps' and 'Plants on Stamps' and an Agricultural Exhibition were organised. Awards were presented to the designers of prototypes of useful devices to increase efficiency in research and culture. Six eminent scientists were honoured during the celebrations for their outstanding contributions to coconut research. Diamond Jubilee Medals were awarded to twenty six persons who served the cause of coconut research

and development for over twenty five years. To educate the farmers on the recent developments in the fields of crop production and protection, the coconut farmers from different states of India were invited to Kasaragod to participate in *Kisan Mela.*

To mark the occasion, the Indian Society for Plantation Crops organised an International Symposium on Coconut Research and Development (ISOCRAD) during December, 1976 in collaboration with the Indian Council of Agricultural Research, the Department of Agriculture of Kerala, Karnataka, Tamil Nadu, Andhra Pradesh and Maharashtra States and that of the Union Territory of Goa, the Agricultural Universities of Kerala, Karnataka, Tamil Nadu and Andhra Pradesh, the Administration of Lakshadweep, the University Grants Commission and the Council of Scientific and Industrial Research. The Posts & Telegraphs Department of India released a special commemorative stamp depicting an early bearing, heavy yielding hybrid coconut palm, symbolizing the most notable research contribution in coconut from India. With the financial assistance from the Technical Advisory Committee of the Consultative Group on International Agricultural Research, a Travelling Seminar was also organised with the focal theme 'Coconut Diseases of Uncertain Etiology', with special emphasis on root (wilt) disease of coconut in Kerala.

This publication 'Coconut Research and Development' contains the papers presented in the nine sessions of the symposium. Among the 80 papers presented and discussed, 64 were original research contributions and the rest on developmental activities. Over 320 delegates from India, the Philippines, Ivory Coast, Sri Lanka, Malaysia and USA in addition to the representatives from Wye College, University of London, Tropical Products Institute, London, and Food and Agricultural Organisation (Rome), participated in the four day long deliberations.

The keen interest evinced by Dr. M.S. Swaminathan, FRS, the then Director-General of ICAR and Secretary to Govt. of India, Department of Agriculture Research and Education, in the conduct of the celebrations and ISOCRAD needs special mention. In bringing out this proceedings, we place on record our appreciation of the efforts of Dr. N.M. Nayar, as Chairman, Programme Committee ISOCRAD. The help rendered to him by Mr. V.A. Bava of CPCRI in typing the manuscripts and by Mr. S.K. Yadava, Librarian of CPRI in preparing the indices is gratefully acknowledged. We are grateful to Mr. M. Narayanan, for the cover design. We are also grateful to M/s Wiley Eastern Limited, New Delhi, the Publishers of this volume for their untiring patience and the understanding shown throughout the preparation of this proceedings.

It is hoped that this publication would prove useful to coconut workers and agricultural scientists all over the world as a ready reference on the status of coconut research and development programmes in mid-seventies.

(K.V. AHAMED BAVAPPA)
President ISPC &
Chairman, ISOCRAD Organising Committee

August, 1983.

CONTENTS

Foreword v
Preface vii

INAUGURAL ADDRESS 1

1. Coconut research : The Next Phase
   M.S. Swaminathan 3

GENETICS AND BREEDING 13-89

2. Identification of prepotent palms in West Coast Tall coconuts based on the early stages of growth of the progeny in the nursery—*K Satyabalan* and *Jacob Mathew 15*
3. Analysis of nut components in the coconut : A study in sampling—*J Meunier, F Rognon* and *M de Nuce de Lamothe 23*
4. Improvement of Dwarf coconuts with special reference to Indian Dwarf Orange palms and their natural hybrids—*CA Ninan 30*
5. Xenia and combining ability in coconut—*F Rognon* and *M de Nuce de Lamothe 38*
6. Coconut improvement by selection and breeding : A review in the light of recent findings—*KVA Bavappa* and *CK Sukumaran 44*
7. The mechanics of hybrid seed production through seed gardens—*MAPP Manthriratna 56*
8. Cytology of coconut — *PK Thankamma Pillai, G Vijayakumar* and *PN Ravindran 62*
9. Genetic potential of some coconut populations of the Philippines—*EN Balingasa* and *CB Carpio 71*
10. Trials with some coconut varieties and hybrids in Papua New Guinea—*JH Sumbak 82*
11. Some observations on the recovery of hybrid seedlings from Dwarf × Tall cross fertilized seed coconuts—*KM Thomas 85*

AGRONOMY AND SOIL SCIENCES 91-165

12. Effect of interculture, irrigation and manuring on coconut in Tamil Nadu, India—*I Henry Louis* and *NR Chandrasekar 93*
13. Effect of moisture stress and irrigation on yield of coconut in Sri Lanka—*V Abeywardena 98*
14. Soils of coconut garden areas in '*maidan*' parts of Karnataka, India—*RS Murthy, NK Barde, SR Nagabhushana, KR Venugopal, CR Shiva Prasad* and *CS Harindranath 107*
15. Soil and leaf analysis in relation to the nutrition of high yielding coconut genotypes—*CB Kamala Devi, M Velayutham* and *M Haridasan 115*
16. Intercropping of coconuts with cacao in Malaysia—*K Ramadasan, T Vanialingam, E Chan, I Abdullah,* and *KC Teoh 120*
17. Fertilizer requirements of adult coconut palms in Sri Lanka—*P Loganathan* and *TS Balakrishnamurti 127*
18. Seasonal influence on yield of Tall × Dwarf and West Coast Tall coconuts in Kerala, India—*UP Bhaskaran* and *K Leela 136*
19. Available micronutrient status of major soil types under coconut in healthy and root (wilt) affected tracts of Kerala, India— *NG Pillai, CB Kamala Devi, PA Wahid* and *CKB Nambiar 144*
20. First experimental results on the manuring of hybrid coconut in Ivory Coast—*P Coomans 152*
21. Mixed farming in coconut gardens : Economics and its effects on root (wilt) disease—*KN Sahasranaman, NG Pillai, NP Jayasankar, VP Potty, Thomas Varkey, PG Kamalakshyamma* and *K Radha 160*

BIOCHEMISTRY AND PHYSIOLOGY 167-228

22. Fermentation characteristics of some yeast types isolated from coconut toddy—*U Samarajeewa, U Pethiyagoda, JD Atputharajah* and *NCP Wijeratne 169*
23. Varietal differences in nut and copra characters—*PA Sarangamath, PB Shantappa* and *DS Kulkarni 181*
24. Variation in glucose content in Andamans coconut—*RB Nair* and *AK Sadanandan 186*
25. The vascular physiology of the coconut palm—*John A Milburn 189*
26. Foliar diagnosis of magnesium and sulphur nutrition in coconut using various leaf positions—*M Jeganathan 194*

27. Changes in the levels of carbohydrate as a function of environmental variabilities in hybrids and Tall coconut palms—*KV Kasturibai* and *A Ramadasan 203*
28. Observations on iron and manganese nutrition of coconut seedlings—*MAT de Silva 210*
29. Foliar absorption and distribution of radioactive phosphorus in healthy and root (wilt) diseased coconut palms—*R Snehi Dwivedi, PK Ray* and *Sunny Ninan 220*
30. Biochemical changes in coconut during maturation and germination—*K Balasubramaniam 221*

TECHNOLOGY 229-290

31. Improvement of traditional methods of wet milling fresh coconut kernel—*JE Cecil* and *WH Timmins 231*
32. Maximizing the utility of coconuts by an integrated process for large scale production of proteins, flour, coconut honey, and oil from fresh coconut kernel and by-products such as fibre, carbon, and chemicals from husk and shell carbon, shell chemicals, cooking gas etc. from shell—*TVP Nambiar 245*
33. Role of sodium dodecyl sulphate in the stabilization of coconut oil/water emulsion—*Ashok K. Goswami 254*
34. Industrial utilization of coconut husk—*GN Prabhu 258*
35. The fibre from coconut fruits—*JV Bhat 259*
36. Coconut palm and palm kernel oils : A comparison—*NC Gangi Reddy, T Obi Reddy, D Atchyuta Ramayya, G Azeemoddin* and *SD Thirmala Rao 274*
37. Activated carbons from coir fibre pith—*A Aslam Ali 279*
38. Building materials from coconut husk and its by-products—*Joseph George 284*

BASIC STUDIES 291-321

39. Effect of cultural practices, irrigation, and manuring on the development of root systems in the coconut palm—*I Henry Louis* and *K Balasubramanian 293*
41. Association of coconut foliar asymmetry with latitude *T Antony Davis 296*
42. Influence of crop mixing of hybrid napier on the root zone microflora of the coconut palm—*VP Potty* and *NP Jayasankar 300*
43. Attempts at vegetative propagation of coconut palm—*WW Schwabe 304*
44. A coconut palm producing pigmy-size barren fruits—*RB Nair 313*

45. Preliminary observation on the floral biology and fruiting of *in vitro* coconut palms—*EV de Guzman, AG Rafols* and *AG del Rosario 316*

DISEASES 323-351

46. Biology of *Ganoderma Lucidum* (Leys) Karst. and control of *Anabe Roga* of coconut—*HC Govindu, ANS Rao, KV Keshava Murthy 325*
47. Bud rot disease of coconut : *A* reappraisal of associated factors—*K Radha* and *Thomas Joseph 333*
48. Red ring disease of the coconut palm—*BP Blair 341*
49. A terminology for the coconut root (wilt) disease—*K Mathen, N Gopinathan Pillai* and *K Radha 342*
50. Control of ganoderma wilt of coconut—*A Papa Rao, B Satyanarayana, K Subramanyam* and *SV Pandit 347*

PESTS 353-397

51. Studies on integrated control of coconut black headed caterpillar *Nephantis serinopa* Meyrick (Lepidoptera: Cryptophasidae)—*L Nadarajan* and *GP Channa Basavanna 355*
52. Release of predators for the control of the coconut scale *Aspidiotus destructor* in Sri Lanka—*PR Dharmadhikari, PACR Pereira, TMF Hassen* and *SV Sinnathamby 356*
53. Biological control of insect pests of coconut : A review —*Chandy Kurian, GB Pillai, J Antony, VA Abraham* and *P Natarajan 361*
54. New developments in the control of pests and weeds of coconuts in Sri Lanka—*P Kanagaratnam 376*
55. Coconut root grubs and their control in Karnataka, India—*GK Veeresh 385*
56. *Aceria (Eriophyes) Guerreronis* : An important pest of African and American coconut groves—*D Mariau 392*
57. Rat damage and its control in coconut groves—*BK Guruprasad* and *K Srihari 393*

DISEASES OF UNCERTAIN AETIOLOGY 399—448

58. A serological test for the detection of the root (wilt) disease of coconut—*JJ Solomon, M Sasikala* and *P Shanta 401*
59. Research on coconut yellow disease of West Africa—*Joseph Giannotti* and *Michel Dollet 406*
60. The association of anomalous RNA with cadang-cadang disease of coconut, and evidence towards a viroid etiology—*JW Randles, Erlinda P Rillo* and *G. Boccardo 410*

61. Attempts to transmit lethal yellowing of coconut palms to suspected vectors—*James H Tsai* 415
62. Histopathology of roots of coconut palm affected with *thal* (wilt) disease — *MP Govindankutty* and *K Vijayachamy* 421
63. Two new coconut diseases in the nursery and on young plantations in Middle Ivory Coast—*JL Renard, D Nicolau, JP Norin* and *G Quillec* 426
64. Investigation on Thanjavur wilt of coconut in Tamil Nadu, India—*T Jaganathan, S Kolandaisami* and *R Ramasami* 433
65. Uncertain etiology diseases of the coconut palm—*Karl Maramorosch* 439
66. Heart rot—A coconut disease of Surinam associated with a trypanosomatid flagellate—*MV Parthasarathy* 441
67. Use of oxytetracycline as prophylactic and therapeutic treatment for lethal yellowing in Florida 442

DEVELOPMENT PROGRAMMES **449—500**

68. Coconut situation and FAO assistance—*KJ Gunawardene* 451
69. The coconut profile of India—*PK Thampan* 453
70. Coconut research and development programmes in the Philippines—*Juan T Carlos Jr.* and *Severino E Cuevas* 464
71. Development programmes of coconut in Sri Lanka—*MSS Fernandopulle* 477
72. An assessment of the coconut industry of Malaysia—*Harcharan Singh Khera* 485
73. Research and extension : The keys to coconut development in Jamaica—*DH Romney* 495

Author Index 501
Subject Index 509

Coconut Research—The Next Phase

M.S. SWAMINATHAN
Member, Planning Commission
New Delhi, India

The coconut palm, by providing food, drink, and shelter, fulfils some of the basic needs in the hierarchical requirements of man. Though *Cocos nucifera* is regarded by most taxonomists as monotypic, there is considerable genetic variability in coconut. While we do not know for certain the centre of origin of this palm, it has been known to occur for over 3000 years in India. The centre of diversity is in the south-east Asian and Melanesian regions. According to FAO statistics, 58.5% of the six million hectares under coconut in the world is in south-east Asia. Another 24.6% of the area occurs in south Asian countries. Therefore, the scientists of this region have a major responsibility to study critically the problems and potential of this wonderful palm.

Major Problems

(a) Production and Productivity

In the last two decades, coconut production has tended to remain static on a global basis. Coconut oil production, now estimated to be about 3 million tonnes/annum, ranks sixth in the world production of about 29 million tonnes of edible vegetable oils. In India, the production went up from 3448 million nuts in 1949-50 to 5961 million nuts in 1974-75. However, the pathway through which this increase in production came about is increase in area We had about 5.96 lakh hectares under this palm in 1949-50. The area in 1974-75 was about 11.1 lakh hectares, almost one-sixth of the world area under this palm. Thus, the yield of nuts per hectare has remained practically stagnant. It was 5344 nuts/hectare in 1974-75 in contrast to 5785 nuts in 1949-50. There have been annual fluctuations in yield of nuts and the highest average yield recorded was 7,012 nuts/hectare in 1953-54. While allowance should be given to difficulties in the collection of accurate statistics and also for the fact that new plantations take time to give optimum yield, we cannot escape the conclusion that *attacking the yield barrier is our first major research problem.*

(b) Stability of Production

Globally, the following four major reasons have been inferred for the decline in the pre-eminent trade position of coconut in the edible vegetable oil market : (i) Failure to replant with superior material over-aged plantations; (ii) Reluctance to use fertilizers; (iii) Market substitutions by petroleum and synthetic detergents; and (iv) Alternative oil crops such as oil palm and soya. To these should be added, as far as India is concerned, the menace of the coconut "root (wilt)" disease in about 2.5 lakh hectares in south and central Kerala. This disease has been known in Kerala for about 95 years now, but its precise cause is still unknown. Diseases of uncertain aetiology occur in other countries as well. Jamaica fortunately could find an answer to the lethal yellowing disease by collecting genetically diverse germplasm and identifying tolerance in Malayan Dwarf. Understanding and solving the problem of root (wilt) is a task of highest priority in India.

(c) Technological Problems

Until recently, several natural products faced the threat of extinction due to the development of synthetic substitutes. Interest in natural products has, however, revived following the end of the era of cheap petroleum products. Though precise physiological data on the efficiency of photosynthesis in coconut are yet to be collected, the potential for yield, which I shall shortly refer to, clearly indicates that we have in coconut, as in other members of the plant kingdom, an excellent solar energy harvesting machine. Ecological and energy conservation principles have placed a premium on natural products raised from renewable forms of energy. However, to capitalize fully on the advantages of natural products, there is need for a considerable step-up of research on all aspects of post-harvest technology.

I would now like to turn from problems to potential and to offer a few suggestions on how we can tap the potential.

Research Approaches

(a) Breaking the Yield Barrier

(i) Potential for yield : We do not have precise data on indices like photosynthetic efficiency, total dry matter production and the manner of partitioning of the total dry matter (i.e., harvest index). Hence calculations of yield potential have to be tentative and somewhat speculative. We also do not know whether cocount has the C_3 or C_4 pathway of photosynthesis (i.e., whether the first detectable product is malate or aspertate, which are 4-carbon compounds, or 3-phosphoglyceric acid synthesized through the Calvin cycle pathway). Leaves of C_3 species tend to assimilate CO_2 at rates of about half or less than half of the C_4 species. Nevertheless, it is useful to put together the available information on yield potential.

According to the report of the Working Group on Coconut Genetic

Resources of IBPGR which met at Kingston, Jamaica, from 27 to 29 April, 1976, yields of 2.6-3.0 tonnes of copra/hectare have been recorded commercially, in contrast to the average worldwide yield of 0.6 tonnes/hectare. Well grown F_1 hybrids have given 5.0 tonnes/hectare. Thus the ratio *Recorded yield* : *Average yield* is at present about 8.33. The FAO Production Yearbook of 1974 refers to productivity in terms of whole nut excluding the fibrous outer husk. For countries, where production data are given in numbers instead of weight, FAO statistics are based on the assumption that the average weight of one dehusked nut is 1 kg. For India, this weight has been assumed to be 0.75 kg.

Another difficulty in yield calculations is the fact that coconut is grown in mixed plantations with other intercrops like banana, tapioca, pineapple cocoa, etc. For example, the yield per tree in Kerala is calculated on the assumption of a population density of 225 palms/ha. The recommended population density is 175 palms/ha. How far is the assumption of 225 palms/ha correct? We need more assistance from statisticians in making reliable estimates of yield.

Having expressed this caution, I would like to indicate the tasks ahead of coconut scientists in improving the yield potential of this palm.

Pillai and Davis (1963) have given figures for partitioning the total biological yield between vegetative and reproductive organs. Their calculations indicate a harvest index of less than 15% in relation to kernel. We however need critical data on the harvest index for kernel and the range of variability for this trait. In rubber, for example, the harvest index for latex production ranges from 3.0% to 11.1%. An analysis of dry matter production under different conditions made by the Central Plantation Crops Research Institute is given in Table 1.

Briefly stated, the yield position expressed as nuts is as follows :

(a) Average yield of nuts per hectare per year in 1974-75 :
  (i) Kerala 4,970
  (ii) Karnataka 5,408
  (iii) Tamil Nadu 8,785
  (iv) Lakshadweep 7,500

(b) Best average yield realized by a farmer : 19,443 nuts/hectare/year

(c) Best yield in a research farm with
  (i) West Coast Tall 21,525 nuts/hectare/year
  (ii) T×D hybrid 30,520 nuts/hectare/year

(d) Calculated yield on the basis of the potential expressed by a single 'super palm' reported from Thazhava village (produces 471 nuts/year) 82,425 nuts/hectare/year

We can use this information to calculate the different kinds of yield gaps which exist in this palm.

TABLE 1. Dry Matter Production in Coconut*

	Pillai & Davis (1963) 40-50 nuts/palm/yr; 12 spathes	Farmers' field : sub-optimal management : 175 palms/ha ; 12 spathes ; 40 nuts/palm/yr : 7000 nuts/ha/year.	Farmers' field : optimum (management) : 175 palms/ha ; 12.1 spathes ; 111.1 nuts/palm/yr : 19,443 nuts/ha/yr.	Research farm : T×D palms & optimum management : 175 palms/ha ; 13.1 spathes ; 174.4 nuts/palm/yr : 30,520 nuts/ha/yr.	Thazhava super-palm : 175 palms/ha ; 22.7 spathes ; 471 nuts/yr/palm : 82,425 nuts/ha/yr.	Kerala state average : 4971 nuts/ha ; 10 spathes : 4971 nuts/ha/ yr.
	(quintal/palm/yr)			(quintal/ha/yr)		
Husk (H)	0.13103	22.93	58.61	77.41	253.69	16.27
Shell (S)	0.05286	2.25	27.88	50.03	115.83	6.57
Kernel (K)	0.06994	12,24	36.89	66.18	153.55	8.70
Spadix	0.03339	5.84	6.04	6.38	11.05	4.87
Spathe	0.02710	4.74	4.90	5.18	8.97	3.95
Petiole with leaf sheath	0.11440	20.02	20.69	21.86	40.04	16.68
Leaflet	0.11335	19.84	20.50	21.65	39.67	16.53
Stem	0.03038	5.32	5.32	5.32	5.32	5.32
Total dry matter production	0.57245	103.18	180.83	254.01	628.12	78.89

*Data compiled by the Central Plantation Crops Research Institute, Kasaragod.

Gap I: If we regard the reported 'Thazhava super-palm' yield of 471 nuts/palm/year as a realizable yield goal, the gap between what may be possible and the best yield so far achieved is quite wide. This is a *research gap* which can be filled only through intensive interdisciplinary research effort. We may call this as Gap I.

Gap II: This is the gap between the best yield obtained in a research farm and by a good farmer. This will need attention both from research and extension workers. Management factors as well as soil fertility and water management problems, and also control of pests will need attention. Thus, Gap II is a *research*-cum-*management gap.*

Gap III: This is the gap between the best average yield realised by a farmer in the State and the State average. This is the *gap which can be filled immediately provided there is a concerted effort by development, extension and research agencies.* Since the scope for area increase is very limited, productivity improvement is vital. For understanding the reasons for Gap III and for developing strategies for overcoming the gap in different areas, we need a critical analysis of the constraints causing this gap. This will help to narrow Gap III, which can be referred to as an *extension*-cum-*resources*-cum-*management gap.*

Constraints Analysis

An analysis of the constraints responsible for the gap between the yield obtained by a good farmer and the average yield of an area will involve cooperative studies by a team consisting of an economist, an extension scientist, a statistician, an agronomist, and a plant protection expert. The constraints can be broadly grouped as follows:

1. *Biophysical and technological constraints:* For instance, gaps in technology, soil health problem, improper water management, inadequate plant protection, poor post-harvest technology.
2. *Socio-economic constraints:* Like lack of credit, deficiencies in input supply, uncertain markets and prices, lack of necessary institutional infrastructure, socio-cultural problems.

If the precise constraints operating in each area are identified, the extension gap can be narrowed to the extent resources will permit, particularly the capacity to mobilize and use inputs. This is the major aim of the operational research projects initiated by ICAR in coconut and other crops.

Reducing the Research Gap

This would need a critical look at our current breeding and production strategies. I hope this will be done during this Symposium. I would like to offer a few suggestions based on the work M.C. Nambiar and I carried out several years ago on Dwarf coconut varieties. The following points would merit consideration.

Dwarf types have distinct markers. In addition, they have distinct genotypic ranges that are identifiable phenotypically, and admit of varying degrees of self or cross-fertilization. For example, Chavakadu Dwarf Green has tapering green nuts characterized by rings and is self-fertilized; Chavakadu Dwarf Orange possesses characters intermediate between Dwarf Green and Tall types and is partially cross-fertilized. Kulasekaram Dwarf Orange and Dwarf Yellow are self-fertilized while Dwarf Green is partially cross-fertilized. Further, Dwarfs are early-maturing, more disease-tolerant though low in yield and its direct attributes. Talls possess good yield components ; however they do not breed true, are relatively disease-susceptible and late bearing.

While Tall × Dwarf hybrids, especially West Coast Tall × Dwarf Orange/Green, have received wide attention, those hybrids belonging to Dwarf × Tall category are yet to be fully exploited for their potential. Preliminary research carried out at CPCRI indicates the relative superiority of D × T hybrids over T × D. Since Tall types produce dwarf genetic segregants in their progeny, it would be worth the effort to search for early-maturing, productive, and disease-resistant segregants in them and more so in the D × T progeny. The chances of locating such segregants would appear to be high in the latter, in view of a possible incorporation of Dwarf cytoplasm in the progeny. The operation of maternal effects in the progeny of D × T to make it superior to T × D would strengthen the need for such a step.

It would be necessary to study the pattern of relationship as shown by the yield of nuts and yield contributing characters over a number of years of bearing for a number of genotypes. This would then help the stable performance of a genotype, once it comes to the bearing stage. Such a study extended to the distinct types of Tall and Dwarf categories and their progeny, would help in predicting the stability of yield and in formulating fresh criteria for the release of varieties.

Attempts are in progress to identify useful characters in the nursery stage. The pattern of leaf-splitting would serve as an example of such a character. Work is in progress (a) to identify useful early stage characters, (b) to use them to tag the genotypic constitution of the individuals, and (c) discover the possibility of useful correlations between nursery stage characters and yield component/yield. The intensification of such research would go a long way in identifying individuals with good yield potential, right at the nursery stage.

A yield index, analogous to harvest index, is provided by the ratio of copra content to the weight of coconut. Good genetic variability exists for yield index in the germplasm. We should try to increase the yield index through plant breeding tools.

Crop Canopy Studies in Relation to Allelopathy

Coconut gardens are increasingly (a) inter-cropped with a wide range

of tuber and other crops, (b) placed under a mixed cropping system involving cocoa, pineapple, pepper, and banana, or (c) developed into a mixed farming system involving fodder, grasses, legumes and animal husbandry. Therefore, scientists should study critically which combinations exhibit 'cooperation' and which show 'competition'. Indices to measure cooperation and competition will have to be developed both on economic and long-term productivity and soil fertility considerations. For example, Nelliat and Krishnaji (1976) have reported a total net return of Rs. 13,757/hectare/annum by intercropping ginger with coconut. Pepper+cocoa+pineapple together with coconut give Rs. 15,661/hectare/year. What are the long term implications of these systems?

"Root (Wilt)" Problem

The CPCRI has brought out a technical bulletin on cocount diseases of uncertain etiology. This contains a summary of our current understanding of coconut root (wilt) and of three other diseases in India. Since "root wilt" has spread to nearly one-third of Kerala and since, in spite of nearly 30 years of research, we have not been able to come to grips either with the precise cause of the malady or its solution, I would like to raise a few questions for discussion.

E.J. Butler described this disease in 1908 as root rot (Bulletin No. 9 of the Imperial Agricultural Research Institute, Pusa). When and why was the name changed to root wilt? Wilt implies systematic vascular invasion. Is there evidence for this? The rotting of the roots has been reported by several investigators. Is root rot the effect or the cause of the disease? Butler did not conclude that *Botryo diplodia* isolated from the rotted root was the pathogen. We need critical studies in this area.

The unit of Nematology at CPCRI has made some significant observations on the association of the nematode with roots of diseased palms. Some evidence of bacterial association with the rotted roots has also been provided. If we have to pinpoint the causes of the disease from amongst the various categories of plant pathogens, all of which have been suspected to be involved in this disease, we have to proceed with some strong and logical assumptions. The association of nematodes and bacteria with localized rotting of roots is one such area which deserves to be pursued vigorously.

We have had some evidence of association of virus or virus-like organisms also. There have been controversies on this aspect and this must be settled without delay to enable further critical studies in this and other directions.

I realise that in diagnostic pathology, the most important need is to establish the Koch's postulates. This is extremely difficult in a plant like coconut where the disease takes many years to manifest itself. But are we sure that internal symptoms do not develop in the palm in the very early stages of infection? This aspect can be settled by intensive comparative

anatomical studies of young seedlings from diseased and healthy areas.

I suggest that we examine carefully the diagnostic, ameliorative and other approaches indicated in the CPCRI Bulletin and evolve well defined *inter-se* priorities. *Until we are able to understand the problem more fully, it may be advisable to refer to this malady as "coconut decline", rather than "coconut root (wilt)".*

Post-harvest Technology

Every part of the coconut plant is valuable. While there has been considerable progress in processing technology, there is scope and need for more intensive research on the better utilization of coconut and coconut products.

Research Related to Developmental Problems

Apart from credit and other input supply problems, developmental agencies face an acute shortage of quality planting material. In the future, more and more emphasis will be on hybrids with a dwarf stature, early prolificity and disease resistance. There is need for research on rapid propagation techniques which can help us to supply superior genetic material for replanting programmes. Tissue culture techniques for vegetative propagation have been standardized in oil palm. Should coconut scientists lag behind?

Scientific inter-cropping and mixed farming techniques, through which productivity and income can be improved without harm to the long term production potential of the soil, need to be standardized and communicated to developmental agencies.

Establishing a Global Grid of Genetic Resource Centres in Coconut

There is need for a systematic sampling of the available genetic variability in coconut in different countries and developing a global grid of genetic resource centres for preserving and classifying the collection and for generating pure as well as panmictic populations for distribution to selection and breeding centres. Large scale replacement of old cultivars with new hybrids is already underway in several countries like Jamaica and Malaysia. We must remember that coconut belongs to a monotypic genus and hence we must collect and conserve as much of the existing variability as possible. If we are to avoid gene erosion on a large scale, the organization of inter-disciplinary collecting expeditions to different coconut growing areas is urgent. Such teams should include competent plant pathologists so that the quarantine implications are fully understood and the necessary precautions adopted. I hope a concrete plan for establishing a global grid of coconut genetic resource centres will emerge from this International Symposium. Areas in Lakshadweep and Andaman and Nicobar Islands would provide suitable locations for the world cocount genetic resource centres.

We in India will be happy to play our part in such cooperative scientific programmes designed to preserve for posterity the fruits of thousands of years of natural and human selection.

References

Nelliat, E.V. and Krishnaji, N. (1976). Intensive cropping in coconut gardens. *Indian Farming* **27** (9) : 9-12.

Pillai, N.G. and Davis, T.A. (1963). Exhaust of nutrients by the coconut palm—a preliminary study. *Indian Coconut J.* **16** : 81-87.

Genetics and Breeding

Chairman: B.R. MURTHY
Rapporteur: K. SATYABALAN

Identification of Prepotent Palms in West Coast Tall Coconuts Based on the Early Stages of Growth of the Progeny in the Nursery

K. SATYABALAN and JACOB MATHEW
Central Plantation Crops Research Institute
Kasaragod, Kerala, India

Abstract

Monthly observations on growth rate and seedling vigour as measured by collar girth and leaf production from the time of germination taken in 599 open pollinated progeny seedlings of 16 selected high yielding families (cultivar : West Coast Tall) indicated highly significant differences in growth rate of progenies between families. Correlations of these growth characters from the first to the ninth month from the time of germination with those of the tenth month showed that correlation was high and positive from the fifth month. This shows that it may be possible to identify palms of superior genetic value (prepotents) even from the fifth month based on these two growth characters of the progeny.

The breeding values of six families worked out for leaf production and collar girth of the progeny during the fifth and tenth months of growth in the nursery and their yield performance in the field showed that prepotent palms, whose progenies would be high yielders, have high breeding values for both these characters. Thus it may be possible to screen a large number of palms for prepotency and identify them based on these growth characters of the progenies in the nursery during the fifth month of growth. In areas where young seedlings of less than six months old are preferred for planting, it is better to select them from five months old seedlings based on these two characters, as they are genetically correlated with yield of adult palms.

Introduction

Selection is normally practised in coconut on the mother palms and in seedlings. Harland (1957) advocated the identification of high yielding mother palms on the basis of their progeny performance and suggested that it should be possible to identify prepotent high yielders from a comparative study of sufficiently large numbers of progenies from open pollinated mothers. Ninan and Pankajakshan (1961) studied the relationship between parent yield and seedling characters of progenies and found that some high yielders showed markedly superior progeny performance than others. Liyanage (1967) reported a positive and significant correla-

tion between number of leaves produced during the first 40 months and yield of copra at the age of 13-14 years. He felt that selecting seedlings on the basis of high leaf number was a quick method of isolating palms of high breeding value. Ninan, Pankajakshan, and Abdu (1964) found that differences between families in vigour and growth rate were highly significant when compared with variations within families. This indicated the possibility of identifying prepotent palms on the basis of the growth of one year old progeny in the nursery. Another quick method for identifying palms of high breeding value (Liyanage, 1969) was by selfing the palms and studying the depression in endosperm and embryo weight in relation to those of open pollinated nuts from the same palms. Satyabalan, Nampoothiri, and Mathew (1975), from their studies on the growth characters of one year old seedlings of some palms and their performance as adult palms, indicated the possibility of identifying prepotent palms in the nursery. With a view to studying the possibilities of identifying prepotent palms on the basis of progeny characters when they are 5-6 months old in the nursery, collar girth and leaf production were studied in open pollinated progenies of 16 high yielding palms of West Coast Tall variety every month from the time of germination till they were 10 months old. These two growth characters have been found to be genetically correlated with yield of adult palms (Nampoothiri, Satyabalan, and Mathew, 1975). The results of this study are presented and discussed here.

Materials and Methods

Girth at collar and leaf production in the nursery were observed at intervals of one month for ten months from their dates of germination in 599 seedlings raised from open-pollinated seednuts collected during January to May from 16 high yielding palms of West Coast Tall variety. The number of seedling progenies varied from 20 to 47. The mean annual yield of the mother palms varied between 76 and 123 nuts during the period 1956-1965. The mature nuts harvested from each palm each month were individually sown in nursery in June 1957. The date of germination of each nut was noted when the tip of the sprout just emerged out of the husk. The number of fully opened leaves and collar girth were recorded in every seedling each month from the date of germination till the seedlings were 10 months old. Data on leaf production and collar girth for each month for all the seedlings of each palm were separately worked out. Coefficients of correlation were calculated separately for total leaf production and collar girth between the first to the ninth month from the time of germination with those of the tenth month separately for each palm.

The breeding value of a palm for any character is expressed as twice the deviation of the individual progeny mean from the overall population mean for that character. The mean yield of progenies of six palms planted in 1960 was recorded. The breeding values of these palms were determined

for leaf production and collar girth to study the relationship between these growth characters during the fifth and tenth months in the nursery with their nut yields as adult palms.

Results and Discussion

Data on leaf production of the progenies of each palm during the fifth and tenth months of growth beginning from the date of germination in the nursery and their coefficients of variation are presented in Table 1. It is evident from the data that in the progenies of palms II/177, O.C. 19, 27N. 368 and 41.588, the total leaf production in fifth and tenth months are high.

The coefficients of correlation of leaf production during the first, third, fifth, seventh, and ninth months and the tenth month for all the palms are presented in Table 2. The data indicate a positive and significant correlation between total leaf production till the fifth to ninth months with that in the tenth month for all the palms. From this it is evident that seedling selection on the basis of leaf production can be made from the fifth month onwards.

Similarly, the average values of collar girth of the progenies of each palm and their CV during the fifth month and tenth month from the time of germination are presented in Table 1. The data indicate that progenies of VI/143, VII/27, X/31, O.C. 19, and 41.588 have better collar girth (more than 9 cm in the fifth month) than those of the rest. Among these, the progenies of O.C. 19 and 41.588 are the most vigorous in growth as they have the highest collar girth in the tenth month. For this growth character, the correlation between collar girth of progenies in tenth month is positive and significant with that in the fifth month onwards for all the palms (Table 3).

Among the different growth characters of a seedling, collar girth and number of leaves of seedling are positively correlated with yield of adult palm (Nampoothiri *et al.*, 1975). Fremond and Brunin (1966) found that rapid and early growth was associated with earliness in flowering and that the number of leaves produced in the first two years could be used to forecast the palm which would be the first to come into bearing. In the present study, progenies of palms O.C. 19 and 41.588 showed higher values for both leaf production and collar girth as early as in the fifth month of their growth. Since the progenies of these two palms are vigorous in growth as indicated by their leaf production and collar girth, they may be identified as being genetically superior (prepotents), as suggested by Harland (1957).

The breeding values of six families whose progenies are now in the bearing stage were worked out vis-a-vis leaf production and collar girth during the fifth and tenth months of growth in the nursery (Table 4). These six families include family 41.588 which has been identified from progeny studies as one of superior genetic value. Their breeding value is high for

TABLE 1. Total leaf production and collar girth during fifth and tenth months from the time of germination

Family no.	No. of seed-lings	Leaf production				Collar girth			
		Fifth month		Tenth month		Fifth month		Tenth month	
		Mean	C.V. (%)	Mean	C.V. (%)	Mean	C.V. (%)	Mean	C.V. (%)
I/55	37	3.95	14.6	6.92	11.0	8.29	8.58	12.74	10.15
II/177	34	4.47	12.6	7.59	8.7	8.48	7.00	12.75	7.15
VI/143	27	3.89	21.8	6.85	13.2	9.28	14.69	13.94	18.04
VII/1	40	3.60	16.1	6.68	11.4	8.44	9.04	12.44	10.35
VII/27	20	3.95	10.0	7.05	7.2	9.14	5.74	13.82	5.76
VIII/23	37	3.57	19.3	6.54	9.9	8.69	8.63	13.25	10.25
VIII/55	42	3.71	16.1	6.52	10.8	8.72	8.82	12.83	8.15
VIII/112	42	3.64	17.0	6.31	10.2	8.53	7.28	12.55	9.26
X/11	47	3.36	18.0	6.34	9.5	8.94	8.47	13.44	7.89
X/14	45	3.60	17.2	6.56	11.1	8.92	6.04	12.95	6.90
X/26	42	3.34	19.6	6.30	11.5	8.57	9.91	12.86	11.72
X/31	23	3.74	12.0	6.70	13.1	9.60	9.59	13.83	8.84
O.C. 6	40	3.40	18.6	6.33	10.4	8.43	9.05	12.39	12.62
O.C. 19	35	4.69	14.4	7.37	11.0	10.02	10.65	14.81	12.73
27N.368	42	4.40	16.7	7.48	10.3	8.94	9.88	13.14	12.21
41.588	46	4.34	16.0	7.44	10.1	9.64	8.00	14.43	10.26
Gen. mean	(599)	3.85		6.81		8.90		13.26	

TABLE 2. Coefficients of correlation of leaf production during the first nine months with that of the tenth month

Sl. no.	Parent palm no.	No. of seed-lings	Coefficient of correlation between leaf production in the 10th month and				
			1st month	3rd month	5th month	7th month	9th month
1	I/55	37	0.3296*	0.3930*	0.4119*	0.5730**	0.7084**
2	II/177	34	—0.1776	0.4767**	0.6214**	0.5480**	0.4658**
3	VI/143	27	0.1408	0.7534**	0.7779**	0.7444**	0.7944**
4	VII/1	40	0.3374*	0.5705**	0.5743**	0.5049**	0.6928**
5	VII/27	20	—0.2518	0.5054*	0.5369*	0.6076**	0.6057**
6	VIII/23	37	0.0605	0.3635*	0.4727**	0.5544**	0.5835**
7	VIII/55	42	0.1813	0.4985**	0.5946**	0.6954**	0.7809**
8	VIII/112	42	0.3414*	0.7182**	0.5444**	0.6863**	0.6259**
9	X/11	47	0.0624	0.5075**	0.4920**	0.5893**	0.6950**
10	X/14	45	0.2434	0.4054**	0.5071**	0.7253**	0.7185**
11	X/26	42	0.2804	0.5158**	0.6007**	0.5905**	0.6325**
12	X/31	23	—0.0843	0.3195	0.5990**	0.4866**	0.7446**
13	O.C. 6	40	0.3338*	0.4553**	0.5434**	0.5981**	0.6451**
14	OC. 19	35	0.3227	0.5272**	0.7595**	0.6875**	0.7799**
15	27N.368	42	—0.1601	0.4671**	0 5975**	0.6727**	0.7106**
16	41.588	46	0.4185**	0.5543**	0.5995**	0.6351**	0.7539**

*Significant at $P=0.05$.

**Significant at $P=0.01$.

TABLE 3. Coefficients of correlation for girth at collar during the first nine months with that of the tenth month

Sl. no.	Parent palm no.	Coefficients of correlation between girth at collar in the 10th month and		
		5th month	7th month	9th month
1	I/55	0.6219**	0.7975**	0.9594**
2	II/177	0.7138**	0.7218**	0.8022**
3	VI/143	0.8406**	0.9026**	0.9755**
4	VII/1	0.7123**	0.6314**	0.8564**
5	VII/27	0.6386**	0.6459**	0.7649**
6	VIII/23	0.8449**	0.7781**	0.9561**
7	VIII/55	0.6984**	0.7844**	0.9310**
8	VIII/112	0.4467**	0.5785**	0.8161**
9	X/11	0.7715**	0.7103**	0.8959**
10	X/14	0.3175*	0.3833**	0.7026**
11	X/26	0.7603**	0.8629**	0.9147**
12	X/31	0.6844**	0.8060**	0.9425**
13	O.C.6	0.7538**	0.7227**	0.9648**
14	O.C.19	0.8714**	0.9116**	0.9720**
15	27N.368	0.4323**	0.4122**	0.4571**
16	41.588	0.7255**	0.8021**	0.9445**

*Significant at $P=0.05$.

**Significant at $P=0.01$.

both the characters and their progenies show high yields. Liyanage (1967) has also reported an association between leaf production of progeny during the first 40 months of their growth and the breeding value of the parent. In our study, we have found that both leaf production and collar girth should be considered for identifying mother palms of superior breeding values. These palms of superior breeding values can be identified on the basis of growth characters of their progeny in the fifth month of their growth in the nursery. This way, it would be easier to screen large numbers of palms for prepotency.

In most of the countries where coconut is grown and also in some states in India, the practice is to plant young seedlings which are 4-6 months old. Foale (1965) has also indicated the need for transplanting 4-5 month old seedlings to prevent a severe setback in growth which occurs when aged seedlings are transplanted and has also stressed the need for selecting them on the basis of vigorous growth characters at that stage. Our study has shown that it is possible to select seedlings during the fifth month after germination on the basis of growth characters like collar girth and leaf production.

TABLE 4. Data on the performance of progenies of six palms and their breeding values

Sl. no.	Parent no.	No. of progenies	Yield of nuts		Breeding values: Leaf production		Breeding values: Girth at collar	
			Mean	C.V.(%)	Fifth month	Tenth month	Fifth month	Tenth month
1	II/177	2	67.0	87.6	1.30	1.58	−0.80	−0.92
2	41.588	3	97.1	5.7	0.90	1.18	1.40	2.28
3	I/55	4	56.9	73.6	0.30	0.18	−1.20	−1.12
4	VIII/55	4	71.4	8.6	0.30	−0.62	−0.40	−0.92
5	X/14	4	76.8	23.1	−0.50	−0.42	0	−0.52
6	VII/1	2	62.8	11.8	−0.50	−0.22	−1.10	−1.72

References

Foale, M.A. (1968). The growth of coconut seedlings: The relationship of endosperm to growth and the effect of nut size and variety on seedling growth. *Oleagineux* **23** : 651-654.

Fremond, Y. and Brunin, C. (1966). Leaf production and earliness in the you coconut palm. *Oleagineux* **21** : 213-216 (in French).

Harland, S.C. (1957). The improvement of the coconut palm by breeding and selection. Circulation paper No. 7/57. *Bull. No. 15*, Coconut Research Institute, Sri Lanka.

Liyanage, D. V. (1967). Identification of genotype of coconut palms suitable for breeding. *Expl. Agric.* **3** : 205-210.

_____(1969). Effects of inbreeding on some characters of the coconut palm. *Ceylon Coconut Quart.* **20** : 161-167.

Nampoothiri, K. U. K., Satyabalan, K. and Mathew, J. (1975). Phenotypic and genotypic correlations of certain characters with yield in coconut. Paper presented at the IV session, FAO Technical Working Party on Coconut Production, Protection, and Processing. Kingston, Jamaica. 14-25 September 1975. FAO, Rome.

Ninan, C. A. and Pankajakshan, A. S. (1961). Progeny studies in coconuts. 1. Relationship between parent yield and seedling characters of progeny with special reference to open pollinated and hybrid progenies of West Coast Tall and its bearing on the concept of prepotency in coconuts. *Indian Coconut J.* **14** : 100-109.

Ninan, C. A., Pankajakshan, A. S. and Abdu, K. M. (1964). Some observations on growth rate and vigour of coconut seedlings. *Indian Coconut J.* **18** : 12-17.

Satyabalan, K., Nampoothiri, K. U. K. and Mathew, J. (1975). Identification of prepotent West Coast Tall palms based on progeny performance. Paper presented at the IV Session, FAO Technical Working Party on Coconut Production,

Protection, and Processing. Kingston, Jamaica. 14-25 September 1975. FAO, Rome.

Discussions

Asana : It might be useful to study two parameters :

(*i*) Measurement of adenylic energy might indicate significant differences in seedling vigour;

(*ii*) Measurement of $^{14}CO_2$ uptake by leaves of seedlings may also be taken up. This measurement has shown some promise in oil palm seedlings selection.

Louis : Did you compare the seedlings of all the parent palms on their yield performance before determining their prepotency ?

Satyabalan : The yield performance of the progenies of only six palms has been studied so far.

Narasimhayya : Basic definition of prepotency should take the CV of the progenies according to Lush, and not CA alone. So, your first selected plant having 87.2% CV may not be prepotent.

Satyabalan: The first palm is not a prepotent one. Only palm nos. 41/588 and O.C. 19 are prepotent. The data on the performance of the progenies of 41/588 only are available.

Venkateswaran : (*i*) Does prepotency imply high concentrations of dominant genes ?

(*ii*) Is it not necessary to study the relationship of yield itself with growth measurements for each month ?

(*iii*) Is it not necessary to fix the month which gives the highest correlation with yield ?

(*iv*) How is the seedling age calculated ?

Satyabalan : (*i*) Prepotency has been taken as the general combining ability. It is possible that it represents the cumulative action of favourable dominant genes.

(*ii*) and (*iii*) Such a study is being undertaken.

(*iv*) From the date of germination.

Shanthamallaiah : Won't seedling vigour as expressed by dry matter production be a more valid criterion as compared to all your other characters ?

Satyabalan : Certainly. But that would be a destructive and time consuming method.

Manthriratne : I presume that your heritability value of 40% was for number of nuts. In Sri Lanka we had obtained a high heritability value of 95% for weight of husked nuts. Is this not a better index ?

Satyabalan : There is a relationship between number of nuts and weight of copra. Therefore, number of nuts by itself is a good index. This is the subject of another paper at the Symposium.

Sriram : (*i*) I understand that elitism exists in plants. But I would like to know whether in the opinion of the authors prepotency is due to dominant genes or the combining ability of the parents (known or unknown).

(*ii*) How were the seedlings grown-in individual bags or in nursery ?

Satyabalan: (*i*) It is presumably due to en block transmission of favourable dominant genes to the progeny.

(*ii*) They were grown in the nursery.

Analysis of Nut Components in the Coconut — A Study in Sampling

J. MEUNIER, F. ROGNON and M. DE NUCE DE LAMOTHE
Institut de Recherches pour les Huiles et Oleaginux, 11 *Square Petrarque*, 75016 *Paris, France*

Abstract

A systematic analysis was made of all nuts produced over a period of three years by two populations of coconut palms of different variability, West African Tall and Polynesia, in order to find out the minimum size of sampling required to determine the average composition of the nuts of a tree or a group of trees.

Seven characters were studied: weight of nut, weight of husked nut, weight of husk, weight of water, weight of shell, weight of endosperm and weight of copra. With the exception of the weight of water and copra, both of which were too variable, one year's observation was found to be enough to compare trees or lines planted in the same trial.

However, because of seasonal and annual variations, to obtain 'absolute' values, it may be necessary to observe 4 nuts every two months for 5 or 6 years to 'know one tree, and one nut every 2 months on 50 trees for 5-6 years to estimate a line. It should be possible to reduce these maxima for more homogeneous material such as hybrids or self-fertilizing Dwarfs.

Introduction

In the last ten years, breeding of the coconut palm *Cocos nucifera* has made spectacular progress. To carry on the improvements still further, a large programme has been set up. This requires making precise observations on varieties, populations, and wild stands and also their descendants so that we are in a position to determine the value of individuals intended as parents in plant breeding or seed production programmes.

The recording of total nut production is easy, but the analysis of the average composition of these nuts offers greater difficulties. Whilst accurate methods have been developed for analysing the nut, after starting with procedure which were sometimes empiric, a procedure for sampling of nuts has yet to be worked out. A trial was, therefore, set up at Port Bouet (Ivory Coast) in 1970 to solve this problem, and to answer the two questions :

(i) How many nuts of a coconut palm must be analysed to characterize it with a certain accuracy ?

(ii) How many palms and how many nuts/palm must be studied to estimate the value of a population with a certain degree of precision ?

Materials and Methods

This study was carried out on two populations of Tall palms planted between 1957 and 1959, *viz.* Polynesia, a population considered to be very heterogeneous (Plot 23), and West African Tall (WAT), which is fairly homogeneous (Plot 21). Fifty trees were chosen at random in each population, and all their nuts were harvested and analysed for 3 years from July 1970 to June 1973. The harvested nuts were marked with the serial number of the palm and the rank of the bunch from which they were taken. They were stored for a month, then dehusked and split, and the endosperm was oven-dried.

Seven characters of each nut were determined : weight of whole nut, weight of husked nut, weight of husk, weight of water, weight of shell, weight of endosperm and weight of copra. These data were fed to a computer for calculating the means, variances and coefficients of variation/tree as a function of :

(a) The *duration* of sampling : 6, 12, 18, 24, 36 months; and the *method* of sampling :
fractional (1 out of 2, 5, 10 nuts),
per bunch (1 out of 2, 5, 10 nuts per bunch),
periodicity (1 nut half yearly, quarterly, 1, 2, 3, 4/harvest, corresponding to 2, 4, 6, 12 nuts, per year respectively).

(b) A combination of both the factors : duration and method of sampling.

The samples were made up by drawing lots amongst all the nuts.

Results

Table 1 gives the results covering all the nuts produced in three years in both populations.

TABLE 1. Nut composition of two coconut populations : West African Tall and Polynesia (analysis of all nuts on 50 trees for 3 years)

Weight (g)	West African Tall			Polynesia Tall		
	Mean	C.V.*	C.V.**	Mean	C.V.*	C.V.**
Nut	1106	12.8	23.1	1208	17.3	15.4
Husked nut	645	14.0	22.0	837	19.0	15.8
Husk	461	19.5	30.7	371	20.0	23.4
Shell	141	17.2	20.4	159	17.2	15.0
Water	119	24.5	48.4	184	38.3	36.4
Endosperm	385	12.5	18.0	493	16.8	14.0
Copra	216	10.8	18.9	279	16.4	15.3

*C.V. : coefficient of variation between trees.
**C.V. : coefficient of variation between nuts (mean per tree).

There is a marked difference between WAT and Polynesia for all characters, and as expected, variability between palms was greater in Polynesia. On the other hand, the nuts of a given palm were much more homogeneous in Polynesia than in WAT. In fact, the variability between palms was greater than variability within palms (between nuts) in Polynesia, whereas the opposite was observed in WAT. This means that for the same desired precision, fewer trees but more nuts/palm must be observed in WAT than in Polynesia.

Weight of water in the nut and, to a lesser degree, weight of husk had very high coefficients of variation, making these characters difficult to observe Detailed analyses of the results showed that several characters showed variations between seasons, between years, etc. which must be taken into account when working out the method of sampling. For example, weight of copra tends to increase around February/March/April at Port Bouet; during 1972-1973 WAT nuts contained about 10% more copra than in the preceding year. Variations may also result from correlation or interaction of two factors (number of nuts and weight of nuts).

Evaluation of the Palm

The attempt to determine the number of nuts that require to be analysed in order to determine the average value of a palm led us to study the coefficients of variation for different characters as a function of time and duration (Table 2).

TABLE 2. Mean of coefficients of variation per tree according to the period of observation (50 trees, all nuts)

Period	Weight of nut	Husked nut	Husk	Water	Shell	Endosperm	Copra
WEST AFRICAN TALL							
First Year	15.01	15.24	21.32	42.96	13.45	12.17	13.87
Second year	25.64	23.44	24.39	49.46	21.04	19.35	19.62
Third Year	16.81	14.54	26.60	32.15	13.28	12.38	14.64
First 2 Years	20.18	21.24	24.37	50.22	19.98	17.09	17.98
Last 2 Years	23.13	21.97	30.77	44.47	19.44	18.45	18.85
3 Years	23.11	22.04	30.69	48.38	20.36	18.03	18.88
POLYNESIA							
First Year	12.71	13.89	17.00	34.53	12.87	11.86	14.69
Second Year	14.47	15.16	19.67	33.81	13.51	13.37	14.09
Third Year	13.71	14.84	22.15	34.78	12.91	12.89	14.22
First 2 Years	14.30	15.14	19.84	35.14	13.61	13.07	14.59
Last 2 Years	15.18	15.69	23.09	35.55	13.64	13.76	14.46
3 Years	15.35	15.76	23.41	36.35	14.98	13.98	15.32

The coefficients of variation for several characters of the nuts produced in one year was smaller than that calculated for longer periods. This means that there were wide fluctuations from one year to the next and that the year could serve as the basic period for analysis of the nuts. In general, the coefficient of variation/palm for all the nuts produced in one year was less than 15% for endosperm, copra and shell (except for WAT in 1971-1972). It was close to that for nut weight and husked nut weight. Furthermore, it remained constant irrespective of the fraction sampled—1/2, 1/5, or 1/10. This value makes it easy to calculate the number of nuts required to obtain a given precision. Thus, 34-36 nuts must be analysed for error to be less than 5% and 18 nuts if it is not to exceed 7%.

If we take into account the frequency of harvesting (every two months), it seems that studying 24 nuts/palm for one year (4 nuts/harvest) is sufficient for comparing palms planted in identical conditions with a precision of 6% for the characters, husked nut, shell, endosperm, and copra, and 6-7% for nut weight. As a precaution and to offset any accidental variations, it is preferable to carry on the analyses for two years with the mean of two years giving the final result. For parents whose "true worth" is being sought, it is obviously necessary to pursue this work for several years (probably 5 or 6). Calculations based on sampling which is fractional instead of periodical also lead to the same result : the analysis of 1 nut out of 5 for two years, i.e., about 40 nuts. Either system can be adopted therefore, according to the distribution of yield throughout the year.

Evaluation of the Line or Population

In this case, the aim is to find out the minimum number of nuts which have to be observed for full knowledge of a line, a type of cross, or a population. The problem differs from the previous one in that it is not necessary to know each individual exactly in order to be able to estimate the mean for a line. For example, the study of the evolution of the mean calculated from the successive drawing of random lots of 25 trees show that the analysis of 1 nut in 5 for 2 years gives a satisfactory estimate of the mean observed. Now this comes down to a simple sampling of trees since it follows from the previous observations that each tree and its "true" value will be known already.

An attempt was then made to study the evolution of the coefficient of variation between trees as a function of the number of nuts analysed by tree and the number of trees observed (Table 3). For a given character, it is surprising to note the relative stability of the coefficient of variation according to the number of nuts analysed. However, irrespective of the number of nuts analysed, it is preferable to study as many trees as possible. This is clear in Polynesia (difference of 2-3 points between coefficients of variation for 25 and 50 trees).

Finally, the precision does not change with the increase in the number

TABLE 3. Coefficient of variation of the mean of the trees for different samplings

Population	Length	No. of trees	Shell			Endosperm			Copra		
			2 nuts/yr	6 nuts/yr	all nuts	2 nuts/yr	6 nuts/yr	all nuts	2 nuts/yr	6 nuts/yr	all nuts
West African Tall	1 yr	25	20.53	22.18	19.45	17.33	18.20	15.17	14.03	14.08	11.50
		50	21.00	19.08	18.49	17.86	15.18	14.07	15.18	12.21	11.27
	2 yrs	25	20.77	20.45	18.02	14.96	14.27	12.46	12.73	11.41	9.78
		50	19.01	18.06	17.04	14.41	13.33	12.23	13.05	11.23	10.47
	3 yrs	25	20.27	19.59	18.29	14.16	13.98	12.69	12.22	11.76	10.19
		50	18.86	17.82	17.15	14.50	13.17	12.51	13.07	11.57	10.84
Polynesia	1 yr	25	20.79		18.64	20.55		19.88	17.07		18.26
		50	18.83		16.65	18.09		16.61	15.42		15.49
	2 yrs	25	21.06		19.92	21.17		20.32	18.11		19.33
		50	18.44		17.30	19.23		17.06	17.29		16.27
	3yrs	25	20.58		19.57	21.96		20.18	19.77		19.47
		50	18.17		17.21	18.91		16.79	17.83		16.42

All nuts : for W.A.T.=40 nuts/tree×year.
for Polynesia=60 nuts/tree×year.

of years for which analyses were made from one to three years. Theoretically, therefore, a single year is enough for obtaining comparative data ; in fact, the means fluctuate annually (Table 4), so that it is necessary to continue observations for several seasons (6 years) in order to be able to estimate the 'absolute' mean.

TABLE 4. Weight of shell, endosperm and copra according to the years (50 trees, all nuts)

Period	West African Tall			Polynesia		
	Shell	Endosperm	Copra	Shell	Endosperm	Copra
First year	131	371	207	156	486	272
Seeond year	139	372	214	157	479	278
Third year	159	428	235	165	508	287

Conclusions

This study has enabled us to define relatively exact basis for sampling of nuts :

Analysis of 1 nut/harvest (6 nuts/year) on 50 trees to characterize a population or a line ;
Analysis of 4 nuts/harvest (24 nuts/year) to define a tree.

Whilst two years of observations seem sufficient when comparing material planted in identical conditions, experience shows that three years cannot lead to comparisons in absolute values. By analogy with the oil palm, we feel that analyses for 6 successive years should give sufficiently precise estimates for most nut components.

The percentage of endosperm (R=endosperm × 100/nut—water) is certainly the most important nut character for plant breeding. This was not taken up in this study. However, as this is the stablest character, the preceding conclusions can perhaps be applied to it also. However, the phenomenon of xenia can intervene for this character, as for all those connected with the endosperm. This was not taken into account in this study.

Our last comment concerns the generalization of the results discussed above, which have been obtained in relatively variable populations of Tall coconuts. These results should be even more valid for more homogeneous populations.

Acknowledgements

This study was carried out with the help of Mr. A. Bachy and Miss L. Fonchain of the I.R.H.O. Statistics Department to whom our thanks are due.

Discussions

Narasimhayya: If we take only one nut per bunch, then there will be no way of estimating the within variance to estimate the total variance of a sample estimate, as a component.

De Nuce de Lamothe: We calculate the means, variances, and variation per tree as a function of :

(1) the length of observation ;

(2) the method of sampling
fractional (1 out of 2, 5, 10,...nuts)
per bunch (1 out of 2, 5, 10,...nuts per bunch)
periodicity (1 nut half yearly, quarterly, 1, 2,...per harvest, corresponding to 2, 4, 6, 12...nuts/year respectively) ; and

(3) a combination of both factors : length and method of sampling.

All these samples were made up by drawing lots amongst all the nuts.

We are interested to know the smallest sample required to characterize a palm or a line. It happens that analysis per bunch gives no more information as a periodical observation and is much more time and work consuming.

Venkateswaran: There is a lot of variation between nuts within even each bunch. Is it not then necessary to study the variation within and between bunches to determine the sample size to be selected for the study ?

De Nuce de Lamothe : The purpose of our study was to characterize a palm and not its bunches. We feel that there is no need to study the variation within and between bunches. There is a need to accurately assess the production of palms with a minimum of physical nut analysis, i.e., with the smallest possible nut sample.

All : Only one nut is selected per bunch for sampling. We know that the performance of nuts within a bunch varies considerably. Therefore, will the selection of one nut at random per bunch for sampling give the correct data ?

De Nuce de Lamothe : The statistical analysis of our data shows that by selecting 4 nuts/harvest over 5-6 years, regardless of the number of bunches, the value of an individual palm is accurately characterized for such characters as weight of copra, albumen, shell, and of husked nut. Some observations over 1 or 2 years are sufficient to compare palms planted under the same conditions but not for getting absolute values.

One nut/harvest (i.e., 6 nuts/year) regardless of the bunches from 50 palms over a 5-6 year period characterizes within 6% accuracy a line, a population, or a type or a cross. Coefficients of variation between palms remain identical whether the sample is made up of 6 nuts or all the nuts produced by the palm.

Improvement of Dwarf Coconuts with Special Reference to Indian Dwarf Orange Palms and Their Natural Hybrids

C.A. NINAN
Department of Botany, Kerala University, Kariavattom, Trivandrum, India

Abstract

The Dwarf Orange coconuts of the west coast of India have long been known to produce a proportion of semi-Tall progenies from seeds obtained after open pollination. They are believed to be products of outcross with Talls though they can be obtained after selfing Dwarfs also. Data are presented to show that such progenies are superior to West Coast Tall palms in yield of nuts, copra content per nut, and percentage of trees in high yielding group in different populations.

Progeny row studies have revealed the existence of significant variation among individual palms in germination percentage of nuts and recovery of natural hybrids and segregants. A trend for linear increase in percentage of such seedlings with increase in seed weight was also observed. It is suggested that by selecting Dwarf seed parents for high germinability of seed nuts and high recovery of colour variants (segregants and D × T hybrids) the hybrid programme could be made more viable. Further by evolving suitable criteria for identifying legitimate hybrids in the progeny and constructing selection indices for seedling characters for picking out superior planting material among hybrids, the whole programme could be geared for improving yields of future plantations of these hybrids. Better recovery of hybrids and segregants could be obtained from mixed seed gardens of Dwarfs and Talls by discarding those Dwarf mother palms which show high failure of germination and death of young sprouts and producing a high percentage of pure Dwarf seedlings. In situations where elaborate operations like emasculation and assisted or deliberate pollination with Tall pollen are not possible, the recovery of hybrids and segregants could be increased by discarding nuts with lower seed weights.

Dwarf coconuts occur in most coconut growing countries of the world. The emphasis in coconut breeding throughout the world is presently centred around the Dwarfs. The main hope of the coconut breeder in his efforts in breeding for improvement of yield, and perhaps also in his battle against diseases of unknown etiology, seems to lie in the efficient manipulation of the Dwarf germplasm. Its potentialities in coconut improvement are discussed in this paper with special reference to the Dwarf Orange coconuts of India.

Indian Dwarfs and their Natural Hybrids

At least two distinct forms of Dwarf coconuts occur in the west coast of India, Dwarf Orange (DO) and Dwarf Green (DG). They differ from each other in a number of well defined characters like stature, colour, size and shape of fruits, copra, and oil content. Rao and Koyamu (1955) observed that 95% of the natural progenies of DG and 80% of those of DO bred true to type. The off-type progenies of Dwarfs are believed to be the result of outcross with Talls.

A comparison of the off-type progenies of DO with those of DG, the reciprocal T×D hybrids, West Coast Talls (WCT) and Dwarf parental types in yield traits like spathe and female flower production, yield of nuts, and estimated copra yields indicates that the open-pollinated progenies of DO are superior to all others for all these traits (Table 1).

TABLE 1. Performance of D×T, T×D, Tall and Dwarf palms*

Variety	Mean no. of spathes	Mean no. of female flowers	Mean yield of nuts	Mean copra content/ nut (gm)	Yield of copra/ palm/ year (kg)
DO×T (Natural hybrid)	13.2	352.4	118.4	207.2	24.4
DG×T (Natural hybrid)	11.4	250.2	69.0	182.3	12.3
T×DG	12.3	375.3	107.0	194.1	20.4
Tall	11.5	251.2	86.7	177.6	15.9
Dwarf Green	8.0	232.7	42.7	40.0	1.6
Dwarf Orange	7.9	164.9	53.6	161.5	8.7

*From Ninan and Satyabalan (1964).

Analysis of yield

Data on yield of nuts and total copra yields were analysed in 8 high yielding trees of DO×T (natural hybrids), 10 WCTs, and 3T×DG palms (Table 2). The hybrids gave significantly higher yields than WCT. Though the number of nuts of DO×T was higher than that of T×DG, the difference between them was not significant.

To check whether the variation in copra yield among the varieties was due to variation in yield of nuts, a covariance analysis was done with the number of nuts as the commitment variate. Here also, the interaction was significant showing that variation in yield among months, and the variation in the yield of copra adjusted for number of nuts were significantly different among the three varieties, but not among different months.

TABLE 2. Yield of nuts and copra in D×T, T×D and WCT

Variety	Mean monthly yield of nuts (number)	Mean monthly yield of copra (kg)
D×T	11.0	2.32
T×D	10.3	2.06
WCT	6.7	1.10

Frequency Distribution of Yield Classes

A comparison of the frequency distribution of different yield classes in WCTs and DO×T hybrids at Kasargod and in D×T hybrids from Sri Lanka shows that while in WCTs, the maximum frequency of trees (36.9%) falls in the yield group 41-60 nuts, among the D×T palms, the highest frequency of trees (24.5% in Sri Lanka and 44.4% in India) falls in the yield class 101-120 nuts/palm/year (Table 3).

TABLE 3. Frequency distribution for yield of D×T hybrids and WCT palms

Yield of nuts/palm/year	Percentage of palms in each yield class		
	West Coast Talls*	D×T hybrid** (Sri Lanka) (1965—68)	D×T hybrid† (India)
Upto 20	8.3	1.1	—
21-40	25.2	1.1	—
41-60	*36.6*	8.9	—
61-80	21.2	12.2	—
81-100	7.1	23.3	11.1
101-120	1.2	*24.5*	*44.4*
121-140	0.3	18.9	33.4
141-160	0.1	6.7	11.1
161 and over	—	3.3	—
Mean yield/palm/year	50.4 (4500 palms at Kasargod)	99 (90 palms)	118.4 (Kasargod 9 palms)
Percentage of palms —yielding more than 100 nuts annually	1.6	53.4	88.9

**From* Ninan, Pankajakshan and Menon, 1964.

***From* Manthriratna, 1971.

†*From* Ninan and Satyabalan, 1964.

Selection of seed parents

The natural hybrids of DO are thus characterized by high copra content/nut, high yield, and much higher frequencies of palms in the high yield group as compared to the local Tall variety. They are also superior to most of the introductions tested at Kasaragod (Ninan *et al.*, 1961). However, individual palms show considerable variation among themselves for various yield traits (Table 4). This will permit carrying out selection in them for further improving their quality and performance.

TABLE 4. Variation in yield of copra among high yielding natural hybrids of the DO with WCT having same yield of nuts

Sl. no.	Tree no.	Yield of nuts/yr	Yield of copra/palm/year (kg)	Yield of copra/palm in WCT having same yield of nuts (kg)
1	O.C.I.	160.2	31.2	22.90
2	XI/1	131.7	28.4	21.20
3	XI/2	106.7	21.1	15.09
4	XI/3	105.8	22.6	15.01
5	XI/4	122.2	26.0	19.89
6	XI/15	129.1	23.1	21.12
7	XI/68	114.5	26.5	18.79
8	XI/69	94.3	20.4	15.04
9	XI/76	101.5	20.7	18.46
	Average	118.4	24.4	18.61

Furthermore, the occurrence of seedlings that look like pure Dwarf seedlings, natural hybrids (resulting from natural crosses with Talls) and hybrid-like segregants in open-pollinated progenies of Dwarfs also makes it necessary to select seed parents that give higher percentages of hybrids and hybrid-like progenies.

Natural hybrids arising from open-pollination

Progenies of individual Dwarf palms show considerable variation in the frequency of natural hybrids (Table 5). Hence, it may be possible to select seed parents giving a higher percentage of natural hybrids. This is a relatively simple exercise requiring only progeny row evaluation in the nursery.

Hybrid-like progenies arising from selfing

We know that deliberate selfing of DO palms also yields progenies resembling DO × T hybrids. This makes it necessary to distinguish between real DO × T hybrids obtained from deliberate crossing and hybrid-like segregants observed among progenies following selfing. If the performance of segregants is encouraging, as has been reported by Bavappa (personal communication), it is possible that more uniform and high yielding

TABLE 5. Percentage of pure Dwarfs and hybrids recovered from natural, self, and cross-fertilized nuts of D$\hat{O}$ belonging to different populations

Source	Trees	No. of nuts sown	Percentage of		
			Ungerminated nuts and dead sprouts	Dwarf seedlings	Seedlings showing colour variation
Progeny rows	No.				
Karthikapally	I	41	14.0	68.3	17.7
	II	8	0.0	25.0	75.0
	III	34	38.3	50.0	11.7
	IV	46	28.4	56.4	15.2
	V	41	41.6	53.6	4.8
	VI	51	3.9	86.3	9.8
	VII	12	16.6	66.7	16.7
	VIII	20	10.0	75.0	15.0
		253	**21.7**	**64.0**	**14.3**
Bulked nuts					
Badagara	11 trees	265	60.7	23.1	16.2
Badagara	10 trees	300	50.7	30.0	19.3
Kasaragod	*D×T cross	209	65.00	16.6	18.1
Nileshwar	*D×T cross	162	21.00	12.3	62.0
Kasaragod	†Dwarf Orange (Self)	89	19.1	46.1	34.8

* Data from ARS, Nileshwar.
† Ninan and Satyabalan, 1964.

progenies could be derived by selfing. The later generations of such palms should also be expected to show less segregation than those of real hybrids. Also, Dwarf palms giving maximum percentages of hybrid-like progenies upon selfing should be believed to possess greater heterozygosity and their crosses with selected Talls could be expected to produce better D×T hybrids.

D×T hybrids

Hybrids of Dwarfs with Talls (as male) studied in earlier years in India, Sri Lanka, and Jamaica have not given the expected results due to high failure of germination of hybrid seeds and high proportions of progenies turning out to be dwarfish (Liyanage, 1956; Ninan and Satyabalan, 1964; Whitehead, personal communication). The yield of some D×T hybrids studied at Nileshwar has also been reported to be poorer

than that of the Dwarf parental type (Patel, 1937). Such hybrids tested at Kasaragod gave comparable performance as the natural hybrids (Satyabalan, 1976); Data presented in Table 5 again reveal that the high failure of seed nut germination reported in earlier years may have been the result of long storage of seed nuts prior to sowing along with those of Tall variety, as has been the earlier practice. By sowing the seed nuts soon after harvest and in a horizontal position with proper shading and watering, germination upto 77%, and 60% recovery of hybrids have been obtained by the Kerala State Agriculture Department. The above work has also shown that a few trees tend to produce mostly dwarfish seedlings despite assisted pollination. Eliminating such trees and selecting those yielding maximum percentage of hybrids could make the hybrid programme more economic.

Seedling selection

In situations where it is not easy to follow the progeny (seedling) performance of individual trees, better recovery of hybrids could perhaps be obtained by selecting nuts for higher seed weight (Table 6). High seed weight may either be due to the inherent attributes of certain trees, or it may be the result of hybrid vigour, as Haldane (1958) had suggested. If it is the former, it should be possible to identify such trees producing heavier seeds for use as seed parents, and if the latter is the case, the seeds could be selected from bulked nuts for weight.

TABLE 6. Percentage of natural hybrids/segregants in relation to seed-weights in DO

Weight of unhusked nuts (g)	No. of nuts sown	No. of ungerminated nuts and dead sprouts	No. of dwarf seedlings	No. of hybrids/ segregants	Percentage of hybrids/ segregants
450-500	11	5	5	1	9.0
501-550	13	7	6	0	0
551-600	7	2	4	1	14.3
601-650	27	11	13	3	11.1
651-700	45	19	18	8	17.8
701-750	52	23	20	9	17.3
751-800	46	26	11	9	19.6
801-850	26	18	3	5	19.2
851-900	29	17	4	8	27.6
901-950	12	6	1	5	41.7
951-1000	11	8	—	3	27.3
1001-1050	13	6	3	4	30.8
1051-1100	8	4	2	2	25.0

Xenia

Ninan *et al.* (1963) have reported that the male parent exerts a definite influence on copra content of seeds derived from cross-fertilization. They obtained significantly higher copra weights in Laccadive Small and Laccadive Micro when pollinated with varieties like Kappadam having large-sized nuts. Rognon and de Lamothe (this symposium) have also reported xenia effect in Red Dwarf coconuts of Ivory Coast.

Seeding selection: D×T hybrids and hybrid-like progenies arising from selfing of DO show the same range of colour variation exhibiting mostly a brick or bronze colour. A low proportion of seedlings show shades of green colour. The colour marker provided a reliable proof of hybridization.

Some Suggestions

Despite the apparent phenotypic uniformity of DO palms (as perhaps in many other Dwarf varieties also), varying degrees of genetic diversity are concealed in individual trees. Some palms are also completely homozygous. Others produce mostly Dwarf progenies even after crossing with Talls. This necessitates adoption of special breeding techniques for improving the yield of their hybrid progenies and hybrid-like segregants. Quite possibly, the off-type progenies of certain trees may be mostly high yielding (prepotent), or certain combinations of Dwarfs and Talls may produce uniformly high yielding hybrids (combining ability). This has to be verified from future experiments involving evaluation of self and cross (D×T) progenies derived from the same Dwarf mother tree. It may be also possible to fix prepotency by selfing. Crosses of Dwarfs showing maximum heterozygosity with known prepotent Talls could also be expected to give superior hybrids. Crossing of known homozygous Dwarfs with inbred Talls might help in the exploitation of hybrid vigour in D×T crosses. Homozygous Dwarfs could also employed for identifying male transmitters among Tall palms (Harland, 1957).

The breeding potential of Dwarfs no doubt needs fuller exploitation on the lines suggested here and possibly also for isolating lines resistant to Kerala wilt. Critical studies of F_2 progenies of DO×T and DG×T hybrids or crosses of DO×T with DGs might be of value in the latter direction, especially since the DGs of India though uneconomic for commercial cultivation show maximum field tolerance (over 90%) to Kerala wilt (CPCRI Ann. Rept., 1972). It is time that coconut breeders resort to recombination breeding in a systematic way using Tall and Dwarf germplasm.

References

Central Plantation Crops Research Institute, (1972). *In* Annual Report for 1971. C.P.C.R.I. Kasaragod, Kerala.

Haldane, J.B.S. (1958). Suggestions for research on coconuts. *Indian Coconut J.* **12** : 1-9.

Harland, S.C. (1957). The improvement of the coconut palm by breeding and selection. Bull. No. 15 : *Coconut Res. Inst.*, Sri Lanka.

Liyanage, D.V. (1956). Intra-specific hybrids in coconut. Bull. No. 7, *Coconut Res. Inst.*, Sri Lanka.

Manthriratna, M.A.P. (1971). Contributor's Report, (Ceylon) Coconut Breeding, 1971. *The Plant News* (Special Issue), FAO, Rome.

Ninan, C.A. and Satyabalan, K. (1964). A study of natural self and cross (Dwarf× Tall) progenies of Dwarf coconuts of the West Coast of India and its bearing on the genetics of the Dwarfs and the putative hybridity of their off-type progenies. *Caryologia* **17** : 77-91.

Ninan, C. A., Pankajakshan, A.S. and Menon, R.M. (1964). Study of yield distribution and copra production in West Coast Tall coconuts. *Indian Coconut J.* **17** : 62-68.

Ninan, C.A., Pankajakshan, A.S. and Radhakrishnan, V. (1962). Preliminary observations on the influence of pollen parent on copra content in coconuts. *Indian Coconut J.* **16** : 174-179.

Ninan, C.A., Pankajakshan, A.S., Satyabalan, K., and Gopinath, P. (1961). A comparison of the performance of some cultivars of coconuts in the Central Coconut Research Station, Kasaragod and Agricultural Research Station, Nileshwar (Pilicode). *Indian Coconut J.* **15** : 12-19.

Patel, J.S. (1937). Coconut breeding. *Proc. Asso. Econ. Biol.*, Coimbatore **5** : 1-16.

Rao, M.B.S. and Koyamu, K. (1955). The dwarf coconuts. *Indian Coconut J.* **8** 106-112.

Rognon, F. and de Lamothe, M. (1976). Xenia and combining ability in the coconut palm. *This Symposium.*

Satyabalan, K. (1976). Coconut hybrids. *Indian Farming.* **27** : 13-16.

Thampan, P.K. and Markose, V.T. (1973). The Dwarf Coconut. Directorate of Coconut Development, Ernakulam.

Xenia and Combining Ability in Coconut

F. ROGNON and M. DE NUCE DE LAMOTHE
France

Abstract

The influence of pollen parent on endosperm characters was studied. Forty-five Cameroon Red Dwarf mother trees were divided into three groups and fertilized with pollens of (1) Cameroon Red Dwarf (Control) ; (2) West African Tall (Copra/nut : 200-205 g) ; and (3) Tahiti Tall (Copra/nut : 311 g).

The copra/nut obtained from the three crosses were (1) Control 220 g ; (2) 258 g ; and (3) 260 g. These results show a very significant effect on the pollen parent on copra/nuts. The results of the second cross suggest a possible effect of heterosis.

Amongst the other characters observed, the relationship $R = \frac{\text{endosperm} \times 100}{\text{husked fruit} - \text{water}}$ was very significantly above the control in the latter. It is probably the same as for copra oil content.

Finally, the shell weight was also significantly more than that of the control in the second and third crosses, but as the shell is a maternal tissue, the phenomenon remains to be explained.

Introduction

In the coconut, the endosperm is the main part of real economic importance. The existence of a direct influence of the genotype of the pollen on the endosperm, as already suggested by Pankajakshan (1967), is therefore of undoubted interest. At Port Bouet, the variations recorded in the copra/nut values of palms of the same progeny population, but planted in different pollen environments, suggested that such an effect of xenia might be responsible for it. A trial was therefore set up in 1974 to appraise the effect of this phenomenon on yield and also in genetic studies.

Materials and Methods

1. *Planting material.* Cameroon Red Dwarf was used as the mother tree because of its good yield after artificial pollination (4-5 nuts/bunch on an average against 2-3 for Yellow Dwarf or Green Dwarf). The yield of copra/nut of Cameroon Red Dwarf × Cameroon Red Dwarf was taken

as the control value.

Three types were chosen as male parents. Of these, Tahiti Tall (TT) is characterised by a large copra/nut and a high value of $R = \frac{\text{endosperm} \times 100}{\text{fruit} - \text{water}}$, but the populations are usually fairly heterogeneous. For the needs of the trial, 15 trees with a high copra/nut (mean=331 g, SD=26.5) were used.

West African Tall (WAT) was introduced into West Africa in the 17th century. It produces a large number of nuts/tree, but has a relatively low copra/nut of only 200-205 g. Cameroon Red Dwarf (CRD) has a fairly small copra/nut content like all the Dwarfs, but shows seasonal variations which can be considerable. The palms for the trial were chosen on their appearance. No CRD was used as both mother tree and pollinator to ensure that there was no selfing.

2. *Methods.* All the nuts in the trial were produced by artificial pollination using the usual IRHO technique (which will be described in an article to be published shortly in *Oleagineux*).

To make sure that pollinations were properly carried out and the crosses were legitimate, blank pollinations were done ; they gave no nuts. Blank pollinations are carried in exactly the same way as normal pollinations, but no pollen is applied. If the inflorescence has been properly isolated and all handling has been correct, there can be no fertilization and no nuts are formed.

The nuts were harvested about 11 months after pollination. After three weeks storage, the following measurements of each nut were taken : weight of whole nut ; of husked fruit ; of husked fruit with water removed ; of shell ; and of copra after oven drying.

The copra oven uses hot air produced by combustion of husks. The humidity of copra at the time of weighing was 5-6%. The oil contents were measured on soxhlet.

3. *Crossing Plan.* Forty-five Cameroon Red Dwarf palms were chosen as mother trees and they were divided into 3 groups of 15 palms, A, B and C drawn by lots. Within each group, the trees were pollinated three times by 15 male parents of each type according to a crossing plan (cf., Table 1). Each mother palm had 3 inflorescences pollinated by CRD, 3 by TT, and 3 by WAT, i.e., for the whole trial $45 \times 3 \times 3 = 405$ artificial pollinations were carried out.

The data for each nut were worked out individually, but only the mean values/pollination were used for the interpretation of results. This avoids exaggerating the importance of the pollinations which produced a larger number of nuts.

For statistical analysis, each replication in each group was considered as a block: A-1, B-1, C-1, A-2, etc. up to O blocks in all. The results given here concern six blocks only (upto C-6), as the nuts of the third replication had not been completely harvested at the time of preparing

TABLE 1. Crossing plan

Mother trees	Inflorescence number								
	(Replication 1)			(Replication 2)			(Replication 3)		
	1	2	3	4	5	6	7	8	9
Group A	CRD*	WAT	TT	WAT	CRD	TT	CRD	WAT	TT
Group B	TT**	CRD	WAT	CRD	TT	WAT	TT	CRD	WAT
Group C	WAT***	TT	CRD	TT	WAT	CRD	WAT	TT	CRD

*CRD=Inflorescence fertilized by Cameroon Red Dwarf pollen.
**TT =Inflorescence fertilized by Tahiti Tall pollen.
***WAT=Inflorescence fertilized by West African Tall pollen.

this paper. The trial started in December 1974, and the last nuts should be harvested in October-November, 1976.

Results and Discussion

Table 2 gives the values obtained for mean copra/nut. The copra of the nuts fertilized by WAT or TT pollen is very much superior to that obtained by pollinating with CRD (a very highly significant difference at 1%). The difference between WAT and TT pollen was not significant.

TABLE 2. Effect of pollen parent on yield of copra/nut (in g) with Cameroon Red Dwarf as mother palms

Blocks	Type of pollen used		
	Cameroon Red Dwarf	West African Tall	Tahiti Tall
1	212	260	265
2	212	249	255
3	227	254	257
4	221	265	262
5	224	263	259
6	222	258	264
Mean	220	258***	260***
%	100	117	118

LSD at 1%=5.2, at 5%=2.5. CV=1.9%.

Table 3 shows the homogeneity of the mean number of nuts/pollination: the negative correlation normally found between copra/nut and number of nuts/bunch cannot, therefore, explain the differences observed in Table 2. A phenomenon of xenia seems to be confirmed here.

Table 4 gives the shell weights observed of the nuts in trial. Significant differences at 1% level were noted in the same way as for copra/nut. It is surprising to find an influence of pollen on shell weight when this (endocarp) is a purely maternal tissue. This may be an effect of metaxenia, but this is still to be confirmed. The quantity of husk/nut does not seem to be affected by the type of pollen (Table 5).

TABLE 3. Effect of pollen parent on number of nuts/pollination with Cameroon Red Dwarf as mother palms

	Type of pollen used		
	Cameroon Red Dwarf	West African Tall	Tahiti Tall
Numer of nuts harvested	352	360	363
Number of nuts/ pollination	4.7	4.7	4.5*

*Not significant

TABLE 4. Effect of pollen parent on weight of shell/nut (in g) with Cameroon Red Dwarf as mother palms

	Type of pollen used		
Blocks	Cameroon Red Dwarf	West African Tall	Tahiti Tall
1	175	185	186
2	170	179	182
3	177	180	184
4	173	187	187
5	170	184	180
6	185	183	189
Mean	175	183	185
%	100	105	106

The relationship R (Table 5) increases in a highly significant manner while comparing CRD with WAT and TT pollens. This increase indicates an improved yield of endosperm in the nut. The partial results of the third replication (Blocks 7, 8, and 9) seem to confirm those of the first two.

A few determinations of oil content were made and it appears, subject to confirmation, that the effect of xenia is seen for this character also as for copra weight (Table 6).

TABLE 5. Effect of pollen parent on weight of husk/nut (in g) and relationship R with Cameroon Red Dwarf mother palms

	Type of pollen used		
	Cameroon Red Dwarf	West African Tall	Tahiti Tall
Shell : Mean	285	297	298(1)
%	100	104	105
$R = \frac{\text{Endosperm} \times 100}{\text{Fruit} - \text{water}}$			
Mean	48.2	50.6	50.9(2)
%	100	105	106

(1) Not significant.
(2) LSD 1%=1.06.

TABLE 6. Variation in oil content in the different crosses

	CRD×CRD	CRD×WAT	CRD×TT
Percentage of oil in dried endosperm	65.7	69.5	69.8

By fertilizing Cameroon Red Dwarf with TT or WAT pollen, instead of with its own pollen, a considerable increase in oil yield was obtained: 26% with TT pollen and 24% with WAT. Whilst the triploid constitution of the endosperm nuclei (Henry, 1957) explains this influence of the pollen on the development of endosperm cells, the small differences between the effects of TT and WAT pollen, on the other hand, is unexpected when the copra/nut content of the two varieties are considered (*see* Material and Methods 1. Planting Material). In effect, the fruit of Cameroon Red Dwarf fertilized by TT pollen does indeed give a copra intermediary to the two parents, but when the pollen is of WAT, the copra obtained is much more than that of either parent. This superiority may be explained by a better combining ability between the Cameroon Red Dwarf and the WAT pollen (additivity and non-additivity).

If we can link this ability of two varieties to combine to give a large copra in the seed, to the productivity of the hybrid arising from that seed a big step forward in coconut breeding will have been taken. It will be possible to eliminate all the least productive crosses very rapidly (one year after pollination) and test in the field only those which are likely to give high yield. The IRHO has undertaken a large experimental programme to verify this hypothesis.

Xenia has other implications, for examp. in the determination of the exact copra/nut yield of cross pollinating pa. ts (or lines planted in the neighbourhood of coconuts of a different type). f the risks of contamination are great, it may be necessary to check t. value in better conditions of isolation. Finally, in the present state of o r knowledge, the use of the effect of xenia to increase production hardly eems profitable. It would be quite another thing if a male sterility factor s discovered since this could do away with the need for emasculations.

Acknowledgements

The authors thank Messrs S. Adoko and M. Legba for their help in carrying out this trial.

References

Pankajakshan, A.S. (1967). Influence of pollen parent on copra content in coconuts (*Cocos nucifera* L.). *Oleagineux* **22**: 299-300.

Fremond, Y. and De Nuce De Lamothe M. (1971). Caracteristiques et production du cocotier hybride 'Nain Jaune de Malaisie' x 'Grand Ouest African'. *Oleaginux* **26** : 459-464.

Henry P. (1957) Recherches sur la croissance et le developpement chez *Elaeis guineensis* Jacq. et chez le *Cocos nucifera* L. Thesis, Faculty of Science, University of Paris.

Coconut Improvement by Selection and Breeding— A Review in the Light of Recent Findings

K.V.A. BAVAPPA and C. K. SUKUMARAN
Central Plantation Crops Research Institute, Kasaragod 670124, Kerala, India

Abstract

The major breeding objectives have been identified as higher yield of oil per unit area of coconut plantation and resistance/tolerance to serious diseases such as root (wilt), 'thattipakka', and stem bleeding.

The breeding systems vary widely in Tall and Dwarf cultivars. The advantages of selecting the best 10% of palms in a given population as mother trees for seed nut collection and breeding purposes have been indicated. Studies on the relationship between yield of nuts, copra content per nut, total yield of copra/palm, and yield of oil/palm showed that in West Coast Tall, the mean copra content/nut, though negatively correlated with yield, does not affect annual outturn of copra/palm, the threshold value being 162.6 nuts, and that the yield of oil/palm and yield of nuts were significantly and positively correlated. The necessity for applying selection pressure on weight of copra/nut and oil percentage in addition to number of nuts has been indicated keeping in view the variability and heritability data available for these characters.

Selfing of West Coast Tall palms confirmed the earlier observation that it is heterozygous for height while Chowghat Dwarf Orange variety is heterozygous for colour, vigour, and stature. Palms which breed true for these characters are also present in the population. In addition to the wide variations observed in the percentage of heterozygotes for vigour realised by selfing or under open pollination of Dwarf Orange or under specific cross combinations with Tall, the progenies were also observed to segregate for colour.

Further experiments are to be taken up for a better understanding of the genetic make up of the Tall and Dwarf varieties. The different approaches that may be pursued for improving their genetic base and the possibilities of realising a higher percentage of hybrids in the Dwarf × Tall crosses are discussed in the light of available data.

Introduction

Charles (1961) made the last comprehensive review on selection and breeding of the coconut palm. However, certain aspects of crop improvement have been subsequently discussed by a number of workers (Ninan

and Satyabalan, 1964 ; Satyabalan, Ratnam, and Kunjan, 1970 ; Satyabalan, Ratnam, and Menon, 1968 ; Bavappa, Sukumaran, and Mathew, 1973 ; Bavappa and Nampoothiri, 1974 ; Liyanage, 1964 ; Nambiar and Nambiar, 1970 ; Satyabalan and Nambiar, 1968 ; Whitehead, 1968). Considerable data have been gathered in the last five years at the Central Plantation Crops Research Institute on various aspects of coconut breeding and a number of programmes have been developed based on theoretical principles. The present paper reports the results of breeding experiments conducted during this period and attempts to suggest certain approaches for future work.

Breeding Objectives

Though it is generally assumed that the primary aim of coconut breeding is to increase yield of copra, in regions affected by serious diseases such as the root (wilt) disease in India, kadang kadang in the Philippines, lethal yellowing in Jamaica, etc., breeding for disease resistance has become as important as yield improvement itself. Since oil is the end product, it will be necessary to keep the yield of oil per unit area (tonnes/ha) as the criterion rather than number of nuts or copra tree/ha as is being done now. The relative importance of various characters in achieving these objectives is discussed in the concerned sections.

Floral Biology and Breeding Systems

Propagation of coconut continues to be exclusively by seed though in the light of the success obtained in the vegetative propagation of oil palm (Smith and Thomas, 1973 ; Rabechault and Cas, 1974), production of coconut plantlets does not seem to be far from reality. Even if this is achieved, coconut improvement programmes through breeding will have to be continued for obvious reasons. A correct understanding of the breeding mechanism of the coconut varieties is, therefore, essential.

Patel (1938) reviewed the floral biology as it related to the West Coast Tall (WCT) variety. He reported only interspadix overlapping which was to the extent of 22%. It is now observed that there is intraspadix overlapping of male and female phases in WCT in about 10% of the bunches. Jack and Sands (1922) in their study of the three Malayan Dwarfs (Ivory yellow, Red and Green) observed that the flowers were as a rule self-pollinated. Whitehead (1965) observed 80% overlapping in a large group of Malayan Dwarfs. Rao and Koyamu (1955), while describing the Dwarf Green and Dwarf Orange types, observed that the former had "maximum purity" owing to high selfing possibility, while the latter had 80% "purity" as a consequence of both self and cross fertilization. However, no detailed study of the breeding system, taking into account the inter and intra-spadix overlapping, seems to have been made in the different coconut cultivars. Such studies on three Tall cultivars (West

Coast Tall, Laccadive Ordinary, and Philippines) and five Dwarfs (Dwarf Green and Orange of India, Dwarf Orange, Yellow and Green from Kulasekharam—reported to be Malayan Dwarfs introduced via Sri Lanka) have shown that overlapping of male and female phases do occur in the above cultivars to varying extents (Table 1). In this, both inter- and intra-spadix overlapping have been transformed into a scale (0—1.00) by dividing the total number of days overlapping by the duration of female phase.

TABLE 1. Inter- and intra-spadix overlapping of male and female phase in eight coconut cultivars (obtained by dividing the total number of days of overlapping male and female phases by the duration of the female phase)

Cultivar	No. of palms observed	Total overlapping*	
		Mean	Range
West Coast Tall	20	0.15	0.04-0.22
Laccadive	10	0.21	0.00-0.35
Philippines	10	0.35	0.10-0.50
Chowghat Dwarf Orange	21	0.66	0.37-0.91
Chowghat Dwarf Green	10	1.00	1.00
Kulasekharam Dwarf Orange	10	0.97	0.93-1.00
Kulasekharam Dwarf Green	12	0.25	0.03-0.51
Kulasekharam Dwarf Yellow	10	0.96	0.92-1.00

*0.00=No overlapping ; 1.00=Complete overlapping.

In a cross between Malayan Dwarf (Red) and Niu Leka, Whitehead (1966) observed that the flowering phases overlapped in the F_1 as in the case of the Dwarf parent. Taking overlapping as a measure of selfing, it may be observed that the highest selfing possibility exists in Chowghat Dwarf Green followed by Kulasekharam Dwarf Orange and Kulasekharam Dwarf Yellow, and the lowest in West Coast Tall and Loccadive Ordinary. It is, therefore, obvious that the breeding system is specific to a cultivar and will have to be determined separately.

Mother Palm Selection

It is generally assumed that selection of mother palm for high yield is ineffective due to its low heritability (Charles, 1961). Estimates of heritability for yield worked out subsequently have shown that it is about 0.5 (Liyanage and Sakai, 1960 ; Nambiar and Nambiar, 1970). It has also been shown that choice of mother palms with high yield either for crossing purposes or for progeny testing appears to be reliable. Of the two methods of mother palm selection, 10% selection method and on the

basis of mean yield of 80 or more nuts annually, Pankajakshan, George, and Marar (1963) found that selecting the best 10% of the palms was more helpful in spotting out genetically superior palms. They also showed that in the absence of yield data for larger number of years, cent per cent efficiency could be obtained even with four years data, if the selection was restricted to the best 5% of the trees. Arasu (1972) obtained more or less similar results in Malaysia where seeds from mother palm selected at the rate of about 8% of the population on visual criteria showed superior performance in flowering. From the variance component analysis of characters influencing productivity in six yield groups, Nambiar and Nambiar (1970) saw that there was substantial additive genetic variation for yield and other associated characters like number of female flowers and percentage set. They also saw that in crossing programmes, mother palms from high yielding groups gave progenies with better performance. Thus selection of the best 10% palms in a given population depending on the number of years for which yield data are available as mother palms should be followed as a matter of routine and seed nut collection strictly limited to such identified trees. Though the advantage of using such mother palms in hybrid vigour exploitation involving Tall and Dwarf parents is not yet known, they can be expected to perform better than others as parents in hybrid seed production as well. A similar "stepladder" breeding procedure has been suggested by Joshi and Dhawan (1965).

At present, selection of mother palms is largely based on the number of nuts, the standard being 80 or more nuts producing a minimum of 12 kg copra per palm per year. Heritability for yield of nuts has been estimated to be about 50%, whereas that for mean weight of copra per nut is 67% (Liyanage and Sakai, 1960). The total out-turn of oil has not so far been taken into consideration in selecting mother palms. Studies on the relationship between yield of nuts, copra content/nut, total yield of copra/palm, and yield of oil/palm in 108 WCT palms, have shown that mean yield of nut is significantly and positively correlated with both annual out-turn of copra and oil, whereas with mean copra content/nut, the relationship was negative and significant. The percentage of oil in copra was not significantly related to yield of nuts (Table 2).

TABLE 2. Correlation of yield of nuts with copra and oil

Components	Coefficient of correlation
Mean copra content per nut	−0.2671
Annual out-turn of copra per palm	0.5608
Percentage oil in copra	−0.0071
Annual out-turn of oil	0.5634

The mean copra content/nut was found to decrease with increase in yield of nuts, but the annual out-turn of copra/palm was not seen to decline. By fitting a second degree equation to the data, the threshold value was found to be as high as 162.6 nuts/palm, showing thereby that selection of mother palms on the basis of yield of nuts can help to increase the out-turn of copra. Similar relationship was found to exist for yield of nuts and annual out-turn of oil also, with the threshold value for yield as 163.8 nuts/palm/year. Even though the mean copra content/nut is negatively correlated with number of nuts, in view of a high threshold value and higher heritability of the former, it may be advantageous to apply selection pressure for both the number of nuts and mean weight of copra. Due consideration in selection for oil percentage, which is independent of yield of nuts, in spite of its relatively narrow variability (68.9—74.6%) may also prove useful. It may be advantageous to study the heritability of this character.

Effect of Inbreeding

Bavappa, Sukumaran, and Mathew (1972) have shown that both Dwarf Green and West Coast Tall (WCT) are heterozygous for height, and depending upon the extent of heterozygosity of the parents involved in a cross, segregation pattern of F_1 population would vary and suggested elaborate breeding experiments to assess the genetic variability in both Talls and Dwarfs for efficient exploitation of hybrid vigour. On the basis of the observation in the open pollinated progenies of WCT, parents heterozygous for stature were identified. They were selfed along with Chowghat Dwarf Orange (CDO).

Out of five WCT parents which had not segregated for dwarfness under open pollinated conditions, three segregated on selfing. The percentage of Dwarf segregants was, however, low (Table 3). Two parents bred true. At the same time, the percentage of Dwarfs obtained was as high as 48 in parents which had segregated under open pollination.

The growth measurements of Tall and Dwarf segregants (Table 4) show that the Dwarfs have smaller number of leaves, less girth, and only about half the height of Talls generally, and Dwarfs have a faster rate of leaf production. At the age of one year, the latter have about two leaves more than the Talls. However, the Dwarf segregants of WCT had less leaves. They also showed inconsistency in the early splitting of leaves unlike the normal Dwarfs. A detailed study of these Dwarf segregants alone can throw further light on their bearing habit, nut characteristics, etc.

The CDO on selfing gave much wider variability (Table 5). Out of the 13 palms, four gave only Dwarfs, while the remaining nine palms gave Dwarf plants and heterozygotes of different colour and stature in varying proportions. Based on colour and vigour, the population could be classified into three groups, viz., (1) Dwarfs with orange (parental) colour,

TABLE 3. Segregation pattern in S_1 progenies of West Coast Tall

Parent	Total seedlings	Dwarf	Inter-mediate	Tall	Percen-tage of Dwarf segre-gants	Percentage of Dwarfs under open pollination*
			(a) Nonsegregating under open pollination			
2/40	7	1	0	6	14.2	Nil
40/414	20	0	0	20	0	0
41/546	7	1	0	6	14.2	0
275/869	16	1	0	15	6.2	0
39.3B/174	1	0	0	1	0	0
			(b) Segregating under open pollination			
41/407	10	4	0	6	40.0	8.3
39.3B/531	27	13	0	14	48.0	10.2
31.3B/538	11	3	2	6	27.2	5.4
40/520	12	3	0	9	25.0	2.3
275/924	13	5	2	6	38.4	3.0

* Data from Bavappa *et al.* (1973).

TABLE 4. Growth measurements in S_1 segregants of West Coast Tall

Variety	No. studied	No. of leaves		Girth (cm)		Height (cm)	
		Mean	C.V. %	Mean	C.V. %	Mean	C.V. %
Tall	112	5.3	18.7	11.0	16.4	128.2	20.9
Dwarf	32	4.7	23.9	8.4	26.1	76.6	26.5

(2) tall vigorous plants with parental colour, and (3) tall vigorous plants with brownish green colour (Table 6). The growth measurements of Dwarfs were different from those of others (Table 6). The CDO is thus heterozygous for colour and growth characteristics.

Only one report is available about the different types of segregants that are realised on selfing CDO (Ninan and Satyabalan, 1964). They observed two types, 'natural off types' and 'pure Dwarfs'. The present study showed three types of segregants, viz., dwarf orange, brownish green and orange heterozygous segregants were obtained from CDO in varing proportions (Table 6).

On the basis of "selfing possibility" and with limited data then available Rao and Koyamu (1956) indicated that CDO was 80% pure. Harland (1957) suggested that CDO might be used to identify prepotent palms and

TABLE 5. Segregation in S_1 progenies of Chowghat Dwarf Orange

Parent	No. of nuts sown	No. of seedlings obtained	Percentage of plants raised		
			Dwarf Orange	Heterozygous segregants	
				Brownish green	Orange
39.3B/647	25	24	83.3	0	16.7
EB/55	25	11	100.0	0	0
EB/57	7	6	100.0	0	0
39.3B/634	21	13	84.6	0	15.4
34.3B/648	14	11	100.0	0	0
EB/77	17	13	69.2	0	30.8
EB/22	24	20	95.0	5.0	0
EB/56	23	21	14.3	0	85.7
XI/71	8	7	42.9	0	57 1
39.3B/649	12	11	100.0	0	0
EB/79	24	23	21.7	69.6	8.7
XISE/3	19	19	10.5	84.2	5.3
EB/21	23	14	28.6	42.8	28.6
Total	242	193	59.6	20.2	20.2

TABLE 6. Mean growth measurements in S_1 segregants of CDO

		Dwarf Orange	Heterozygous segregants	
			Brownish green	Orange
No. studied		*319*	*129*	*106*
Girth (cm)	Mean	9.9	12.5	13.4
	C.V. (%)	19.0	18.3	10.8
Height (cm)	Mean	81.1	131.6	129.2
	C.V. (%)	24.3	21.3	9.5
No. of leaves	Mean	7.1	7.4	8.7
	C.V. (%)	17.1	19.2	10.3

also as an "autodiploid" in breeding experiments (Swaminathan and Nambiar, 1961). Ninan and Satyabalan (1964), while discussing the segregation in CDO, had however raised doubts about the utility of this cultivar for the above purposes. The present study has clearly shown that though the CDO cultivar as a whole is highly heterozygous, some trees are homozygous (Table 5). These could be made use for prepotency studies and production of autodiploids. This also brings us to another important

point that in WCT and CDO, every tree has in it a store of genetic variability and before breeding and genetic experiments are taken up, information on genetic constitution of the parent should be obtained.

In this context it may be interesting to consider the distribution of CDO Their population is extremely limited as compared to WCT and the two cultivars are grown intermixed. Any outcrossing of the CDO has, therefore, necessarily to be with WCT only, and this would add to the heterozygosity of the population. In WCT on the other hand, outcrossing is by and large between Talls only.

The implications of such a wide variability for stature, vigour and colour in WCT and CDO are indeed very much from the point of view of hybrids production and exploitation of hybrid vigour in coconut. The first question that one is inclined to ask is whether in the place of the present low recovery, a higher proportion of hybrids in CDO × WCT crosses can be realized. Though not homozygous, homogeneous lines seem to exist in WCT and CDO for growth characters and colour, which on crossing may be expected to give cent per cent population of hybrids, if complementary or epistatic gene action are not involved in the realization of parental or intermediate types. Homogeneous lines, both in WCT and CDO, can also be isolated in sufficient numbers by selfing new individuals or the S_1 segregants, as the case may be.

Another question relevant in this context is whether all the hybrids (100%) realized in a cross combination after appropriate selection of parents are going to be high yielders. For this, a better understanding of the genetic basis of hybrid vigour for yield is required in coconuts.

CDO × WCT Crosses

While the above aspects have to be investigated through further breeding and genetical experiments, refinement of the existing crossing programmes for production of hybrids deserves immediate consideration. Ninan and Satyabalan (1964) reported that 65% of the Dwarf Orange × Tall nuts sown were lost due to nongermination (30%) and death of sprouts (35%). Perusal of Table 7, however, shows a different picture.

The germination percentage in D × T in 13 families ranged from 55 to 100% (mean : 71%). The death of sprouts was negligible. Bulk sowing of CDO × WCT nuts gave 88% germination with 1.5% mortality of sprouts. In this context, it is pertinent to point out that nuts of CDO require special care, and if stored after harvest, dry up fast causing low germination. The attention required in the nursery is also equally important. Irrigation and shade if not provided in time and adequately can bring about both reduction in germination and death of sprouts. The observations made earlier of unduly low germination and death of sprouts may be due to these causes.

Data in Table 7 also show that the percentage of brownish green segre-

TABLE 7. Germination and segregation pattern in CDO×WCT crosses

Parents	No. of nuts sown	Percentage germination	Percentage* of		
			Vigorous segregants		Dwarf Orange
			Brownish green	Orange	
98×40/414	1	78.6	36.4	9.1	54.5
196×27S/954	5	100.0	100.0	—	—
B.19×40/419	12	58.3	71.4	28.6	—
110×39/225	6	83.3	40.0	20.0	40.0
96×40/414	14	78.6	54.5	27.3	18.2
103×41/405	8	75.0	50.0	33.3	16.7
132×27S/954	8	87.5	71.4	—	28.6
98×41/405	9	77.8	85.7	14.3	—
96×4B/124	8	62.5	60.0	40.0	—
94×39/144	15	66.7	50.0	30.0	20.0
167×1/41	9	55.6	80.0	—	20.0
186×40/419	11	54.5	66.7	16.6	16.6
110×39/204	7	57.1	100.0	—	—
Total	**126**	**70.6**	**62.9**	**18.0**	**19.1**

*Calculated from the number of seedlings.

gants with imposed hybridity (hybrids) realized varies from 36 to 100% (mean : 63%). Though information on the genetic status of the Dwarf and Tall parents of these crosses for colour and vigour are lacking, the possibility of realising cent per cent hybrid population by appropriate selection of Dwarf and Tall parents as mentioned earlier seems to be possible.

Colour Studies in CDO and WCT

The pattern of colour segregation of CDO after self and open pollination, and controlled crossing was studied. The petiole of the second functioning leaf from bottom was observed on the abaxial side 1 cm below the leaf bearing portion. The colour shades were found to vary widely (Table 8). In the orange, there were three shades while in the brownish green, which is the colour of the WCT, there were seven groups into which majority of the progenies fell. The orange colour of the CDO and green colour of WCT, therefore appear to be quantitative rather than qualitative. It is also interesting to note that the Dwarfs and one group of heterozygous segregants have the same orange colour, while the "off types", hybrids, and S_1 progenies of WCT are brownish green as distinct from orange.

TABLE 8. Percentage segregation for colour in CDO self, open, CDO×WCT and WCT self palms*

Population		Orange**			Brownish green**						
		5 YR 7/11	7.5 YR 7/11	10 YR 8/10	10 YR 6/8	10 YR 7/10	7.5 YR 6/9	7.5 YR 5/7	5 Y 6/7	2.5 Y 6/8	2.5 Y 5/5
CDO self											
Dwarf		22.62*	64.3	11.6	—	—	—	—	—	—	—
Heterozygous segregants	Brownish green	—	—	—	30.18	13.2	12.26	11.32	12.26	—	8.4
	Orange	17.8	65.75	12.32	—	—	—	—	—	—	—
CDO open											
Dwarf		21.55	67.24	8.62	—	—	—	—	—	—	—
Heterozygous segregants	Brownish green	—	—	—	20.0	5.0	38.33	11.66	—	5.0	—
	Orange	20.0	40.0	40.0	—	—	—	—	—	—	—
CDO×WCT											
Dwarf		—	100.0	—	—	—	—	—	—	—	—
Heterozygous segregants	Brownish green	—	—	—	40.35	19.2	—	—	10.5	26.3	—
	Orange	—	73.3	20.0	—	—	—	—	—	—	—
WCT self		—	—	—	8.1	5.4	16.2	—	19.6	—	8.8

*Cases of less than 5% occurrence not included.

**Colour designations according to Nicolson's Colour Chart.

Nature and Origin of Heterozygous Segregants

The data now available give some insight into the nature and origin of the heterozygous segregants hitherto referred to as "off types" and "natural cross Dwarfs (NCD)". On selfing, open pollination, or crossing with WCT, CDO segregates for both colour and vigour in varying proportions (Table 9). On selfing, in addition to the Dwarf orange, greenish brown and orange coloured vigorous plants are also realised almost in equal proportion. It has also been shown that the brownish green Tall segregants (off types) give Dwarfs on selfing (Ninan and Satyabalan, 1964). In nature, CDO has been outcrossing with WCT and a large proportion of them are heterozygous for colour and vigour. Since orange and brownish green colours appear to be quantitative, plants selected for orange colour can give brownish green segregants. The brownish green segregants (off types) are, therefore, recombinants for colour and vigour. Under open pollination and on crossing, the proportion of these segregants increased from 23%, to 37% and 63%, respectively (Table 9) due to imposed hybridity.

TABLE 9. Segregation pattern of CDO under self, open, and controlled cross pollinations

Combination	No. of families studied	No. of nuts sown	No. of seedlings obtained	Percentage of		
				Dwarf Orange	Heterozygous segregants	
					Brownish green	Orange
Self	40	734	554	57.0	23.3	19.1
Open	37	279	226	60.2	36.7	3.1
CDO×WCT	13	126	89	19.1	62.9	18.1

Only the brownish green segregants have been studied so far from the economic point of view, and they have been reported to be high yielders having good copra characteristics (Satyabalan, 1956; Ninan and Satyabalan, 1964). However, it is likely that a small proportion of these segregants are Tall parental types with no heterotic effect for yield. The observation that all the plants selected as hybrids do not yield equally well lends support to this contention. It is also possible that the orange coloured vigorous segregants may prove to be high yielders. This is being checked.

Acknowledgement

The authors are thankful to Mr G Vijayakumar for portion of the data on overlapping of male and female phases and to Mr Jacob Mathew for statistical analysis.

References

Arasu, N.T. (1972). Coconut improvement in West Malaysia. pp. 302-307. *Proceedings of the Cocoa and Coconut Conference* (Eds. R.L. Wastie, and D.A. Earp). Inc. Soc. of Planters, Kuala Lumpur, Malaysia.

Bavappa, K.V.A., Sukumaran, C.K., and Mathew, J. (1973). A study of F_1 hybrids of Tall × Dwarf coconut and its bearing on the genetics of dwarfness. *J. Plant. Crops* **1** (Suppl.) : 1-6.

Bavappa, K.V.A. and Nampoothiri, K.U.K. (1974). Recent trends in coconut breeding. *Indian J. Genet.* **34A** : 58-65.

Charles, AE. (1961). Selection and breeding of coconut palm. *Trop. Agric Trin.* **38** : 283-296.

Harland, S.C. (1957). The Improvement of Coconut Palm by Breeding and Selection. *Bull. Coconut Research Institute*, No. 15. Ceylon.

Jack, H.W. and Sands, W.N. (1922). The dwarf coconut palm in Malaya. *Malayan Agric. J.* **10** : 4-13.

Joshi, A.B. and Dhawan N.L. (1965). Genetic improvement in yield with special reference to self-fertilising crops. *Indian J. Genet.* **26A** : 101-113.

Liyanage, D.V. (1964). Mass selection and progeny testing in coconuts. pp. 51-58. *Proc. FAO Technical Working Party on Coconut Production, Protection and Processing.* 2nd session Colombo. FAO, Rome.

Liyanage, D.V. and Sakai, K.I. (1960). Heritabilities of certain yield characters of coconut palm. *J. Genet.* **57** : 245-257.

Nambiar, M.C. and Nambiar, K.P.P. (1970). Genetic analysis of yield attributes in *Cocos nucifera* L. var. West Coast Tall. *Euphytica* **19** : 543-551.

Ninan, C.A. and Satyabalan, K. (1964). A study of natural, self, and cross (Dwarf × Tall) progenies of Dwarf coconuts of West Coast of India and its bearing on the genetics of Dwarfs and putative hybridity of the off-type progenies. *Caryologia.* **17** : 77-91.

Pankajakshan, A.S., George, M. and Marar, M.M.K. (1963). A study of some procedures of selecting mother palms in coconut. *Indian Cocon. J.* **16** : 47-62.

Patel, J.S. (1938), The Coconut—A Monograph. 313 pp. Government Press, Madras.

Rao, M.B.S. and Koyamu, K. (1955). The dwarf coconut. *Indian Cocon. J.* **8** : 106-112.

Satyabalan, K., Ratnam, T.C., and Kunjan, P.V. (1970). Hybrid vigour in nut and copra characters of coconut hybrids. *Indian J. Agric. Sci.* **40** : 1088-1093.

Satyabalan, K., Ratnam, T.C. and Menon, R.M. (1968). Need for selection among dwarf pollen parents in the production of Tall × Dwarf coconut hybrids. *Indian J. Agric Sci.* **38** : 155-160.

Satyabalan, K. and Nambiar. M.C. (1968). The present position of coconut improvement by hybridization in India. pp. 1-5. *Proc. FAO Technical Working Party on Coconut Production, Protection, and Processing.* (3rd session.) Jogjakarta. FAO, Rome.

Satyabalan K., (1956). A note on the performance of Natural Cross Dwarf (female) × Tall (male) in coconut. *Indian Cocon. J.* **9** : 166-173.

Swaminathan, M.S. and Nambiar, M.C. (1961). Cytology and origin of the Dwarf coconut palm. *Nature* **192** : 85-96.

Whitehead, R.A. (1965). The flowering of *Cocos nucifera* Linn. in Jamaica. *Trop. Agric. Trin.* **42** : 12-19.

Whitehead, R.A. (1966). Some notes on Dwarf coconut palms in Jamaica. *Trop. Agric. Trin.* **43** : 277-294.

Whitehead, R.A. (1968). Selecting and breeding coconut palms resistant to lethal yellowing disease. A review of recent work done in Jamaica. *Euphytica* **17** : 81-102.

The Mechanics of Hybrid Seed Production Through Seed Gardens

M.A.P.P. MANTHRIRATNA
Coconut Research Institute of Sri Lanka, Lunuwile, Sri Lanka

Abstract

In the establishment of isolated seed gardens for hybrid seed production, a correct balance between Dwarf (seed) parent and Tall (pollen) parent has to be maintained. Excess Tall (pollen) palms would be a luxury in view of the space they occupy which can otherwise be planted up with Dwarfs. On the other hand, too few or badly distributed 'pollen' palms may lead to reduce seed set.

Data are presented on three types of distribution patterns, (a) compact block of Dwarfs surrounded by Tall palms; (b) alternating rows of Dwarfs and Talls; and (c) Dwarfs and Talls in the ratio of 81:9. The techniques of emasculation that are now adopted are described which minimise the risk of pure Dwarf progenies. This is vital in the absence of genetic markers for the type of seed parent (Dwarf Green, variety *nana* form *pumila*) that is widely used in Sri Lanka's Seed Gardens.

Date relating to production and legitimacy of *pumila*×*typica* natural cross hybrids (as judged by nursery studies) are presented.

Introduction

The feasibility of establishing isolated seed gardens for large scale seed production in order to circumvent the disadvantages and high cost of seed production through controlled hand pollination has been recognised in most coconut growing countries.

Sri Lanka's first spatially isolated seed garden for the production of *typica*×*typica* seed was established in 1955 at Ambakelle in a forest reserve where 800 m of thick jungle served as an isolation barrier (Liyanage, 1955). When the results of field trials of *typica*×*pumila* and its reciprocal hybrid (Coconut Research Institute of Ceylon, Ann. Rept., 1965) were made known, this seed garden was gradually 'adjusted' to produce *pumila*×*typica* hybrid seed without defeating its primary objective of mass production of *typica* x *typica* seed, because Sri Lanka requires both types of seeds for implementing her National Replanting Programme (Manthriratna, 1975).

Two hectares of Dwarfs (variety *nana*, form *pumila*) were established in

1962 followed by nine hectares of *pumila* and *typica* in alternate rows in 1966. The hybrid seeds gathered from these palms were further evaluated in the gardens of small holders in most coconut growing areas of the country. Under the Seed Garden Expansion Project, an additional 83 ha was established at Ambakelle during 1972-1974 using the two colour forms of the variety *nana* (*eburnea*, Dwarf Ivory Yellow and *pumila*, Dwarf Green) as seed parents together with hand pollinated *typica* seedlings as eventual pollen parents in the ratio 81:9.

Two vital factors that have to be taken into account for the successful operation of a seed garden for the mass production of elite seed are (1) the degree of spatial isolation required to eliminate chance cross fertilization with alien pollen; and (2) the degree of control exercised to prevent the liberation of undesirable pollen through accidental opening of spathes or faulty emasculation.

Techniques of emasculation and safeguards that are now adopted are discussed along with the results of nursery studies which give an insight into the degree of legitimacy of seed production in Sri Lanka's first coconut seed garden.

The Operation of Isolated Seed Gardens

(a) The degree of spatial isolation. Work conducted in Sri Lanka in the early 1950's on the degree of penetration of a forest barrier by coconut pollen indicated that even when winds are favourable, no pollen was found beyond 350 m of jungle (Manthriratna, 1965). Studies on pollen dispersal at the IRHO Station in Ivory Coast (de Nuce de Lamothe and Rognon, 1972) have shown that 'the rate of setting of emasculated coconut becomes very small further than 150 m from a large pollen source. In addition, contamination from pollen coming from trees more than 150 m away is all the more unimportant in that other pollinators are closer at hand'. These authors conclude that 'fertilization by extraneous pollens are thus negligible when the seed garden is isolated by 200 m of forest'. In Sri Lanka, the honey bee *Apis indica* is an important insect vector for pollen transfer and it has a foraging distance of about 750 m in open country (Liyanage, 1961). In establishing our first seed garden, we therefore left a forest barrier of about 800 m, subsequently reduced it to about 500 m, to prevent contamination with both insect and wind transported pollen. In Port Bouet, de Nuce de Lamothe and Rognon (1975) consider 300 m as adequate isolation to ensure a satisfactory legitimacy rate.

(b) Ratio of seed to pollen parents. The correct balance between seed parents and pollen parents has to be maintained. Excess pollen parents would be a luxury in view of the space they occupy which can otherwise be planted up with more Dwarf (seed) parents. On the other hand, too few pollen parents would make roguing difficult and the resulting bad distribution of pollen donors may lead to reduce seed set. In this regard, de

Nuce de Lamothe and Rognon (1972) has reported that in Ivory Coast fertilisation is normally assured upto 100 m from a pollen source made up of five trees. They use one 'pollinator' for five mother trees with the spacing varying according to the variety of the parents—Dwarfs being planted closer together than Talls.

In Sri Lanka's first seed garden, No. 5 field of Dwarfs was planted as a compact block spaced 6.7 m × 5.5 m. Field No. 9 was planted with alternating *typica* and *pumila* rows where the distance between rows was 7.9 m and the distance within a row 7.9 m for *typica* and 6.7 m for *pumila*. In fields 10-14, 83 ha of seed garden was planted in a ratio of 81 seed parents : 9 pollen parents.

(c) **Safeguards in emasculation work.** The technique now adopted minimizes the risk of accidental fertilization of Dwarf female flowers with Dwarf pollen from the same palm or with Dwarf pollen from other Dwarf palms within the seed garden, a problem that was encountered in the mid-sixties, resulting in the release of an appreciable quantity of illegitimate seed. The problem becomes more acute when the *pumila* form of Dwarf is used as the seed parent, for it is difficult to identify hybrids with green stem colour from spurious seedlings produced as a result of pollination of *pumila* with *pumila* pollen, although it may be sometimes possible to identify the two groups on the basis of such characters as speed of germination, vigour and early splitting of leaves.

To overcome this drawback, which could assume serious proportions when a large extent of seed garden is in full production, the following technique is now adopted. Spathes are split open longitudinally 3-6 days before they would naturally open. At this time, all the male flowers are closed so that even the act of splitting the spathe does not release any pollen through disturbance. The spikelets are cut about the 5 cm above the female flowers and the remaining male flowers are manually stripped off. The male flowers, cut spikelet ends, and other debris are then distroyed by burying. Button counts which would give a rough estimate of yield are taken at 12 weeks from the date of emasculation.

Results

(a) **Percentage set of emasculated female flowers.** During the period March 1975-February 1976 in Field No. 5, the inflorescences on 388 palms were emasculated and 38,410 button nuts were developing 12 weeks from date of emasculation (mean: 99 nuts/palm). During the period March-September 1976, 22,041 *pumila* × *typica* hybrid seed nuts were harvested from 381 palms (seven palms lost by red weevil *Rhyncophorus ferrugineus* infestation). The yield appears moderate, but this may almost entirely be due to the very low rainfall received at the Seed Garden—1346 mm during March 1975-February 1976 and only 368 mm during January-September 1976. This same field yielded 175 hybrid nuts per

palm in 1971 when favourable weather prevailed. As this is a compact block of *pumila* surrounded by *typica*, the yield of the palms standing at distances 5, 15, 25, 35, 45, 55, 60, 80, 85, and 90 m from likely pollen sources was studied. There appeared to be no differences in yield between *pumila* seed palms standing at the edge of the plantation and therefore in close proximity to the pollen source and those that were at the centre of the plantation. In fact, some of the highest yields—120-180 nuts/palm — were recorded at the centre of the plantation. Thus pollen, whether wind-borne or carried by insect vectors, is not limiting.

During this period, in Field No. 9, inflorescences on 471 *pumila* palms in this field (where *pumila* and *typica* are in alternate rows) were emasculated and 42,074 button nuts were developing 12 weeks from date of emasculation (mean : 89 nuts/palm). Drought effects were particularly severe in this field and crops have been poor.

In field No. 5, 58% of the palms showed a potential yield of over 90 nuts/palm/year as compared with 45% in field No. 9. The comparatively poor setting in this field, where pollen sources are near at hand, is mainly attributable to the fact that the palms are younger and therefore more susceptible to drought which was experienced during the past 18 months.

For Field No. 10, this is the first year of flowering and it may be too premature to assess the results. However, over 80% set of emasculated female flowers was observed at the periphery of the plantation which is 200 m from the nearest pollen source, the *typica* pollen donors in this field having still not flowered.

(b) **Legitimacy of hybrid seed.** The success of a seed garden is gauged not only from the quantity of seed that can be produced but also on the quality or legitimacy of seed produced.

Large scale production of *pumila* × *typica* hybrid seed commenced in 1975 using the improved emasculation techniques described previously. A nursery where 5,144 hybrid seed nuts were paid was examined carefully and the following classification was made :- Hybrid seedlings with green petiole colour (Hy-G) : 65.9% ; Hybrid seedlings with reddish brown petiole colour (Hy-RB) : 31.4% ; Dwarf green (*pumila*) seedlings: 1.2% ; Twin seedlings : 0.1% ; Seedlings with ivory yellow petiole colour (Mutants ?) : 0.7%.

There were 51 seed nuts without embryos but with normal mesocarp, endocarp and endosperm. The reasons for the occurrence of a very low fraction of pure Dwarfs is under investigation. We do not think that this is due to faulty emasculation, for it has been our experience that even under very careful controlled pollination of form *pumila* with *typica* pollen, a few pure *pumila* progenies are obtained. De Nuce de Lamothe and Rognon (1972) has reported that if castrations were properly carried out, the percentage of pure Dwarfs from Malayan Dwarfs Yellow was less than 5% and the legitimacy was in the neighbourhood of 95-100%.

In Sri Lanka, the normal practice is to issue reddish brown colour form

of hybrid (Hy-RB) first, as these are unmistakably hybrids, using the petiole colour as a useful and reliable genetic marker. The green colour form of hybrid (Hy-G) is the next to be issued for it can be identified from a pure *pumila* seedling on its vigour.

We would expect less problems when the *eburnea* or yellow-fruited form of Dwarf is in flower, for it should be possible to identify their hybrids with *typica* pollen from pure Dwarf yellow progeny. The usefulness of the yellow and red-fruited forms of Malayan Dwarf where their colour provides a good genetic marker has been reported by Whitehead, Thompson, and Williams (1966).

Discussion

The techniques of premature emasculation described in this paper would guarantee hybrid seed of the highest quality particularly if a seed garden is planted with a green form of Dwarf which does not provide a suitable genetic marker for identification of hybrids from spurious selfed progeny of Dwarfs. Contrary to expectations, yields from pre-emasculated bunches have been exceptionally heavy, and some bunches had to be selectively thinned to prevent bunch droop and eventual immature nut fall. The occurrence of pure Dwarf *pumila* progeny has been reduced to near 1%, so that hybrid seedlings can be issued with confidence. In view of the high seed set in a pure stand of Dwarfs, we expect that a ratio of 81 seed parents: 9 pollen parents would be a satisfactory combination still allowing for ultimate rogueing of the pollen donors.

Acknowledgements

Thanks are due to the Superintendent and field staff, Coconut Seed Garden, Ambakelle, for all field operations leading to production of hybrids, and nursery staff of Research Nursery, Bandirippuwa Estate, for planting and maintenance of the hybrid seedlings. Careful scrutinising of seedling characters and nongerminations were done by Mr V.U de S Jayasuriya, Research Assistant.

References

de Lamothe, M. de Nuce and Rognon, F. (1972). The production of hybrid coconut seed by controlled natural pollination. *Oleagineux*. 27 : 483-487.

de Lamothe, M. de Nuce and Rognon, F. (1975). Assisted pollination and contamination by undesirable pollens. *Oleagineux*. 30 : 359-364.

Liyanage, D.V. (1961). The use of isolated seed gardens for coconut seed production. *Ceylon Coconut Quart*. 12 : 121-124.

Manthriratna, M.A.P.P. (1965). Coconut pollen. *Ceylon Coconut Quart*. 16 : 102-110.

Wanthiratna, M.A P.P. (1975). Selective use of improved planting material for rehabilitating Sri Lanka's Coconut Industry. *Proc. FAO Technical Working Party on Coconut Production, Protection, and Processing* (4th session), Kingston, Jamaica. 14-25 Sept. 1975. FAO, Rome.

Whitehead, R.A., Thompson, B.E. and Williams, L.V. (1966). A genetic marker of use in coconut seed production. *Oleagineux* 21 : 153-154.

Cytology of Coconut

P.K. THANKAMMA PILLAI, G. VIJAYAKUMAR and P.N. RAVINDRAN
Central Plantation Crops Research Institute,
Kasaragod 670124, Kerala, India

Abstract

The chromosome number in coconut is $2n=32$. Karyomorphological studies show slight differences between Tall and Dwarf varieties. Meiosis was generally regular in Tall cultivars and in hybrids between Tall and Dwarf, while several irregularities have been reported in the Dwarf and semi-tall cultivars. Pollen fertility is very high in Talls and hybrids as compared to that in Dwarfs and semi-talls. Meiotic irregularities are commonly met within the 'spicata' palms and these are believed to have originated from Talls.

Free nuclear division has been reported in coconut milk. C-mitosis leading to high ploidy level and several chromosome abnormalities occur in developing endosperm. In Philippines 'makapuno' nuts, the endosperm development is very abnormal. An inverse relationship between ploidy level and oil content has been also observed by some authors.

The two existing views on the origin of Dwarfs from Talls, namely, mutant origin or by continuous inbreeding, are presented. Another possibility that both Talls and Dwarfs might have had a common origin in a single ancestral form has been proposed.

Introduction

Cytological studies on coconut are few, though the palm is of great economic importance and has been used by man from time immemorial. The first report appeared in 1929 when Santos reported the gametic number of a Philippine coconut variety to be 16. Subsequently, reports on chromosome number have been published by several workers (Janaki Ammal, 1945; Venkatasubban, 1945; Sharma and Sarkar, 1956; Ninan, Pillai, and Joseph, 1960; Abraham, Mathew, and Ninan, 1961). Their studies and those that followed have confirmed the somatic number of coconut to be $2n=32$ (Nambiar and Swaminathan, 1960; Swaminathan and Nambiar, 1961; CCRS Annual Report, 1962-63; Raveendranath and Ninan, 1973). Nambiar and Upadhyaya (1961) outlined a pretreatment staining procedure—fixing—for the study of coconut root cells.

The review is divided into three parts, karyomorphology, meiotic

studies, and endosperm cytology, along with a concluding section on cytological evidences on the origin of Dwarf coconuts.

Karyomorphology

Nambiar and Swaminathan (1960) found that the majority of chromosomes in Tall palms had sub-median centromers and that they differed considerably in length. In the West Coast Tall (WCT) variety, two pairs of chromosomes were much longer and three pairs relatively short. They observed two satellited chromosome pairs, the satellites occurring on the long arm of chromosome VI and short arm of chromosome IX. Sharma and Sarkar (1956) also observed two pairs of SAT-chromosomes in the coconut variety studied by them. Raveendranath and Ninan (1963) compared the karyotypes of WCT, spicata, Chowghat Dwarf Green (CDG), and Chowghat Dwarf Orange (CDO) and found that the main distinguishing feature between the karyotypes of Tall and Dwarf forms was the presence of the secondary construction in Talls, on the long arm of chromosome VI, while in Dwarfs, on the long arm of chromosome III. But, this stated difference does not seem to be consistent. In the material studied in our Institute, chromosomes VI and XII were found to be satellited (Ann. Rep. 1962-63; 1973). The total length of the chromosome complement was higher in CDG than in WCT. Table 1 gives the comparative features of the WCT and CDG karyotypes.

TABLE 1. Relative length and index of the chromosomes of WCT and DG varieties*

Chr. no.	WC Tall		Dwarf Green	
	Relative length (in microns)	S.A. / L.A. (index)	Relative length (in microns)	S.A. / L.A. (index)
I	9.11	0.55	8.92	0.60
II	8.36	0.50	8.38	0.58
III	7.46	0.59	8.06	0.60
IV	7.04	0.59	7.28	0.58
V	6.91	0.61	7.04	0.65
VI	6.91	0.71[1]	6.80	0.72[3]
VII	6.80	0.74	6.58	0.65
VIII	6.49	6.68	6.43	0.71
IX	6.34	0.66[2]	5.80	0.74
X	6.01	0.81	5.80	0.80
XI	5.91	0.88	5.58	0.79
XII	5.40	0.89	5.37	0.75[4]
XIII	5.18	0.88	5.03	0.74
XIV	4.77	0.77	4.53	0.76
XV	4,32	0.72	4.23	0.80
XVI	3.76	0.89	3.97	0.83

*WCT data from Nambiar and Swaminathan (1960); DG data from Thankamma Pillai and Vijayakumar (unpublished).

[1]Satellite on the long arm.

[2]Satellite on the short arm.

[3]Satellite on the short arm.

[4]Satellite on the long arm.

Meiotic Studies

Nambiar and Swaminathan (1960) and Nambiar, Thankamma Pillai, and Vijayakumar (1970) observed significant differences in the meiotic behaviour between different cultivars of Tall and Dwarf forms, and between open pollinated and inbred populations. WCT and Laccadive Ordinary, another Tall cultivar, showed normal meiosis. Nambiar and Swaminathan (1960) observed many meiotic abnormalities in the cultivars Apricot and Dwarf Red.

Pachytene analyses conducted by the two senior authors on CDG showed that it had 7 subterminal, 7 submedian, and 2 median chromosomes. The short arm of chromosome VI and long arm of chromosome XII have nuclear organizer regions (Ann. Rep. CPCRI. 1973). This observation differs from that of Nambiar and Swaminathan (1960) on Talls and Raveendranath and Ninan on Dwarfs (1973). Thankamma Pillai and Vijayakumar (unpublished data) studied the meiosis of nine cultivars and hybrids (Table 2) and found that percentage of abnormalities was highest in Dwarf Green and Dwarf Orange. In D×T and T×D hybrids, chromosome abnormalities and sterility were very slow. The higher chromosome abnormalities and sterility in Dwarfs may be due to the higher degree of inbreeding in them. Nambiar et al. (1970) have also studied the cytology of open pollinated and inbred lines (also Ann. Rep. CPCRI, 1971).

Spicata are Tall palms differing from ordinary Talls in inflorescence character and breeding behaviour. They produce unbranched inflorescences and show a high degree of suppression of male flowers. Their cytology has been studied by Ninan and his coworkers (Ninan et al., 1960; Ninan and Satyabalan, 1963; Ninan and Nambiar, 1974). The meiosis was irregular with inversions, translocations, and many other abnormalities. Like Talls, spicata palms are predominantly outbreeders. They are believed to have arisen from Talls through mutation. However, Child (1974) considered spicata as a distinct variety because of the existence of a Dwarf form also.

In addition to the above studies on karyomorphology and meiosis, there have also been reports on the cytology of an abnormal palm (Thankamma Pillai and Vijayakumar, 1972), on palms affected with root (wilt) disease (Nambiar and Prasannakumari, 1964) and also on a bulbiferous palm (Raveendranath, Nair, and Ninan, 1975), Parthenogenesis was also known to occur (Venkataraman, 1928). The only report on haploidy was by Whitehead and Chapman (1962) who isolated a haploidy seedling from 31 twin seedlings raised by them. Ninan and Raveendranath (1965) has observed a haploid embryo in a WCT palm.

Endosperm Cytology

As early as in 1927 Quisumbing and Juliano studied the development of the ovule and the embryosac in coconut. The development of the endo-

TABLE 2. Meiotic behaviour of some varieties and hybrids

Cultivar/ hybrid	Chiasma frequency		Percentage of irregularities at				Percentage of pollen sterility (non-stainability)
	per cell	per bivalent	Diakinesis and Metaphase	Anaphase I & II	Telophase I & II	Sporad stage	
WC Tall	28.9	1.8	6.4	1.9	0.3	0.7	3.6
Laccadive Ordinary	27.6	1.7	7.6	1.8	1.7	0.9	3.5
Andaman Giant	28.5	1.8	4.9	2.1	2.5	1.0	3.0
CDG	26.8	1.7	26.1	8.5	6.6	9.4	32.2
CDO	27.1	1.7	19.6	7.9	5.1	6.6	21.9
T×D hydrid	28.5	.8	6.8	1.8	1.3	0.8	2.9
D×T hybrid	27.6	1.7	10.3	2.8	2.6	2.5	7.8

sperm has been described in detail by Cutter and coworkers (Cutter, Wilson, and Dube, 1952 a, b; Cutter and Freeman, 1854; Cutter, Wilson, and Freeman, 1955). They made interesting observations on the occurrence of free nuclei in the liquid syncytial endosperm commonly known as coconut milk. Free nuclear divisions in the coconut water have also been reported by Dutt (1953) and Abraham and Thomas (1962). But biochemical analysis of coconut water by Mondal, Mandal, and Biswas (1970a, b) did not support the above view on the presence of free nuclei.

Abraham and coworkers (Abraham and Mathew, 1963; Abraham, Ninan, and Gopinath, 1966) noted that in about 6 month old nuts, the nuclei of the developing endosperm tissue varied considerably in size. They found that the tissue adjacent to the endothelium was normally triploid ($3x=48$), less frequently hexaploid ($6x=96$), and still less frequently dodecaploid ($12x=192$). They proposed that higher ploidy levels arose by c-mitosis. They also recorded an inverse relationship between ploidy levels of endosperm and oil content. In the Tall variety, the outer, middle, and inner parts differed in the oil content, the percentage being 75.7, 54.1 and 41.1, respectively. They analysed Laccadive Tall, S.S. Apricot, CDG, CDO, and Philippine makapuno nuts and found that the last one had the lowest oil content and also the highest ploidy level (Abraham, 1963; Abraham et al., 1965).

The Philippine makapuno coconuts are peculiar in having loose jelly like endosperm filling the entire cavity. They do not germinate and this is ascribed to an incompatibility reaction between a normal embryo and abnormal endosperm (Abraham et al., 1965). These authors reported high ploidy levels ($48x$ and above) in the buttery endosperm which according to them arose through amitosis and nuclear fusion. Cruz and Ramariz (1968) found two types of cells in this endosperm, normal cells and microcells. They thought that the latter originated from normal cells through budding. Chromosome counts ranged from 32 to 96 ($2x$ to $6x$) with 48 as the most frequent number.

Recently, de Guzman and colleagues have succeeded in culturing the embryo from these nuts on artificial medium and have reported a high recovery of makapuno character (de Guzman, 1969; Balaga and de Guzman, 1970; de Guzman and del Rosario, 1974; de Guzman, Rafols, and del Rosario, *this Symposium*).

Cytological Evidence on the Origin of Dwarf Coconuts

Two hypotheses have been advanced to explain the origin of Dwarfs. The first one considers Dwarfs to have evolved by a recessive mutation from Talls (Handover, 1919; Anonymous, 1921; Jack and Sands, 1922; Pancho, 1960). According to the second hypothesis, the Dwarfs and semi-Talls occurring in nature are the products of several generations of inbreeding of Tall palms (Nambiar and Swaminathan, 1960; Swaminathan and Nambiar, 1961).

Comparative studies on the meiosis of Talls and Dwarfs (Sharma and Sarkar, 1956; Nambiar and Swaminathan, 1960; Ninan et al., 1961; Abraham et al., 1961; Ann. Rep. CPCRI, 1972, 1973) reveal that meiosis in the former was more normal. It was therefore assumed that the Talls were the ancestral types, and that the Dwarfs, semi-Talls, and spicata were the derived ones. In support of this, it has been pointed out that the Philippine Dwarf palm Tambulilid is known to be of recent mutant origin (Pancho, 1960).

One criticism that can be levelled against the hypothesis on the origin of Dwarfs from Talls by a process of inbreedin is that in many Pacific Islands, natural inbreeding isolated populations of coconut have been existing for thousands of years. If continued inbreeding leads to Dwarfs, we would expect predeminantly Dwarf populations in these areas. But this is not the case (Whitehead, 1966). There are also no cytological morphological, or genetical evidences to prove such a hypothesis, Moreover, some Dwarfs, such as the Fijian Dwarf, are highly heterogeneous and generally outbreeders. These conditions should not happen if the origin of Dwarfs has been through continuous inbreeding. It is therefore possible that both Talls and Dwarfs had a common origin from a single ancestral form and they underwent a certain degree of divergence during the course of evolution. The Dwarfs have got definite adaptive value in its early seed bearing habit, and greater seed production. In the course of domestication and co-existence much natural crossings might have taken place leading to the establishment of intermediate populations and the present day cultivated Dwarfs. Experimental verification of any of these hypotheses is not easy in a species like coconut, and much more basic studies are required before we can arrive at an acceptable conclusion on the origin of Dwarfs.

Acknowledgements

The authors are thankful to Mr M.C. Nambiar, Project Co-ordinator-cum-Breeder (Spices & Cashew), Central Plantation Crops Research Institute, Kasaragod, and to Dr N.M. Nayar, Joint Director, Central Plantation Crops Research Institute, Regional Station, Vittal, for their help.

References

Abraham, A. (1963). Chromosome constitution and oil content in the coconut endosperm. *J. Indian Bot. Soc.* **42A** : 1-3.

Abraham, A., and Mathew, P.M. (1963). Cytology of coconut endosperm. *Ann. Bot.* 27 : 505-512.

Abraham, A. and Thomas, K.J. (1961). Notes on the embryo culture of coconut. *Proc. FAO Tech. Working Party on Coconut Production, Protection, and Processing,* (1st session) India. pp. 253-254.

Abraham, A. and Thomas, K.J. (1962). A note on the *in vitro* culture of coconut embryos. *Indian Coconut J.* **15** : 84-88.

Abraham, A., Mathew, P.M., and Ninan, C.A. (1961). Cytology of *Cocos nucifera* L. and *Areca cateshu* L. *Cytologia* **26** : 327-332.

Abraham, A., Ninan, C.A. and Gopinath, P. (1965). Cytology of development of abnormal endosperm in Philippine makapuno coconuts. *Caryologia* **18** : 395-408.

Abraham, A., Ninan, C.A. and Gopinath, P. (1966). Cytology of endosperm in some varieties of coconut. *Indian J. Genet.* **26A** : 234-246.

Anonymous (1921). Further information about dwarf coconuts. *J. Jamaican Agric. Soc.* **26** : 282-287.

Balaga, H.Y. and de Guzman, E.V. (1970). The growth and development of coconut makapuno embryos *in vitro*. II. Increased root incidence and growth in response to media composition and to sequential culture from liquid to solid medium. *Philipp. Agric.* **53** : 551-565.

Central Coconut Research Station, Kasaragod. (1964). *Annual Report 1962-63.*

Central Plantation Crops Research Institute. (1971, 1973). *Annual Report, 1969-70* and *Annual Report 1972.*

Child, R. (1974). *Coconuts.* 2 ed. 335 pp. Longman.

Cutter, V.M. Jr., Wilson, K.S. and Dube, G.R. (1952a). The isolation of living nuclei from the endosperm of *Cocos nucifera. Science* ; **115** : 58-59.

Cutter, V.M. Jr., Wilson, K.S. and Dube, G.R. (1952b). The endogenous oxygen uptake of tissues in the developing coconut fruits of *Cocos nucifera. Amer. J. Bot.* **39** : 51-56.

Cutter, V.M. Jr. and Freeman, B. (1954). Development of syncytial endosperm of *Cocos nucifera. Nature* **173** : 827-828.

Cutter, V.M. Jr., Wilson, K.S. and Freeman, B. (1955). Nuclear behaviour and cell formation in the developing endosperm of *Cocos nucifera. Amer. J. Bot.* **42** : 109-115.

Dutta, M. (1953). Dividing nuclei in coconut milk. *Nature* **171** : 799-800.

FAO (1971). Plant News, Special Issue. Coconut Breeding. pp, 16., AGP : NL/14, FAO, Rome.

de Guzman, E.V. (1969). The growth and development of *Cocos nucifera* L. *in vitro*. I. The induction of rooting. *Philipp. Agric.* **53** : 65-78.

de Guzman, E.V. (1970). The growth and development of coconut makapuno embryo *in vitro*. III. Resumption of root growth in higher sugar media. *Philipp. Agric.* **53** : 566-579.

de Guzman, E.V. and del Rosario, A.G. (1974). The growth and development in soil of makapuno seedlings cultured *in vitro. Philipp. Res. Bull.* **21** : 1-16.

de Guzman, E.V., Rafols, A.G. and del Rosario, A.G. (1976). *This Symposium.*

Handover, W.P. (1919). The dwarf coconut. *Malayan Agric. J.* **7** : 295-297.

Jack, H.W. and Sanders, W.N. (1922) The dwarf coconut of Malaya. *Malaya Agric. J.* **10** : 4-13.

Janaki Ammal, E.K. (1945) *Chromosome Atlas of Cultivated Plants.* by C.D. Darlington and E.K. Janaki Ammal. Allen and Unwin, London.

Morechal, H. (1928). Observations and preliminary experiments on the coconut with a view to developing improved seednuts. *Fiji Agric. J.* **1** : 16-45.

Mondal, H., Mandal, R.K. and Biswas, B.B. (1970a). Nucleic acids in coconut water. *Plant and Cell Physiol.* **11** : 177-181.

Mondal, H., Mandal, R.K. and Biswas, B.B. (1970b). Absence of free nuclei in coconut water as revealed from biochemical studies. *Nucleus* **13** : 10-18.

Menon, K.P.V. and Pandalai, K.M. (1960). The Coconut Palm : A Monograph. Indian Central Coconut Committee, Ernakulam, India.

Nambiar, M. C. (1960). Pollen irradiation and culture of pollen tubes in coconut. *Curr. Sci.* **29** : 317-318.

Nambiar, M.C. and Swaminathan, M.S. (1960). Meiosis in pollen sterile and pollen fertile varieties of coconut. *Curr. Sci*, **29** : 234-236.

Nambiar, M.C. and Swaminathan, M.S. (1961). Chromosome morphology, microsporogenesis, and pollen fertility in some varieties of coconut. *Indian J. Genet.* **20** : 200-211.

Nambiar, M.C. and Upadhyaya, M.D, (1961). Prestaining treatment and squashing for somatic chromosomes of the coconut palm. *Stain Tech.* **36** : 31.

Nambiar, M.C. and Prasannakumari, T.O. (1964). Effect of root (wilt) disease on microsporogenesis in coconut (*Cocos nucifera*). *Indian Coconut J.* **17** : 93-97.

Nambiar, M.C., Thankamma Pillai, P.K. and Vijayakumar, G. (1970). Cytological behaviour of first inbred generation of coconut. *Indian J. Genet.* **30** : 744-752.

Ninan, C.A. and Satyabalan, K. (1963). Cytogenetic studies in the genus *Cocos* : II. Some observations on the spicata character in coconut (*Cocos nucifera*). *Indian Coconut J.* **16** : 109-114.

Ninan, C.A. and Satyabalan, K. (1964). A study of natural self and cross (Dwarf× Tall) progenies of Dwarf coconuts of the west coast of India and its bearing on the genetics of Dwarfs and the putative hybridity of their off-type progenies. *Caryologia* **17** : 77-91.

Ninan, C.A. and Raveendranath, T.G. (1965). A naturally occurring haploid in the coconut palm (*Cocos nucifera* L.) *Caryologia* **18** : 619-623.

Ninan, C.A. and Raveendranath, T.G. (1972). Why *spicata* palms do not breed true? Chromosome studies provide the answer. *Coconut Bull.* **3** : 2-4.

Ninan, C.A. and Raveendranath, T.G. (1975). A study of the karyotype of *spicata* and *typica* varieties of coconut and its bearing on the breeding behaviour of *spicata* palms. *New Botanist* **11** : 81-87.

Ninan, C. A. and Nambiar, M.C. (1974). Cytology and origin of spicata coconuts (*Cocos nucifera* L. var. *spicata*). pp. 175-188. *In* P. Kachroo (Ed.) *Advancing Frontiers in Cytogenetics*. Hindustan Pub. Corp., New Delhi.

Ninan, C.A., Pillai, R.V. and Joseph, J. (1960), Cytogenetic studies in the genus *Cocos*. I, Chromosome number in *C, australis* and *C nucifera* var. *spicata* and *androgena*. *Indian Coconut J.* **13** : 129-134.

Ninan, C. A., Pankajakshan, A.S., Satyabalan, K. and Gopinath, P. (1961). A comparison of the performance of some cultivars of coconuts in the Centra Coconut Research Station, Kasaragod, and the Agricultural Research Station, Nileshwar (Pilicode). *Indian Coconut J.* **15** : 12-19.

Pancho, J.V, (1960). The Tambulilid, *Coconut Bull.* **13** : 403-404.

Quisumbing, E. and Juliano, J.B. (1927). Development of ovule and embryo sac of *Cocos nucifera*. *Bot. Gaz.* **84** : 279-293.

Raveendranath, T.G. and Ninan, C.A. (1973). A study of somatic chromosomes of Tall and Dwarf coconuts (*Cocos nucifera*) and its bearing on intervarietal variation and evolution in coconuts. *J. Plant. Crops* **1** : 7-22.

Raveendranath, T.G., Nair, P.N. and Ninan, C.A. (1975). Chromosomes of a bulbiferous palm. *Coconut Bull.* **6** : 2.

Santos, J.K. (1929). Cytological study of *Cocos nucifera* L. *Philipp. J. Sci.* **37** : 417-437.

Sharma, A.K. and Sarkar, S.K. (1956). Cytology of different species of palms and its bearing on the solution of problems of phylogeny and speciation. *Genetica* **28** : 361-488.

Swaminathan, M.S. and Nambiar, M.C. (1961). Cytology and origin of the dwarf coconut, palm. *Nature* **192** : 85-86.

Tammes, P.L.M. (1955). Review of coconut selection in Indonesia. *Euphytica* **4** : 17-24.

Thankamma Pillai, P.K. and Vijayakumar, G. (1972). Cytology of an abnormal coconut palm. *Indian J. Genet.* **32** : 303-305.

Venkataraman, K. (1928). *Parthenogenesis in coconut.* Yearbook, Department of Agric., Madras. pp. 29-32.

Venkatasubban, K.R. (1945). Cytological studies in Palmae : Chromosome numbers in a few species of palms of British India and Ceylon. *Proc. Indian Acad. Sci.* B **22** : 193-207.

Whitehead, R.A. and Chapman, G.P. (1962). Twinning and haploidy in *Cocos nucifera* L. *Nature* **196** : 1228-1229.

Whitehead, R.A. (1966). *Sample survey and collection of coconut germplasm in the Pacific Islands.* Ministry of Overseas Development, Overseas Research Publication No. 16. HMSO, London.

Discussion

B.R. Murthy : What is the comparative cytology of (a) Dwarfs obtained from Tall palms ; (b) Dwarfs obtained by inbreeding; and (c) different Dwarfs varieties and their crosses ?

Ravindran : There are no conclusive data on these. (a) Cytology of the Dwarf segregants of a Tall palm has been reported. They had very high degree of meiotic abnormalities and pollen sterility of 43%. (b) We have not come across any information on this. (c) Cytology of different Dwarfs like those from India and Malaysia have been studied. However, data on the cytology of D×D hybrids are not available.

Genetic Potential of some Coconut Populations of the Philippines

E.N. BALINGASA and C.B. CARPIO
Philippines Coconut Authority, Agricultural Research Branch
Bago-Oshiro, Davao City

Abstract

Six Tall and two Dwarf coconut populations were observed to study the genetic potentials. The rate of fruit set varied inversely with the number of female flowers. Tagnanan and Baybay populations gave meat : nut less water ratios of 0.46 and 0.44, respectively and also possessed the highest copra content/nut (304 g and 288 g spectively). The copra/nut content of Catigan and Tacunan populations of 209 g and 213 g was also high for Dwarf populations.

The male phase of Catigan lasted 24.6 days and of Tacunan 23.3 days. The female phases lasted for 8.6 and 8.1 days, respectively. Self fertilization occurs in both the populations. Intra-inflorescence overlap of male and female phase of Catigan lasted 6.6 days and of Tacunan 4.6 days. The mode of pollination was semi-direct.

Introduction

Little research has been undertaken in the realm of coconut breeding in the Philippines. Most often, works were confined to the description of varieties, but since the characters to be studied are complex, the observations had not been sufficiently precise. The characteristics of even such widespread types as Laguna and San Ramon are not fully known, and under the same denomination, often very diverse types are covered. Certain varieties were described merely as botanical curiosities.

The genetic variability of coconuts in the Philippines is likely to be great. The country lies in south-east Asia, a probable centre of origin of the coconut (Merril, 1936, 1937) and the great number of islands favours the existence of interesting ecotypes. Jumella and Hubert (cited by Copeland, 1931) stated that there were more than 40 varieties in the Philippines. Copeland (1931) and Alzina (1931) reported 15 varieties or forms. Carlos (1963) reported three varieties which he divided into various forms and further subdivided them into types. Balingasa *et al.* (1972, 1974) and

Balingasa (1975) were also of the opinion that a wide genetic variability existed in the Philippines. There are complications, however, in collecting and establishing the real identity of these coconut populations because of varied dialects used by the people in different areas and wrong nomenclature.

The prime objective of this study was to identify the basic merits of coconut populations on the basis of a sound genetic potential analysis and to establish the breeding behaviour of two Dwarf populations.

Materials and Methods

During travels to coconut producing provinces, eight phenotypically distinct populations were found and observations were carried out on them (Table 1).

TABLE 1. Details of coconut populations studied

Populations	Number of palms studied	Age in years	Observation time*		Location
			From 1974	Until 1975	
Catigan (CAT)	50	14	Aug.	Sept.	Catigan, Davao City
Tacunan (TAC)	44	8	Aug.	Sept.	Tacunan, Davao City
Laguna (LAG)**	110	18	Aug.	Sept.	Bago-Oshiro, Davao City
Bago-Oshiro (BAO)	100	60	Aug.	Sept.	Bago-Oshiro, Davao City
San Ramon (SNR)	100	60	Sept.	Aug.	San Ramon, Zamboanga City
Zamboanga (ZAM)	100	55	Sept.	Aug.	San Ramon, Zamboanga City
Baybay (BAY)	81	25	Sept.	Aug.	Baybay, Leyte
Tagnanan (TAG)	100	20	Nov.	Sept.	Tagnanan Estate Inc., Mabini, Davaodel Norte

*Represents harvests for one year. All were harvested monthly, except TAG which was harvested in 45 day cycles.

**Planted at the PCA Davao Research Centre, Davao City with seed nuts obtained from the BPI Tiaong Experiment Station.

Six of these populations belonged to the Tall type. CAT and TAC were Dwarf types. The Dwarf populations were green forms and possessing fairly large nuts. They differed from each other and even more from Malayan Dwarf.

The data on the analysis of the observed populations are given in Table 2.

TABLE 2. Leaf analysis of various populations

Population	Percentage mineral composition of leaf No. 14 (based on dry matter)							
	N	P	K	Ca	Mg	Na	Cl	S
CAT	1.88	0.150	1.477	0.311	0.257	—	0.272	—
TAC	1.76	0.127	1.388	0.207	0.243	—	0.236	—
LAG	1.99	0.156	1.632	0.382	0.209	0.008	0.119	—
BAO	1.88	0.169	0.884	0.407	0.270	0.108	0.263	—
TAG	2.10	0.164	1.440	0.410	0.200	—	0.669	0.224
BAY	1.32	0.127	1.559	0.283	0.115	0.054	0.760	0.174
SNR	2.01	0.154	1.003	0.519	0.295	0.022	0.329	0.197
ZAM	2.15	0.152	0.106	0.402	0.252	0.051	0.193	0.244
Critical Levels	1.80 – 2.00	0.120	0.800 – 1.000	0.500	0.300	Uncertain		

*Fremond *et al.* (1966).

The different factors which combine to determine the number of nuts per tree were examined: (*i*) number of bunches ; (*ii*) number of female flowers ; and (*iii*) rate of fruit set. Nut component data (weights of husk, shell, and fresh meat) were also likewise collected.

To get reliable data on weight, one nut sampled at random was taken from every five harvested nuts. Sample nuts were stored till the husk dried up and their weights were determined together of all the nuts sampled from a tree. Rates of leaf fall were recorded after initially marking the first open leaf after the spear (leaf rank) as the basis for subsequent counting (using different colour paints during each counting). Recording was done at six months intervals.

In the Dwarf populations, the floral biology was also observed daily for one year additionally.

Results and Discussion

Nut production. The number of nuts produced varies with a number of external and internal factors. This character has been reported to exhibit 48% heritability (Liyanage and Sakai, 1961). Hence the populations were studied for the various components of yield (Table 3).

The number of productive bunches/tree/year was the most stable character with a CV of 22% (Table 4). The only remarkable variation

TABLE 3. Variability in nut production in the populations*

	Annual yield/tree			
	Bunches harvested	Nuts harvested	Female flowers	% fruit set
CAT	10.5±0.3	61.2±3.7	146.1± 9.8	42
TAC	9.6±0.9	69.8±5.5	315.2±35.6	22
LAG	14.0±0.2	156.4±3.8	609.2±50.7	26
BAO	12.4±0.3	105.6±2.9	297.4±12.8	36
BAY	14.4±0.2	71.3±2.0	338.6±12.7	21
TAG	14.5±0.3	91.1±2.8	203.5± 6.0	45
SNR	14.3±0.1	84.2±2.0	258.5±10.1	33
ZAM	15.2±0.3	66.1±1.8	235.4± 9.7	28
Mean	13.1±0.4	88.2±3.1	300.5±18.4	29

*Confidence interval based on 99% limit.

TABLE 4. Variability for yield components in the populations

Population	Coefficient of variability (%)			
	Bunches harvested	Nuts harvested	Female flowers	Mean
CAT	23	43	47	37.7
TAC	59	32	75	55.3
LAG	15	26	87	42.7
BAO	24	28	43	31.7
BAY	12	25	34	23.7
TAG	18	21	20	20.0
SNR	9	23	39	23.7
ZAM	17	28	41	28.7
Mean	22	30	50	

noted was between Dwarfs and Talls. The number of harvested nuts and the number of female flowers varied widely among populations. The degree of variation was higher for number of bunches (Table 4). Similarly, the rate of fruit set varied among populations. This is one character, which although partly governed by genetic factors, is influenced considerably by climatic variations. In CAT, severe nut fall occurred at about 6-7 months as the crown was laden with bunches of about 10 developing nut

each and more. It appeared that the leaf axil attachment was not sufficiently strong to support such a large number of nuts. However, fruit set percentage was high due to lesser number of female flowers.

Nut component characters. The data are presented in Table 5. In coconut breeding, too much attention had been focused on size of nuts and not enough on nut component characters. Currently, crop breeding programmes show much concern for improving the harvest index which measures the economically useful part of the total biological production

TABLE 5. Nut component characters of the various populations*

Population	Quantity/nut (in g)			Meat
	Husk	Shell	Meat	Nut minus water
CAT	464± 8.5	189±2.9	418±4.6	0.39
TAG	412±14.7	213±6.5	426±6.4	0.41
LAG	343± 6.4	208±4.7	389±8.2	0.41
BAO	389± 7.2	236±3.8	427±7.0	0.41
BAY	466±10.5	274±5.2	576±11.1	0.44
TAG	406± 6.9	317±4.5	608±7.8	0.46
SNR	430± 8.8	236±3.4	452±6.2	0.40
ZAM	423± 8.6	235±4.2	425±7.9	0.39

*Weights rounded into whole figures and confidence interval values computed to 99% limit.

The ratio $R = \frac{\text{Weight of fresh meat (g)}}{\text{Weight of nut less water (g)}}$ indicates the portion of the nut (fresh meat) considered as the most useful part. Since the quantity of water is very variable even between nuts within a population and the dry matter content of this water is very small (Foale, 1968), the weight of nut less water is taken. Observations which include the water content of the nut (weight of husked nut, for example) makes comparison between populations difficult (De Nuce de Lamothe and Rognon, 1976). Large seasonal variations were noted on nut component weights, but the relationship R hardly varies as the weight of husk and shell varied proportionally with the fresh meat weight. This observation corroborates with that of De Nuce de Lamothe *et al.* (1976).

On an average, TAG had the highest quantity of fresh meat and R value (0.46), followed by BAY with an R value=0.44. These R values are excellent ratios. These two populations deserve immediate attention for taking up combining ability tests in them.

TABLE 9. Duration (days) and sequence of male and female phase*

Population	Phase duration		Intra-inflorescence overlap	Inter-inflorescence overlap
	Male	Female		
CAT	24.6	8.6	6.6	1.0
TAC	23.3	8.1	4.6	4.7

*Mean values of one year observation.

complete for the CAT populations and 50% complete for TAC. In CAT, there is a break of one day when no male flower is available on the same palm, but since the pollen emitted by the male flowers on the same inflorescence preceding the break is presumably still viable, self fertilization can still occur.

Seasonal variation of phases. Condition in Davao is characterized by no moisture deficit the whole year round. Mean rainfall record (for the 10 year period 1965-75) shows 12.3 cm in March (lowest) and 30.37 cm in May (highest). For coconut, 12.3 cm rainfall between two relatively high rainfall months (15.3 cm in February and 22.5 cm in April) poses no water deficit problem with a high moisture retaining capacity of the soil.

The length of male phase did not appreciably vary with season. It is quite difficult to relate the variations to the moisture condition in this locality since it has no distinct dry or wet season. For both the populations, the end of male phase and start of female phase vary correspondingly, so that intra-inflorescence overlap of the phases is hardly influenced by duration of the female phases.

Overlapping by the male phase of the succeeding inflorescence is strongly influenced by duration of the female phase (inflorescence n) in relation to the opening of the next inflorescence ($n+1$). This kind of overlap is high in TAC and minimal in CAT (Tables 10 and 11).

The sexual behaviour of the two Dwarf populations can be classified into just one type, type IV, i.e., semi-direct self fertilization (cf., Rognon, 1976), which is more or less complete overlapping of female phases, partly by the male phase of same inflorescence and partly by the male phase of following inflorescence. A simultaneous overlap within inflorescence n, and between n and $n+1$ can occur. Rognon (1976) has noted four types of overlap: Type I - strict cross pollination: on an average no overlapping of the phases; Type II—indirect self pollination: overlapping occurs exclusively with following inflorescence; Type III—direct self pollination; female phase is entirely covered by male phase of same inflorescence; Type IV—semi-direct self fertilization: more or less

TABLE 10. Seasonal variation in the duration of male and female phases and their overlapping in CAT*

Month	Male phase (n)**	Female phase (n)		Male phase start ($n+1$)***
		Start	End	
January	25.2	18.5	28.1	25.9
February	25.3	18.9	27.6	27.9
March	23.6	17.8	25.5	24.6
April	24.6	18.0	26.3	25.4
May	24.7	19.0	25.1	24.4
June	25.9	21.0	29.8	28.4
July	26.4	18.8	27.1	27.7
August	23.3	18.5	24.3	25.3
September	23.2	15.1	24.7	22.9
October	24.4	17.3	26.6	24.0
November	23.4	15.0	25.9	23.4
December	24.6	17.5	27.2	25.7
Mean	24.6	17.9	26.5	25.5

*Observation from September 1974 to August 1975.
**(n) Refers to the same inflorescence.
***($n+1$) Refers to the succeeding inflorescence.

TABLE 11. Seasonal variation in the duration of male and female phases and their overlapping in TAC*

Month	Male phase	Female phase (n)		Male phase start ($n+1$)
		Start	End	
January	24.8	20.0	27.8	23.9
February	24.6	20.6	27.8	24.7
March	23.1	19.9	26.2	22.8
April	22.5	19.3	25.0	22.4
May	22.2	17.9	25.5	19.6
June	22.2	18.0	25.8	19.4
July	22.2	17.0	26.4	21.1
August	22.8	17.1	26.4	20.1
September	21.4	16.5	25.5	20.6
October	25.8	20.3	29.2	24.3
November	23.4	17.7	27.0	22.3
December	24.0	19.2	27.5	23.6
Mean	23.3	18.6	26.7	22.1

*Observation from May 1974 to April 1975.

complete overlapping of female phases partly by the male phase of same inflorescence and partly by the male phase of following inflorescence.

A larger amount of self pollination takes place in CAT than in TAC due to longer duration of overlap within the same inflorescence (6.6 days *vs* 4.6 days) in CAT. Regarding the one day break, when the male phase of the same inflorescence is over, the pollen emitted in the preceding 48 hr by the same inflorescence will be viable, and this will prolong the self-pollination period.

Summary and Conclusion

This study was conducted to determine the characteristics of some coconut populations. Thus, six Tall and two Dwarf populations were observed for one year for nut production, nut component characters, and other related characters. For Dwarf populations, the floral biology was also analysed.

Variations were noted for the various characters both within population and among populations. Rate of fruit set varied inversely with number of female flowers. For nut component characters, Tagnanan and Baybay populations gave the highest meat÷nut less water ratios of 0.46 and 0.44. In addition, they also had the highest quantity of copra/nut (304 g and 288 g, respectively which is equivalent to 3.3 and 3.5 nuts/kg copra). The Catigan and Tacunan populations (both Dwarf) gave 209 g and 218 g copra/nut or 4.8 and 4.7 nuts/kg copra, respectively. This is unusually high for Dwarf populations.

Acknowledgement

Great appreciation is due to the Tagnanan Estate, Inc., for the utmost cooperation extended in this study. Tagnanan population was observed in this plantation. Similarly, the Visayas State College of Agriculture where the Baybay population was observed extended similar cooperation. To them and all others who helped in this study, the authors are very grateful.

References

Alzina, F.I. (1931) On the palms which are called *Cocos* and their great usefulness. *Philippine Agric.* **20** : 435-446.

Balingasa, E.N. and Carpio, C.B. (1972). Collection and evaluation of coconut cultivars, *Ann. Rept., 1971-72.* pp. 88-90. PHILCORIN, NSDB, The Philippines.

Balingasa, E.N., Carpio, C.B. and Santos, G.A. (1974). Coconut varieties in the Philippines. *Proc. Crop Sci. Soc.* Philippines, May 16-18, 1974.

Balingasa, E.N. (1975). Research program in coconut breeding in the Philippines. *Proc. FAO Technical Working Party on Coconut Production, Protection, and Processing.* (4th session) Kingston, Jamaica, 14-25 Sept. 1975. FAO, Rome.

Carlos, Jr. J.T. (1963). Agronomic studies on some cultivars of coconut (*Cocos nucifera* L.) in the Philippines. MS thesis, UPLB College, Laguna, Philippines.

Copeland, E.B. (1931). *The Coconut.* Macmillan, London.

De Nuce de Lamothe, M. and Rognon, F. (1976). The hybrid Port Bouet 121 : New results. *Oleagineux* **30** : 457-465.

Fremond, Y., Ziller, R. and De Nuce de Lamothe, M. (1966). *The Coconut Palm,* pp. 227 Intl. Potash Inst., Berne.

Foale, M.A. (1968). The growth of the young coconut palm II. The influence of nut size on seedling growth in three cultivars. *Aust J. Agric. Res.* **19** : 927-937.

Liyanage, D.V. and Sakai, K.I. (1961). Heritabilities of certain yield characters of the coconut palm. *J. Genet.* **57** : 245-252.

Merril, B.D. (1936). Essay in geobotany in honour of William Albert Satchell. pp. 47-61. *Cited by* Menon and Pandalai, The Coconut—A Monograph.

Merril, B.D. (1937). Proc. Amer. Phil. Soc. p. 78. *Cited by* Menon and Pandalai, The Coconut—A Monograph.

Rognon, F. (1976). Floral biology of the coconut. *Oleagineux* **31** : 13-18.

Trials with some Coconut Varieties and Hybrids in Papua New Guinea

J.H. SUMBAK
Agriculture Research Centre, Department of Primary Industry, Bubia, Lae
Papua New Guinea

Abstract

By the end of 1976, about 35 hectares of Malayan Dwarf mother palms have been planted out in Papua New Guinea's hybrid seed programme. Hybrid seed has become available early in 1979. Trials under way at Keravat (New Britain) and Bubia (New Guinea mainland) will determine the appropriate male parent(s).

Growth measurements taken 18 months from field planting clearly showed the superiority of hybrid seedlings over Tall types. At Bubia, Dwarf×Rennel Island hybrid was outstanding. Its uniformity was particularly striking and first flowering is expected within 30 months of field planting. The Dwarf×Gazelle Tall also performed well and the Dwarf×West African Tall hybrid looked impressive despite the fact that nursery selection was not possible. All the Tall types were inferior to the hybrids. The Kar Kar Tall source suffered very badly from *Drechslera* leaf spot at Bubia and there is no doubt that this genotype is particularly vulnerable to this disease. At Keravat where *Drechslera* did not constitute a severe problem, the Kar Kar type appears to be above average. It was superior to all the Tall types except Renel Island.

Blocks of potential male parents have been established at Bubia and Keravat while additional hybrids (particularly Dwarf×Kar Kar and Dwarf×Markham) will be tested.

Introduction

Some coconut stands in Papua New Guinea are about 90 years old while many are over 60 years old and are in need of replanting. In order to provide superior planting material, a hybrid coconut seed production scheme was undertaken in 1973 on the same lines as in Ivory Coast and elsewhere. By the end of 1976, about 35 have been planted with Malayan Dwarf (of the "red" type mainly). This area will be extended to 54 ha and this has been estimated to provide sufficient seed for replanting at least 3,000 ha each year. The first hybrid seed has become available early in 1979.

This paper deals with some coconut variety or source (termed "type") trials that have been laid out at Keravat (New Britain) and Bubia (on the New Guinea mainland).

Methods

The following five hybrid and four Tall types are being assessed :
(1) Markham Tall (MT); (2) Gazelle Tall (GT); (3) Kar Kar Tall (KKT); (4) Rennel Island Tall (RIT); (5) Malayan Dwarf (MD)×RIT; (6) MD× FMS (Federated Malayan States): (7) MD×ST (Solomons Tall); (8) MD ×GT (Gazelle Tall) ; and (9) MD×WAT (West African Tall).

Of these, types (4), (5), (6) and (7) were obtained from Solomon Islands.

Experimental design. The trials have been laid out at two locations. The main planting at Keravat has 3 spacings (7.5, 8.5, and 10.0×6.0 m giving 205, 160, and 167 palms/ha, respectively) as main plots and types as subplots. Each subplot contains 12 palms. It has 2 replications. A second trial has been planed at Bubia, as a back-up to the Keravat trial. In this, 9 types have been planted at 7.5 and 10.0×6.0 m spacings with 12 plants/type. At Bubia, the Natava source was planted in March 1975; MD×WAT in May 1975 and all the other types in February 1975.

Experimental procedures. The four types originating in Solomon Islands were collected in November 1973, then quarantined and grown in polythene bags at Keravat and then sent to Bubia. Type 8 was obtained from the hybrid seed production block. Type 9 was imported in October 1974 and quarantined at Keravat and Bubia. Types 1 and 3 were grown in normal nurseries at Bubia. Type 2 was air-freighted to Bubia in the form of germinated seedlings and field planted immediately.

Results

Observations on the Bubia plantings only are discussed here. Data on height, height gain, frond production, and basal circumference measurements 18 months after transplanting as well as the time lapsed between seed collection and time taken to 18 months from field planting are given in Table 1. Some of the MD×ST and MD×FMS appear to be Dwarfs instead of hybrids or perhaps a yellow version of hybrid. This should be resolved once flowering commences, but for the present, they are recorded as Dwarfs.

Drechslera incurvata leaf spot was found to affect severely the Kar Kar type seedlings and four were killed (see also, Sumbak, 1975).

Discussion

Both at Bubia and Keravat, the hybrids showed considerably better growth than Tall types. The MD×RIT hybrid was especially outstanding at both sites for vigour and uniformity. It is expected to flower within

TABLE 1. Growth measurements of varieties and hybrids 18 months after transplanting

Type	Height (cm)	Height gained (cm)	Frond production	Basal circum ference (cm)	Time collection to measurement (months)
1. MT	434	288	13.8	83	25
2. GT	400	320	15.4	69	25
3. KK	371	256	14.5	66	22
4. RIT	437	270	14.3	94	33
5. MD×RIT	603	421	18.6	121	33
6. MD×FMS	449	313	16.6	102	33
7. MD×ST	437	312	17.0	102	33
8. MD×GT	470	321	17.5	109	31
9. MD×WAT	323	249	16.4	53	26

about 30 months of transplanting. Of the other hybrids, MD×GT appeared to be a little ahead of MD×ST and MD×FMS. The lack of nursery selection and the slow germination and initial development (perhaps as a result of transportation) make it difficult to assess MD×WAT at this stage. This hybrid is perhaps a little more susceptible to *Brontispa logissima* attack than some of the other types. The pest is however easily controlled.

The Tall types did not show much differences among themselves except that the Kar Kar type was particularly susceptible to *D. incurvata*. Where this disease is not a hazard, the Kar Kar type appears to be better than the others. It is doing well at Keravat and in an extensive Tall types trial in Papua, it proved to be one of the two best types.

As both the Kar Kar and Markham sources appear to be distinctive in some characteristics from the general PNG (Papua New Guinea) type, their use as parents in a hybridization programme would be desirable.

Conclusion

All the hybrids appear to be superior to the Tall types at 18 months from field planting. Among these, the MD×RIT hybrid is the most outstanding and could well be the hybrid selected for future use in Papua New Guinea.

References

Sumbak, J.H. (1975). Leaf spots of coconuts. *Papua New Guinea Agric. J.* **26** (2, 3 and 4) : 43.

Some Observations on the Recovery of Hybrid Seedlings from Dwarf × Tall Cross Fertilized Seed Coconuts

K.M. THOMAS*
Coconut Hybridization Scheme, Department of Agriculture
Trichur, Kerala, India

Abstract

Percentage germination and recovery of hybrid seedlings were observed in a seedling population raised from 6123 coconut seeds obtained from 500 Dwarf Orange palms after hand pollination with pollen from selected Tall palms. The seeds were sown immediately after harvest. The percentage of germination (84.9 – 88.9%) was much higher than those obtained by earlier workers and was comparable with the germination percentage of West Coast Tall seed coconuts. The percentage mortality of sprouts observed (2.4—4.4%) was also much lower than that reported by earlier workers. The hybrid seedlings identified on the basis of petiole colour six months after germination amounted to 62.4—74.1%. This was far higher than that reported earlier. The variance tests of homogeneity of proportion of hybrid seedlings between mother palms and between centres where hybridizations were carried out showed that there were real differences between mother palms and between centres in the proportion of hybrid seedlings obtained. This may make it possible to identify palms which produce greater percentage of hybrids.

Introduction

The Dwarf Orange and Dwarf Green are the most important types of Dwarf coconuts observed on the west coast of India. The Dwarf Green type is believed to be 100% self fertilized. In Dwarf Orange, both self and cross-fertilizations occur (Rao and Koyamu, 1955; Satyabalan, 1958). It is a practice amongst the farmers of Kerala to sow open pollinated nuts of Dwarf Orange palms and select seedlings possessing copper or green coloured petioles for planting, as these are believed to be hybrids resulting from natural cross fertilization. These seedlings are more vigorous and productive than pure orange offsprings. In Malaysia, the green variety of Malayan Dwarfs has also been reported to give a proportion of 'semi-tall' progenies. Jack (1925) considered them as natural crosses of Dwarfs

*Presently, Special Agricultural Development Unit, Ponkunnam, 686506, Kottayam District, Kerala, India.

with Talls. Similar occurrence of natural hybrids from Dwarf palms has been documented by Dwyer (1938), Tammes (1949, 1955), and Liyanage (1956) also. A comparison of the yield performance of these off-type progenies of Dwarf Orange and Green types showed that they were superior to Dwarfs and Talls and even to the introductions (Ninan *et al.*, 1961; Ninan and Pandalai, 1962).

As the percentage recovery of such natural hybrids or off-types from the open pollinated Dwarf Orange palms is low, attempts had been made to produce true hybrids by controlled Dwarf×Tall crosses, but the results were reported to be not encouraging due to the low germination of cross fertilized nuts and also the appearance of a good proportion of Dwarf types (Patel, 1937; Liyanage, 1956; Ninan and Satyabalan, 1964).

However, in most of these reports, the crossings had been carried out on only very limited numbers of palms and the number of seeds obtained was also few. During 1974-75, the Kerala State Department of Agriculture launched a massive breeding programme to produce Tall×Dwarf and Dwarf×Tall seed nuts. This Project provided an opportunity to examine the germination and other characteristics of large numbers of Dwarf×Tall seed nuts. Some of these results are presented here.

Materials and Methods

In Trichur District, where this work was carried out, 500 Dwarf Orange palms were selected at three centres, Chavakkad, Irinjalakuda, and Kodungallur. They were grouped into five units of 100 palms each for convenience. The pollination technique consisted of emasculating the male flowers five days after the spathes were fully split open and later when the female flowers became receptive (this usually occurs on the 15th or 16th day and is indicated by the ivory colour and oozing of nectar from the stigma) hand pollinating them successively for three days using pollen collected from selected Tall palms. Unlike as in the case of Tall×Dwarf crossings, the inflorescences were not bagged mainly because the Dwarf palms are standing widely apart and chances of contamination with pollens of other Dwarf palms are considered negligible.

Mature nuts were harvested from December 1975 to April 1976 and sown immediately in two nurseries at Irinjalakuda and Karunagapilly. Normal planting and after care were followed in the nursery. A total of 6123 nuts were sown. The seedlings were scored when they were about six months old. Hybrids were identified by their green or copper coloured petioles.

Results and Discussions

The percentage germination of seeds obtained in the present study (84.9 and 88.9%; cf. Table 1) was much more than that obtained by Liyanage (1956) and Ninan and Satyabalan (1964). The normal germination rate

TABLE 1. Germination details of D×T hybrid seed nuts

Nursery and unit or seed source	Total seeds sown	% seed germination	% Yellow Dwarfs (on seed basis)	% D×T (on seed basis)	% D×T (on seedling basis)	% Dead sprouts (on seed basis)
I. Irinjalakuda						
(i) Chavakkad I	1120	82.7	18.8	59.8	72.4	4.0
(ii) Chavakkad II	844	88.3	14.3	72.7	82.4	1.2
(iii) Irinjalakuda III	1377	83.6	17.0	64.7	77.4	1.9
(iv) Kodungallur IV	373	85.8	12.9	69.7	81.2	3.2
(v) Kodungallur V	913	86.2	34.5	49.6	57.6	1.9
Total/Mean	4627	84.9	20.1	62.4	73.5	2.4
2. Karunagappilly						
(i) Chavakkad	823	89.7	10.3	75.3	84.0	3.9
(ii) Kodungallur	673	88.1	15.1	68.2	77.4	4.8
Total/Mean	1496	88.9	12.5	72.1	81.1	4.3

for ordinary West Coast Tall seed coconuts in Kerala State varies from 80 to 90% (Hariharan, 1976; Personal communication). So the rate of germination observed in the present study is comparable to that obtained for West Coast Tall seed coconuts.

So also, the percentage mortality of sprouts observed in this study (2.4 and 4.3%) was very much lower than that (34.4%) recorded by Ninan and Satyabalan (1964). In the present instance, the seeds were harvested only when they were fully mature and they were sown immediately after harvest. In this context the germination data collected from the Kazhakootam Nursery (Trivandrum District) was interesting. Here, when 3067 Dwarf × Tall seed nuts produced under this scheme in three centres were sown after 1-3 months of storage, the ungerminated and dead sprouts amounted to 26.6%. It is not clear if the previous workers had also given any storage or after-ripening treatments to the Dwarf × Tall seeds before they were sown. If so, this might have been the reasons for their recording lower germination percentage and greater mortality in sprouts.

Similar results were obtained for production of hybrids also. This came to 62.2-72.1%. These are far higher than the 17.1% reported by Ninan and Satyabalan (1964).

Variance tests of homogeneity of proportion of hybrid seedlings between mother palms and between centres, both on the basis of seednuts sown and seedlings obtained, showed that the x^2 values were highly significant. This indicated that there were real differences between mother palms and between centres in the proportion of hybrid seedlings produced. As individual palm records are available, the result has the practical advantage of identifying those palms which produce a greater percentage of hybrids. This would help to confine future pollination work to those palms only.

Acknowledgement

The hybridization work and subsequent studies were carried out under the guidance of Mr. G.K. Unnithan, Joint Director of Agriculture (Coconut Development), Directorate of Agriculture, Trivandrum. Grateful thanks are also expressed to Mr. P.S.D. Nair, Deputy Director of Agriculture, Trichur, for providing necessary facilities, Mrs. K. Syamala Devi, Junior Agricultural Officer, Irinjalakuda, for technical assistance and Prof. E.J. Thomas, Kerala Agricultural University, Trivandrum, for statistical scrutiny of the results.

References

Dwyer, R.E.P. (1938). Coconut improvement by seed selection and plant breeding. *New Guinea Agric. Gaz.* **4** : 24-102.

Jack, H.W. (1925). Dwarf Coconut. *Trop. Agri.* **64** : 75.

Liyanage, D.V. (1956). Intraspecific hybrids in coconuts. *Bull. Coconut Res. Institute*. No. 7. Ceylon.

Ninan, C.A., Pankajakshan, A.S., Satyabalan, K. and Gopinath, P. (1961). A comparison of the performance of some cultivars of coconuts in the Central Coconut Research Station, Kasaragod and the Agricultural Research Station, Nileshwar (Pilicode). *Indian Coconut J.* **15** : 12-19.

Ninan, C.A. and Pandalai, K.M. (1962). Recent trends in coconut breeding in India. *Indian Coconut J.* **15** : 97-104.

Ninan, C.A. and Satyabalan, K. (1964). A study of natural, self, and cross (Dwarf× Tall) progenies of Dwarf coconuts of the west coast of India and its bearing on the genetics of Dwarfs and the putative hybridity of their off-type progenies *Caryologia*. **17** : 77-91.

Patel, J.S. (1937). Coconut breeding. *Proc. Assoc. Econ. Biol.* **5** : 1-16.

Rao, M.B.S. and Koyamu, K. (1955). The Dwarf coconut. *Indian Coconut J.* **8** : 106-112.

Satyabalan, K. (1958). A note on the comparative study of the seedlings of natural cross dwarf (Dwarf female×Tall male) and those of pure Dwarf (self pollinated) in the nursery. *Indian Coconut J.* **11** : 102-105.

Tammes, P.L.M. (1949). Native cultivation of coconuts, especially in East Indonesia. Meded. Dept. Econ. Zaken No. 11 : 72.

Tammes, P.L.M. (1955). Review of coconut selection in Indonesia. *Euphytica* **4**: 17-24.

Discussions

Nelliat : Four types of seedlings are observed in the Dwarf Orange nursery, viz., small sized orange, small sized bronze, large sized orange, and large sized bronze. Have you worked out the percentage of each of these ?

Thomas : No, not yet.

Agronomy and Soil Sciences

Chairman : H.R. ARAKERI

Rapporteur : M. VELAYUTHAM

Effect of Interculture, Irrigation and Manuring on Coconut in Tamil Nadu, India

I. HENRY LOUIS and N.R. CHANDRASEKAR
Tamil Nadu Agricultural University, Coconut Research Station Veppankulam, Tamil Nadu, India

Abstract

The effect of two levels each of cultural, manurial, and irrigational operations on growth characters and yield of nuts was studied at three and eight years age in a field experiment laid out in a split plot design with three replications.

At three years, manuring increased height, girth at collar, number of leaves per year, number of leaves on the crown, length of leaves, and number of leaflets per leaf. Irrigation produced significant increase in height only. Cultural operations either alone or in combination with irrigation or manure did not have any effect on growth characters.

At eight years, manuring and irrigation together increased number of leaves and length of stem. Early and uniform flowering and increased yield of nuts per palm were also observed in these treatments. Irrigation alone increased number of leaves but cultural operations did not produce any significant effect on any of the characters. Interaction was observed only between manure and genotype and in the production of leaf.

Introduction

The State of Tamil Nadu in India grows about 109,000 ha under coconut and ranks third in India for area and second for production of coconuts. About a third of this area lies on the east coast where the soil is laterite, loamy and annual rainfall is below 1500 mm. Adequate information on the cultural and manurial requirements of coconut for this area is not available.

The present field experiment was laid out to study the effect of various agronomic practices like interculturing, irrigation, and manuring on growth and yield of nuts. The summary of the observation taken for the first eight years is presented in this paper.

Materials and Methods

The experiment has been laid out in a split plot design with all combinations of three variables, viz., cultural operations (with and no

operations), irrigation (with and no irrigation), and manuring (with and no manuring) each at two levels as the main-plot treatments, and selected and unselected seedlings of East Coast Tall variety as sub-plot treatments, and three replications. The subplot consists of eight palms, four selected and four unselected. The seedlings were planted in pits of 1 m^3 at 7.5 m spacing. A guard row of 16 seedlings, eight selected and eight unselected seedlings, has been provided around each main plot. Additional guard rows have been provided along the irrigation channels. The entire experiment consists of 192 experimental and 384 guard seedlings planted in 1965.

The cultural operations consist of ploughing with an iron plough in June-November and working with a cultivator in January-February. The irrigation treatment consists of pot watering all seedlings during the first three summers. Thereafter, only those seedlings receiving irrigation are irrigated once every fortnight during summer in the basins by subchannels. The palms receiving manure are given this as detailed in Table 1.

TABLE 1. Manuring schedule (in g) of the experiment

Age of palm	Ammonium sulphate	Superphosphate	Muriate of potash
I Year	45.5	45.4	90.7
II Year	90.0	68.1	136.1
III Year	136.0	91.0	181.0
IV Year	181.4	113.4	228.8
V Year	226.8	185.9	362.9

The growth characters were measured in the third and eighth years of growth. These consisted of seedling height, collar girth, number of leaves, length of leaves, number of leaflets, height of stem, age at first flowering, and nut yield. The data are presented below.

I. Observations in the Third Year

1. *Seedling height.* Manuring and irrigation produced significant increase in height of seedlings. The interaction between manuring and cultural operation was also significant.

2. *Collar girth.* Manuring alone among the three treatments and four interactions produced significant increase in collar girth. It was 0.67 and

1.13 m in the two manuring treatments (CD=0.10 m). Collar girths for the two cultural operations treatment were 0.91 and 0.89 m and for the two irrigation treatments 0.88 and 0.92 m.

3. *Number of leaves produced.* Again, manuring alone produced more leaves in the third year, the two manuring plots producing 7.0 and 9.9 leaves (CD=0.6) during the year.

4. *Leaf length.* Both manuring and no cultural operations produced significant increases in length of leaves. The length of leaves in manured plots was 3.3 m and nonmanured plots 1.9 m, and in plots with and without cultural operation was 2.4 m and 2.8 m, respectively (CD=0.25). The interactions between manuring and cultural operations and manuring and irrigation were also significant.

5. *Leaf number.* In this case also, manuring alone showed a significant increase in number of leaves. The number of leaves in the no manure and manured plots was 8.0 and 10.8, respectively (CD=1.0).

II. Observations in the Eighth Year

1. *Total number of leaves produced.* Manuring and irrigation produced significant increases in total number of leaves produced. Palms receiving manure produced 91 leaves, while those without manure produced only 62.2 leaves (CD=4.7 leaves). Likewise, palms receiving irrigation produced 84.3 leaves while those without irrigation 76.6 leaves. Manured palms produced more leaves irrespective of irrigation; also, irrigation had no effect on leaf number in palms not receiving any manure. Manured palms with irrigation recorded 98.8 leaves while unmanured palms with irrigation produced 70.5 leaves.

2. *Height of stem.* The stem height was measured from the ground level to the lowest edge of the crown. Manuring had a highly significant effect on height. Palms receiving manure recorded 1.7 m height and those not receiving manure recorded only 0.5 m height (CD: 0.4). The palms in the two irrigation treatments showed 1.1 m (without irrigation) and 1.3 m (with irrigation) height.

3. *Number of palms commenced flowering.* As with all other characters studied, manuring had a profound effect on flowering also, with palms in the manured plots flowering earlier than the rest (Table 2). Further, a higher percentage of palms in manured plots came to flowering at eight years. A similar effect was seen in palms raised from selected nuts.

TABLE 2. Effect of various treatments on flowering

Treatment	Palms from unselected nuts		Palms from selected nuts	
	Time of first flowering in months	%-age of palms flowered	Time of first flowering in months	%-age of palms flowered
$C_0I_0M_0$	Note flowered	—	87.0	33%
$C_0I_0M_1$	65.3	100%	83.0	100%
$C_0I_1M_0$	88.0	8%	87.0	17%
$C_0I_1M_1$	69.0	100%	65.0	100%
$C_1I_0M_0$	91.3	17%	92.0	33%
$C_0I_0M_1$	80.3	17%	68.3	50%
$C_1I_1M_0$	98.5	8%	88.0	17%
$C_1I_1M_1$	67.0	92%	67.3	100%

Summary and Conclusions

The results presented here are in the nature of a progress report only. The data simply show the importance and value of manuring to coconuts in promoting early growth and inducing early flowering. The data also show usefulness of irrigation. The palms raised from selected nuts have also responded better to the agronomic operations. These are best illustrated from the cumulative yield of nuts from the various treatments (Table 3).

TABLE 3. Effect of different treatments on cumulative yield of nuts

Treatment	Cumulative yield of nuts
$C_0I_0M_0$	18
$C_0I_0M_1$	360
$C_0I_1M_0$	197
$C_1I_1M_1$	1027
$C_1I_0M_0$	12
$C_1I_0M_1$	291
$C_1I_1M_0$	—
$C_1M_1M_1$	1262

Acknowledgements

The authors are thankful to Dr. S.R. Sree Rangasamy, Principal, Krishi Vigyan Kendra, for suggestions and corrections made while preparing this paper. They also thank the Indian Council of Agricultural Research for financial assistance.

Discussions

Nelliat : Shall I conclude from your paper that irrigation is not necessary under Veppankulam conditions?

Louis : No. The positive effects of water are given in my text: (1) irrigation produced significant increase in height of seedlings and number of leaves. (2) Irrigation in combination with manure advanced flowering period by 22 months.

Venkateswaran : What is the number of months by which flowering has been advanced and yield increased as a result of manuring and irrigation separately?

Louis : By manuring alone, the palms flowered 24 months earlier and gave 272% increase in yield. Irrigation in alone failed to contribute to the advancement in flowering and increase in yield.

Asana : Did I understand you correctly that there was an interaction between variety and manurial treatment? If so, what sort of interaction did you observe? This is an important question in relation to variability in yield.

Louis : A significant increase in the total number of leaves produced was observed due to the interaction between cultural operation and selections.

Kulkarni : What was the initial fertility status of these soils?

Louis : The major nutrient content of the soil was 0.364% N, 0.0003% P_2O_5, and 0.0005% K_2O with pH in the range of 5.8-6.8.

Effect of Moisture Stress and Irrigation on Yield of Coconut in Sri Lanka

V. ABEYWARDENA
Coconut Research Board, Lunuwila, Sri Lanka

Abstract

A coconut inflorescence carries about sixteen female flowers at the time of opening of the spathe. About two-thirds of this number is lost through immature nutfall over the first six months of nut development. Yield variations are due to variations in this immature nutfall arising possibly from inadequate supply of soil moisture.

Work in Sri Lanka has been directed primarily towards establishing a quantitative relationship between rainfall and crop variations and it met with considerable success towards 1967. This enabled us to forecast crops a year ahead with considerable accuracy ($r=0.93$). Such forecast of crops for a given estate or restricted area involved as much as twelve rainfall variables. A forecast for the whole country on this basis would necessitate the consideration of a number of rainfall stations. This would therefore involve a prohibitively large number of rainfall variables in the production function. To obviate this difficulty a different approach based on "droughtiness", that is, the antithesis of rainfall was adopted. Forecasts of coconut production in Sri Lanka through this index of droughtiness have been very successful.

As a logical follow up of these investigations, an irrigation experiment was commenced recently involving supply of different quantities of water at different frequencies to the palms, in order to ascertain how much of this nut loss through immature nutfall could be arrested through watering. Even at this very early stage of the experiment, the watered palms showed significant increase in yield over the control.

Introduction

The importance of an adequate supply of soil moisture in minimising nutfall and thereby increasing coconut yields was first stressed by Ferguson (1923) and by a number of others later. Yet, there existed contradictory views about the direct cause of immature nutfall. Gadd (1923) and MacDonald (1924) observed that drought caused nutfall, while Park and Fernando (1940) observed that nutfall was heavier during the rains. At the same time, the local planters believe that rains following a drought give rise to nutfall. Abeywardena (1971) reconciled these

three views as an expression of the same phenomenon, in which nutfall occurs purely as a result of moisture stress arising from drought. He also adduced experimental evidence to show that immature nutfall was heavier following a dry period.

While the consensus of opinion attributed yield variations in coconut to variations in soil moisture supply due to varying rainfall conditions, a quantitative definition of a relationship between rainfall and crop yields leading to efficient crop forecasts was elusive until 1967. Salter and Goode (1967) stated that "with so great a time lapse between the initiation of leaf and inflorescences primordia and flowering and with many other inflorescences in various stages of development present at the same time, it has been found difficult to relate accurately growth, flowering, or yield responses to any particular climate conditions".

Abeywardena (1968) evolved a production function (r=0.93) relating coconut yield to rainfall. However, this approach was applicable to a given estate or small region only and further, the production function even for a given estate involved about 12 rainfall variables. Consequently, a forecast for the whole of Sri Lanka covering areas with widely different rainfall patterns, would necessitate a prohibitively large number of rainfall variables in the production function.

Part I of this paper describes the derivation of a "drought index" based on rainfall designed to overcome the above difficulties and also indicates the efficiency of this drought index in providing crop forecasts a year ahead for Sri Lanka as a whole. Part II of this paper records the initial yield responses shown in an irrigation experiment conducted in Sri Lanka as a logical follow up of the success shown by the drought index.

Materials and Methods

I. *Drought Index*

The derivation of a drought index based on rainfall rests basically on the logic of determining the extent to which rainfall fails to provide the minimum requirements of soil moisture for optimum production. Therefore, to evolve an efficient drought index, answers have to be found to the following questions : (1) What is the minimum quantity of rain in a month, below which moisture stress in the palm can result in immature nutfall ? (2) Subject to this minimum, what is the rate at which droughtiness increases with every cm reduction in monthly rainfall ? (3) How does droughtiness increase when there are successive droughty months ? For instance, if there are two successive months with only one inch (2.5 cm) rain, will total droughtiness for the two-month period be the sum of drought scores of the two individual months, or, is it something more ? If so, how much more ? (4) For a given quantum of rainfall, say one inch (2.5 cm) in a month, is droughtiness the same for any month of the

year, or, is it higher during months having longer day lengths ? (5) To what extent does heavy rainfall preceding a dry month, lessen the droughtiness of a particular dry month ? Can we quantify this sobering effect in relation to the degree of previous heavy rainfall and the time lag between the period of heavy rainfall and dry month ?

Crop and rainfall data of Bandirippuwa Estate over a 25 year period were statistically analysed for answering the above questions. For a start, the score for droughtiness, when rainfall per month is 10 inches (25.4 cm) or more was considered to be unity. On this basis, we used hypothetical multipliers commencing from 1.1, 1.2, 1.3, etc., to denote the rate of increase of droughtiness with every inch (2.5 cm) decrease in rainfall in a given month, and calculated for each year an integrated drought index based on monthly scores corresponding to each of the above multipliers. This was followed up by calculating a correlation coefficient (r_{xy}) with yield as y and the previous year's drought index as x. The multiplier providing the maximum correlation was considered to be the answer to the first question.

The answer to all other questions were similarly obtained by a process of iteration leading to the maximisation of correlation coefficients, thereby giving rise to a score card for droughtiness.

II. *Irrigation Experiment*

This experiment conducted at Ratmalagara Estate on a sandy-loam soil consisted of pouring water within a radius of 150 cm around the base of the palm, the surface run-off being avoided by a circular bund of earth around each palm. The experiment was divided into three sub-experiments corresponding to the following three yield groups : (1) high yielding : 85 nuts/palm/annum ; (2) mid yielding : 60-84/nuts/palm/annum ; and (3) low yielding : 35-59 nuts/palm/annum.

Each sub-experiment was laid out in a randomized design with the following four treatments replicated five times : (1) Control (only rainfed); (2) Single dose of 88 gallons (400 l)/palm once a week; (3) Single dose of 88 gallons (400 l)/palm once a fortnight; and (4) Double dose of 176 gallons (800 l)/palm once a fortnight.

Watering was done only if during the week following the last watering, the total rainfall was less than 0.5 inches (1.25 cm). If it was more, watering was postponed by a certain number of days depending on the quantum of rainfall received during the week.

Result

I. *Drought Index*

The score card for droughtiness obtained by the above method and the method of scoring are given in Appendix.

Ten representative rainfall stations spread out over the main coconut

growing areas in Sri Lanka were selected and drought index was calculated for each year for the period 1945-1975. A multiple regression equation relating the total coconut production in Sri Lanka (y) with the previous year's drought incidence of 10 rainfall stations ($x_1 - x_{10}$) was calculated. The multiple correlation coefficient was 0.96.

A comparison of the total production as estimated by the normal method practised in Sri Lanka and the production predicated on the basis of the above equation is shown in Table 1. A very close prediction may be observed in it.

TABLE 1. Comparison of observed and predicated production of coconuts

Year	Observed production (nuts in millions)	Predicated production (nuts in millions)	Percentage error of production
1945	1851	1965	+7.8
1946	1562	1720	+10.1
1947	1542	1673	+0.8
1948	1974	1950	−1.2
1949	1978	2037	+3.0
1950	2095	2044	−2.4
1951	2354	2244	+4.7
1952	2574	2407	−6.5
1953	2403	2184	−9.1
1954	2349	2290	−2.5
1955	2746	2785	+1.4
1956	2661	2416	−9.2
1957	2229	2232	+0.1
1958	2201	2275	+3.4
1959	2491	2514	+0.9
1960	2362	2384	+0.9
1961	2796	2746	−1.8
1962	2993	2994	0.0
1963	2704	2739	+1.3
1964	3148	3094	−1.7
1965	2835	2876	+1.4
1966	2621	2495	−4.8
1967	2577	2563	−0.5
1968	2764	3007	+8.8
1969	2616	2667	+1.9
1970	2605	2758	+5.9
1971	2799	2777	−0.8
1972	2958	3073	+3.7
1973	2272	2615	−4.7
1974	2353	2534	+7.7
1975	2773	2771	−0.1

II. *Irrigation Experiment*

The response to watering in the first and second year of application is shown in Table 2.

TABLE 2. Effect of irrigation on nut yield (ha/year)

Treatment	Nuts/ha/annum (1974-1975)			Weighted average
	Low yielding	Mid yielding	High yielding	
Control	8375	10411	16181	10734
Single dose weekly*	9007	12052	17320	11972
Single dose fortnightly	9262	11278	17142	11624
Double dose fortnightly	8548	12271	16378	11785

*Single dose : 400 l/palm.

Conclusion

Coconut crop forecasts based on the drought index are far more precise, meaningful, and convenient than any based on precipitation data. Yet, the score card for droughtiness derived by the method explained needs refinement. The minimum gap allowed for in this method of scoring is one inch (2.5 cm). This, we feel is too coarse. For example, rainfall in a month of 1.05 inches (2.7 cm) or 1.95 inches (4.8 cm) would get the same score for droughtiness.

Moreover, if crop forecasts are to be done for very large regions, such as India, where the latitude differences may differ considerably, it would be necessary to divide the total coconut area into reasonably homogeneous zones, and work out separate score cards for droughtiness, for each zone and make separate forecasts.

The counter-measure to droughtiness, that is, of supplying water to palms during dry periods is effective to a certain degree (cf. Table 2). But, it is not impressive enough when it is considered that the average nut loss due to moisture stress is two-thirds. This may be because data have been reported for only two years, and these years were particularly good rainfall years. Further, with about 3½ years life cycle of a bunch of coconuts from the primordium to the mature bunch, it may take about four years to show a worthwhile response. This experiment will be continued for about 10 years to evaluate the true potential reponse to irrigation.

Acknowledgements

I am deeply indebted to the officers of the Biometry Division, Coconut Research Board, Lunuwila for their assistance in conducting the experiments and statistical analyses of data.

References

Abeywardena, V. (1968). Forecasting coconut crop using rainfall data. *Proc. F.A.O. Working Party on Coconut Production, Protection, and Processing*, (3rd Session) F.A.O., Rome.

Abeywardena, V. (1971). Crop losses in coconut through button shedding and immature nutfall. *Ceylon Cocon. Planters' Rev.* 6 : 97-105.

Gadd, C.H. (1923). Nutfall of the coconuts. Bull. No. 53, Dep. Agric., Sri Lanka.

Ferguson, J. (1923). *Coconut Planters' Manual.* Ceylon Observer Press, Colombo.

MacDonald, J. (1924). Rep. Dep. Agric., Kenya. 106 p.

Park, M., and Fernando, M. (1941). Diseases of village crops in Ceylon, Govt. Press, Colombo.

Salter, P.J. and Goode, J.E. (1967). Crop responses to water at different stages of growth Res. Rev. No. 2. Comm. Bur. Hort. and Plant. Crops, East Malling, Madistone, Kent.

APPENDIX
(Tentative scores for droughtiness)

Length of dry spell (months)	Level at which wet spell is broken					
	1" (2.5 cm)	2" (5.0 cm)	3" (7.5 cm)	4" (10.0 cm)	5" (12.5 cm)	6" (15.0 cm)
1	68.82	43.01	26.88	16.80	10.50	6.56
2	27.53	17.20	10.75	6.72	4.20	2.62
3	11.01	5.88	4.38	2.69	1.68	1.05
4	4.40	2.75	1.72	1.08	0.67	0.42
5	1.76	1.10	0.69	0.43	0.27	0.17
6	0.70	0.44	0.28	0.17	0.11	0.07
7	0.28	0.18	0.11	0.07	0.04	0.03
8	0.11	0.07	0.04	0.03	0.02	0.01

Droughtiness of a given year at a given rainfall station is scored on the monthly rainfall values for the year using the above score card.

Suppose the level at which the wet spell is broken is 2 inches (5.0 cm). then only the first two columns of scores will be used generally except in exceptional circumstances. If it is taken as 2" (5.0 cm), only those months that have less than 2" (5.0 cm) rain get a score for droughtiness.

If it is a single month less than 2″ (5.0 cm), it will get a score from the first row, i.e., 68.82, if less than 1 inch (3.5 cm), and 43.01, if more than 1 inch (2.5 cm).

If there are two consecutive months with less than 2″ (5.0 cm) in each month, then it will get the corresponding score relevant to each single month and also a value from the second row to indicate the additional effect of the two-monthly stretches. For a stretch of more than one month, the higher rainfall value in any of the months is used to get the score. If there are, say, three consecutive months less than 2″ (5.0 cm), it gets scores for single months scores for two-monthly periods, and also a score for the three-monthly period from the third row.

Examples.:

	(Rainfall values)		
	Year		
	1953	1954	1955
January	4.24	4.84	1.28
February	3.16	2.06	1.36
March	6.28	12.82	3.49
April	15.00	14.28	12.24
May	0.89	11.81	17.29
June	14.49	1.10	4.93
July	16.69	4.89	1.00
August	0.71	4.48	0.21
September	3.89	3.95	16.73
October	22.08	13.43	11.06
November	5.11	6.41	11.82
December	0.76	13.63	2.10
	Scoring for droughtiness		
	68.82	43.01	43.01
	68.82		43.01
	68.82		17.20
			43.01
			68.82
			17.20

Residual effect of previous heavy rain. If a dry period is preceded by heavy rainfall, then droughtiness is lessoned. To make allowance for this, the following table is to be used.

Level of previous rainfall (inches)*	Previous month	Two months prior
10″-11″+	0.8	1
12″-13″+	0.7	1
14″-15″+	0.6	0.8
16″-17″+	0.4	0.7
18″-19″+	0.1	0.6
20″-21″+	0	0.4
22″-23″+	0	0.3
24″ and over	0	0.2

*One inch is 2.5 cm.

Consider the example given earlier in 1953; 0.89″ in May got a score of 68.82. This was preceded by 15 inches of rain in the previous month. The corresponding value in the second table for 15″ (37.5 cm) of rain in the previous month is 0.6. Therefore, the score of 68.82 is multiplied by 0.6 to give the score 41.29.

Similarly, 0.71″ in August had a rainfall of 16.69″ in the previous month which has a multiplier 0.4. It also has a rainfall of 14.49 two months prior, carrying another multiplier 0.8. Therefore, its earlier score has to be multiplied by 0.4 as well as 0.8. Thus, its adjusted score is $68.82 \times 0.4 \times 0.8 = 22.02$, Again, 0.76″ in December was preceded by 22.08″ two months before. This has a multiplier 0.3. The drought score is $68.82 \times 0.3 = 20.65$.

Thus, the adjusted droughtiness for the three years will be as follows :

1953	1954	1955
41.29	27 53	30.11
22.02		43.01
20.65		17.20
		30.11
		68.82
		17.20

Adjustment for increased droughtiness during periods of longer day length. The period April-September has longer day lengths. It is also known to be more moisture sensitive. Thus, a given intensity of dry spell brings about more droughtiness during this period.

Discussions

Bhaskaran : Have you taken day length as a factor in seasonal variation of crop production within 2 years ?

Abeywardena : Yes, moisture sensitivity is high during periods of long day lengths ?

Shanthamallaah : How is the assessment made of the actual levels of moisture stress due to which the palms have suffered moisture stress ?

Abeywardena : The assessment is made on a relative basis depending on the duration of the dry period.

R.N. Rao : Have you correlated between any cyclone effects and immature nin drop ?

Abeywardena : No. We get no cyclone in Sri Lanka.

Nelliat : What is the basis for fixing watering level at 88 gals. (400 litres app.)/ palm ?

Abeywardena : Based on our earlier findings that effective droughtiness for coconut arises at a critical value of 2 in. (5.1 cm.)/month.

Fremond : What is the lay out of the experiment ? And the number of palms per plot ?

(2) How do you explain the high yield of the control ?

Abeywardena : The design was a randomised block design with four treatments and six replications. A plot was a single palm.

(2) The high yield of the control is because the experimental block was on a good soil and the area receives pretty good rainfall

Asana : How does excess soil moisture influence button drop ? Does it affect it the same way as moisture stress ?

Abeywardena : Excess soil moisture, if it is through precipitation, will affect yields due to reduction in the hours of sunshine.

Venkateswaran : What are the factors which have been included in the production function ? Have you taken into consideration the effect of temperature ?

Abeywardena : The factor was the drought index. Temperature was not included as within the latitude range of Sri Lanka, temperature is not limiting.

Soils of Coconut Garden Areas in '*Maidan*' Parts of Karnataka, India

R.S. MURTHY, N.K. BARDE, S.R. NAGABHUSHANA, K.R VENUGOPAL, C.R. SHIVA PRASAD and C.S. HARINDRANATH

National Bureau of Soil Survey and Land Use Planning, Regional Centre, Bangalore, India

Abstract

Soils from the coconut garden areas in *maidan* region of Karnataka (parts of Hassan, Tumkur, and Bangalore districts) were studied. The geology of the area consists of Dharwarian schists and peninsular gneisses with younger granites. Generally, the coconut gardens occupy the low lands (valley bottoms, river and stream banks). The soils are deep to very deep alluvial and colluvio-alluvial in origin, light yellowish brown, reddish brown to dark gray brown, coarse loamy to fine loamy, occasionally fine to very fine in some horizons, well drained, rapid to slowly permeable, non-calcareous or calcareous families of Inceptisols and Entisols. Studies of eleven representative soil series reveal a range of pH between 5.5 and 9.5, low to medium and high moisture retentivity, low to high available potash and phosphorus fixing capacity, presence of felsic minerals and lighter fractions of Bangalore district soils and ferromagnesian suite in the fractions of sand in Hassan and Tumkur district soils, where they are 'made up' by addition of extraneous materials as a part of management practice.

Introduction

India grows one million ha under coconuts. Of these, 15% area is accounted for by Karnataka. In Karnataka, major portion of the coconut gardens is located in the coastal areas and the rest is distributed in the interior *maidan* regions. This is an undulating open area with an annual rainfall of 60-70 cm and devoid of dense forests. This area was studied to find out the physiographical, morphological, chemical, and mineralogical variations.

The area selected for this study is situated in the central and south-eastern parts of Karnataka and are located between 12°30'-13°45' N and 76°00'-77°30' E and distributed in Channapatna, Ramanagaram, Turuvekere, Chikanayakanahalli, Tiptur, Arsikere, and Channarayapatna taluks of Bangalore, Tumkur and Hassan districts. In general, the area has a semiarid, subtropical climate with an average annual rainfall of 60-70 cm.

The maximum precipitation occurs during June to September. The mean maximum temperature is 35°-40°C and mean minimum temperature 10-15°C.

Geologically, the area dates back to Archean era. The dominant rock types are granites and granite gneisses with intrusions of dolerites and diorites. Quartzites and schistose rocks are common in Tumkur and Hassan districts.

The general topography of the area is ridge and valley type. The coconut gardens in these areas occupy valley bottoms, and stream and river banks. A glance at the map of the area in parts of Tumkur and Hassan districts clearly indicates the distribution of coconut gardens in all the valley areas, while it is more concentrated along the major drainage line in Bangalore district.

The differences with regard to physiographical, soil morphological, analytical, and mineralogical characteristics, and management practices are briefly discussed in this paper.

Materials and Methods

The soils occurring in these areas are grouped under eleven soil series based mainly on their morphological characteristics like depth, colour, texture, structure, consistency, presence of gravels, and soil reaction. The different soil series recognised are Kanatur, Hamplapura, Mattigatta, Gandhalu, Huliyar, Arsikere, and Bendekere in Tumkur and Hassan districts, and Suvarnamukhi, Huluvadi, Kanva, and Virupakshapura in Bangalore district.

Soils of Bangalore district are predominantly reddish brown to yellowish brown, coarse loamy to fine loamy and non-calcareous with pH of 5.6-7.5. The soils of Tumkur and Hassan districts are deep to very deep, light yellowish brown to reddish brown and dark gray brown, coarse loamy to fine loamy on the surface, with finer grades in the subsoil. These are mostly calcareous with pH 7.5-9.5.

The above soils were analyzed to determine mechanical composition by International pipette method for alkaline soils and by hydrometer method for neutral and acidic soils, physical constants by Keen, Raczkowski methods ; electrical conductivity using 1:2.5 soil water ratio by Solubridge; pH using 1:2.5 soil water ratio by Beckman pH meter; cation exchange capacity by Hissinks method; the exchangeable sodium and potassium leaching with neutral normal ammonium acetate and estimating in the flame photometer ; potash fixing capacity by wetting and drying process; exchangeable calcium and magnesium by leaching with normal sodium chloride for calcareous soils and estimation with EDTA method, available potash by ammonium acetate extraction and available phosphorus by Bray method.

The sand fractions separated from the soils were treated with bromoform (specific gravity: 2.9) to separate light and heavy mineral fraction which were studied under microscope to identify the different minerals.

TABLE 1. Morphological characteristics of soil types of coconut areas in *maidan* parts of Karnataka

Sl. no.	Series name	Soil colour		Soil texture		Soil structure		Soil depth (cm)	Calcareousness	Special features
		Surface soil	Subsoil	Surface soil	Subsoil	Surface soil	Subsoil			
1	2	3	4	5	6	7	8	9	10	11
1.	Arsikere	Brown to dark brown	Dark gray brown to very dark gray brown	Coarse sandy loam	Fine sandy clay loam to clay	Granular	Strong subangular blocky	100-120	Violent in deep subsoil	Two cycles of deposition, coarse roots in sub-surface.
2.	Bendekere	Strong brown to dark brown	Red to dark reddish brown	Gravelly loamy sand	Gravelly sandy clay loam	Coarse granular	Medium subangular blocky	60-100		Coarse roots throughout the soil profile
3.	Kanatur	Strong brown yellowish red	Very dark grayish brown	Loamy sand to coarse sand	Silty clay to gravelly clay	Single grain to granular	Strong angular blocky	150-200	Strong to violent in subsoil	Plenty of medium to fine iron and lime concentrations in the subsoil. Abrupt changes in horizon colour and texture throughout
4.	Mattigata	Light yellowish brown	Light yellowish gray	Sandy loam	Sandy loam, sandy clay loam	Single grain to granular	Medium subangular blocky to massive	150-200	Strong throughout	Abrupt changes in colour and texture throughout

(Contd.)

(*Contd.*)

Sl. no.	Conductivity mmhos/cm	CEC (meq %)	Exchangeable basis (meq %)				Available nutrients				Potassium fixing capacity
			Ca	Mg	Na	K	Org. C%	$CaCO_3$ %	P_2O_5 ppm	K_2O ppm	
1.	0.1-0.3	17.3-24.3	8.1-12.1	2.7-10.3	0.3-1.4	0.3-0.6	Nil-0.4	Trace-4.0	Nil-3.4	207.3-236.2	340-880
2.	0.1-0.1	9.4-14.8	2.7-11.9	0.5-4.7	0.4-0.9	0.2	0.1	Trace	Nil-8.2	183.2-202.4	420-800
3.	0.1-1.0	6.21-23.6	3.4-14.4	0.5-10.9	0.4-0.6	0.2-0.5	Nil-0.3	Nil-24.4	Nil-2.2	183.0-291.0	400-860
4.	0.1-3.9	7.5-11.4	2.7-6.8		0.7-4.9	0.2-0.3	0.2-0.7	0.2-1.0	Nil-38.6	Nil-225.4	200-280
5.	0.2-0.5	10.5-14.5	8.7-13.1		1.0-1.6	0.2-0.9	0.2-0.4	Nil	Nil-8.9	Nil-272.6	160-500
6.	0.3-0.5	18.3-22.0	15.4-18.9		1.4-2.8	0.3-6.5	0.2-0.6	0.4-3.8	Nil-5.9	Nil-294.7	100-280
7.	0.1	3.4-10.4	2.9-8.9		0.05-1.99	0.2-0.3	0.2-0.3	Nil	Nil-18.2	Nil-188.5	180-250
8.	0.1-0.2	10.4-17.9	6.1-11.8	0.5-3.0	0.3-1.1	0.1-0.4	Nil-0.3	Nil	Nil-118.9	Nil-197.6	120-440
9.	0.1-0.2	3.1-19.8	1.1-17.1	0.2-1.1	0.7-1.2	0.1-0.9	Nil-0.6	Nil	Nil-38.6	Nil-245.8	20-240
10.	0.1-0.9	6.1-14.0	1.9-12.3	0.1-2.1	0.3-1.3	0.1-0.5	Nil-0.3	0.2-2.5	Nil-42.8	Nil-212.1	180-260
11.	0.1-0.2	6.8-12.9	2.5-8.7	0.2-4.6	0.3-0.6	0.1-0.3	0.1-0.3	Nil	Nil-14.3	Nil-262.4	120-240

*The figures give the range of values obtained for various characters when soil profiles were studied from different depths.

Results and Discussion

The results of various studies conducted on these soils are presented in Tables 1 and 2. The morphological characters of seven series recognized in Tumkur and Hassan districts reveal that they are mostly colluvic alluvial (with exception of Bendekere series, which is an *in situ* soil developed from gneisses) in origin. Most of the series have pronounced morphological differences in colour, texture, structure, permeability, and presence of gravel in the soil profile. These differences may be mainly due to the addition of extraneous materials as a part of management practices. In contrast to the above, four series of Bangalore district are alluvial in nature with stratified profile characters.

The soils of Tumkur and Hassan districts are moderate to moderately well drained with moderate to moderately slow permeability excepting for Huliyar series which is poorly drained with slow permeability. The soils of Bangalore district are well drained with moderately rapid to rapid permeability.

Soils of Tumkur and Hassan districts have higher water holding capacity and moisture equivalent in majority of the series, ranging 37-49% and 18-39%, respectively. Volume expansion of some layers are in the range 18-30%, cation exchange capacity ranges 14-31 meq/100 g, the available potash is more than 200 ppm in most of the horizons, and the potash fixing capacity is also on the higher side.

Soils of Bangalore district have a medium to low water holding capacity and low moisture equivalent of 21-37% and 10-20%, respectively. Cation exchange capacity ranges 6-17 meq/100 g. The available potash is slightly more than 200 ppm on the surface. The potash fixing capacity is low to medium.

The mineralogical studies of these soils show a marked difference in mineral distribution in different layers. It is pronounced in the soils of Tumkur and Hassan districts, where the top 50-60 cm soils show a concentration of ferromagnesian minerals. In contrast, the soils of Bangalore district show a higher concentration of felsic minerals like quartz and felspar.

In Tumkur and Hassan districts, coconut seedlings of $2\frac{1}{2}$-3 years age are planted 8-10 m apart in pits of $1 m^3$ after filling with sand and red soil. Then, they are watered till the seedlings are established. Later, materials like fine sandy soil and weathered material are added on the surface at rate of about 500 cart loads/ha (one cart load=about 750 kg) every year or once in two years during the pre-monsoon period April-May The plants are not irrigated after they are established.

Acknowledgements

The authors acknowledge the help and assistance given by the laboratory and cartographic staff of the Centre for the preparation of the paper.

Soil and Leaf Analyses in Relation to the Nutrition of High Yielding Coconut Genotypes

C.B. KAMALA DEVI, M. VELAYUTHAM and M. HARIDASAN
Central Plantation Crops Research Institute, Kasaragod, Kerala, India

Abstract

Seasonal changes in the nutrient composition of index leaf and available nutrien status of a ten year old coconut planatation on acid sandy loam soil were evaluated in three high yielding coconut genotypes (West Coast Tall, Tall×Dwarf, and Dwarf×Tall) growing under three fertilizer levels. Seasonal changes in leaf nutrients status confirmed that the fourteenth leaf could be taken as the index leaf under the local conditions. Available K was a limiting nutrient which was reflected in deficient K concentration in leaf of control plots. An inverse relationship between K and Mg content of leaf was observed. Leaf concentration of N was not significantly influenced by fertilization. Even at the highest level of fertilizer application was below the critical limit proposed by IRHO. However, yield data indicated that the critical limit could possibly be lowered to suit the West Coast of India conditions. No significant variation was observed in P content of leaves due to fertilisers or genotypes. Fixation of P in the soil appeared to be accentuated during monsoont months. NPK fertilization increased the concentrations of Mn, Zn, Fe, and Cu in the leaf while that of Ca, S, Fe, B, and Mo were unaffected.

Introduction

Yield performance coupled with soil and/or leaf analyses are usually taken into account for developing suitable manurial schedules for field crops. In the coconut, the technique of leaf analyses has been developed by the IRHO in Ivory Coast and this has made it possible to establish critical limits for different nutrients and consequently to adjust manuring to maintain the nutrient status at adequate levels. From the management point of view, this approach amounts to 'fertilizing the crop' as against 'fertilizing the soil'. This paper brings out the need and relevance of soil and plant analyses in the mineral nutrition and long term management of coconut plantations.

Material and Methods

The information presented in this paper is drawn from a field experiment

initiated in 1965 in this Institute to determine the response of three genotypes (West Coast Tall, Tall × Dwarf, and Dwarf × Tall) to three levels of NPK fertilizers on red sandy loam soil. It is laid out in a randomized block design with three replications and six palms/plot. The three levels of NPK fertilizer are F_0: 0-0-0; F_1; 500-500-1000; and F_2: 1000-1000-2000 g/palm annuably with N applied as ammonium sulphate, P as superphosphate, and K as muriate of potash. One-third of the annual dose is surface applied in April-May before the onset of the south-west monsoon rains and raked in. The remainder is spread during September-October in the basins of palms within a radius of 1.8 m after removing the top 25 cm soil which is put back after fertilizer application. Leaf and soil samples for the study were collected in 1975. Leaf samples (totalling 162) were collected at bimonthly intervals using 14th leaf as the index leaf (cf. Chapman, 1964). Soil samples (totalling 81) were collected three times during the year in January, May and September from the basins of palms from the top 0-50 cm layer from a distance of 1m from the palm. Standard analytical procedures were followed (cf. Black *et al.*, 1965; Jackson, 1967).

Results and Discussion

Leaf analysis. The seasonal variation in the concentration of nutrients in the index leaf was negligible (cf. Table 1). This was so in both fertilized and unfertilized palms. There was also no appreciable difference among the three genotypes in the leaf content different elements.

The effect of fertilization on the foliar status of nutrients was a very significant increase in K, a very modest increase in N, and hardly any change in P (Table 1). Leaf analyses carried out on these palms in

TABLE 1. Concentration of nutrients in 14th leaf*

Nutrient level	F_0	F_1	F_2
N%	1.43-1.62	1.46-1.80	1.47-1.61
P%	0 111-0.123	0.121-0.127	0.122-0.130
K%	0.40-0.56	0.74-1.17	0.99-1.41
Ca%	0.29-0.34	0.30-0.34	0.30-0.33
Mg%	0.31-0.39	0.28-0.35	0.23-0.37
S %	0.85-0.96	1.14-1.17	1.15-1.21
Fe—ppm	273-328	282-339	302-481
Mn—ppm	389-485	635-757	808-945
Zn—ppm	13.0-14.6	26.2-28.2	30.8-37.5
Cu—ppm	11.6-12.0	20.6-21.2	22.7-23.5
B—ppm	13.6-15.7	14.0-14.7	14.4-15.0
Mo—ppm	0.67-0.77	0.73-0.77	0.70-0.77

*Each value is mean of nine determinations.

1971 indicated that fertilisation at F_2 level increased the leaf N content from 1.40% at F_0 to 1.55% (Kamala Devi, 1972). In the present analysis, the leaf N concentration was below the critical limit of 1.8% set by the IRHO (cf., Fremond, 1964) even at the F_2 level. It seems that this limit of 1.8% N is on the upper side for at least the west coast of India. The response of WCT palms to fertilizers was linear upto the F_2 level, but in the hybrids it was so upto the F_1 level only. One of the reasons for the lack of increase in N level in the leaf may be due to the depletion from foliage through heavy rainfall experienced in this tract. Preliminary studies by Cecil and Pillai (1973) indicate such a possibility.

The most marked effect of fertilisation on foliar status was for K. The K concentration of leaf in F_0 plots was well below the critical limit of 0.8% in all instances. This was raised to sufficiency level in palms which received fertilizers. The foliar diagnosis of K deficiency has been successfully used in Ivory Coast to increase copra yield from 1 to 2 ton/ha (Ziller and Prevot, 1962).

The effect of NPK fertilization on Mg level was that it decreased with increase in the level of manuring. Ziller and Prevot (1962) have pointed out that K-Mg antagonism was pronounced when leaf K concentration was above 0.55. This trend points out that regular K fertilisation on soils having a low cation exchange capacity (5.5 me/100 mg) may soon bring out the antagonism between K and Mg which may have negative effect on number of bunches (cf. Fremond, 1964).

Among the trace elements, the leaf content of Mn, Zn, Cu, and Fe increased with NPK fertilization. The leaf status of B and Mo remained unchanged.

Soil analysis. No information is available on calibrating soil nutrient status with yield of nuts. The available nutrient levels in the soil is given in Table 2. The built up of K in soil is reflected in higher leaf K content in fertilized palms. A comparison of soil available nutrient status between 1971 and 1975 indicate a build up in P. but not in N and K. The fixation of P appears to be accentuated in acidic soils (pH 4.3-5.1) during the monsoon months June to September. Such a phenomenon of alternate fixing and release of P as the season changes from wet to dry has been observed also in laterite soils by Muliar and Wahid (1973). This suggests for a change in the time of application of P fertilizers to after the south-west monsoon in order to enhance its availability. This needs further experimental verification.

Changes in the level of secondary nutrients in the soil due to NPK fertilization showed more or less a similar trend as in leaves. The exchangeable Mg level slightly decreased in fertilized plots which also explains the low Mg status in the leaf in such palms. Among the trace elements, a slight increase in Fe and significant increase in exchangeable Mn, and an absence of any effect on Zn, Cu, B, and Mo were noticed. The former effect is mainly due to the lowering of pH in fertilized plots from 5.3 to

TABLE 2. Variations soil nutrient content under different levels of fertilizers

Nutrient level (ppm)	F_0	F_1	F_2
N	414-434	424-462	434-452
P	17-21	53-75	142-195
K	15-22	38-45	50-64
Ca	425-435	430-436	439-452
Mg	145-156	123-147	106-129
S	34-35	47-48	51-53
Fe	1.2-1.5	1.6-2.1	2.2-2.6
Mn	7.6-8.5	13.0-14.4	13.8-14.8
Zn	2.9	2.8-2.9	2.9-3.0
Cu	0.93-0.95	0.89-0.96	0.92-0.97
B	0.24-0.25	0.24-0.25	0.27-0.30
Mo	0.02-0.03	0.02-0.03	0.02-0.03

N—total N; P—Bray's P; K, Ca, Mg, and Mn—with 1→1 amm. acetate (one normal acetate) *N* ammonium acetate (pH 7.0); S—with Margan's reagent; Cu—with 0.02 *N* EDTA; B—hot water soluble: Mo—with Tamm's reagent; Zn—with dithizone.

4.0. The implications of this on the trace element nutrition of coconut has been discussed by Kamala Devi *et al.* (1975) which is corroborated by the results from the present study.

Acknowledgement

The authors are thankful to Dr K.V. Ahamed Bavappa, Director, for his keen interest and advice.

References

Black, C.A., Evans, D.D., Ensminger, L.E., White, J.L., Clark, F.E. and Dinauer, R.C. (Eds.). (1965). *Methods of Soil Analysis*. Part 2: Chemical and Microbiological properties. pp. 1572. American Society of Agronomy, Madison, Wis., U.S.A.

Cecil, S.R. and Pillai, N.G., (1973). Note on the mineral losses from coconut leaves by folier leaching. *Ind. J. Agric. Sci.* **43**: 611-612.

Chapman, H.K. (1964). Foliar sampling for determining the nutrient status of crop. *World Crops* **16**: 36-46.

Fremond (1966). The contribution of I.R.H.O. to the study of mineral nutrition of the coconut palm. pp. 97-107. *In Proc. FAO Technical Working Party on Coconut Production, Protection, and Processing*. 2nd session, Colombo, Nov. 1964. 452 pp. FAO, Rome.

Jackson, M.L. (1967). *Soil Chemical Analysis*. 498 pp. Prentice Hall, New Delhi.

Kamala Devi, C.B., Nelliat, E.V. and Pillai, N.G. (1973). Nutritional studies on high yielding coconut genotypes. *J. Plant. Crops* 1 (Suppl. 1): 67-69.

Kamala Devi, C.B., Wahid, P.A., Pillai, N.G. and Sankaranarayanan, M.P. (1975). Effect of NPK fertilizers on trace element nutrition of three coconut genotypes. *J. Plant. Crops* 3: 11-13.

Muliar, M.K. and Wahid, P.A. (1973). Note on the movement and availability of phosphorus in laterite soil as influenced by heavy phosphorus application with special reference to coconut. *Indian J. Agric. Sci.* **43**: 527-528.

Ziller, R. and Prevot, P. (1962). Foliar diagnosis, a method of studying mineral nutrition—its application to the coconut palm. *Indian Coconut J.* **15**: 156-159.

Discussions

Thomas : 1. How did you arrive at the 14th leaf as the best index leaf ? Is it based on analysis and comparison in levels of other leaves also?

2. Will your study lead to fixing or critical levels of nutrients in coconut leaves under Indian conditions?

Velayutham : 1. The stability of nutrient concentration round the year in the 14th leaf was originally proposed by IRHO. This has been confirmed by the CPCRI for West Coast (Kerala) conditions also. Comparison with nutrient levels in other leaves was not made.

2. This is envisaged in the full programme of the investigation to be carried out within the next few years.

Venkateswaran : Information was furnished on the results of a manurial experiment carried out by the Veppankulam Coconut Research Station in farmers' fields. K at 450g/palm gave a significant response, whereas at 900g, the response was slightly negative probably due to the synergestic action of K and Mg in the former and antagonistic effect in the latter.

Velayutham : I agree with this conjecture. But it has to be confirmed by leaf analysis for both K and Mg at different levels of applied K.

Narasimhayya : Did the response curves of yields of nuts of the three genotypes reach the plateau with the three doses of fertilizers? What are the differences among their curves?

Velayutham : The response curves of the two hybrids show a plateau between F2 and F3 levels, whereas that of the WCT is linear upto the F3 level. However, since the palms are in the early bearing stage, yield data are available for a few years only.

Fremond : Did I understand correctly that N application brought about N increase in the leaf, but no response in the palm in terms of production?

Velayutham : Application of N along with P and K produced a nonsignificant increase in leaf concentration and significant increase in nut production. Even at the highest level of fertilizers, N content of leaf was below the critical limit proposed by the IRHO.

Intercropping of Coconuts with Cacao in Malaysia

K. RAMADASAN, T. VANIALINGAM, E. CHAN, I. ABDULLAH and K.C. TEOH
Malaysian Agricultural Research and Development Institute (MARDI), Cacao and Coconut Branch, Teluk Anson (KR, IA, and KCT), Highlands Research Unit, Highlands Estate, Klang (TV), and Research Department, United Plantations Berhard, Teluk Anson (EC) Malaysia

Abstract

Intercropping offers an effective solution to the problem of increasing productivity of existing coconut areas in Malaysia.

Coconut is grown as a monocrop on fertile alluvial clays in a large acreage of land on the west coast of peninsular Malaysia. A considerable proportion of this area can be underplanted with cacao. Small scale trials in the fifties were highly encouraging. Large scale commercial cacao plantings under coconuts had become a reality by the mid sixties. A boost to this cropping system has been given by the favourable prices for cacao beans in recent years, coupled with low and unstable economic returns from coconut monoculture and the provision of a ready-made shade system. Intercropping accounts for a major part of the rapid expansion of the cacao industry in the country.

The present situation with respect to planting materials, cultural practices, fertilizer inputs, pests and diseases, hervesting and processing, as well as yields and profitability is considered and the main areas of research are discussed.

The establishment of new coconut plantings derived from high yielding hybrid materials could significantly enhance the potential of this cropping system.

Introduction

The coconut is a long-established traditional crop in Malaysia. The increasing demand for vegetable oils in the world market led to the etsablishment of large coconut plantations in the early part of this century. By 1924, nearly 2,00,000 ha were planted under coconuts in peninsular Malaysia. Low returns due to poor copra prices led to a number of the plantations switching over to more profitable crops like rubber and oil palm in the fifties. This trend was arrested in the sixties by the introduction of cacao as an intercrop. During and since this period, coconut acreage in peninsular Malaysia has remained static - losses in plantation acreage being more or less made up by small-holder plantings. In addition there are about 55,000 ha under coconuts in Sabah and 17,000 ha in Sarawak (Child, 1974). The Malaysian government has now embarked on a coconut replanting and rehabilitation scheme aimed at improving the livelihood of small coconut farmers (Lela, 1971). Increasing the returns

from existing land by suitable measures, including intercropping offers the best prospect for rapidly improving the productivity of existing cacao nut holdings. While bananas, coffee, and pineapple, were being recommended in the early days of the replanting and rehabilitation programme, cacao has increasingly come into the picture and has become the principal intercrop recommended today. Although Cheesman (1948) considered the interplanting of cacao under coconuts on coastal clay as unorthodox, test plantings showed that cacao performed far better under these conditions than it did either under rubber or oil palm (Allen, 1953). About 32,000 ha are now cropped in this manner, and a further 1,00,000 ha of coconut small holdings are considered suitable for intercropping with cacao (Wong, 1961).

Current Cacao Planting Practice

Planting materials. In the early years after the Second World War, Amelonado introduced from West Africa was found to be superior and more uniform and therefore was recommended for commercial planting (Rosenquist and Sockalingam, 1953). Unfortunately, both Amelonado and Trinitario material proved highly susceptible to cacao die-back (Haddon, 1961). A limited range of Upper Amazone material was then introduced. This material as well as some Upper Amazon × Amelonado and Upper Amazon × Trinitario hybrid progenies proved more vigorous and somewhat tolerant to die-back. For this reason, selected progenies, one or both parents of which are Upper Amazon lines, have become preferred material although they exhibit considerable variability. Current breeding programmes are aimed at identifying suitable parental combinations which perform well in terms of growth and yield, tolerance to die-back, and bean quality (Chee, 1971 ; Edwards, 1971 ; Arasu and Phang, 1971).

Field planting. Tall coconuts are normally planted at 9m on the triangle or square, while Dwarf coconuts are planted at 6m. Cacao is planted in two rows 3 m apart under Talls, or in a single row under Dwarfs in the avenues between palm rows Spacing within cacao rows varies from 1.8 to 2.4 m. Normally seedlings of upto four months age are used for interplanting.

In many areas, the coastal alluvial soil is poorly drained, and then drains are constructed in every or alternate avenues. The normal shade regime under coconuts appears to be satisfactory for cacao growth. Where vacant points exist, these are filled with a shade plant like *Glyricidia maculata.*

It is customary to plant out seedlings with the youngest whorl of leaves hardened. To reduce transplanting shock, temporary palm frond shade is provided. Some planters prefer to provide supplementary shade in the form of shrub by plants.

Maintenance. The young cacao plants are normally pruned to only

one jorquette at a height of about 1.2m. Volunteer chupon shoots which arise on the stem or trunk are periodically removed.

Accurate information on fertilizer requirements is lacking. The principal nutrients that are required for young cacao seedlings are nitrogen and phosphate. When they come to bearing, potassium becomes the most important nutrient which must be balanced by adequate nitrogen and phosphate (Ng, 1968, 1971). In addition, moderate amounts of limestone are used to obtain a suitable soil pH and also to provide calcium.

Leaf-eating insects constitute a serious danger to the cacao crop They are controlled with an integrated programme of control. The incidence of diseases like die-back is countered by pruning and removing the diseased tissues Prior to planting cacao, the fields are sprayed to eradicate the weeds, and supplementary control in the form of ring-weeding is practised for upto two years. Once the cacao is well established, the shade provided jointly by cacao and coconuts should be adequate to suppress all weeds.

Harvesting and processing. The cacao comes into bearing in the second year after planting. The pods are then harvested and processed into beans.

Effect of Cultivation of Cacao on Coconut Growth and Productivity

In intercropping, two main factors are of concern : (1) the extent to which the two crops are compatible, i.e., whether the intercrop will depress the yield of the primary crop ; and (2) the type of yields that can be obtained from the intercrop.

Experience so far in Malaysia indicates that growth and yield of coconuts is not adversely affected by cacao (Leach, Shepherd, and Turner, 1971). The initial cultivation and suppression of weeds during the establishment of cacao would have a beneficial effect on the coconuts. When the cacao comes into production, the competition between the two crops can be expected to set in. In normal practice this is minimized by proper manuring of cacao. There is evidence that improved management, better drainage, and fertilizer inputs applied to cacao benefit coconut yields (Tables 1 and 2) and that absence of manuring depresses coconut yields (Tam, 1968). It may be argued that productivity of coconuts could be straight away increased by providing these inputs, particularly fertiliser, without any intercrop at all ; this is not an economic proposition given the low and unstable copra prices. Estimates of profitability are given in Table 3.

It has been calculated that the average profit margin is M$ 1.54/kg for cacao and M$ 0.17/kg for coconut. With an yield of 700-2500 kg copra/ha, the net profit would be M$ 119.00, 425.00/ha. With an additional yield of 500-1000 kg dry beans/ha, the combined profits would go upto M$ 889.00-1,965.00/ha. With improved planting materials and better cultural practices, further increases in income can be envisaged.

TABLE 1. Copra yields (kg/ha) of Malayan Talls* on neighbouring plots with and without interplanted cacao

Year	Cacao planted in 1967		Neighbouring plot without cacao	
1960	1,164.8		1,448.5	
1961	1,523.2		1,299.2	
1962	1,657.6		1,045.3	
1963	1,717.3	$\bar{x}$=1,627.7	1,314.1	$\bar{x}$=1,209.6
1964	1,687.4		1,090.1	
1965	1,597.8		1,224.5	
1966	2,075.7		1,075.2	
1967	1,612.8		1,344.0	
1968	2,404.2	$\bar{x}$=2,210.1	836.3	881.1
1969	1,687.4		925.85	
1970	2,538.6		895.98	

(Extract from an IRHO technical report to Messrs. Barlow Boustead)
*Approximately 40 years old when interplanted with cacao.

TABLE 2 Copra yields (kg/ha) from various estate fields before and after interplanting with cacao

Coconut variety	Year of planting	Year inter-planted with cacao	Mean copra yields for 5 years before interplanting	Mean copra yields after interplanting 1971-75
	1926	1971	1,508.2	2,120.5
	1926	1971	1,717.3	1,926.4
	1927	1967	1,971.2	2,075.7
Malayan	1927	1968	2,030.9	2,254.9
Tall	1927	1968	1,911.4	2,016.0
	1927	1968	2,045.8	2,105.6
	1928	1971	1,806.9	1,926.4
	1930	1968	1,941.3	2,120.5
	1930	1968	2,135.4	2,180.2
	1931	1964	2,165.3	2,254.9
	1936/37	1964	2,045.8	2,075.7
Dwarfs	1940/41	1964	1,881.6	2,001.0
	1940/41	1966	2,075.7	2,256.4

(Data from Messers United Plantations)

TABLE 3. Yield of cacao interplanted with coconut under estate conditions (Dry beans in/kg/ha)

Coconut variety	Year planted	Stand/ha	Yield in 1975
	1966	951	1190.6
	1969	1010	1085.3
Malayan Talls	1969/70	886	968.8
	1969170	886	916.1
	1970	973	813.1
	1971	867	747.0
	1972	689	542.1
	1972/73	756	156.8
	1973	803	169.1
	1973	847	—
	1968	864	759.4
Dwarfs	1968-69	642	600.3
	1969/70	736	619.4
	1971	886	412.2

Areas of Research

The earlier breeding efforts in Malaysia have been to develop cacao varieties suitable for monoculture on inland soils (Arasu and Phang, 1971). These should be now reorientated towards producting superior genetic materials which perform well under coconuts. Yields may be increased considerably, if clonal plantings are resorted to. Hence, implementation of an integrated programme of research on vegetative propagation and related problem merits top priority (Ramadasan and Arasu, 1976). There are also possibilities for raising the potential of mixed cacao-coconut plantings with high yielding forms of coconut. In this, the development of intervarietal hybrids offers the brightest prospect (Arasu *et al.*, 1976). If it is possible to relate early juvenile characteristics to final growth and yield patterns, the advantage to breeding and selection in a perennial crop is only too obvious. More studies are required to determine the optimum cacao density and planting pattern such that there is maximum efficiency in utilization of available light and land. Deep planting techniques may enable the tapping of different soil zones by the two species. In this context, studies on root distribution and physiological activity assume importance. This also has its relevance to fertilizer inputs. Pruning practice should be studied in relation to obtaining a photosynthetically efficient canopy.

There are also in addition the several problems which are specific to either of the crops, like the antagonistic relationship between calcium and

potassium, type and time of fertilizer placement, foliar diagnosis of cacao and control of diseases and pests These are not being discussed here.

Discussion

Intercropping of coconuts witn cacao has been only recently introduced as a solution to the problem of low productivity of coconut lands. The phenomenal growth in acreage and production is a clear indication that this cropping system is here to stay as an integral component of the agricultural scene in Malaysia.

Acknowledgement

The authors thank the Director of MARDI and M/s. Barlow Boustead Estates Agency and United Plantations for permission to present this paper. They are also grateful for the encouragement, constructive criticism, and helpful suggestions from the following : Dr. W.P. Ting, Mr. C.L. Chan, and Mr. N.T. Arasu of MARDI ; Dr. Ng Siew Kee, Research Department, M/s. United Plantations, and Mr. P.S. Chew of Highlands Research Unit. The authors are also indebted to Mr. C.N. Williamson, Manager of Torkington Estate and Mr. D.T. Ho, Manager of Kuala Bernam Estate, for valuable discussions on production economics.

References

Allen, C.F. (1953). Investigations into the cultivation of cacao in Malaya. *Malay. Agric. J.* **36** : 147-163.

Arasu, N.T. and Phang, C.I. (1972). Cacao improvement in West Malaysia. pp. 28-42, in *Cocoa and Coconuts in Malaysia* (ed. R.L. Wastie and D.A. Earp), Incorporated Society of Planters, Kuala Lumpur.

Arasu, N.T., Vanialingam, T. and Chan, E. (1976). Interpopulation crosses in coconut improvement. Presented at SABRAO (Malaysia) National Symposium. Breeding Researches for Progress in Malaysia (in press).

Chee, Y.F. (1972). A review of some cacao hybrids at the Cacao Research Station, Sabah. pp. 22-27, in *Cocoa and Coconuts in Malaysia* (Ed. R. L. Wastie and D.A. Earp), Incorporated Society of Planters, Kuala Lumpur.

Cheesman, E.E. (1948). Report on potentialities for the cultivation of cacao in Malaya, Sarawak, and North Borneo. HMSO, London.

Child, R. (1974). *Coconuts*. 2nd ed. pp. 335. Longmans, London.

Edwards, D.F. (1969). Hybrid seed-gardens : some practical considerations. *Cocoa Growers' Bull.* **13** : 14-19.

Haddon, A.V. (1961). Variety trials of seedling cacao in Malaya. *Malay. Agric. J.* **43** : 169-232.

Leach, J.R., Shepherd, R. and Turner, P.D. (1971). Underplanting coconuts with cacao in west Malaysia, Part I : Planting. *Cocoa Growers' Bull.* **16** : 21-26.

Ng, S K. (1968). Fertiliser problems in mixed cacao-coconut planting. pp. 25-31 in *Cacao and Coconuts in Malaya* (Eds. J.W. Blencowe and P.D. Turner), Incorporated Society of Planters, Kuala Lumpur.

Ng, S.K. (1971). A review of factors influencing the fertilizer requirements of cacao plantings in Malaysia., *Planter* **47** : 514-531.

Lela, O.B.M. (1972). The coconut replanting and rehabilitation scheme in West Malaysia. pp. 444-448, in *Cocoa and Coconuts in Malaysia* (Eds. R.L. Wastie and D.A. Earp), Incorporated Society of Planters, Kuala Lumpur.

Ramadasan, K. and Arasu, N.T. (1976). Vegetation propagation of *Theobroma cacao* L. and related problems. Presented at Malaysian National Plant Propagation Symposium, Kuala Lumpur.

Rosenquist, E.A. and Sockalingam, T. (1953). Amelonado cacao in Malaya. *Malay. Agric. J.* **36** : 164-180.

Wong, I.F.T. (1972). Suitable cacao soils in West Malaysia. pp. 127-135, in *Cocoa and Coconuts in Malaysia* (Eds. R.L. Wastie and D.A. Earp). Incorporated Society of Planters, Kuala Lumpur.

Discussions

Khera : The speaker said that intercropping coconuts with cacao will tremendously increase the attractiveness of the coconut industry. My question is : What is the scope for intercropping oil palm with cacao, as investment in oil palm is more profitable than similar investment in coconuts ?

Ramadasan : The scope can only be evaluated with the availability of more research data. Experimentation is in progress.

Pujari : What are the important micronutrients required for coconut crops ? What is the best method of application from seedling stage to bearing stage ?

Ramadasan : This question does not come within the scope of our paper.

Manthriratna : What is the proposed (recommended) planting distance and planting systems for the new coconut/cacao combination ?

Ramadasan : This is now being looked into. Final recommendation will have to take into account shade requirements for cacao, competition between cacao and coconuts as well as economical considerations.

M.R.N. Rao : Are there any important problems with thread blight and/or animal pests ? Has intercropping of cacao been tried in oil palm ?

Ramadasan : There is at present no serious problem with thread blight. Animal pests, particularly rats and squirrels, are serious pests in some areas. Work to develop control measures is in progress.

Observational trials so far carried out have not found intercropping oil palm with cacao to be promising. Early vegetative growth is satisfactory, but yields have been disappointing under the current standard oil palm densities. Research is in progress on manipulation of oil palm densities to take into account cacao intercropping in addition to other technical problems, eg., differential nutrient requirements of the two crops.

Rohini Iyer : Do you notice any build up of *Phytopathora* in your country since this is a pathogen on both crops ?

Ramadasan : *Phytopathora* does not appear to be a serious problem. Black pod disease could be minimized with more frequent harvest of ripe pods during the rainy season, appropriate pruning techniques to open up the canopy, as well as effective elimination of diseased material. This is, however, an important area of current research. The technical expertise to control or prevent any serious outbreak in the future is being developed now.

Veeresh : Cockchafers are said to be serious pets in Malaysia and it seems that some natural agents have been developed to control them. What are they ?

Ramadasan : Cockchafers can be controlled easily with insecticidal treatments. Search for natural enemies has been taken up in our overall research programmes on pest control.

Narayanappa : When budding is practised, what root stock is used ? When clonel material is available, layering will be easier than budding. Which are the recommended commercial varieties ?

Ramadasan : Amelonado seedlings are used as root stocks.

Budding is the best, easiest and most economical method of vegetative propagation in Malaysia, in the light of the existing experience in rubber industry. Hybrid material with one or both parents of selected Upper Amazon clones are recommended for cultivation.

Fertilizer Requirements of Adult Coconut Palms in Sri Lanka

P. LOGANATHAN and T.S. BALAKRISHNAMURTI
Coconut Research Institute of Sri Lanka,
Lunuwile, Sri Lanka

Abstract

Field experiments carried out on adult palms under different soil and climatic conditions showed that coconut responds to the application of N.P. and K fertilizers. Based on these experiments, three fertilizer mixtures are proposed for manuring adult coconuts, two mixtures to suit the soil conditions in the west and intermediate zones and the third for the dry zone. The proposed fertilizer recommendations per palm are : west and intermediate zones – (a) 1.4 kg Sulphate of ammonia + 0.8 kg rock phosphate + 1.8 kg muriate of potas ; (b) 1.1 kg sulphate of ammonia + 0.9 kg rock phosphate + 1.1 kg muriate of potash; dry zone – 1.4 kg sulphate of ammonia + 0.5 kg double super phosphate + 1.1 kg muriate of potash. Statistical methods employed in the derivation of the fertilizer recommendations from the experimental data are discussed.

Introduction

Commencing in 1935, with the first ever statistically designed fertilizer field experiment on coconut, the Coconut Research Institute of Sri Lanka has been conducting, over the past four decades, field experiments and laboratory investigations on the fertilizer needs of coconut. These experiments, though not covering fully the different soil and climatic conditions under which coconut is cultivated in Sri Lanka, form the basis of the past and current fertilizer recommendations by the Institute.

Despite the long period of experimentation, the fertilizer recommendations have been based at different times, on the result of only one statistically designed factorial field experiment (Abeywardena, 1963; Eden. Gower, and Salgudo, 1963). These recommendations are given in Table 1. Of the several experiments being conducted, three have been in progress sufficiently long. The data from these experiments have been analysed statistically and presented herein together with revised fertilizer recommendations based on these data.

TABLE 1. Past and current fertilizer recommendations for adult coconut in Sri Lanka (i) Prior to 1963

Soil type	Ingredients (kg/palm/year)							
	Sulphate of ammonia (20.6% N)		Saphos phosphate (28.5% P_2O_5)		Muriate of potash (50.0% K_2O)		Total	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
White cinnamon sands and coastal marine sands; Laterites	0.79	0.78	0.68	0.56	0.68	0.56	2.14	1.80
Loams and sandy loams	0.68	0.56	0.56	0.45	0.56	0.45	1.80	1.46
Clay soils	0.68	0.56	0.56	0.45	0.45	0.34	1.69	1.35
Lateritic gravels	0.68	0.56	0.68	0.56	0.68	0.56	2.03	1.69

(a) Estates which have not been manured for a long time.

(b) Estates which are regularly manured.

(ii) Between 1963 and 1967

Soil type	Ingredients (kg/palm/year)			Total
	Sulphate of ammonia (20.6%N)	Saphos phosphate (28.5%P_2O_5)	Muriate of potash (50.0%K_2O)	
Cinnamon sands and coastal marine sands; laterites and lateritic gravels of southern and western provinces	1.125	1.125	1.350	3.600
Lateritic loams of southern and western provinces	1.287	1.031	1.287	3.600
Lateritic gravels and lateritic loams of north-western province	1.125	0.900	1.125	3.150
Non-lateritic reddish brown loams and sandy loams	0.900	0.900	0.900	2.700
Estuarine Clay soils	60.00	0.600	0.600	1.800

(iii) Since 1967 to date

Soil type	Ingredients (kg/palm/year)			
	Sulphate of ammonia (20.6% N)	Saphos phosphate (27.5% P_2O_5)	Muriate of potash (60% K_2O)	Total
Cinnamon sands and coastal sands; lateritic loams and lateritic gravels of wet zone	2.250	0.900	1.350	4.500
Lateritic loam and lateritic gravels of intermediate zone	2.025	0.900	1.125	4.500
Deep reddish brown loams and sandy loams				
Deep alluvial loams, and estuarine and lagoon clay soils	1.800	0.900	0.900	3.600

Materials and Methods

1. *NPK factorial experiment at Ratmalagara Research Station, Madampe.* The experiment was laid out in 1948 using six months old coconut seedlings on a virtually jungle land in an area where the soils are generally well drained loamy sand to sandy loam, overlying sandy clay loam with lateritic iron stone gravels and laterities. This land is in the Intermediate Rainfall Zone of Sri Lanka with a mean annual rainfall of about 1600 mm.

The experimental design consists of a $3\times3\times3\times3$ factorial arrangement for the three nutrients N, P and K in 6 blocks of 9 plots each, where the higher order interactions are confounded with that of blocks. There are 18 palms in each experimental plot. Each plot is separated by a single row of guard row palms. During the period 1958-1964, sulphate of ammonia, saphos phosphate, and muriate of potash were being supplied at the levels 0, 0.675, and 1.350 kg/palm/year respectively. From 1949-1957 (seedling stage) fertilizers were being applied at reduced rates (Loganathan, Balakrishnamurti, and Mathes, 1975). In 1965, each level of N, and K fertilizers were increased by 0.675 kg/palm/year, and for P, the first and second levels alone were increased to 0.45 and 0.90 kg/palm/year. Mean yield of the period 1970-1973 was adjusted for the mean yield of the period 1961-1964 by covariance analysis to correct for the previous fertilizer regime.

2. *NPK experiment at Naiwala Estate, Veyangoda.* This experiment was laid out in 1967 on adult coconut palms. The soil is typical of

coconut lands in the West Zone of Sri Lanka (mean annual rainfall : 2600 mm). The soil type is similar to that at Ratmalagara. The experimental design consists of boxes central composite rotatable second order design (Harder *et al.*, 1957). There are 15 plots each of 18 palms. The levels (kg/palm/year) of fertilizers are given in Table 2.

TABLE 2. Fertilizer levels in the NPK experiment at Veyangoda

Sulphate of ammonia	Saphos phosphate	Muriate of potash
N_0 0	P_0 0	K_0 0
N_1 1.094	P_1 0.819	K_1 0.450
N_2 2.187	P_2 1.638	K_2 0.900
N_3 3.281	P_3 2.457	K_3 1.350
N_4 4.374	P_4 3.276	K_4 1.800

The yield data for the period 1970-1975 were statistically analysed and production functions fitted. The yield for each combination of treatments was estimated from these production functions.

3. *Experiment on the forms of N and P fertilizers at Pothukulama Research Station, Pallama.* A long term fertilizer experiment to compare three forms of N fertilizers (from 1970, only two forms of N) and two forms of P fertilizers was commenced in 1967 on a sandy loam soil using seedlings. The mean annual rainfall of the area is about 1300 mm.

Soil samples were collected in March 1975 and May 1976 (three and six months after the immediately preceding fertilizers applications) from manure circles of four concentrated superphosphate, four saphos phosphate, and two control plots. All these plots had nearly the same soil profile characteristics. In each plot, two palms out of 15 palms were randomly selected. Soils were sampled at four depths from two borings from manure circles of two palms.

Available P was determined by extracting these soils with 0.5 *M* $NaHCO_3$ at pH 8.5 (Olsen *et al.*, 1954). Leaf samples were collected from the 14th leaf of all palms of each plot, the samples composited and leaf P-concentrations were estimated (Loganathan *et al.*, 1975).

Results

1. *NPK factorial experiment at Ratmalagara.* Statistical analysis of yield data for the combined period 1961-1964 and 1970-1973 showed that both the linear and quadratic components of the responses for all three nutrients were statistically significant. A highly significant PK interaction was also shown. The following quadratic production function is fitted for the entire yield data of the combined period.

$$y = 1819.461 + 122.821\ N + 451.813\ P + 100.258\ K - 10.133\ N^2 - 50.010\ P^2 - 3.296\ K^2 + 0.724\ NP - 1.425\ NK - 7.439\ PK$$

where y=expected yield of copra (kg/ha/year) ; N=sulphate of ammonia (kg/palm/year) ; P=saphos phosphate (kg/palm/year ; and K=muriate of potash (kg/palm/year).

Exchangeable K and available P values of the soils (0.30 cm) collected from the manure circles of the different treatments are shown in Table 3.

TABLE 3. Exchangeable K and available P of fertilizers—treated plots at Ratmalagara Research Station

Fertilizer treatment	Muriate of potash (kg/plam/year)		
	0.675	1.350	2.025
	Saphos phosphate (kg/palm/year)		
	0.450	0.900	1.350
Exchangeable K (me/100g.)	0.23	0.47	0.55
Available P (μg/g)	4.30	7.40	13.20

2. *NPK experiment at Naiwala.* Yield data for the period 1970-75 showed that except for 1972, the responses to K were significant and linear. The other two elements did not show any response. No significant quadratic effect or interaction among the nutrients was also seen. Mean response to K for the period 1970-75 increases upto the height level of K suggesting that the dosage of K for maximum yield is above 2.025 kg/palm/year.

Exchangeable K and available P values of the soils (0-30 cm) collected from the manure circles of the different treatments are shown in Table 4.

TABLE 4. Exchangeable K and available P of fertilizers—treated plots at Naiwala Estate

Fertilizer treatment	Muriate of potash (kg/palm/year)				
	0	0.450	0.900	1.350	1.800
	Saphos phosphate (kg/plam/year)				
	0	0.819	1.638	2.457	3.276
Exchangeable K (me/100 g)	0.13	0.15	0.17	0.22	0.36
Available P (μg/g)	3.40	12.70	21.70	25.60	30.60

3. *Forms of N and P experiment at Pothukulama.* The distribution of $NaHCO_3$—extractable P has been a satisfactory indicator of available P for coconut (Nethsinghe, 1965), and therefore, the distribution of this

form of P is considered in the comparison of saphos phosphate and concentrated superphosphate, $NaHCO_3$—P greater than 5-9 ppm in the surface soil is considered sufficient for coconut. Below this level, coconut responds to P-fertilizer application (Nethsinghe, 1963). Adequate amounts of available P are present down to about 40-50 cm in the superphosphate plots whereas P-availability is very much lower in the saphos phosphate plots.

P-concentrations in the 14th leaf of the control, superphosphate, and saphos phosphate treatments are shown in Table 5. Although it was not statistically significant, P-concentrations after superphosphate treatment were higher than that after saphos phosphate treatment.

TABLE 5. Effect of P fertilizers on P content in the 14th leaf in the Pothukulama experiment

Treatment	Plot Number	Leaf P (%)
Control	1	0.113
	2	0.126
	Mean	**0.120**
Saphos phosphate	1	0.118
	2	0.121
	3	0.125
	4	0.131
	Mean	**0.124**
Concentrated superphosphate	1	0.129
	2	0.130
	3	0.135
	4	0.147
	Mean	**0.135**

Discussion

The production function worked out for the Ratmalagara experiment showed that the rates of fertilizers for maximum yield were : sulphate of ammonia=1.116 kg/palm/year ; saphos phosphate=0.7785 kg/palm/year; and muriate of potash 1.962 kg/palm/year.

The quantity of N in this experiment was almost the same as in the 3×3×3 NPK experiment carried out at Bandirippuwa estate (Lunuwile) during 1935-1965 where the rate of N for maximum yield was 1.260 kg/palm/year. But the K rate was much higher at Ratmalagara than at Bandirippuwa (0.666 kg/palm/year). The soil type at

Ratmalagara and Bandirippuwa are similar, but the mean annual rainfall at Ratmalagara is about 1600 mm compared to 1900 mm at Bandirippuwa. This difference in rainfall cannot account for the large difference in the K requirements of the palms in the two stations. The highest level of muriate of potash tested at Bandirippuwa was 0.675 kg/palm/year, and therefore, it is not known whether higher rates such as 2 kg muriate of potash/palm/year would have given higher yields as at Ratmalagara. The maximum yield of 2215 kg/ha/year at Bandirippuwa as compared to 3511 kg/ha/year at Ratmalagara indicated the potential for higher yield at Bandirippuwa, had higher levels of potash been applied. Another possible explanation is the age of the experimental palms in the two areas : 18-25 years old at Ratmalagara against 30-60 years old at Bandirippuwa.

The response to K at Naiwala estate was similar to that at Ratmalagara. Both have the same soil type, but Bandirippuwa receives higher rainfall. At Naiwala, K has given responses consistently even at the highest level tested (1.8 kg muriate of potash/palm/year). It is likely that the amount of K for maximum yield at Naiwala is higher than this level. Tables 2 and 3 show that the exchangeable—K of the plots receiving 1.8 kg/palm/year at Naiwala is even lower than that of the plots receiving 1.35 kg/palm/year at Ratmalagara. This suggests that there is more loss of K at Naiwala. Therefore, the recommendation for the wet rainfall zone lateritic soils as at Naiwala should be slightly higher than that of the intermediate rainfall zone.

Ratmalagara experimental results show that the N rate for maximum yield was 1.116 kg sulphate of ammonia/palm/year. In the wet zone, where the soils are subject to heavy leaching, it can be expected that a higher level of N would be required for maximizing yield. However, Naiwala soils, though in the wet zone, did not respond even to lower levels of N. The soil and leaf analysis also did not show any deficiency of N. The reason for this is not clear.

The dosage of P for maximum yield at Ratmalagara was 0.765 kg saphos phosphate/palm/year. At Bandirippuwa, there was no response to P for 25 out of the 30 years of experimentation and this was explained as due to the lavish quantities of bone meal applied before the experiment was started (Nethsinghe, 1963). The lack of response to P at Naiwala may be due to the high levels of available P in these soils as compared to Ratmalagara soils (Tables 2 and 3).

The results discussed so far show that there is no major difference in the dosage of fertilizers for maximum yield between wet and intermediate zone lateritic soils which are considered poor in fertility.

Considering the above facts, the following fertiliser mixture is proposed for the sandy clay loam soils with lateritic gravels and laterites and sandy soils of wet and intermediate zones such as the cinnamon, coastal, marine and lagoon sands : sulphate of ammonia=1.4 kg/palm/year ;

saphos phosphate=0.8 kg/palm/year; and muriate of potash=1.6 kg/palm/year.

For soils, which are relatively rich in fertility such as deep reddish brown and yellowish brown loams, sandy loams, sandy clay loams, and esturine and lagoon clay soils, the following mixture is proposed : sulphate of ammonia=1.1 kg/palm/year; saphos phosphate=0.8 kg/palm/year ; and muriate of potash=1.2 kg/palm/year.

These soils are deep and have higher cation exchange capacity. Hence, they have large amounts of nutrients stored in them. The leaching losses of K and N would also be less than in the poor fertility soils discussed earlier. Therefore, the N and K dosages in this mixture are lower.

Phosphorus movement and uptake studies at Pothukulam have shown that rock phosphate is inferior to concentrated super phosphate treated soils. This is probably due to the low organic matter content (0.4% organic C), relatively low acidity (pH 5.8), and inadequate rainfall of the area (1300 mm). Comparison of the copra yield would have been a better and more direct measure of the relative efficiencies of the two sources of P fertilizers. But, unfortunately, due to severe red weevil damage of palms, the yield analysis of this experiment has not been reliable.

Because the sandy soils of dry zone (the northern and eastern provinces) are similar to the soils at Pothukulam and their climatic conditions are not also much different, the results of the Pothukulam experiment could be extended to the sandy soils of dry zone. These soils are coarser textured, have lower organic matter content, higher pH, and lower rainfall than at Pothukulam, and therefore, the conditions are even worse for solubilizing rock phosphate. Soil analysis of samples from estates in the dry zone sandy areas which received regular applications of rock phosphate showed lower available P than those of intermediate zone soils. Therefore, a soluble form of P fertilizer such as concentrated super phosphate is recommended in the fertilizer mixture for the sandy soils of the dry zone. The recommended mixture is : sulphate of ammonia=1.4 kg/palm/year ; concentrated superphosphate =0.5 kg/palm/year ; muriate of potash=1.2 kg/palm/year.

The K dosage in this mixture is lower than that in the wet and intermediate zone sandy soils because the leaching loss of K and the potential yield in the dry zone are lower.

In summary, the three mixtures proposed here contain less N and more K than the present mixtures. Of these mixtures, two contain saphos phosphate as at present, while the third has concentrated superphosphate. The latter is meant for use in sandy soils of the dry zone only.

Acknowledgements

We thank Mr. V. Abeywardena, Biometrician for assistance in statisti-

cal analysis and members of the Staff, Division of Soils, for help in laboratory and field work. The field experiments were initiated by Dr. M.L.M. Salgade and Dr. D.A. Nethsinghe, past Soil Chemists of the Institute.

References

Abeywardena, V. (1963). Economics of fertiliser use. *Trop. Agri.* **119** : 1-20.

Eden, T., Gower, J.C., and Salgade, M.L.M. (1963). A factorial experiment on coconuts. *Empire J. Exptl. Agric.* **31** : 283-295.

Harder, R.J., Hardward, M.E., Mason, D.D., and Moore, D.P. (1957). An investigation of some of the relationships between copper, iron and molybdenum in the growth and nutrition of lettuce : I. Experimental and statistical methods for characterizing the response surface. *Soil Sci. Soc. Amer. Proc.* **21** : 59-64.

Loganathan, P., Balakrishnamurti, T.S., and Mathes, D.T. (1975). Response of coconut (*Cocos nucifera* L.) to N, P and K fertiliser application on a lateritic gravel soil. *Ceylon Coconut Quart.* (Submitted for publication).

Nethsinghe, D.A. (1963). Maintaining fertility on coconut lands. *Trop. Agri.* **119** : 1-12.

Nethsinghe, D.A. (1965). Annual Report of the Soil Chemist. *Ceylon Coconut Quart.* **16** : 9-24.

Olsen, S.R., Cole, C.V., Watanabe, F.S. and Dean, L.A. (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. Circ. No. 939. USDA, Washington, D.C.

Seasonal Influence on Yield of Tall × Dwarf and West Coast Tall Coconuts in Kerala, India

U.P. BHASKARAN and K. LEELA*
Kerala Agricultural University, Horticulture College, Vellanikara 680651 Trichur, Kerala, India

Abstract

In the tropical monsoon climate of Kerala, annual rainfall and coconut production show distinct seasonal fluctuations. Seasonal variations in yield and nut character are attributed to the cyclic influence of varying seasons on different critical stages during the spadix development from 'spadix primordia initiation' to 'maturity of nuts.' Seasonal rains affecting spadix growth at five critical stages are found to influence the yields in different seasons of succeeding four years. Temperature, humidity, wind, and sunshine hours have only conjoint influence with the main effects of rainfall on yield. Effect of seasonal rains is more pronounced in Tall × Dwarf indicating that this cultivar is more sensitive to low and erratic rainfall. Ultimate cause-effect analysis indicates that coconut yield is related to soil moisture status, and that by providing optimal moisture in the critical states, stabilisation and enhancement of seasonal yields are possible.

Introduction

Coconut production in Kerala (India) show significant seasonal variations in yield. Annual yields also show marked fluctuations, but it does not follow any specific trend as in the case of seasonal variations. Several reports are available on the effects of seasons on different yield attributes and yield of coconut (Park, 1934; Patel, 1938; Cooke, 1953; Marar and Pandalai, 1959). Seasonal influence on yield behaviour of Tall x Dwarf cultivar has not been assessed so far. So, a season-wise analysis was made to study the influence of seasonal factors on the developing spadix and yield of nuts in Tall × Dwarf and West Coast Tall cultivars.

Materials and Methods

Meteorological observations recorded at the Station during 1950-1971 on

* Now at the Directorate of Research and College of Horticulture, Vellanikkara 680 651, Trichur.

rainfall, number of rainy days, temperature, humidity, sunshine hours and wind velocity were classified according to seasons as: south-west monsoon (SWM)—June-September; north-east monsoon (NEM): October-November; and hot weather period (HWP): February-May. The variability among the three seasons in a year and within the seasons during 22 years was assessed. Observations were recorded on spadix production, spadix abortion, female flower production, setting percentage, yield of nuts, and nut characters on 40 palms each of West Coast Tall and Tall × Dwarf cultivars grown in a red sandy loam soil of the Station. Variations in yield and nut characters of each cultivar were also assessed within seasons and between seasons during the 22 years. Influence of seasons on the growth of individual spadix, and the spreadover effect of a specific season on the developing spadices in the crown were also analysed with reference to the growth model of spadix. Correlations were also worked out between seasonal rainfall and yield in different seasons of succeeding four years.

Results

Analysis of Seasonal Factors

Variations in rainfall and number of rainy days are presented in Table 1. In a normal year, 88% of rainfall and 80% of rainy days in a year are registered in SWM. Annual fluctuations are also lowest in this season. Hot weather rains are quite unstable. During low rainfall years, significant increases in rains and number of rainy days are recorded in NEM.

Temperature is highest in HWP and lowest in NEM with maximum diurnal variations. Humidity is highest in SWM and lowest in HWP. Wind velocity is highest in HWP and lowest in SWM. Lowest sunshine hours are recorded in SWM (Table 2). Among the seasonal factors, rainfall and its distribution show the widest seasonal and annual fluctuations.

(a) *Yield attributes.* Observations on spadix production, abortion of spadix, female flower production, and setting percentage have been classified according to season (Table 3). In both the cultivars, 43-50% of the spadices produced in a year are harvested during HWP. The number of bunches harvested during NEM is the lowest (23-26%).

In West Coast Tall, 72.6% of the aborted spadices are accounted for in SWM. This in turn reduces the yield in this season. Spadix abortion is lowest in HWP.

Female flower production is another factor influencing nut yield. In both the cultivars, about 50% of annual female flower production is accounted for in HWP. Female flower/spadix is also high during this seasons. Botton setting is highest during NEM, but the differences among seasons are not applicable.

(b) *Nut characters.* Analyses of three years' data (Table 3) showed that size and weight, of whole nut and dehusked nut kernel thickness, and

TABLE 1. Seasonal variation in rainfall, number of rainy days, and yield of coconut

Season	Annual rainfall (22 years : 1950-71)			Years of (16) normal rains		Years of heavy rain/ yield			Years of low rain/ yield		
	Mean	% of annual mean	C.V. (%)	Mean	% of annual mean	Mean	% of annual mean	% increase over annual mean	Mean	% of annual mean	% decrease/increase over annual mean
1	2	3	4	5	6	7	8	9	10	11	12
					(i) Rainfall in cm						
HWP	36	9	74	27	7	63	12	134	10	4	−62
SWM	314	83	23	343	88	448	83	31	222	82	−35
NEM	30	8	41	21	5	32	6	55	37	13	+80
Annual mean	379	—	20	391	—	544	—	39	270	—	−31
					(ii) Number of rainy days						
HWP	13	10	57	11	9	24	17	118	7	6	−41
SWM	92	76	8	97	80	103	71	6	86	79	−11
NEM	16	15	33	13	11	18	13	38	17	15	+27
Annual mean	121	—	12	121	—	145	—	20	109	—	−10

1	2	3	4	5	6	7	8	9	10	11	12
					(iii) Yield of WC Tall (No. of nuts/palm)						
HWP	17	46	47	—	—	30	43	77	11	57	−36
SWM	10	28	55	—	—	22	32	112	4	23	−59
NEM	9	26	49	—	—	17	25	85	4	20	−59
Annual mean	36	—	39	—	—	68	—	89	18	—	−49
					(iv) Yield of Tall × Dwarf (No. of nuts/palm)						
HWP	46	53	29	—	—	65	49	42	23	57	−49
SWM	23	27	56	—	—	41	31	80	4	10	−83
NEM	17	20	39	—	—	26	19	50	14	33	−21
Annual mean	86	—	30	—	—	132	—	54	41	—	−53

HWP : Hot Weather Period. SWP : South-West Monsoon Period NEM : North-East Monsoon Period.

TABLE 2. Seasonal variation in temperature, humidity, wind, and sunshine

Seasons	Mean temperature (°C)		Mean humidity (%)	Mean wind velocity (km/hr)	Bright sunshine hours/day (mean)
	Maximum	Minimum			
Hot Weather Period	32.9	24.5	82.4	2.4	8.4
South-West Monsoon	26.4	23.5	95.8	1.1	3.4
North-East Monsoon	31.0	21.0	86.8	1.5	8.1

TABLE 3. Seasonal influence on yield attributes and nut characters

Yield attributes	West Coast Tall			Tall × Dwarf		
	HWP	SWM	NEM	HWP	SWM	NEM
Spadix production (% of annual mean)	50.2	26.8	24.0	42.8	30.6	26.5
Abortion of spadices (% of total aborted)	10.7	72.6	16.6	(Not recorded)		
Female flower production (a) (% of annual mean)	53.8	31.4	14.8	51.3	25.5	23.2
(b) Mean per spadix	47.2	36.1	27.6	46.9	25.8	27.0
Button setting (% of total female flowers)	31.5	30.6	37.9	38.9	34.7	36.2
Nut characters						
Vol. of whole nut (cc)	3327	2696	2267	2861	2485	2108
Vol. of dehusked nut (cc)	544	472	409	467	393	333
Wt. of whole nut (g)	1365	1010	917	1187	990	898
Wt. of dehusked nut (g)	544	462	392	465	383	371
Kernel thickness (mm)	12.1	10.1	11.1	11.7	10.1	10.7
Wt. of copra/nut (g)	194	173	166	173	166	147

copra content are all maximum during HWP in both the cultivars. Lowest value for all the characters except kernel thickness is recorded in NEM. Kernel thickness is lowest in SWM. Between the cultivars, WCT showed higher values for all these characters in all the seasons.

Growth analysis of spadix in relation to crop weather seasons.

The growth period of spadix from primordium initiation to ripening of nut has been assessed to be 44 months (Patel, 1938; Child, 1964). The important stages in the growth and development of spadix and nuts are spadix primordia initiation, initiation of rachillae and female flowers, ovary differentiation, linear development of spadix, fruit set, kernel development, and maturity of nut. It has been seen that the critical stages in spadices initiated during SWM and harvested in HWP are not exposed to hot dry months.

Seasonal variations in yield of nuts.

About 50% of the annual yield is obtained during HWP (cf. Table 1). Annual yield fluctuations are more during SWM (cv: 53%). In "high yielding years", WCT shows more seasonal and annual yield increases. In "low yielding years", greater seasonal and annual yield depressions are shown by T×D.

Conclusion

Annual rainfall and coconut production in Kerala follow certain patterns according to seasons. Eventhough, a current season's rainfall and yield are not related to each other, seasonal rains are found to influence yield in succeeding seasons. Because of the prolonged growth period comprising 44 months (Patel, 1938; Child, 1964), each spadix is subjected to cyclic influence of seasons at different critical stages. As spadix production in coconut is a continuous process, each season will have a spread over influence on all spadices in the crown which are in different critical stages of growth. This seasonal functions on critical growth stages may be responsible for the good yields obtained during HWP and lower yields and smaller nut size harvested during SWM and NEM seasons.

Seasonal yield reduction in eight seasons (1.3-62.0%) and annual yield reduction for three years (14.1-39.9%) were recorded after poor rainfall in a NEM season. Such prolonged effect of drought are also reported by Park (1934) in Sri Lanka. Similarly, a well distributed high rainfall in NEM season, increases yields during the next 7-10 seasons (1.2-86.0%) and annual yields during the next 2-3 seasons (8.4-62.6%). These benefits are attributed to the effect of favourable soil moisture reserves and stress free conditions of the critical stages of spadix growth.

Poor hot weather rains also markedly reduce seasonal yields during the subsequent 7-8 seasons (1.3-37.0%) and annual yields in the next 2-3 years (5.8-25.3%). But, high rainfall in HWP does not cause any increase in seasonal or annual yield. Probably, the distribution and intensity of additional rains might not be adequate to bring about any favourable change in soil environment that can relieve the adverse effects or dry weather on the developing spadices. Patel and Anandan (1936) have also

Available Micronutrient Status of Major Soil Types Under Coconut in Healthy and Root (Wilt) Affected Tracts of Kerala, India

N.G. PILLAI, C.B. KAMALA DEVI, P.A. WAHID and C.K.B. NAMBIAR
Central Plantation Crops Research Institute, Kasaragod, Kerala, India

Abstract

A survey of coconut plantation in Kerala State was carried out. In this, 733 surface soil samples were collected at about 6.5 km intervals and analyzed for available micronutrients in five major soil types. Because of the low values encountered in a majority of cases, the following soil types are more likely to be deficient of certain elements : coastal sandy and reclaimed marshy soils for Mn, sandy loam soils for Zn, sandy loam and coastal sandy soils for Mo, and coastal sandy soils for B. The distribution of available Cu was uniform in the different soil types excepting coastal sandy soils.

The root (wilt) disease affected tracts showed a significant reduction in the levels of the following micronutrients as compared to healthy tract : Fe, Mn, and Zn in laterite, reclaimed marshy, and coastal sandy soils ; Zn in alluvial soils ; and Mn and Zn in sandy loam soils. The variation in Cu, B, and Mo content in the different soil types between healthy and disease affected tract was negligible.

The intensity of deficiency of Mo, Zn, and Mn was 83, 48, and 48 per cent, respectively. The intensity of deficiency of Zn was above 47 per cent in all soil types in only the disease affected tract and that of Mo above 60 per cent in both healthy and disease affected tracts.

Introduction

The root (wilt) disease is the most serious malady of coconut in Kerala state. Though considerable work has been done in the past three decades, the nature of the disease has not yet been determined. In the present study, a comprehensive survey of the micronutrient status of Kerala was undertaken in all the coconut soil types having diseased and healthy palms. In the past, Rajagopal (1969), Deb, Sachdev, and Wahid (1973), and Mohapatra, Bhat, and Devaraju (1975) have studied the Kerala soils, but their sample numbers were too small to draw general conclusions.

Materials and Methods

The survey of the coconut growing areas of the State was carried out in 1971. It covered five different soils, laterite, alluvial, reclaimed marshy, coastal sandy, and sandy loam. Soil samples were collected at about 6.5 km intervals. Each sample was collected from the basins of five palms at 1.5 m from the bole an 0.50 m depth. Altogether, 733 samples were collected of which 268 were from laterite soils, 128 from alluvial, 95 from reclaimed marshy, 83 from coastal sandy, and 159 from sandy loam soils. The samples from different soil groups were categorized into three groups, viz., (1) healthy (soil samples collected from basins of healthy palms in healthy areas) ; (2) foliar yellowing (samples collected from root (wilt) affected palms showing foliar yellowing) ; and (3) foliar yellowing+rubbery kernel (samples collected from basins of root (wilt) affected palms having foliar yellowing associated with rubbery kernel). Air-dried samples were analysed for available micro-nutrients using the method employed by the All India Coordinated Scheme on Micro-nutrients of Soils 1969) for Cu and Mo and Jackson (1967) for Fe, Mn and B, and Shaw and Dean (1951) for Zn.

Results and Discussion

General characteristics of the soils. The physico-chemical properties of the soils are given in Table 1. The reclaimed marshy soils include the *kole* lands of Trichur district, *kaipad* lands of Cannanore district, *pokkali* soils of Ernakulam district, and peaty or *kari* soils of Alleppey and Kottayam districts (Koshy and Verghese, 1972). These are acid soils with a very low pH. Addition of varying amounts of silt and clay is often done to the coastal sand to improve its physical characteristics. Sandy loam soils include the red sandy loam of Cannanore, Calicut, Malappuram, and Trivandrum districts.

Available micronutrient status. The micronutrient status of different soils is presented in Tables 2 and 3. The exchangeable Fe content of different soils can be considered to be satisfactory, though instances of deficiencies were noticed. The high content of exchangeable Fe in reclaimed soils, almost twice that of laterite, may probably be due to increased solubility of Fe under seasonal submergence. Variation in exchangeable Fe content was particularly high in reclaimed soils. Alluvial, coastal sandy, and sandy loam soils did not vary much in their Fe content. In the case of available Cu, all the soils were found to contain sufficient quantities. Though the mean values indicated that the level of Zn was sufficient in all the five soils, nearly half the samples had less than the critical level of available Zn. Most of the deficient areas belonged to the root (wilt) affected treats of South and Central Kerala.

B was sufficient in all soils. As many as 83% samples contained less

TABLE 1. Physico-chemical properties of the soils

Soil group	Mechanical compositions (%)*			pH* (1 : 2.5 soil : water)
	Clay	Silt	Sand	
Laterite	17 (10 - 39)	11 (2 - 20)	64 (49 - 87)	4.0 - 6.8
Alluvial	18 (9 - 32)	7 (1 - 18)	75 (50 - 89)	4.2 - 7.1
Reclaimed marshy	15 (9 - 26)	4 (0 - 14)	79 (64 - 91)	3.7 - 6.5
Coastal sandy	7 (4 - 11)	1 (0 - 8)	92 (87 - 95)	5.2 - 8.3
Sandy loam	17 (9 - 30)	4 (1 - 14)	79 (69 - 90)	4.8 - 8.6

* Each value is the mean of 20 samples. Figure in parentheses denote range.

TABLE 2. Available micronutrient status (ppm) of different soils

Micronutrient	Laterite	Alluvial	Reclaimed marshy	Coastal sandy	Sandy loam
	Mean and range	Mean and range	Mean and range	Mean and range	Mean and range
Exchangeable Fe	7.47 Trace—37.20	5.96 Trace—24.60	14.23 Trace—102.00	3.66 Trace—17.40	4.71 0.9—22.80
Cu	3.27 Trace—20.00	2.71 Trace—11.66	2.08 Trace——9.00	1.25 Trace— 2.44	2.47 Trace—24.60
Zn	1.20 Trace— 3.70	1.20 Trace— 3.80	0.90 Trace— 2.88	0.97 Trace— 2.44	0.61 Trace— 3.60
B	0.28 0.04— 0.66	0.26 0.02— 1.60	0 27 0.02— 0.83	0.18 0.02—0.46	0.22 0.03— 0.69
Mo	0.05 Trace— 0.76	0.04 0.01— 0.08	0.04 Trace— 0.07	0.01 Trace— 0.02	0.02 Trace— 0.07
Water soluble Mn	0.82 Trace— 8.64	1.29 Trace— 8.64	0.94 Trace— 7.20	0.08 Trace— 1.26	1.39 Trace— 7.20
Exchangeable Mn	11.81 Trace—48.24	9.67 Trace—39.00	3.38 Trace—36.00	0.38 Trace— 5.76	7.16 Trace—52.20
Available Mn	12.63 Trace—53.30	10.88 Trace—42.80	4.32 Trace—41.60	0.45 Trace— 7 90	8.48 Trace—52.70
Easily reducible Mn	36.72 Trace—144.00	33.94 Trace—144.00	8.66 Trace—61.40	1.56 Trace—22.32	18.27 Trace—109.80
Active Mn	49.73 Trace—162.30	44.81 1.10—176.20	8.66 Trace—59.80	2.01 Trace—30.20	26.38 Trace—140.70

TABLE 3. Percentage of soil samples falling below critical limits*

Micronutrient	Laterite		Alluvial		Reclaimed marshy		Coastal sandy		Sandy loam		Total %
	Healthy	Diseased†	Healthy	Diseased†	Healthy	Diseased†	Healthy	Diseased†	Healthy	Diseased†	
Fe	0.0	16.0	5.9	23.8	0.0	10.0	0.0	31.9	0.0	12.2	13.6
Cu	12.2	4.0	10.4	3.5	16.7	3.9	25.9	46.9	35.3	25.2	14 8
Zn	15.8	54.0	5.9	47.6	5.9	51.3	0.0	57.4	9.0	60.9	47.9
B	9.8	6.9	5.9	7.1	6.0	11.9	29.3	3.5	15.1	18.2	12.3
Mo	97.5	59.2	95.8	66.7	94.4	67.5	100.0	100.0	97.0	99.9	83.1
Exchangeable Mn	8.5	29.2	29.4	40.5	87.9	75.0	93.9	100.0	3.0	99.9	47.7
Easily reducible Mn	79.5	97.6	85.3	88.3	88.3	100.0	100.0	100.0	96.9	100.0	98.0
Active Mn	2.4	31.2	17.6	27.8	83.3	93.4	93.5	100.0	6.0	79.1	46.0

* The critical limits (threshold values) are 2 ppm for Fe (Olsen and Carlson, 1950), 0.6 ppm for Cu (Bear, 1965), 0.5 ppm for Zn, 0.1 ppm for B (Eaton and Wilcox, 1939), 0.05 ppm for Mo (Grigg, 1953), 3 ppm for exchangeable and 100 ppm for reducible Mn (Sherman and Harmer, 1943) and 20 ppm for active Mn (Jones and Leepers, 1951).

† 'Diseased' includes all samples from root (wilt) affected areas and consists of the two categories, foliar yellowing and foliar yellowing + rubbery kernel.

TABLE 4. Mean values of available micronutrient status (ppm)

	Fe	Mn	Zn	Cu	B	Mo
Critical Limits	*2.0*	*3.0*	*0.5*	*0.6*	*0.1*	*0.05*
Laterite						
1. Healthy	11.33	14.15	1.70	2.42	0.22	0.07
2. Foliar yellowing	7.54	8.54	1.02	4.45	0.28	0.05
3. Foliar yellowing+Rubbery kernel	3.10	6.31	0.55	2.97	0.24	0.04
Alluvial						
1. Healthy	7.23	10.33	2.44	2.14	0.33	0.02
2. Foliar yellowing	5.90	8.55	0.88	3.44	0.21	0.05
3. Foliar yellowing+Rubbery Kernel	8.50	9.81	0.75	3.49	0.27	0.05
Reclaimed marshy						
1. Healthy	17.75	6,82	2.15	2.20	0.24	0.04
2. Foliar yellowing	9.69	1.81	1.09	1.91	0.26	0.04
3. Foliar yellowing+Rubbery kernel	8.63	0.99	1.19	3.40	0.25	0.04
Coastal sandy						
1. Healthy	5.32	0.72	1.97	1.23	0.15	0.01
2. Foliar yellowing	3.07	0.16	0.28	1.29	0.20	0.01
3. Foliar yellowing+Rubbery kernel	2.29	0.36	0.49	0.57	0.33	0.00
Sandy loam						
1. Healthy	4.45	14.63	0.88	2.62	0.20	0.02
2. Foliar yellowing	4.78	5.33	0.35	3.02	0.22	0:02
3. Foliar yellowing+Rubbery kernel	4.29	5.33	0.04	3.29	0.29	0,02

Mo than the critical limit. This must be because the soils are generally acidic. Similarly, nearly half the samples were deficient in exchangeable Mn and almost all in reducible Mn.

Micronutrient status in relation to root (wilt) disease. About half of the samples collected from diseased trees were deficient for Zn and all soils showed deficiencies for Mo and easily reducible Mn (Table 3). When the micronutrient content in different soils is considered against the three categories, viz., healthy from healthy tract, foliar yellowing, and foliar yellowing+rubbery kernel from disease affected tract (Table 4), we again find that though certain soils and certain disease categories show deficiencies for certain micronutrients, no really consistent and universal relationship is noticed between any micronutrient deficiency and incidence of root (wilt) disease, based on the threshold values. However, healthy areas had comparatively higher status of Zn and Mn.

Acknowledgement

Grateful acknowledgement is made to Dr. K.V. Ahmed Bavappa, Director for his encouragement and Dr. Ch. Krishnamoorthy and Dr. M. Velayutham, for reading the manuscript and helpful suggestions.

References

All India Coordinated Scheme on Micronutrients of Soils (1969). Annual Progress Report for 1968-69. 89 pp. Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur.

Deb, D.L. Sachdev, M.S., and Wahid, P.A. (1973). Some aspects of soil fertility problems of major coconut growing acid soils of Kerala. Paper presented at the Symposium on Acid Sulphate and Other Acid Soils of India, Trivandrum, February 1973. Indian Society of Soil Science, New Delhi.

Eaton, P.M. and Wilcox L.V. (1939). The behaviour of boron in soils. *Tech. Bull.* 596. U.S. Dept. Agric., Washington, DC.

Grigg, J.L. (1953). Determination of available molybdenum in soils. *N.Z.J. Sci.* Technol. A. **34** : 405-414.

Jackson, M.L. (1976). *Soil Chemical Analysis.* 485 pp. Prentice Hall, New Delhi.

Jones, L.P.M. and Leeper, G.W. (1951). Available manganese in acid, natural and alkaline soils. *Plant and Soil* **3** : 154.

Koshy, M.M. and Verghese, T. (1972). 'Soils of Kerala'. pp. 144-157, in *Soils of India* 296 pp. Fertilizer Association of India, New Delhi.

Mitchell, R. L. (1965). Trace elements in soils. pp. 320-368. in Bear, F.E. (Ed.) : *Chemistry of the Soil.* 515 pp. Reinhold Publishing Corp., New York.

Mohapatra, A.R,, Bhat, N.T., and Devaraju, C. (1975). Evaluation of micronutrient status of soils from healthy and yellow leaf disease affected arecanut gardens. *J. Indian Soc. Soil Sci.* **23** : 71-75.

Olsen, R.V. and Carlson. C.W. (1950). Iron chlorosis of sorghums and trees as related to extractable soil iron and manganese. *Proc. Soil Sci. Soc.* Am. **14** : 109-112.

Raiagopal, V. (1969). Distribution of maganese and molybdenum in the soils of Kerala and the effects of molybdenum on the growth of cowpea. M. Sc. (Ag.) Thesis. University of Kerala, Trivandrum.

Shaw, E. and Dean, L.A. (1951). Use of dithizone as an extractant to estimate the zinc status of soils. *Soil Sci.* 73 : 341-347.

Sherman, C.D. and Hasmer, P.H. (1943). The manganous-manganic equilibrium of soils. *Proc. Soil Sci. Sec. Am.* 7 : 398-405.

Discussion

Thomas : You have found that some trace elements are deficient in disease affected areas. What is the practical significance of this observation ? Do you say that the disease can be prevented by correcting the deficiency ? Do you contemplate carrying out any studies in this line ?

Pillai : Our study has established the consistently low status of Zn, Mn, and Fe in certain soil types in only the disease affected tracts as against the healthy areas. The possibilities of correction or prevention of the disease are under experimentation.

First Experimental Results on the Manuring of Hybrid Coconut In Ivory Coast

P. COOMANS
Institut de Recherches pour les Huiles et Oleagineux Station, Port Bouet, Ivory Coast

Abstract

Mineral nutrition experiments carried out at Port Bouet in sandy soils with low mineral content have shown that it is necessary to apply a balanced fertilizer containing N, K, and Mg to hybrid coconut palms from the time of planting. Fertilizer requirements are in the following descending order : potassium chloride, kieserite, and urea. They have a beneficial effect on vegetative development, induce earliness of flowering, and help to attain copra yields of 3,400 kg/ha in year in 4½-5½ years. The results of the experiments have made it possible to prepare a provisional manuring schedule for the hybrid coconut variety Port Bouet No. 121 for the agroclimatic conditions of south-eastern Ivory Coast.

Introduction

Under its crop diversification policy, Ivory Coast decided in 1966 to plant 20,000 ha of coconut grove in the coastal zone to the east of Sassandra. The first plantings were done with improved local material, the yield of which, in the best conditions, reaches 3 tonnes copra/year/ha. In 1970 with the development of the hybrid between the Malayan Yellow Dwarf and West African Tall coconuts (Hybrid Port Bouet No. 121), plantings have been taken up with it in Ivory Coast. This paper sums up the results obtained in the first two experiments planted, results of which have led to the establishment of a manuring schedule for south-east Ivory Coast.

Experimental Conditions

Experiment PB-CC 16. It was planted in May 1970 on Sodepalm's Amavible plantation (Oil Palm Development Company, the Ivory State corporation responsible for implementing oil palm and coconut programmes) a few km north-east of Port Bouet Station. The soil is sandy (Table 1) and chemically poor. The experiment was laid out in a 3^3 factorial design to study the effect of P, Mg, and K applied in the form

TABLE 1. Experiment PB-CC 16 : Soil analyses (Tertiary sands)

Sand		Depth in cm	
		0—15	16—30
Grain size distribution			
Clay	%	5.9	7.4
Loam	%	1.8	1.4
Fine sand	%	13.0	13.9
Coarse sand	%	79.3	77.3
pH			
Water		5.05	5.00
KCl		4.05	4.10
Total elements			
P	ppm	120	116
C	%	0.69	0.49
N	%	0.051	0.040
K	p. 1000	0.250	0.370
Ca	p. 1000	0.085	0.100
Mg	p. 1000	0.170	0.205
Na	p. 1000	0.225	0.200
Exchange capacity meq per 100 g		3.35	3.15
Exchangeable elements			
K	meq per 100 g	0.06	0.05
Ca	,,	0.37	0.30
Mg	,,	0.09	0.06
Na	,,	0.01	0.02
Sum of exchangeable bases		0.53	0.43
Degree of saturation %		16	14

of bicalcic phosphate, kieserite, and potassium chloride. Nitrogen, in the form of urea, was tried at two levels, presence-absence, in split plots. The main plots (24 experimental palms) and split-plots have been planted with equal numbers of Ghana Yellow Dwarf (GYD) × West African Tall (WAT) and Equatorial Guinea Green Dwarf (EGGD} × WAT palms at a spacing of 8.5 m in equilateral triangles with a density of 160 palms/ha. The manuring rates applied since planting are given in Table 2.

In Year O, one-third of the dose was applied two months after planting (July) and two-thirds at the end of rainy season (November). From Year 1, it was split into two applications : before and after the long rainy season (April-August). The fertilizer is spread broadcast in a circle corresponding to the perpendicular of the leaves during the first years, and within 1.0-1.5 m radius from Year 4 onwards. It is followed by light hoeing.

Experiment PB-CC 18. This was laid out in October 1970 a few hundred

TABLE 2. Experiment PB-CC 16 : Manuring rates in kg/palm/year

Years of planting	Urea N_1	Bicalcic phosphate			Potassium Chloride	Kieserite	
		P_1	P_2	K_1	K_2	Mg_1	Mg_2
0	0.1	0.2	0.4	0.3	0.6	0.15	0.30
1	0.2	0.4	0.8	0.5	1.0	0.25	0.50
2	0.4	0.6	1.2	0.9	1.8	0.45	0.90
3	0.5	0.8	1.6	1.2	2.4	0.60	1.20
4 and onwards	0.5	0.8	1.6	1.2	2.4	0.60	1.20

metres from the first in a factorial design, $3\times2\times2\times2$ (three modes of spreading and two levels each of N, K, and Mg), to study the effect of N, K, and Mg, on GYD × WAT hybrid. It also compares split applications (April-July-November) with manuring given in one lot, before (April) or after (July) the long rainy season. The planting density is 160 palms/ha. Each elementary plot consists of 6 rows of 8 palms each with a net plot size of trees (4 rows of 6 palms). As in experiment PB-CC 16, the fertilizer is spread broadcast at the rates shown in Table 3.

TABLE 3. Experiment PB-CC 18 : Manuring rates in kg/palm/year

Years	Urea N_1	Potassium chloride		Kieserite		Bicalcic phosphate*
		K_1	K_2	Mg_1	Mg_2	
1	0.3	0.4	0.8	0.2	0.4	0.3
2	0.4	0.8	1.6	0.4	0.8	0.6
3	0.5	1.0	2.0	0.5	1.0	0.9
4	0.75	1.0	2.0	0.5	1.0	0.9
5 and onwards	0.75	1.2	2.4	0.6	1.2	0.9

*Same rate for all trees.

Factors observed. To determine the effect of mineral elements on growth, girth, number of leaves produced, and number of leaflets/leaf, observations were taken annually in June. From Year 3, observations were taken on flowering also ; also, dates of first harvest and nut yield/palm were recorded. The copra/nut was determined from the second year of harvesting. For leaf analysis, samples were taken each year in February (dry season).

Results

1. *Growth and development.* The statistical analyses of girth measurements taken in experiment PB-CC 16 showed that during the early months of growth, N application produced significant positive effect. This diminished from the third year.

The effect of N was seen in the first year in the colouring of the foliage. This difference disappeared two years after planting, by which time the leguminous cover had properly established. The phosphatic fertilizers showed no action in early years. The application of K showed the most effect with an increase of 28% in girth over control at 3 years. Both the levels of KCl showed the same results.

The effect of Mg was visible from Year 1 as a gain of 8% in girth at 3 years. Both the levels produced nearly similar effects. The K-Mg interaction was very marked from the beginning: the action of Mg appears only in the presence of K and that of K is strengthened in the presence of Mg.

The observations made on PB-CC 18 confirmed those on PB-CC 16 and the need for N+K+Mg manuring right from the time of planting. Various times of spreading showed no significant differences in growth although split applications generally give better results. For instance, the marked effect of split applications of N was a gain of 25% in girth in the first two years as compared to the control N_0. The effect of the split N applications tailed off sharply from the third year. Also, the effect of Mg appeared only in the presence of N. The best results were obtained when Mg was applied in split dose in the presence of N. Poorest growth was recorded when the two fertilizers were applied before the rainy season, in April.

2. *Flowering.* In experiment PB-CC 16, the first inflorescences appeared 30 months after planting. The beneficial effect of N, K and Mg on early flowering was fully confirmed (Table 4). The positive

TABLE 4. Experiment PB-CC 16 : Effect of fertilizers on flowering (at 48 months)

Fertilizer	Levels	% of flowering palms	Number of inflorescences/palm
N	0	59.6 (100)	5.9 (100)
	1	72.8* (122)	7.4* (125)
P	0	59.9 (100)	6.0 (100)
	1	68.2 (114)	7.0 (117)
	2	70.5 (118)	7 0 (118)
K	0	35.5 (100)	2.6 (100)
	1	83.1**(234)	8.5**(327)
	2	80.1**(226)	8.9**(342)
Mg	0	54.0 (100)	4.9 (100)
	1	73.5**(136)	7.9* (161)
	2	71.2* (132)	7.2* (147)

influence of these various fertilizers was confirmed in experiment PB-CC 18 also.

3. *First yields.* The first harvest in experiment PB-CC 16 was made 54 months after planting. The response to fertilizer in terms of nut yield/palm was clear and very considerable (Table 5). The application of N, K, Mg to GYD×WAT hybrid increased copra/ha yield by 16

TABLE 5. Experiment PB-CC 16 : Effect of fertilizers on the first yields (in number of nuts/palm)

Fertilizer	Levels	Yield during Year 5	
		GYX×WAT Hybrid	EGGD×WAT Hybrid
N	0	45.6 (100)	39.4 (100)
	1	62.3* (137)	49.5 (126)
P	0	47.8 (100)	39.3 (100)
	1	60.4 (127)	47.0 (120)
	2	53.6 (112)	47.1 (120)
K	0	16.8 (100)	16.4 (100)
	1	70.1**(417)	56.6**(346)
	2	74.8**(445)	60.3**(369)
Mg	0	40.4 (100)	30.4 (100)
	1	67.0* (166)	50.2* (165)
	2	54.4 (135)	52.7* (174)

K-Mg interaction	Mg_0	Mg_1	Effect	Mg_0	Mg_1	Effect
K_0	16.7	16.9	+ 0.2	17.3	15.3	− 2.0
K_1	39.5	87.0	+47.5	28.9	77.8	+48.9
Effect	+22.8	+70.1	$\frac{+47.3^*}{2}$	+11.6	+62.5	$\frac{+50.9^*}{2}$

times in the first year as compared to the unfertilized control. The effect on EGGD×WAT was somewhat less. The effect of phosphatic manuring was not always significant, even though at P_1 level, it increased the number of nuts/palm in GYD×WAT hybrid by 26%.

The total quantity of N-K-Mg fertilizer applied during the four years preceding bearing was 1480 kg/ha. The corresponding cost, spreading included, was 59,200 CFA Francs (40 CFA Francs/kg spread). With the sale price of copra at 60 Francs/kg (the price fixed by the Agricultural Products Stabilisation Fund in the Ivory Coast), the profit after deduction of all processing costs, was about 25 CFA Francs/kg copra. In these conditions, therefore, an increase in yield of 2,370 kg/ha would cover the outlay involved. Thus, the differences in yield were such that the profit realized in the very first harvesting campaign with a N-K-Mg manuring amply made up for the cost of fertilizers applied from the beginning.

In experiment PB-CC 18, the first harvests were made in 57 months after planting. This experiment, set up in the short rainy season, showed a time lag of one year by comparison with the preceding one which profited from a long rainy season assuring a good start, although there was only a six months lapse between the dates of planting.

Interpretation and Discussion

1. *K-Mg relationship.* In experiment PB-CC 16, K-application, even at the lowest levels, induced a Mg-deficiency in the absence of kieserite as shown by the appearance of chlorosis in the first year of planting. This was accompanied by a decrease in the Mg-content in proportion to KCl application, which was very large in the absence of Mg-fertilizer, the Mg levels being 0.176 and 0.101, respectively for treatments K_1Mg_0 and K_2Mg_0. This sensitivity to induced Mg deficiency was much greater in the hybrid than in West-African Tall (Brunin, 1970). This character comes from the Dwarf, especially the Red Dwarf and Yellow Dwarf, which are both very sensitive to K-Mg imbalance (Table 6).

TABLE 6. Optimum potassium and magnesium manurings

Year after planting	Potassium chloride (kg/palm)			Kieserite (kg/palm)		
	Principal effects	Response surfaces		Principal effects	Response surfaces	
	Rates 1 of PB-CC 16 for year 0 Rates 2 of PB-CC 18 for the following years	Cumulative optimum rates	Annual optimum rates	Rate 1 of PB-CC 16	Cumulative optimum rates	Annual optimum rates
0	0.3	0.453	0.453	0.15	0.210	0.210
1	0.8	1.275	0.822	0.25	0.666	0.456
2	1.6	2.789	1.514	0.45	1.616	0.950
3	2.0	4.587	1.798	0.60	2.446	0.830
4	2.4	7.341	2.754	0.60	3.416	0.970

On the other hand, Mg manuring had no effect on K content in the leaves. However, certain trees in the plots receiving the highest rate of kieserite, in absence of KCl showed K-deficiency symptoms as revealed by foliar discoloration in the form of rust-coloured patches (K=0.762% for the K_0Mg_2 plots).

2. *Correlations between characters observed and leaf content.* In experiment PB-CC 16, the correlation between characters observed and K-content was already positive in the first year ($r=+0.514^{**}$ for girth at 14 months) ; it proves clearly that the principal deficiency is of K_2O.

During the early years, it is however impossible to determine the action of K and Cl to growth, as there is a very close relationship between vegetative characters and K and Cl content on the one hand, and positive correlations between these two elements (LA 71 : $r=0.973^{***}$, LA 72 : $r=0.930^{***}$; LA 73 ; $r=0.963^{***}$) on the other.

In Year 4, on the other hand, the partial coefficients of correlation was % of flowering trees-K content (Cl constant) $r=0.736^{***}$; and % of flowering trees-Cl content (K constant) $r=-0.421^{**}$. They indicate that the positive effect of KCl was certainly due to the K ion.

In the first year, there was no direct correlation between vegetative observations and N-content. In Year 2, the relationship became positive and significant ($r=+0.546^{*}$ for girth at 26 months), taking only the plots receiving K and Mg into consideration, thus indicating the importance of these two elements.

In Year 3, the relationship became negative ($r=-0.498^{**}$), but it was probably linked to an effect of dilution occurring as a result of acceleration of foliar emission just before flowering. On the other hand, in Year 4, the correlations between N content, the flowering precocity and first yields, became positive and highly significant ($+0.562^{***}$, and $+0.468^{***}$, respectively). This indicates that N has a direct action on these characters.

Although kieserite acts very favourably on all the factors observed, no relationship was observed between vegetative growth and Mg-content.

Conclusion

From these experiments conducted on tertiary sands, it emerges that a balanced N-K-Mg manuring is indispensable for hybrids planted in poor soil from the time of planting.

The fertilizers had a very clear effect on vegetative development which was reflected in precocity of flowering and first yields. The positive effect of the elements applied was directly correlated with their absorption. Considering the effects observed, the fertilizer could be classified in order of decreasing priority as follows : Potassium chloride, kieserite, and urea.

The K-Mg interaction was very marked : the effect of Mg appeared only in the presence of K and the effect of K was stronger in the presence of Mg. In the absence of Mg, the high K rate became depressive and induced Mg-deficiency.

P did not appear to be indispensable at the early stage, but the absorption of this element from the fourth year indicated a positive effect in the later years.

On the basis of the experimental results obtained, a provisional manuring schedule, as given in Table 7, is recommended for young plantations

TABLE 7. Fertilizer recommendation for hybrid coconut plantations

Year after planting	Weight in kg/palm			
	Urea	Potassium chloride	Kieserite	Application
0	0.20	0.4	0.2	1/3 of the dose 2½months after planting, 2/3 in November
1	0.30	0.8	0.4	½ dose July-August
2	0.40	1.5	1.0	½ dose October-November
3	0.50	2.0	1.0	One spreading in July, August or September
4	0.75	2.4	1.0	—do—

of hybrids planted at a density of 160 palms/ha on ferralitic tertiary sands, as occuring in south-east Ivory Coast. From the third year, the rates can be adjusted on the basis of leaf analysis results.

No significant difference between the various times of application was observed although split dressings especially of nitrogenous and magnesium fertilizers, gave best results. As the effect was clear only on vegetative characters, splitting is advised during the first three years only.

References

Brunin, C. (1970). La nutrition magnesienne des cocoteraies en Cote d'Ivoire *Oleagineux* **25** : 269-274.

Brunin, C., Coomans, P. and Ouvrier, M. (1975). Etude de la nutrition minerale des jeunes cocotiers hybrides en pepiniere. *Oleagineux* **30** : 251-258.

Coomans, P. (1975). Influence des facteurs climatiques sur les fluctuations saisonniers, et annuelles de la production du cocotier. *Oleagineux* **30** : 153-159.

Mixed Farming in Coconut Gardens : Economics and its Effect on Root (wilt) Disease

K. N. SAHASRANAMAN, N. G. PILLAI, N. P. JAYASANKAR, V. P. POTTI, THOMAS VARKEY, P. G. KAMALAKSHY AMMA, and K. RADHA
Central Plantation Crops Research Institute, Regional Station, Kayamkulam, Krishnapuram, Alleppy District, Kerala, India.

Abstracts

A mixed farming programme, consisting of cultivation of fodder grasses and legumes in the interspaces of coconut, maintaining milch cows, and recycling of cattle wastes, is in progress at the Institutes at Kasaragod and Kayangulam. Increase in nut yield, improvement of soil nutrient status, and increased activity of beneficial microorganisms were observed in the experimental plots. At Kayangulam, where the palms are affected by root (wilt) disease, foliar yellowing was reduced but the treatment had no effect on the other symptoms like flaccidity and leaf necrosis. An evaluation of the economics of the practices, taking into account all the inputs and income from coconut and milk, showed that mixed farming could increase per hectare income considerably. Employment potential also increased several fold due to introduction of this system in coconut gardens.

Introduction

In systematically planted gardens, the rooting pattern of coconut provides sufficient interspace for intercropping without adversely affecting the main crop (Kushwah *et al.*, 1973). The canopy of coconut also permits about 30% of the light to filter through it when the palm is grown up. The forage crops, whose economic produce consists of vegetative tissues, can grow well under this partial shade. These conditions have been well exploited in Sri Lanka, the Philippines, and Malaysia by introducing mixed farming in coconut gardens by growing pastures and maintaining milch cows which are allowed to graze (Goonasekera, 1954; Rodrigo, Emilio, and Lorenzo, 1960; Childs and Groom, 1964; Santhirasegaram, 1966; Ohler, 1972).

Under the conditions existing in Kerala, India, where coconut is grown in 7 lakh ha and per capita land holding is only 0.22 ha, there is even a greater need to increase the productivity of coconut gardens. Hence trials were taken up at two centres of the Institutes at Kasaragod and

Krishnapuram to test the overall benefit of mixed farming by growing fodder grasses and legumes and maintaining milch cows. The results are presented here.

The coconut plantations in central Kerala are affected by root (wilt) disease which reduces the yield of coconut considerably and thus causes considerable economic loss to cultivators. Because of this, this trial gave special emphasis to study the effect of mixed cropping on root (wilt) affected gardens.

Materials and Methods

1. *Trials with fodder grasses and legumes.* Four grasses and legumes were tested as pure crops or mixtures in a field trial laid out in randomized block design with four replications. The treatments were : hybrid napier (T_1); *Stylosanthes gracilis* (T_2); *Pueraria javanica* (T_3); *Centrosema pubescens* (T_4); Hybrid napier+*Stylosanthes gracilis* (T_5); Hybrid napier+*Pueraira javanica* (T_6), and hybrid napier+*Centrosema pubescens* (T_7). The total area under trial was 1.3 ha with 471.5 m^2/plot. Further details about seed rate, spacing, manuring, etc. are given elsewhere (CPCRI, 1976). The observations/analyses done were for (1) nutrient status of soil and coconut leaf tissues; (2) soil microflora; (3) yield of coconut; and (4) foliar conditions of the palms by indexing for root (wilt) disease.

Soil and leaf samples were collected twice, before the start of the dairy unit and after running the experiment for three years. The soil samples were analysed for available K and P, and exchangeable Ca and Mg, besides pH. Leaf samples were analysed for major and secondary nutrients. For microbiological studies, total bacteria, nitrogen fixing bacteria, and denitrifiers were estimated. The yield data of the experimental palms indexed into four groups according to the intensity of disease (cf. Radha and George, 1973) were compared to pre-treatment yield; as also control palms (where no intercropping was done) of the same age groups and intensity of disease. The data on production of flower bunches and female flowers were also gathered.

2. *The dairy unit.* Eight graded Brown Swiss cows supplied by the Indo-Swiss Project were maintained for five years (1971-1975). For details about the management of animals, please see CPCRI (1976). The animal wastes were returned to the experimental fields.

3. *Economics.* The records of all inputs and outputs of the experimental field and dairy were maintained for evaluation of economics.

Results and Discussion

The fertility status of the soil did not show any significant difference between treatments. Leaf nutrient content, especially of potash, was however increased in the mixed farming plots (Table 1). Similarly, the beneficial

TABLE 1. Effect of mixed farming on leaf nutrient status

	N	P	K	Ca	Mg
Pre-treatment (1971) Mean values (per cent)	1.63	0.15	0.92	0.23	0.17
Post-treatment (1974) Mean values (per cent)	1.81	0.18	1.46	0.42	0.22

microflora also proliferated in all the treatments. The highest number of soil bacteria was observed in *S. gracilis* plots, but the nitrogen fixing organisms were maximum in the hybrid napier+*C. pubescens* plots. The highest number of denitrifiers was found in plots cultivated with hybrid napier, which is definitely a disadvantage when the crop is grown alone. The *S. gracilis*+hybrid napier combination proved to be the best among the combined treatments because of its low level of denitrifiers and comparatively high proliferation of nitrifiers.

The yield of coconut was increased by 28% (with mixed farming) (Table 2). This increase in yield could be attributed to the build up of beneficial microflora and nutrient status of the soil due to mixed farming practices and higher uptake of nutrients by the palms.

Indexing of palms for disease intensity revealed that foliar yellowing was reduced considerably even though the palms deteriorated further with respect to other symptoms like flaccidity and necrosis of leaves. The improvement in the Mg status of the leaf in treated plots could have been a reason for the reduction of foliar yellowing.

The cost accounting of the Project (Table 3) show that by maintaining eight milch cows in 1.3 ha under mixed farming practices, a profit of Rs 6693.00 was obtained in five years from the dairy alone with a cost benefit ratio of 1:1.06. But, when the income from coconuts was also taken into account, the profit went upto Rs. 18,064.00 with a cost benefit ratio of 1:1.15. If the dairy work is done by the owner family, the cost benefit ratio will go up further to 1:1.37, providing the farmer family with employment worth Rs. 424.00/month.

Trials at Kasaragod. The study at Kasaragod has the specific objective of finding out the economics of raising fodder grasses and legumes in coconut gardens and maintaining milch cows by a farmer family having a small holding. Five graded Jersey cows are being maintained by a farmer family in 1.04 ha coconut gardens. Hybrid napier and *S. gracilis* are grown as fodder crops. The organic recycling and hygienic disposal of animal wastes are carried out through a gobar gas plant of $3m^3$ capacity. This may prove to be of additional advantage since the used-up slurry, in addition to containing more N, mixes completely and quickly with the soil, and improves soil physical properties and moisture holding capacity

TABLE 2. Effect of mixed farming on nut yield

Disease index*	Control plot			Percentage increase/ decrease	No. of palms	Pre-treatment yield/ palm/year	Percentage increase/ over pre-treatment period	Estimated net response (%) (col. 8-5)
	No. of palms	Nut yield/ palm/year at commencement	Nut yield/ palm/year at completion					
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
0-10	10	58.3	62.4	+7.0	10	50.3	36.0	29.0
11-25	68	31.1	29.2	−6.1	68	33.7	25.5	31.6
26-50	8	20.9	18.1	−13.4	8	22.5	8.9	22.3
51 and above	22	19.5	21.4	+9.8	22	19.0	24.7	14.9
Overall	108	30.5	29.9	−2.0	108	31.4	26.1	28.1

*After George and Radha (1973).

TABLE 3. Economics of mixed farming in coconut gardens (Abstract only)

(In Indian Rupees)

A. Krishnapuram

(a) Capital expenditure for five years (1970-1975)

Total expenditure	26,213.02
Total appreciation	1,300.00
Total depreciation	4,016.10

(b) Income, expenditure, and cost benefit ratios for the experimental period

	Dairy	*Dairy+Coconut*
Total income	1,19,596.95	1,35,010.44
Total expenditure	1,12,903.34	1,16,946.49
Cost benefit ratio (Hire labour)	1 : 1.06	1 : 1.15
Expenditure (Substracting labour charges)	87,441.09	
Cost benefit ratio* if family itself attended to agrostology work	1 : 1.37	

B. Kasaragod

(a) Capital expenditure	*1975-76*	*1972-76*
Total expenditure	5,211.00	39,790.00
Total appreciation	5,251.00	15,121.00
Total depreciation	3,275.00	10,496.00

(b) Income expenditure, and cost benefit ratio for the experimental period

Total income	36,577.55	1,24,547.04
Total expenditure	24,477.65	80,603.46
Cost benefit ratio	1 : 1.50	1 : 1.50
Total income for the farmer family for labour & management	12,099.90	43,943.58
Wages earned by the farmer family	7,921.50	21,094.81

*Note : The owners' family will get an employment worth Rs. 424.00/ month from the project.

of the soil (Srinivasan, 1974). This gas plant meets the full requirements for light and fuel of the farmer family and dairy. The slurry is used in the experimental field as manure. Most of the work in the dairy is carried out by the farmer family. Every item of expenditure and income is accounted for economic evaluation. The data collected for four years were cost-accounted (Table 3).

The beneficial nature of mixed farming was quite evident at this Centre also and the yield of coconuts increased by 18%. The farmer family, which manages the operations of the project, earned Rs. 43,944.00 in a four year period. During 1975-76, the family earned Rs. 12,100.00. The cost benefit ratio in this case worked out to 1 : 1.50.

Taking into account all the labour inputs for the project and as compared to a pure culture of coconut, it has been estimated that the annual employment potential increased from 150 man-days/ha to 1000 man-days by the introduction to mixed farming in coconut gardens.

Acknowledgements

We are thankful to Dr. K.V. Ahamed Bavappa who pioneered the project and for his sustained interest. We are grateful to Dr. N. M. Nayar for critically going through the manuscript. The help rendered by the Indo-Swiss Project, Intensive Cattle Development Project, and Kerala Veterinary Department is gratefully acknowledged. We are also indebted to the Centre for Development Studies and Dr. H. Hiremath, Professor of Economics, University of Agricultural Sciences, Dharwar, for helpin in the cost-accounting of the project.

References

Central Plantation Crops Research Institute (1976). *Mixed Farming in Coconu, Gardens.* Final Report of Agrostology Project 1970-1975. 13 pp. CPCRI, Kasaragod.

Childs, A.H.B. and Groom, C.G. (1964). Balanced, farming with cattle and coconuts. *E. Afr. Agr. Forest. J.* **29** : 206-207.

George M.V. and Radha, K. (1973). Computation of disease index of root (wilt) disease of coconut. *Indian J. Agric. Sci.* **43** : 366-370.

Kushwah, D.L., Nelliat, E V., Markose, V.T., and Sunny, A.F. (1973). Rooting pattern of coconut. *Indian J. Agrin.* **18**: 71-74.

Ohler, J.G. (1972). Cattle under coconut. *Ceylon Cocon. Quart.* **23** : 103-107.

Rodrigo, P.A., Emilio, K.M. and Lorenzo, C.Z. (1969). Yield performance of some old coconut groves in the Philippines. *Coconut Bull.* **14** : 187-194 and 209.

Santhirasegaram, K. (1966). Utilisation of the space among coconuts for intercropping. *Ceylon Coconut Planters Review.* **4** : 43-46.

Srinivasan, H.R. (1974). Gobar gas plants—promises and problems. *Indian Fmg.* **23 (11)** : 29-33.

Biochemistry and Physiology

Chairman : R.D. ASANA

Rapporteur : N.P. JAYASANKAR

Fermentation Characteristics of some Yeast Types Isolated from Coconut Toddy

U. SAMARAJEEWA, U. PETHIYAGODA,
J.D. ATPUTHARAJAH and N.C.P. WIJERATNE
Coconut Research Institute of Sri Lanka, Lunuwile, Sri Lanka

Abstract

Coconut sap (exudate from unopened inflorescence) is allowed to ferment freely in collecting pots undar natural conditions, and the product is either consumed fresh, bottled and pasteurized, or distilled. The distillate on maturati on is called arrack. The fermentation is brought about by wild yeasts and bacteria leading to products with variable characteristics. It may be possible to obtain a high quality liquor with consistent characteristics by controlled fermentation of sap using pure yeast cultures. High ambient temperature and method of collection (tapping) pose special problems in preventing spontaneous fermentation of sap. Traditional methods were employed to suppress fermentation.

This study describes the isolation and identification, of micro-organisms associated with fermentation. The patterns of utilization of sugars in the sap and alcohol and of acid production during uncontrolled natural fermentation are compared with those of several pure yeast isolates from coconut toddy. Based on the above observations a high alcohol yielding yeast strain was selected for further study. The quality characteristics of the fermented product, its clarification, and the possibility of adopting controlled fermentation at village technology level are discussed.

Introduction

In the early production of fermented beverages such as beers and wines, the fermentations were carried out by using unknown mixtures of micro-organisms found naturally in the raw materials. Following the work of Pasteur and Hansen, the use of selected yeasts was gradually introduced into liquor industries with the object of achieving a greater degree of control over fermentation and production of more uniform and improved products. Addition of either a pure strain of yeast or a mixture of yeast strains of known origin to the "wort" or "must" is now the standard practice in the manufacture of the above products.

The fermentation of coconut sap, however, continues to be carried out by a natural process by unknown yeasts and bacteria. These organisms

bring about the conversion of sucrose in coconut sap to ethyl alcohol, acetic acid, and many other secondary products. The constituents of the fermented liquor vary with the combination of micro-organisms present in the particular instance, leading to inconsistency of the product. The fermented product of coconut sap is consumed fresh, bottled and pasteurised, or distilled to prepare arrack. The liquor has the disadvantages of high acidity and variable taste due to the unregulated nature of formentation and distillation processes.

It may be possible to control fermentation by using selected yeast strains under controlled conditions. This can improve the quality of the products and increase alcohol yields. The problems associated with controlled fermentation of coconut sap differ from those where other starting materials are employed. The setbacks are due to two major factors, the method of collecting sap and the tropical atmospheric temperatures.

In almost all liquor industries, the solid plant component containing the carbohydrate source for fermentation is brought to the factory, and either the expressed juice or a comminuted suspension constitutes the fermentation base. Under such conditions, the extract or solution could be handled in a manner to retain sterility or is sterilized. It is then inoculated with desirable micro-organisms before any wild yeasts and bacteria commence their action. Coconut sap is tapped from the unopened inflorescence of the palm and the exudate is collected in earthenware pots for periods exceeding 10 hours. The fermentation process starts immediately in the pots, being brought about by micro-organisms which may happen to settle in the collecting pot. It takes a further 6-12 hours before the sap is delivered at the processing plant. During this period, considerable change could be caused by the variety of micro-organisms present in the sap.

The second factor, temperature, too plays a vital role. The normal atmospheric temperature 27-32°C enhances microbial activity. The lack of temperature control contrasts with other fermentation industries where this factor can be regulated within the winery or brewery.

Several attempts to study characteristics of the microflora from toddy are reported in the literature. Browning and Symons (1916) isolated *Saccharomyces* strains, associated molds, and bacteria from toddy. Comparative studies on the factors necessary for growth and fermentation by yeasts isolated from coconut, palmyrah, and kitul toddy (Liyanage and Senthishanmuganathan, 1970) and the effect of ultraviolet radiation on yeasts (Jayathillake and Senthishanmuganathan, 1972) have been studied earlier. Cowap and Geake (1932) have dealt with the effectiveness of lime as an antiferment. Analytical characteristics of toddy (Anonymous, 1972) and use of bentonite for clarification (Anonymous, 1973) are also on record. Jansz *et al.* (1975) has made a detailed study of hydrogen sulphide production during fermentation of coconut sap.

We are not aware of any reports of any complete and systematic investigation on the fermentation of toddy carried out with the objective of achieving controlled fermentation.

In this study, we present some of the fermentation characteristics of yeasts isolated from coconut and palmyrah toddy samples collected from three localities in Sri Lanka and the possibility of controlled fermentation using selected strains adaptable to a village technology level.

Materials and Methods

Toddy samples at different stages of fermentation were collected from three localities of the country. Unfermented or slightly fermented coconut sap for experimental work was obtained by collecting the sap overnight in smoke-sterilized pots. For isolation of organisms, toddy at 1, 2, 3 and 4 days of fermentation were streaked in the following media in Petri dishes and single colonies of organisms were isolated for further multiplication : (a) Wort Agar (WA) ; (b) Sweet toddy agar (STA)—2.5% Agar-Agar in unfermented sweet toddy ; (c) Porato Dextrose Agar (PDA) ; and (d) Nutrients Agar (NA).

The Petri dishes were left at room temperature (30±2°C) for 48 hr.

Morphology of isolates. Yeasts were stained with neutral red/methylene blue. Bacterial colonies were examined for their reaction to Gram's stain. The shapes, budding, and chain formation of the organisms, and their distribution were noted and the sizes were measured using an eye piece fitted with a micrometer scale.

Fermentation of coconut sap. 0.1 ml of bromophenol blue solution was added to 100 ml of unfermented coconut sap (pH=4.0) which was then sterilized at 10 psi (0.66 kg/cm^2) pressure for 10 min in Bijou bottles with Durham tubes. The sterilized sap samples were inoculated under sterile conditions with the yeast isolates and left at room temperature for 48 hr. The bromophenol blue indicator was selected to suit the pH changes during fermentation of sap. Gas collection in the tubes and colour changes of the medium were used as indicators of fermentation and acidification (oxidation), respectively. (Bromophenol blue in 10 g water containing 2.5 ml of 0.1 *N* sodium hydroxide. The solution was then made to 25 ml).

Fermentation tests on pure sugars and alcohols. The above procedure was repeated with the following sugars and sugar alcohols in phenol red/peptone water medium, glucose, fructose, galactose, sucrose, lactose, maltose, sorbitol, and mannitol.

Hydrogen sulphide production. Blackening of lead acetate paper attached to the lid of MacCartney bottles containing sterile coconut sap inoculated with pure yeast strains were noted.

Time course study on natural fermentation. Unfermented coconut sap was kept open in a 20 lit pot and samples were withdrawn for assay of total sugars, alcohol, and total acidity at 10 hour intervals.

Time course study on controlled fermentation. 150 ml portions of unfermented coconut sap were sterilized in 500 ml conical flasks at 10 psi (0.66 kg/cm^2) for 10 min. The flasks after cooling were inoculated with equal volumes of yeast suspensions in 0.1% Tween 80. The contents of the flasks were analysed as in the above experiment.

Multiplication of isolates. The pure cultures of yeasts on STA slopes were transferred aseptically to 10 ml of unfermented, sterilized coconut sap. After 48 hr, the rapidly fermenting sap (10 ml) was added to 10 volumes of sterile coconut sap. The process was stepped up till 10 litre cultures were obtained. The 10 litre cultures were maintained in 20 litre flasks fitted with an air trap at the tip and an outlet tip at the bottom. Necessary volumes of fermenting sap were withdrawn from this stock culture to seed fresh coconut sap. The cultures were not aerated.

For pasteurisation of coconut sap and introduction of pure yeast cultures unfermented coconut sap was heated and maintained at 90°C for 20 min in 20 litre earthenware pots. The mouths of the pots were closed with muslin. The sap was allowed to cool and the inocula introduced. The fermented toddy was analysed after 2 days for alcohol and total acids and daily thereafter.

Clarification of the fermented sap. Selection of a suitable clarificant. 2g of the following substances were shaken with 25 ml sap and allowed to stand for three days ; fresh egg white; milk; bentonite (montmorillonite), activated charcoal; potassium hydroxide; calcium chloride; and sodium chloride. Based on this preliminary screening, concentrations of bentonite upto 1% were added to the sap and allowed to stand in glass cylinders for 24 hr. Clarity of the solutions were measured using a Beckmann UV spectrophotometer at 800 nm (path length 1 cm). The same procedure as for bentonite was used to find the amount of fresh egg white needed for clarification.

In a second set of experiments, 2.5% fresh egg white (volume) was used in fermented sap and the samples were examined at 24 hour intervals to determine the optimum time required for clarification.

Alcohol percentages (v/v) were read on an ebulliometer. Estimations of the following constituents were done by the standard methods adopted for sugars and wines. (Methods of Analysis. Association of Official Analytical Chemists, 1975) : Total acids, volatile acids, sugars, residue, ash, water soluble and insoluble, ash, alkalinity of water insoluble ash, total tartaric acid, and glycerol.

Results

Morphology of organisms

Four distinct morphological types of yeasts were isolated. (a) Spherical : 5—7μ size, 30—45% ; (b) Oval : 2—5μ × 5—12μ, showing lateral budding, 30—50% ; (c) Pear shaped: 5—13μ, showing polar budding, 3—30%; (d) rods: 2—5μ × 12—23μ, showing lateral budding, less than 1%.

No chain formation was observed in any of the cultures. The dominant bacterial type was diplococci. Gram positive rods were also occasionally observed.

Fermentation of coconut sap

Of the 33 isolates of yeasts studied, 31 produced gas, one metabolized the medium without producing gas, and the other was inactive. Organisms that do not contribute to alcoholic fermentation were also therefore utilizing the sap.

Carbohydrate tests. The number of isolates showing oxidation and fermentation of a total of 33 isolates, was as follows :

Sugar/Sugar alcohol	Oxidation (colour change)	Fermentation (gas evolution)
Dextrose	33	31
Fructose	31	31
Galactose	29	15
Sucrose	31	29
Maltose	23	31
Lactose	13	2
Sorbitol	6	0
Mannitol	0	0

Non-sucrose fermenting yeasts were present in toddy.

Hydrogen sulphide production. Twenty-nine types out of 33 produced hydrogen sulphide during fermentation. This agrees with the earlier reports on hydrogen sulphide production (Jansz *et al.*, 1975).

Time course study on natural fermentation showed the following features (Fig. 1): (a) A maximum alcohol level of 6.5% was reached in three days.

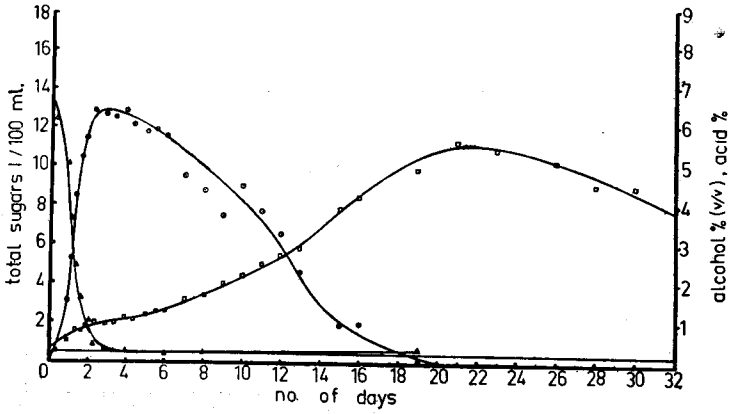


Fig. 1. Natural fermentation of coconut sap.

The corresponding acidity was 1.0%. The alcohol content dropped to zero in 20 days. (b) A maximum acidity of 5 3% was reached on the 21st day and then it started dropping probably due to oxidation of acid to CO_2 and water. (c) Total sugar content dropped from 13.0% to 0.5% by the third day and remained constant. An acidity of 1.0% may be inhibiting further fermentation. Sugar too was a limiting factor at this stage.

Time course study on controlled fermentation

Using steam-sterilixed coconut sap and the culture y11 the following observations were made (Fig. 2): (a) A maximum alcohol content of 9.3% was attained in four days and then it remained constant for two days. (b) After the sixth day, alcohol level started dropping and rcached 5.5% on the 34th day. (c) Acidity remained at 0.3% throughout the experiment; (d) Total sugar dropped below 1.0% in four days.

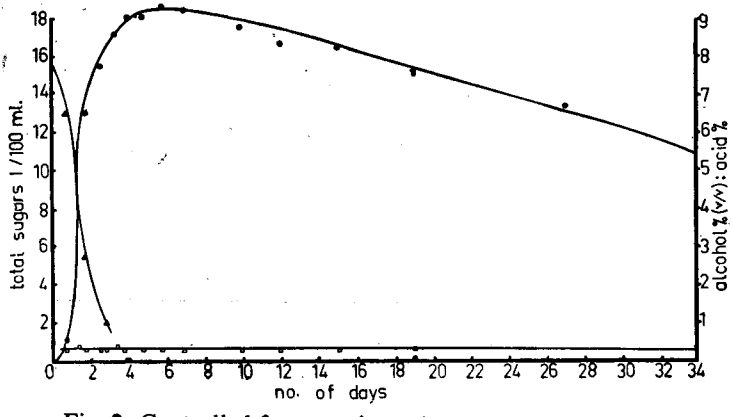


Fig. 2. Controlled fermentation using yeast culture y 11.

Thus, by controlling acid production, it is possible to prolong the alcoholic fermentation to attain higher alcohol yields.

Using an isolate of pear-shaped yeast cells, a maximum of 8.3% alcohol was produced (Fig. 3). The fermentation process was slow, taking 12 days

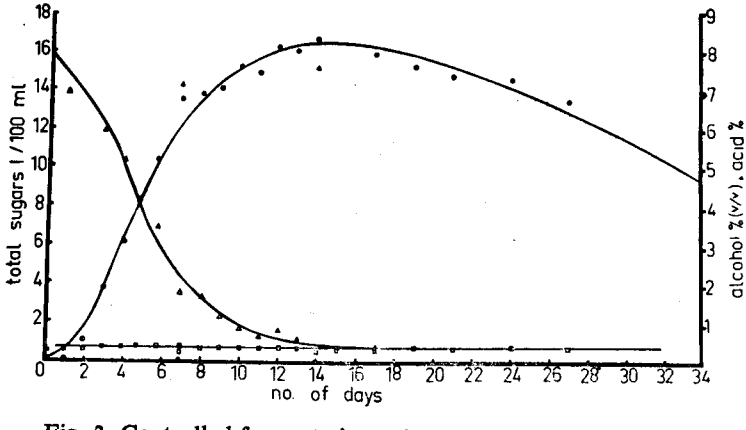


Fig. 3. Controlled fermentation using pear-shaped yeast cells.

to reach the maximum alcohol content. Here too acidity remained at 0.3%. It may be possible to use this type of organism to obtain a liquor of lower alcoholic strength for direct consumption without distillation.

Continuous fermenting cultures

Varying alcohol levels of 9—10% were obtained after five days of fermentation. The acidity remained below 0.4%. The culture was maintained uncontaminated for nine months, though steam-sterilized coconut sap was introduced and fermented sap removed at 5—7 day intervals.

The culture was also used for seeding large volumes of pasteurized (90°C for 20 min) unfermented sap in 20 litre earthenware pots. The alcohol levels of 9—10% was reached in pots in four days. It was possible to remove the sap after fermentation and introduce fresh pasteurized sap for fermentation. This method had the limitation of the culture becoming contaminated after 2—3 such changes.

Clarification of fermented sap

Of the various substances tried for clarification, only bentonite, fresh egg white, and milk were effective. Bentonite was the most efficient.

Bentonite. Figure 4 indicates the correlation between the percentage of

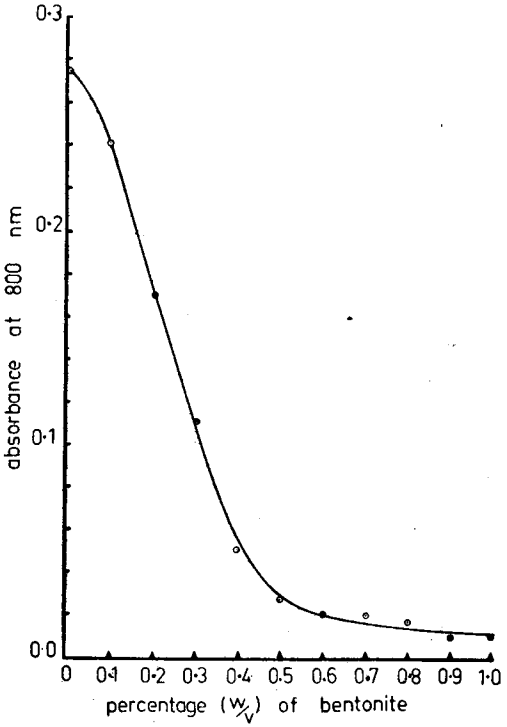


Fig. 4. Effect of bentonite concentration on degree of clarification of fermented sap.

bentonite and extent of clarification. The minimum amount of bentonite that was necessary to bring about maximum clarification in 24 hours was about 0.5%. The bentonite treated fermented sap had the same clarity of 2—3 months old untreated samples. The clarified liquor had a "metallic" taste imparted by the bentonite.

Fresh egg white. 2.5% fresh egg white clarified the fermented sap in four days to the same extent as 0.5% bentonite (Fig. 5). Use of fresh egg white would be more acceptable as it is already used in the arrack industry as a clarificant.

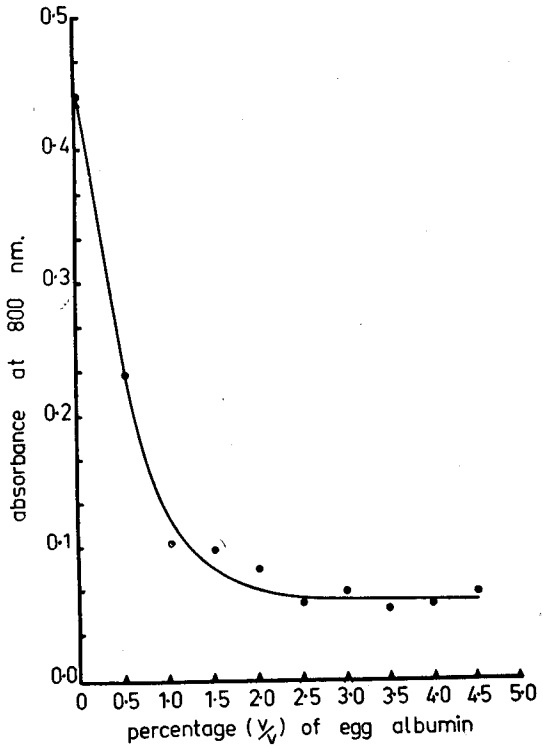


Fig. 5. Effect of egg albumin concentration on degree of clarification of fermented sap.

Physical characterstics of controlled fermented sap

Appearance. Brownish yellow and turbid.

Taste. Slight bitterness which is not retained on the tongue for more than a minute or two. It did not give the characteristic taste and smell of toddy (the naturally fermented sap) (Fig. 6).

Analytical characteristics of controlled/fermented sap

The comparative analytical figures for controlled-fermented sap using four isolated yeast strains y11, y32, y37A, and y75 (all spherical yeasts) along with the analytical figures for naturally fermented sap and dry white wines (Hernstein and Jacob, 1948) are given in Table 1.

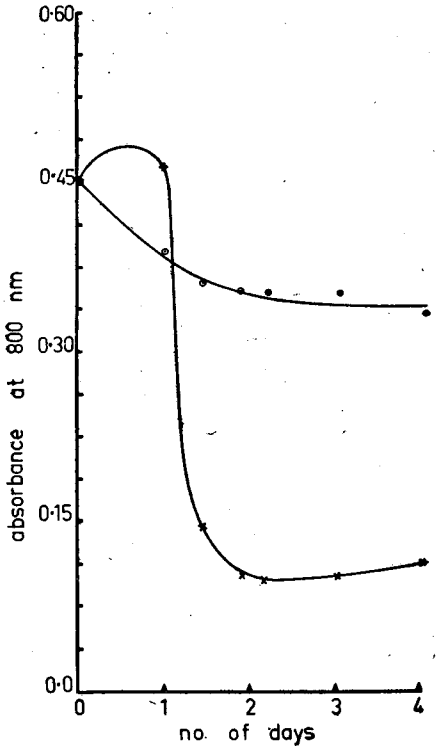


Fig. 6. Physical characteristics of controlled fermented sap.

TABLE 1. Comparison of analytical characteristics of naturally fermented coconut sap, controlled fermented coconut sap dry white wine and naturally fermen ted toddy

	Controlled fermented toddy yeast strarn used				Natural fermented toddy	Dry white wine*
	y11	y37A	y32	y75		
Alcohol % (v/v)	10.0	10.0	9.2	9.3	6.3	12.15
Acid %	0.4	0.4	0.5	0.4	0.6	
Total sugars (g/100 ml)	0.3	0.4	0.4	0.6	0 8	0.1
Extract (g/100 ml)	2.8	2.8	3.1	3.5	4.3	2.0
Total ash (g/100 ml)	0.4	0.4	0.4	0.2	0.2	0.4
Water soluble ash	0.3	0.3	0.3	0.2	0.2	
Water insoluble ash	0.1	0.1	0.02	0.01	0.0	
Alkalinity of water soluble ash (ml of 0.1 *N* HCl)	25.3	19.0	21.8	11.2	14.6	28.7
Alkalinity of water insoluble ash	23.6	22.0	22.6	11.4	12.9	13.5
Tartaric acid (g/100 ml	0.1	0.2	0.2	0.04	1.2	0.3
Total free acid (as tartaric acid)	0.7	0.7	0.8	0.8	1.01	
Volatile acids (as acetic acid)	0.1	0.1	0.1	0.1	0.2	0.1
Fixed acids (as tartaric acid)	0.6	0.6	0.7	0.6	0.7	
Glycerol (g/100 ml)	0.4	0.2	0.4	0.2	0.2	0.7

*Data from Herstein and Jacobs, 1948.

The controlled-fermented sap is characterized by high alcohol content, low acidity and low residual sugars. The tartaric acid content was comparatively lower than in naturally fermented sap. The analytical figures for controlled-fermented sap are comparable with that of dry wines except for the slightly high volatile acid content and low alcohol and glycerol contents.

Discussion

Arrack, the distilled product of naturally fermented toddy, is characterized mainly by very high acidity, high ester content, and somewhat higher alcohol content in comparison with the more acceptable liquors produced by controlled fermentation using other raw materials. All these factors are due to the nature of the microflora acting on coconut sap. Thus, the possibility of obtaining a more refined liquor by controlled fermentation is beyond doubt. The presence of the non-sucrose fermenting organisms in the natural microflora may be contributing substantially to the increase in secondary products.

The presence of non-H_2S producing yeasts among the isolated yeast strains indicate the possibility of combining this character with the better fermenting yeast.

The time course experiments indicated the possibility of achieving higher alcohol levels by preventing acidification. This was achieved in the experiments with the isolated strains. Since high acidity and high ester contents adversely affect the quality of arrack, controlled fermentation, where the acidity could be kept at a minimum, should give a better liquor.

It is possible to get low alcohol products using other types of yeasts, as observed with strain y23. It is also possible to get a "dry toddy" (comparable with the term "dry wine") by allowing complete fermentation or a "sweet toddy" (comparable with the term "sweet wine") by arresting fermentation at a predetermined stage.

The drop in alcohol content on using serial cultures in studying controlled fermentation was interesting (Figs. 2 and 3). This may be due to slow aerobic oxidation. However, no acid was produced. The same effect was not observed, when fermentation was done in 20 litre flasks, probably due to the gas trap which prevented the entry of air.

The use of clarificants reduced the time of storage necessary, thereby reducing the chances of acidification. The taste of fermented sap resembled beer due to a slight bitterness when consumed before clarification. Since the cost of production was low and the alcohol content was higher than in beer, this product may gain a ready market among consumers who dislike toddy either for its low alcoholic content or the characteristic "sulphurous" taste.

Since coconut sap is generally collected in small quantities by villagers

by tapping a few trees it may be possible to utilize controlled fermentation on a small scale. A few pots of 5-6 gallon (about 22-27 litres) capacity and glassware that could be used to maintain a near sterile culture are the only simple equipments needed. The collected unfermented sap could be heated to boiling to destroy all the organisms and the culture could be added on cooling. After 3-4 days, the sap will be ready for consumption. If the liquor is to be distilled, it could be transported while the fermentation is going on, or bottled after fermentation and pasteurized.

Since this method is similar to preparation of curd practised in villages, the technique does not involve complicated technological innovation.

Acknowledgements

We thank Mr. M.P. Tissera for the technical assistance, and Mr J.E. Premaratne and Mr. M.A. Perera for supplying the unfermented coconut sap. We acknowledge also the assistance of Mr. W.F.A. Fernando and Mr. P.M.J. Fernando in laboratory experiments.

References

Anonymous (1972). Processing of toddy. p. 39. *Ann. Rep. Central Food Technological Research Institute, Mysore, India.*

Anonymous (1973). Processing of toddy, p. 51. *Ann. Rep. Central Food Technological Research Institute, Mysore, India.*

Browning, K.C. and Symons, C.T. (1916). Coconut toddy in Ceylon. *J. Soc. Chem. Ind.* **35** : 1138-1142.

Cowap, J.C. and Geake, F.H. (1932). The analytical characteristics of coconut toddy. *Analyst* **57** : 627-628.

Herstein, K.M. and Jacobs, M.B. (1948). *Chemistry and Technology of Wines and Liquors.* pp. 316-321. 2nd ed. D Van Nostrand, New York.

Jansz, E.R., Jeyra, E.E., Abeyratne, D.J. and Premaratne, I.G. (1975). Control of hydrogen sulphide formation in coconut toddy. *J. Natu. Sci. Council Sri Lanka* **3** : 1-10.

Jayatilaka, P. and Sentheshanmuganathan, S. (1972). Effect of ultraviolet radiation on yeasts isolated from fermented saps of palmyrah, coconut, and kitul. *Proc. Ceylon Assoc. Adv. Sci.* **28** : 108.

Liyanage, A.W. and Sentheshanmuganathan, S. (1970). Comparative studies of yeasts isolated from fermented saps of palms in Ceylon. *Proc. Ceylon Assoc. Adv. Sci.* **26** : 97.

Association of Official Agricultural Chemists. (1975). *Methods of Analysis.* 12th ed. AOAC, Washington, D.C.

Discussion

Sreemulanathan : What is the process adopted in smoke sterilization ? We have found that smoke sterilization is not effective. Smoke sterilization consists of smoking and flaming, and flames lick the pot. So it is partially a flame sterilization.

Samarajeeva : The washed, sun-dried, and cleaned pots are inverted on a low coconut log raft erected about 30 cm above ground level. A fire is lit underneath. The pots are thereby partially 'flamed' in addition to being smoke-sterilized.

Sane : 1. Is it possible to use chemicals to arrest unwanted fermentation soon after tapping ?

2. Have you studied the aldehydes produced by the strains of yeasts you have isolated ? The study of aldehyde is important because they may impart flavour to the fermented material.

Pethiagoda : 1. Yes. Several chemicals are available that could be used to arrest fermentation. The problem is to find an acceptable one that would do this only temporarily, as the sap has eventually to be fermented by a selected yeast. This is not so easy.

2. There has been considerable study of the aldehydes produced during uncontrolled fermentation brought about by wild yeast populations. With our selected strains, we have not yet got down to studying the production of aldehydes. Aldedydes are among the most important chemicals that produce undesirable flavours and smells.

Ittoop : What is the container used for carrying toddy in Sri Lanka ? It has been reported by the medical profession that amoebiosis is very common among toddy drinkers, and this has seen attributed to arecanut leaf sheath (leaf base) used for carrying toddy ?

Pethiagoda : 1. Clay pots for collections and scooped out bottle gourds for collection and transport on the cottage scale. Where collection is made for the distillaries, wooden barrels are employed.

2. There has been, as far as I am aware, only a suggested connection between amoebiosis and unhygienic containers for toddy. On the contrary, indigenous opinion is that toddy is an effective treatment for amoebiosis.

Varietal Differences in Nut and Copra Characters

P.A. SARANGAMATH, P.B. SHANTAPPA and D.S. KULKARNI
University of Agricultural Sciences, Regional Coconut Research Station, Arsikere, Karnataka, India

Abstract

Nuts were sampled from the coconut cultivars of Spicata, Gangabondam, Fiji, Kaithathali, Laccadive Dwarf, Andaman Dwarf, West Coast Tall, Philippines, S.S. Green, Hybrid, and Kappadam. These were analysed for moisture, protein, phosphorus, potassium, calcium, magnesium, crude fibre, and total mineral contents. Correlation coefficients were worked out for various constituents. A high correlation was found between yield of copra and ash content ($r=0.6982$).

Introduction

The coconut is the most useful palm. The principal use of coconut is in manufacture of copra, from which oil is extracted and cake is, obtained as a by-product. Copra is also used in cooking and confectionary. It is, therefore, useful to know the chemical characteristics of coconut kernel and copra. Such analyses have been carried out earlier by Child (1964), Rao (1967), Subramanyam and Swaminathan (1959), Verghese (1952), and Pillai and Satyabalan, (1962).

An attempt has been made in this study to determine the variations in nut and copra characters of 11 coconut cultivars grown at Arsikere in Hassan district, Karnataka, India.

Materials and Methods

Fully mature (13 months old) nuts of 11 coconut cultivars, Spicata, Gangabondam, Fiji, Kaithathali, Laccadive Dwarf, Andamans Dwarf, West Coast Tall, Philippines Ordinary, Laccadive Ordinary, SS Green, and Kappadam, grown at the Regional Coconut Research Station, Arsikere, were harvested during the last week of September 1969, and air-dried at room temperature for copra. Yield of copra with and without husk was recorded and per cent of copra with and without husk was calculated. After extracting copra, each sample was analysed for moisture ash, mineral content, crude protein, crude fibre, calcium, magnesium, potas-

sium, nitrogen, and phosphorus at the Regional Research Station Mudigere, in early 1971. Moisture was estimated gravimetrically, N by Kjeldahl method, Ca and Mg were determined by EDTA method, K on flame photometer, and P and crude fibre, as prescribed in A.O.A.C. (1970). Protein content was calculated by multiplying N content by 6.25.

Results and Discussions

Yield of coconut and copra depends upon various factors such as variety, age of palm, soil, climate of the area, maturity of nuts, season of harvest, period of storage, etc. The present study showed that much variability for most constituents was exhibited both within a cultivar and between cultivars (Tables 1 and 2).

TABLE 1. Variability in cultivars for nut characters

Cultivar	Weight of nut (g)		Weight of copra	Percent of copra		Moisture percentage in copra
	With husk	Without husk		With husk	Without husk	
Spicata	640	350	165	26	47	6.0
Gangabondam	490	310	155	32	50	2.5
Fiji	745	318	143	19	43	3.8
Kaithathali	453	248	115	25	46	3.3
Laccadive Dwarf	713	387	178	25	46	4.0
Andaman Dwarf	685	375	202	30	54	4.0
West Coast Tall	705	380	165	23	43	4.0
Philippines	665	375	205	31	55	4 0
Lacadive Ordinary	595	340	160	26	46	3.0
SS Green	730	390	185	25	47	4.0
Kapadam	613	313	133	21	42	4.0

Copra. The percentage of copra in dried whole nuts ranged from 19% (Fiji) to 32% (Gangabondam), while the percentage of copra in husked nuts varied from 42% (Kappadam) to 55% (Philippines). The copra content in husked nuts was 50% or more in the cultivars Gangabondam, Andamans Dwarf, and Philippines.

Moisture. This varied from 2.5% (Gangabondam) to 6% (Spicata). Marar and Padmanabhan (1960) have observed that if moisture content in copra exceeds 5% and relative humidity is 86% and more, then the quality of copra deteriorates at a fast rate.

TABLE 7. Variation in chemical composition of copra in coconut cultivars

Name of cultivar	N %	P %	K %	Ca %	Mg %	Ash %	Protein %	Crude Fibre %
Spicata	1.17	0.04	1.68	0.020	0.007	2.5	7.3	5.6
Gangabondam	1.15	0.05	1.70	0.020	0.010	2.8	7.2	5.7
Fiji	1.00	0.11	1.87	0.029	0.011	3.5	6.4	5.0
Kaithathali	1.20	0.17	1.64	0.020	0.011	3.0	7.5	5.9
Laccadive Dwarf	1.14	0.14	1.89	0.021	0.010	2.7	7.2	7.2
Andamans Dwarf	1.10	0.18	1 41	0.024	0.006	2.3	6.3	4.5
West Coast Tall	0.94	0.12	0.97	0.016	0.019	2.7	5.9	6.3
Philippines	0.72	0.15	1.62	0.048	0.007	2.9	4.5	5.9
Laccadive Ordinary	1.00	0.16	1.69	0.024	0.009	2.5	6.4	5.5
SS Green	1.02	0.13	3.20	0.024	0 019	3.0	6.4	4 9
Kappadam	1.10	0.11	2.97	0.014	0.008	2.9	6.9	5.8

Fibre. It varied from 4.5% (Andaman Dwarf) to 7.2% (Laccadive Dwarf).

Minerals. Copra is a poor source of minerals. Ash content did not show much variability. However, the Ca content of Philippines (0.048%) was more than three times that of the cultivar showing the lowest Ca content, namely, Kappadam (0.014%). A high positive correlation was found between yield of copra and ash content (r=0.6982).

Protein. The protein content also did not show much variation.

In general, copra is a good source of protein, crude fibre, and potassium, and a fairly good source of phosphorus and magnesium.

Acknowledgement

We thank Prof. S.D. Kololgi, Chief Scientific Offcer, Regional Research Station, Mudigere, for providing facilities and giving valuable suggestions.

References

A.O.A.C. (1970). *Methods of Analysis.* 11th ed. AOAC, Washington, USA.

Child, R. (1964), *Coconuts.* 216 pp. Longmans Green, London.

Rao, C.H. (1957). Growing coconuts in coastal Andhra. *Coconut Bull.* **11**: 143-151.

Marar, M.M.K. and Padmanabhan, V. (1960). Preliminary studies on the storage of copra in plastic lined gunny bags. *Coconut Bull.* **14**: 7-10.

Subramanyan, V. and Swaminathan, M. (1959). Coconut as a food. *Coconut Bull.* **13**: 153-158.

Verghese, E.J. (1952). Food value of coconut products. *Indian Coconut J.* **5**: 119-129.

Pillai, R.V. and Satyabalan, K. (1960). A note on seasonal variation in yield, nut characters and copra content in a few cultivars of coconut. *Indian Coconut J.* **12**: 45-55.

Discussions

Carlos: Please clarify what you mean by Philippine variety. We have a wide range of coconut diversity in the Philippines.

Sarangamath: The plant material was supplied from CPCRI, Kasaragod, under the name Philippines Ordinary.

R.V. Pillai: 1. The plants available at Arsikere are all open-pollinated progenies. They cannot be taken as standard cultivars.

2. What is the hybrid used in the study?

3. The number of samples is too low. Hence, general conclusion cannot be drawn.

Sarangamath: 1. Agreed. But some samples were got from CPCRI, Kasaragod also.

2. T x D hybrid.

3. But two nuts/palm have been sampled which is an adequate sample size. The

present results are only indicative, and the information will be useful for selecting material for further studies.

D'Souza: What is the correlation between nutritive values of coconut water and copra?

Sarangamath: Earlier workers have observed that if coconut water contains more of potash, yield of copra is also more.

Variation in Glucose Content in Andamans Coconut

R.B. NAIR and A.K. SADANANDAN

Central Plantation Crops Research Institute, Research Centre, Sipighat, Port-Blair, Andamans, India

Abstract

Tall and Dwarf palms did not show any significant differences between them in the glucose content of 6-month old tender nut water. The total variation ranged from 2.0% to 6.9%. No correlation was observed between glucose content and different colour groups (types) in Tall palms. Glucose content became generally higher as the nut size reduced from giant to medium, small and micro.

Introduction

The tender coconut water is a delectable and nourishing drink for all, especially for the sick and convalescent. From time immemorial, seafarers used to carry coconuts with them in the ships' holds to serve as food and drink. The wide spread of coconuts in the uninhabited tropical islands of Indian and Pacific oceans has itself been ascribed to this habit.

In Nicobar Islands, it forms a daily food to the local people and their domestic animals like pig, cow, and dogs.

The sweetness of the water and meat is due to the presence of glucose. While testing the differences in sweetness of tender nut water of coconuts in Andaman and Nicobar Islands, considerable variations were observed for this character between palms of different Tall types in the same tract and also from tract to tract. Hence, the present study was taken up.

Materials and Methods

Six months old fruits of Tall and Dwarf forms and types of coconut growing under identical conditions and of uniform age at the Government Coconut Plantation at Corbyn's Cove, Port Blair, were used for the study. The glucose content was estimated as given in the Methods of Analysis, A.O.A.C. (Page 289 ; 9th ed. ; 1960), at the Soil Testing Laboratory, Port Blair.

Results and Discussion

The percentage of glucose content in different forms of coconut varied widely, from 2.0% to 6.9%. There was a tendency for sweetness to increase as the nut size reduced from giant to medium, small and micro (Table 1).

TABLE 1. Variation in glucose content of 34 Tall and 6 Dwarf* coconut palms

% Glucose	Type			
	Giant	Medium	Small	Micro
2.0-2.9	1	4	—	—
3.0-3.9	1	11	7*	—
4.0-4.9	—	10	—	—
5.0-5.9	—	2	1	2
6.0-6.9	—	—	—	1

*Dwarf Yellow.

Pillai, Sukumaran and Pandalai (1959) estimated the glucose content in 6-month old West Coast Tall coconuts as 3.6%.

There is a common belief that the water of the Dwarf coconut forms of Andamans (locally known as "king coconut") and the soft kernel (known as "Malai") are sweeter than those of Tall types. The study showed that the yellow 'king coconut', which occurs relatively more frequently in the Islands, contains only 3.3% glucose. This value is even less than the 4.0% glucose content of Tall palms.

There is also another school of thought that the colour of the nut has some influence on sweetness of the milk and that palms producing reddish (orange) or yellowish nuts produce sweeter water and tastier kernel as compared to greenish types/varieties. However, data given in Table 2 show no such correlation.

TABLE 2. Glucose content in Tall and Dwarf coconuts

% Glucose	Variety/Type		
	Greenish	Yellowish	Reddish
2.0-2.9	5	—	—
3.0-3.9	10	6*	3
4.0-4.9	9	1	—
5.0-5.9	4	—	1
6.0-6.9	1	—	—

all *been*

Acknowledgement

We are indebted to Dr. K.V. Ahamed Bavappa, Director for suggesting the problem, to Mr. K.S. Yadav, then Soil Chemist, Department of Agriculture, A & N Islands for giving facilities for carrying out the work in his laboratory and to Mr. Rajasekharan Nair, Department of Statistics, University of Kerala for interpreting the data.

References

Pillai, N.G. Sukumaran, C.K., and Pandalia, K.M. (1959). Studies on the changes in the chemical composition during different stages in the developing coconut. pp. 132-151. *Proc. First Conf. Coconut Res. Workers, India.* Indian Central Coconut Committee, Cochin.

A.
rato

The Vascular Physiology of the Coconut Palm

JOHN A. MILBURN
Department of Botany, University of Glasgow, Glasgow, Scotland, United Kingdom

Abstract

Little is known about the basic physiology of the coconut palm despite its considerable economic importance. As a consequence, we are poorly informed when attempting to understand basic requirements of yield and also the course of vascular infections such as the lethal yellowing disease.

The paper describes preliminary experiments on coconut palms growing in Miami, USA. Diurnal relations were studied using both pressure bomb and porometry. Xylem sap pressures were found to vary between 2 bars by night to around 12 bars by day. Phloem sap was collected by tapping exudation induced in immature inflorescences by repeated slicing (the traditional techniques). Changes in sap concentration and pressure were mentioned at different times. It appears that sap concentration is maintained homeostatically to a considerable extent, as in other plants, and is driven through the sieve tubes by pressure. Positive pressures were measured up to about 10 bars. The physiology of other plants are compared with that of coconut and physiological and pathological implications are discussed.

Introduction

It is surprising how little is known concerning the vascular physiology of palms in view of their considerable economic importance. Some early studies by Bose (1927) were not followed up. Recently, our ignorance of their vascular physiology has been spotlighted by serious epidemics of pathogénic diseases of coconut and other palms, some of which have been given considerable publicity, e.g., lethal yellowing disease. Within the last decade, considerable studies have been made to elucidate and unravel the intricate vascular organisation of palms using the shuttle microscope (Zimmermann and Tomlinson, 1972) and also the ultrastructural organisation in the vascular system (Parthasarathy, 1974). Despite the widespread use of the pressure bomb, introduced by Scholander *et al.* (1965), it has not been applied to palm physiology except quite recently (Milburn and Zimmermann, 1977 *a*, *b*). Since vascular transport in both phloem and xylem is mediated by water, we cannot underestimate the overall importance of changes in water potential. Though toddy has been

Discussion and Conclusions

It seems that the water relations of *Cocos* palms accord closely with those of many other vascular plants. Xylem sap pressures decreased to around −10 bar by day and rose to about −2 bar at night. These changes are broadly correlated with climatic conditions on a diurnal basis in monsoon weather, but can be limited by stomatal control in dry weather during a drought.

Phloem transport in the palms seems to be driven by hydrostatic gradients. The direction of transport would follow from changes in osmotic potential in accordance with Munch's (1930) hypothesis. The pressures measured directly in an interrupted phloem transport system broadly correspond with the pressures which might be expected from osmotic potential measurements of sap and xylem sap pressure measurements. The derivation of a turgor pressure from osmotic potential measurements and the xylem sap tension measurements made in the leaves must be tentative, bearing in mind that these sites were some metres apart on the experimental palms. The sum is based on a theoretical balance which might not strictly apply.

The observation that phloem exudation increased around mid-day is surprizing and contrary to the observations of Bose (1927) because one would expect the turgor pressure in the phloem to decrease in response to an increasing xylem sap tension. Possibly, photosynthetic assimilation more than overcomes the reduced water potential by increasing the solute potential in phloem, and thus raising the osmotic gradient and turgor pressure.

There can be no doubt that the phloem system is sensitive to mechanical interference. The primary effect of this is to suspend exudation. If the effect is to cut off a developing sink from the supplying tissues we may conjecture that on restoration of conduction the flow rate would be increased. Since rapidly conducting phloem may be driven by hydrostatic gradients, we may conjecture that the technique advised by toddy tappers may have a scientific basis. A similar effect has already been shown for *Ricinus* (Milburn, 1971).

Finally, we may enquire how the vascular physiology of the coconut palm may be expected to transmit vascular pathogens. The main requirement for xylem mediated transport is that a pathogen can pass through the pit membranes which interrupt xylem sap flow at fairly frequent intervals. This apart, pathogens will move freely with the transpiration stream. So too, in the case of phloem transport, pathogens can pass along the sieve tube system depending on the hydrostatic pressure gradients. The direction of flow will be governed by phloem loading and unloading processes. As yet, we have little information regarding the effect pathogens may exert on phloem loading and great deal of experimental work must be done to augment these admittedly preliminary studies.

Acknowledgements

I gratefully acknowledge the assistance of Professors M.H. Zimmermann and P.B. Tomlinson throughout these investigations.

References

Bose, J.C. (1927). Plant Autographs and their Revelations. Longmans Green, London.

Die, J. van and Tammes, P.M.L. (1975). Phloem exudation from monocotyledonous axes. pp. 196-222 *In* Encycl. Plant Physiol. N.S. Vol. 1. Transport in the Phloem. Eds. M.H. Zimmermann and J.A. Milburn, Springer-Verlag, Berlin.

Milburn, J.A. (1971). An analysis of the response in phloem exudation on application of message to *Ricinus*. *Planta* (Berl.) **100** : 143-155.

Milburn, J.A. (1974). Phloem Transport in *Ricinus*. Concentration gradients between source and sink. *Planta* (Berl.) **117** : 303-319.

Milburn, J.A. and Zimmermann, M.H. (1977 a). Preliminary studies on sap flow in *Cocos nucifera* L.I. Water relations and xylem transport. *New Phytol.* **79** : 535-541.

Milburn, J.A. and Zimmermann, M.H. (1977 b). Preliminary studies on sap flow in *Cocos nucifera* L. II. Phloem transport. *New Phytol.* **79** : 543-558.

Munch, E. (1930). *Die stoffbewegungen in der Pflanze*. Fischer, Jena.

Parthasarathy, M.V. (1974). Ultrastructure of phloem in palms. III. Mature phloem. *Protoplasma* **79** : 265-315.

Scholander, P.F. Hammel, H.T., Bradstreet, E.D. and Hemmingson, E. (1965). Sap pressure in vascular plants. *Science* **148** : 339-346.

Zimmermann, M.H. and Tomlinson, P.B. (1972). The vascular system of monocotyledonous stems. *Bot. Gaz.* **133**: 141-155.

Zimmermann, M.H. (1974). Long distance transport. *Plant Physiol.* **54** : 472-479.

Foliar Diagnosis of Magnesium and Sulphur Nutrition in Coconut Using Various Leaf Positions

M. JEGANATHAN
Coconut Research Institute of Sri Lanka, Lunuwile, Sri Lanka

Abstract

In coconut the generally accepted leaf for sampling has been the 14th, since this appeared to be the most sensitive to treatment. However, many workers have found it necessary to employ other leaves in investigating particular problems.

Our own work on magnesium deficiency and sulphur nutrition has shown that the 14th frond may not be the best leaf position for all nutrients. Further, in a differential irrigation trial, samples taken from a specified leaf rank failed to display consistency for all elements.

Present evidence indicates that adherence to a specified leaf rank for all nutrient elements is not tenable.

Introduction

The foliar diagnostic approach to studies on the nutrition of coconut has been employed for at least two decades in various coconut growing countries. The generally accepted sampling leaf has been the 14th since this appeared to be the most sensitive to treatment (IRHO, 1961). Several workers have, however, considered other leaves as being more appropriate for their own particular requirements (Green, 1958; Baseden and Southern, 1959; Krishna Marar, 1961; Verghese, 1961; Southern, 1969; Smith, 1969).

Data from foliar diagnosis could be used either for *diagnostic use* to decide which nutrient or nutrients are causing poor growth, or for *predictive use* to decide how much response one could expect from the application of fertilizers (Van Den Driessche, 1974). To study the former, it will not be necessary to have precise information on the relationship between foliar nutrient concentration and growth. On the other hand, for predictive use, precise information is required on this relationship, which is conditioned by rigid standardization in sampling procedures. A tissue most sensitive for one nutrient may not show the same sensitivity in respect of another.

Hence, in standardizing leaf sampling for foliar diagnostic purposes,

particular attention should be paid to possible variability in respect of different elements within the selected leaf and provisions made for selecting different standard leaf ranks to accommodate such variation.

This aspect will be emphasized in this paper based upon observations made by Nethsinghe (1961) on megnesium nutrition, de Silva (1973) on S nutrition, and on leaf content of major nutrient elements in a differential irrigation trial.

Experimental

Magnesium experiment (Nethsinghe, 1961). In the late 1960s, magnesium deficiency occurred widely in some of the coconut growing districts of Sri Lanka. The characteristic visual symptoms are a general yellowing of the mature fronds, which however retains the normal green colour on either side of the petiole and adjoining the midribs of leaflets.

Leaflet samples were taken from ten healthy and ten affected (yellow) adult palms at Mattegoda and Walgama estates. The 10th to the 13th leaves were chosen in which the leaflets were all yellow. Fifty leaflets from either side of the midregion of the leaves were sampled and the laminae analysed for N, P, K, Ca, Mg, Fe, and Mn.

As the results of the first study were not consistent, a second sampling was done at Walgama estate where leaflets from the 1st and 6th fronds were sampled as described above. Being young fronds, in both healthy and affected palms, the leaflets were apparently green and healthy.

Sulphur experiment (de Silva, Anthonypillai, and Mathes, 1973). A fertilizer experiment begun in October 1966 at Ratgama in the west zone of Sri Lanka on a lateritic gravelly soil to study the yield response of adult coconut palms to the application of S, Zn, and B in different quantities was used for this. The experimental layout was a composite design, and consisted of 15 plots of 18 palms each. All plots were given a basal treatment of N, P, and K fertilizers annually. Each of the factors, S (as elemental S), Zn (as zinc oxide), and B (as sodium borate) were tested at five rates of application as given below :

Sulphur : 0, 1125, 2250, 3375, and 4500 g S/palm annually;
Zinc : 0, 110, 220, 330, and 440 g Zn/palms annually; and
Boron : 0, 35, 70, 105 and 140 g B/palm.

The first differential manuring was carried out in June 1968 and repeated annually. Records of nut yields were maintained and the results expressed as copra equivalent using the copra index value of 0.32.

Leaf sampling. Samples from the 1st, 6th, 10th, 14th and 17th leaves were taken from this fertilizer experiment. In each plot in the fertilizer experiment, 10 healthy palms were selected, and from each of these palms, six leaflets were taken from the mid region from each of the leaves of mentioned rank. The 60 leaflets thus collected from each leaf category

were pooled to form a composite sample. The samples were collected within three consecutive days between 7.30 and 11.30 a.m. on each day. The samples were processed and analysed for total S.

Irrigation experiment. The experiment was commenced in 1973 to study the effect of irrigation on yield of palms with a standard fertilizer treatment. It was conducted at Ratmalagara estate on a sandy loam soil in the intermediate rainfall zone.

Twenty palms were selected from each of the yield categories, 35-59, 60-84, and more than 85 nuts/palm/year (i.e., low, medium, and high yielders). Four treatments were imposed on each of the yield categories, control—no water, 88 gallons water/palm/week, 88 gallons water/palm fortnightly, and 176 gallons water/palm fortnightly (88 gallons water is equivalent to 5.08 cm rainfall, one gallon : 4.54 litres).

Samples were collected from the 1st, 6th, 9th, and 14th leaves of selected palms. As in the case of the S experiment, six leaflets were taken from each leaf position. Samples were taken from each category of yielders, within the four irrigation treatments. They were collected within five consecutive days, between 8.00 and 9.30 a.m. on each day and analysed for N, P, K, Ca, and Mg.

Results and Discussion

Magnesium experiment. Samples from the yellow palms at Mattegoda estate have significantly lower Mg contents than those from healthy palms, as also N, P, and Mn (Table 1). A similar pattern is observed with

TABLE 1. Mean chemical analysis (over dry basis) of coconut leaflet samples taken from 10th-13th fronds of ten green and yellow palms (Nethsinghe, 1961)

		N%	P_2O_5%	K_2O%	Ca%	Mg%	Fe ppm	Mn ppm
Mattegoda Estate								
Green	Mean	2 34	0.288	1.50	0.291	0.135	185	207
	SE	0.05	0.009	0.07	0.027	0.016	14	18
Yellow	Mean	*1.95	*0.241	1 68	0.307	*0 041	213	*73
	SE	0.05	0.013	0.10	0.020	0.007	12	15
Walgama Estate								
Green	Mean	2.32	0.285	1.33	0.304	0.102	155	234
	SE	0.05	0.007	0.14	0.024	0.016	12	18
Yellow	Mean	*1.80	0.254	†2.10	0.336	*0.015	153	*49
	SE	0.05	0.013	0.07	0.008	0.004	11	5

*Significantly lower than composition of samples from green palms.
†Significantly higher than composition of samples from green palms.

samples from Walgama estate, except that here K showed a significantly lower content in the affected palms. When the 1st and 6th fronds were sampled at Walgama estate (Table 2), a deficiency of Mg in the samples from the yellow palms was clearly visible.

TABLE 2. Mean chemical analysis (oven dry basis) of coconut leaflet samples taken from 1st and 6th fronds of ten green and ten yellow palms, Walgama Estate (Nethsinghe, 1961)

		N%	P_2O_5%	K_2O%	Ca%	Mg%	Fe ppm	Mn ppm
1st frond								
Green	Mean	1.87	0.321	2.23	0.254	0.172	115	35
	SE	0.08	0.011	0.13	0.026	0.011	11	7
Yellow	Mean	1.88	0.322	2.40	0.233	*0.060	118	37
	SE	0.09	0.006	0.06	0.020	0.007	10	5
6th frond								
Green	Mean	2.37	0.327	1.54	0.404	0.194	172	236
	SE	0.07	0.011	0.14	0.053	0.025	12	29
Yellow	Mean	2.41	0.358	1.74	0.490	*0.063	145	146
	SE	0.05	0.004	0.06	0.040	0.010	6	12

*Significantly lower than composition of samples from green palms.

These data show the importance of correct selection of the sampling from chlorotic leaves as affected palms show considerable variation in the content as several nutrient elements when compared with samples from healthy palms. This was to the extent of even preventing precise identification of the elements causing the deficiency. In contrast, samples drawn from fronds too young to show visual symptoms showed the expected variation in Mg contents.

Foliar spraying of the affected palms with 1-2% solution of $MgSO_4$ restored the fronds to a healthy green colour within a few months, thus confirming the diagnosis. A magnesium content of 0.25-0.30% in the leaflets of the 6th frond would indicate sufficiency of Mg, while if Mg content fell below 0.20%, deficiency symptoms can be expected (Nethsinghe *et al.*, 1962).

Sulphur experiment (Table 3). Both from the number of significant factors and the dimensions of the multiple correlation coefficient (expressing leaf S as a function of the three added nutrients and their interactions), it is apparent that the 6th leaf is more sensitive that any of the other leaf positions. Therefore, the 6th leaf was chosen for the nutritional investigations on S in adult coconut palms.

For all leaf positions including the 6th leaf, the S-concentration in the leaf tissue was negatively correlated with the applied levels of S. However,

TABLE 3. "t" values for significance of regression for effects of applied sulphur on the sulphur concentration of different leaves (de Silva *et al.*, 1974)

Factor	Leaf position				
	1st leaf	6th leaf	10th leaf	14th leaf	17th leaf
B	-2.02	-3.13*	0.24	-1.29	-0.25
Zn	-0.23	0.27	-2.74*	0.63	-0.83
S	-0.86	-3.64*	-1.65	0.37	0.25
B^2	-0.05	4.46**	8.31***	3.20*	-2.65*
Zn^2	-2.95*	3.46*	7.34***	0.73	-4.01*
S^2	1.58	13.22***	6.93***	9.14**	4.87**
B×Zn	0.51	-0.57	-2.88*	-1.07	-0.67
B×S	0.33	2.82*	0.98	0.61	0.22
Zn×S	-0.33	0.44	0.55	-1.26	-0.68
Multiple correlation coefficient	0.7518	0.9455	0.9045	0.8615	0.7607

*Sig. at 5% level ; **Sig. at 1% level ; ***Sig. at 0.1% level

the positive correlation of the quadratic effect of S indicated that the response curve could in fact take on a concave form. This is shown in Fig. 1 for the effects of treatments on the concentration of S in leaf tissue.

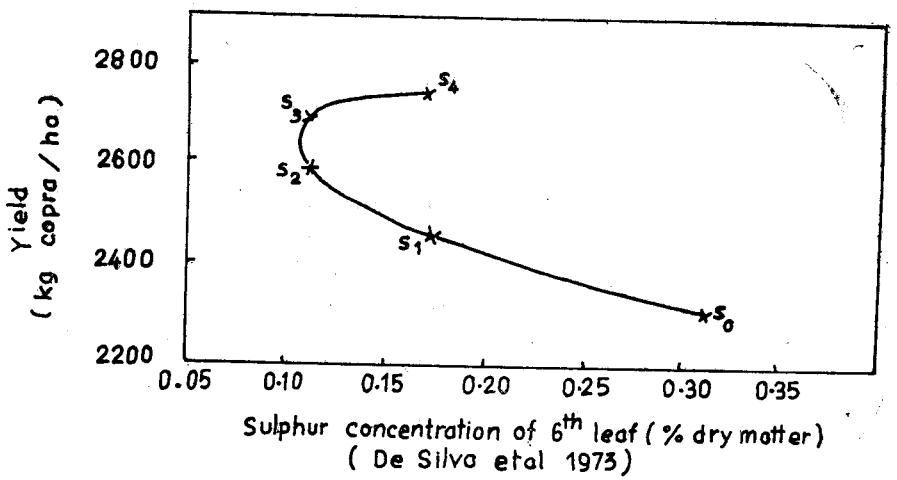


Fig. 1.

The minimal concentration of S was also seen to be associated with a relatively high supply of S. This suggests that in this plantation, S was probably a limiting factor for growth and production. This observation

is explained in terms of Steenbjerg and Jakobsen's concept of the "quotient of utilization", which is defined as the reciprocal of concentration, low concentrations being associated with high quotients of utilization. It appears that when the S levels are stepped up, there is probably a resulting increase in the vegetative growth of tissues, that causes a dilution effect on S in leaf tissues.

The S concentration in the tissue initially decreases when S supply increases (Fig. 2). This trend then changes sign and takes on the familiar C-shaped curve described as the Steenbjerg and Jakobson effect for a nutrient in minimum. Yield in this study refers to the fruit and does not include vegetative dry matter as in the work of Steenbjerg and Jakobson.

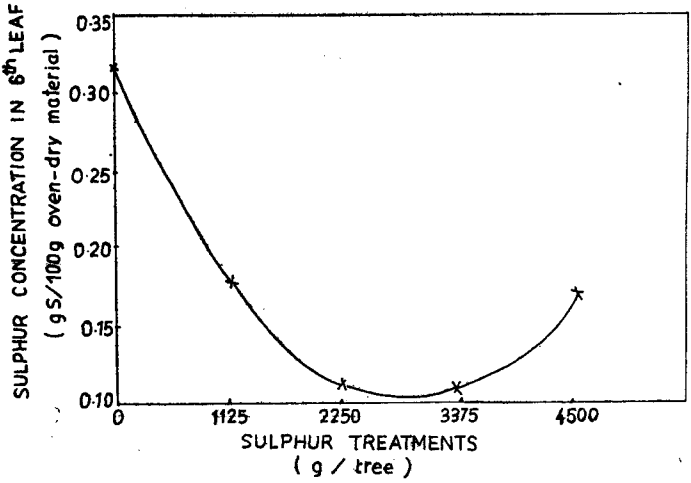


Fig. 2.

The study of S nutrition has illustrated that care in selecting the 6th leaf has helped in the interpretation of experimental data, and therefore, its value for future predictive use.

Irrigation experiment (Table 4). In the low and medium yielders, none of the leaf positions showed response to treatment. However, in the high yielders, significant responses were obtained for N with respect to leaf position one, for K for leaf positions six and nine, and for Mg for leaf position nine. Although there appears to be some response in the younger and less mature leaves analysed, leaf 14 did not display any response in variation of nutrient content. The results of this experiment are, however, inconsistent.

Van Den Driessche (1974), quoting a few examples from forest tree irrigation trials concluded that there was no simple rule governing the effect of moisture supply on nutrient concentrations of leaves. However, he did not refer to any growth response data with irrigation. We observe (Table 5) that there is no relationship between yield groups and leaf

TABLE 4. Irrigation experiment : analysis of variance

Source	DF	SS	MS	VR
	(a)	Nitrogen-First leaf		
Treatment	3	0.213845	0.071282	3 68*
Error	16	0.309785	0.019362	
	(b)	Potassium-Sixth Leaf		
Treatment	3	0.457878	0.152626	3.89*
Error	16	0.627708	0.039232	
	(c)	Potassium-Ninth Leaf		
Treatment	3	0.367191	0.122397	4.05*
Error	16	0.483834	0.030240	
	(d)	Magnesium-Ninth Leaf		
Treatment	3	0.005773	0.001924	3.80*
Error	16	0.008092	0.000506	

*Sig. at 5% level.

TABLE 5. Nutrients in the 14th leaf of the control palms

Yield of nuts/ palm/year	% in dry matter				
	N	P	K	Ca	Mg
Nuts 35-59	2.01	0.13	1.35	0.36	0.26
Nuts 60-84	1.92	0.13	1.27	0.35	0.26
Nuts above 85	2.17	0.14	1.49	0.24	0.23
Mean	2.03	0.13	1.37	0.32	0.25

TABLE 6. Optimum leaf nutrient values in the 14th leaf quoted by IRHO (Fremond *et al.*, 1966)

(% *in dry matter*)

N	P	K	Ca	Mg	Fe ppm	Mn ppm
1.80-2.00	0.12	0.80-1.00	0.50	0.30	50	60

nutrient status between yield groups and leaf nutrient status for the control palm in this experiment. These values are almost comparable with the optimum leaf nutrient values quoted by IRHO (Table 6 ; Fremond, Ziller, and de Lamothe, 1966). Our data show that the values for Ca and Mg are lower, and for K much higher than those of IRHO. The figures in Table 5,

represent the average of five palms for each yield category and therefore may be less accurate. However, the analytical figures for the control palms merely indicate that the nutrient conditions of the palms were satisfactory. It appears therefore that some other major factor is limiting the yield response to added fertilizer. In this trial, yield responses were obtained for differential irrigation (Abeywardene, personal communication) suggesting that inadequate water has been limiting the yield response and not nutrients.

The fact that some young and less mature leaves showed some degree of response to differential irrigation suggests that it is desirable to carry out further sampling studies to see whether any further responses could be expected with time.

These experiments clearly show that for the interpretation of foliar analysis in coconut, whether for diagnostic or for predictive purposes, one cannot always be limited to a specified leaf rank.

Acknowledgements

I thank Mr. V. Abeywardene, Biometrician, for statistical guidance and Dr U. Pethiagoda, Director, for helpful criticism in the preparation of this paper.

References

I.R.H.O. (1963), General directions for coconut leaf analysis. 234-242 pp. *In* FA Technical Working Party on Coconut Production, Protection and Processing, Trivandrum, India, 1961. FAO, Rome.

Baseden, S.C. and Southern, P.J. (1959). Evidence of potassium deficiency in coconut palms in coral-derived soils in New Ireland from analysis of nut water, husks, fronds, and soils. *Papua and New Guinea Agrl. J.* 11 : 101-115.

de Silva, M.A.T., Anthonypillai, G.M., and Mathes, D.T. (1973). Preliminary investigations on the sulphur nutrition of coconut. 60 p. *Ceylon Assoc. Adv. Sci. Proc. 29th Ann. Session Part I.*

Premond, V., Ziller, R. and De Nuce de Lamothe M. (1966). *The Coconut Palm.* 227 pp. International Potash Institute, Berne.

Green, A.H. (1958). The diagnosis of nutrient deficiencies in coconut palm. 6 : 15-18 pp. *In* Proceedings of the Ninth Pacific Science Congress. Bangkok, Thailand, 1957.

Krishna Marar, M.M. (1963). Introductory paper on coconut soils. 167-182 pp. *In* FAO Technical Working Party on Coconut Production, Protection and Processing. Trivandrum, India. 1961. FAO, Rome.

Nethsinghe, D.A. (1963). Annual Report of the Soil Chemist for 1961. 20-21 pp. Coconut Research Institute of Ceylon, Lunuwile.

Nethsinghe, D.A., de Silva, M.A.T. and Nedimala, D.E.G. (1962). Diagnosis and correlation of magnesium deficiency in coconut palms. *Proc. Ceylon Assoc. Advan. Sci.* Part I.

Coast Tall × Chawghat Dwarf, Chawghat Dwarf × West Coast Tall, and West Coast Tall palms growing under rainfed conditions were used in the study. Ten palms from each of the category were selected. Leaf samples were drawn from the yougest fully opened leaf once every month for 12 months. Each time, two leaflets from the middle of the leaf were collected between 10 A.M. and 11 A.M. and they were dried immediately at 95°C in a hot air oven. The finely powdered samples were analysed for carbohydrate fractions.

Total carbohydrates were extracted according to the method of Hagedon and Jenson (1933). Total sugars and starch were extracted according to the method of Highkin and Frankel (1962). For sugar estimation, the method of Somogyi (1952) was employed.

The mean temperatures were recorded using maximum/minimum thermometer housed in a Stevenson's screen. Hours of bright sunshine were recorded using a Campbell Stokes type sunshine recorder.

Results and Discussion

The results are presented in Figs. 1 and 2 and Tables 1 to 3. Considera-

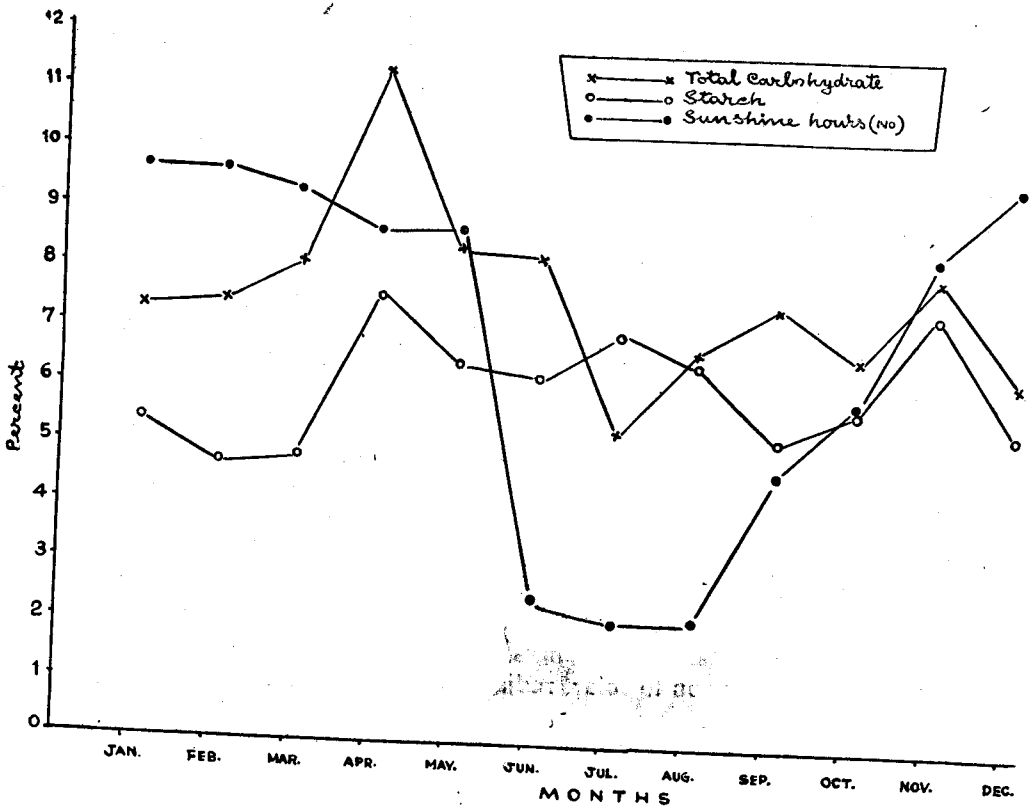


Fig. 1. Seasonal changes in total carbohydrates, starch and sunshine hours in the hybrid WCT × G.

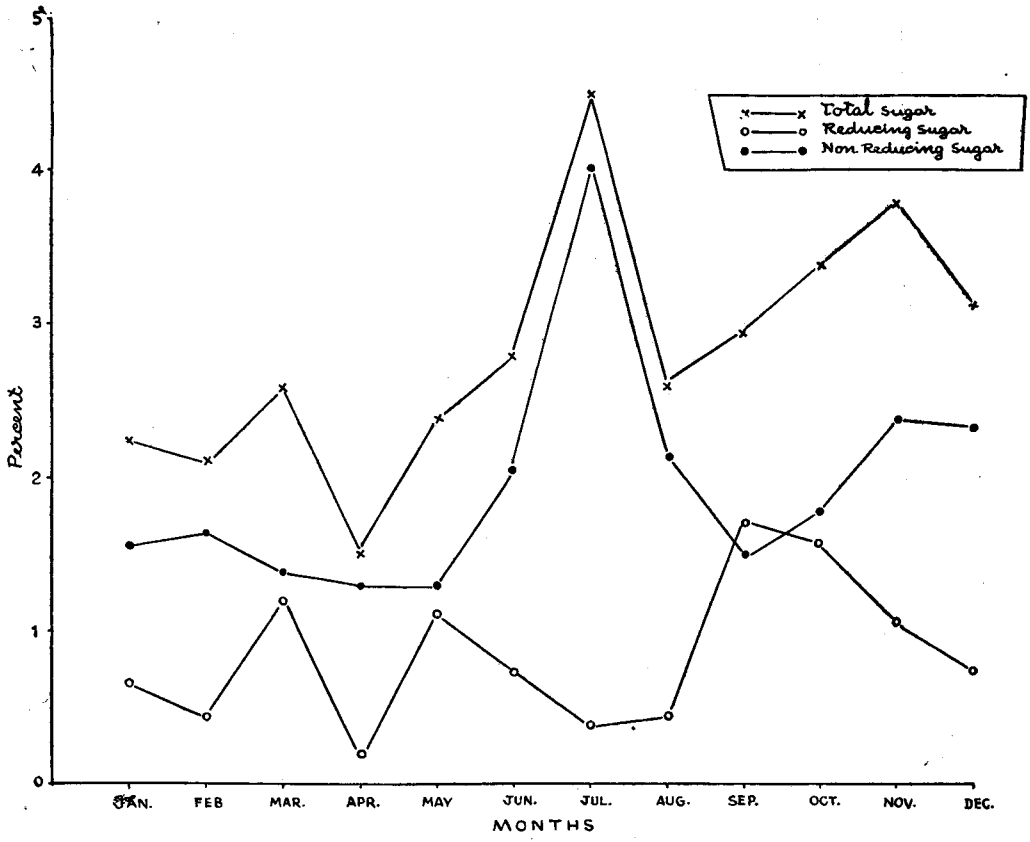


Fig. 2. Seasonal changes in sugar levels in the hybrid WCT×G hybrid.

ble variation in the carbohydrate fractions were noted during different months in all the types studied. The seasonal variation also showed the same trend in all of them. These seasonal changes as obtained in T×G hybrids are shown in Figs. 1 and 2. The total carbohydrate and starch content showed a rapid increase during the months of April and November (Fig. 1). In both the fractions, the concentration was reduced by 30-50% during July-October. The number of sunshine hours was maximum, ranging 8-10 hr/day during January to May and again in November and December, whereas during June-September, the number of sunshine hours was lowest ranging from 2-4 hr/day only.

The total sugar content as well as the non-reducing fractions showed an increase during July, and again later in November (Fig. 2).

The hybrids and Tall palms showed considerable variation between them in the total carbohydrate, starch, and sugar fractions. The magnitude of changes in the levels of carbohydrate fractions in different months was more in the hybrids. The mean temperature recorded during this period of study also ranged from 27°C to 31°C. The data on the rainfall recorded during the study are represented in Table 3.

TABLE 1. Total carbohydrate and starch contents in the leaves of coconut hybrids and cultivars (expressed in mg/100 mg dry weight)

Month	Total carbohydrate				Starch			
	WCT×G	WCT×CDO	CDO×WCT	WCT	WCT×G	WCT×CDO	CD×WCT	WCT
January	7.39	6.98	7.15	8.68	5.38	5.21	4.62	4.22
February	7.48	8.25	7.53	6.08	4.79	4.19	5.55	5.94
March	8.10	7.98	7.10	8.73	4.85	5.20	5.15	6.11
April	11.55	10.39	9.98	9.23	7.64	6.91	6.87	7.18
May	8.55	9.78	9.08	6.64	6.28	6.03	4.14	4.12
June	8.28	9.03	8.90	6.64	6.18	6.01	6.98	6.21
July	5.28	4.78	6.63	6.75	6.67	6.27	6.60	6.30
August	6.68	6.34	4.15	6.05	6.40	6.30	5.92	6.02
September	7.53	5.18	6.33	7.73	5.17	4.82	4.67	4.97
October	6.63	8.25	6.00	7.63	5.69	6.09	5.25	5.17
November	8.03	8.03	7.95	9.63	7.53	7.29	5.46	5.07
December	6.25	5.53	5.94	6.03	5.39	5.36	5.45	5.12

TABLE 2. Total sugar, reducing and non-reducing sugar fractions in the hybrids and WCT palms (expressed in mg/100 mg dry weight)

Month	Total sugars				Reducing sugars				Non-reducing sugars			
	WCT × G	WCT × CDO	CDO × WCT	WCT	WCT × G	WCT × CDO	CDO × WCT	WCT	WCT × G	WCT × CDO	CDO × WCT	WCT
January	2.20	2.50	1.7	1.8	0.63	0.70	0.32	0.71	1.57	1.80	1.38	1.09
February	2.10	1.90	2.3	2.2	0.45	0.47	0.47	0.86	1.65	1.40	1.83	1.34
March	2.60	2.20	1.2	1.7	1.20	0.71	0.36	0.82	1.40	1.50	0.84	0.88
April	1.50	1.70	1.5	1.3	0.20	0.30	0.32	0.21	1.30	1 40	1.18	1.09
May	2.40	1.50	1.9	1.4	1.10	0.46	0.40	0.61	1.30	1.10	1.50	0.79
June	2.80	2.80	3.2	3.1	0.75	0.61	0.88	1.69	2.05	1.20	2.34	1.41
July	4.50	4.20	4.5	3.4	0.44	0.77	0.34	0.39	4.06	3.43	4.16	3.01
August	2.60	2.10	2.6	1.8	0.46	0.50	0.53	0.75	2.14	1.60	2.07	1.05
September	3.20	3.60	3.4	3.4	1.70	1.62	1.50	1.75	1.50	1.98	2.90	1.65
October	3.40	2.50	3.8	3.3	1.57	1.31	1.67	1.54	1.83	1.20	2.13	1.76
November	3.80	4.70	4.6	4.3	1.41	2.10	1.98	2.12	2.39	2.60	2.62	2.18
December	3.12	3.60	3.6	3.8	0.78	0.76	0.93	0.83	2.34	2.80	2.67	2.97

TABLE 3. Mean sunshine hours per day and total rainfall in different months

Month	Average daily sunshine hours	Total monthly rainfall (mm)
January	9.9	—
February	9.8	—
March	9.5	13.5
April	9.0	19.4
May	9.0	160.0
June	2.8	1332.3
July	2.3	954.2
August	2.3	986.1
September	4.9	545.1
October	5.6	254.1
November	8.6	67.0
December	9.7	—

The seasonal changes in the carbohydrate fractions were found to be related to the changes in the number of sunshine hours per day. The number of sunshine hours are highest during January-May, when a rapid increase in the total carbohydrate and starch contents is noted. The period of sunshine falls sharply to very low levels of 2-3 hr/day during June-August, when a rapid decline in total carbohydrate and starch content also observed. A slight increase in these fractions noted in November again corresponds with an increase in sunshine hours.

The alcohol soluble sugar content recorded a peak during July which coincides with low total carbohydrate and starch contents and low sunshine period. As much as 80% of soluble sugar content was found in the non-reducing fraction during the month of July. Thus, higher contents of carbohydrate and starch in the leaves are the result of higher sunshine hours per day while the increased soluble sugar content, especially the non-reducing fraction is due to low sunshine hours per day. The period of high rainfall also appears to have some association with rapid changes in the soluble fractions of the carbohydrates. Since the temperature did not record much variability during the period of study, the observed changes could not be related to this factor.

The rate of production of leaves in WCT palms is higher during June-November (Marar and Pandalai, 1957). The period of active mobilization of carbohydrates observed during the present study coincides with the period of active leaf production. The leaf production during the period of study was higher (about 8 leaves) in the hybrids than that in the WCT (about 6 leaves). The magnitude of changes in carbohydrate fractions appears to influence the growth. The increase in carbohydrate content in April ranges from 30-42% in the hybrids, as against about 6% in the WCT. The increase in the concentration of alcohol soluble sugars in July was 42-54% in the hybrids, while it was only about 8% in the WCT.

These results indicate that the hybrids are more efficient than WCT in mobilization of carbohydrates. The period of active synthesis on the other hand seems to follow the period of high sunshine hours.

In coconut palm, the development and growth of inflorescence are intimately associated with the development and growth of leaves (Patel, 1938). The present study indicates that the synthesis and mobilization of carbohydrates in the leaves follow a definite pattern and it is influenced by the seasonal changes in solar radiation and precipitation. The period of increase in dry matter is associated with the rapid increase in the starch content in the leaves. More intensive studies at the subcellular, cellular and organ level in association with detailed studies on the sequences of morphogenesis in the developing bud in young palms would be helpful to understand the critical phases, if any, in the growth and development of inflorescence in coconut palm. Information on this aspect of physiology would be helpful for determining the best period for application of inputs that would ensure maximum productivity.

References

Hagedorn, H.C. and Jenson, B.N. (1933). Zur Microbestimmung des Blutzuckers mittels Ferricyanid. *Biochem. Z.* **135** : 46-58.

Highkin, H.R. and Frankel, F. (1962). Studies of growth and metabolism of barley mutant lacking chlorophyll b. *Plant Physiol.* **37** : 314-320.

Marar, M.M.K. and Pandalai, K.M. (1957). Influence of weather factors on the coconut crop. *Indian J. Meteorol. Geophys.* **8** : 1-11.

Patel, J.S. (1938). *The Coconut*, A monograph. 102 pp. Govt. Press, Madras.

Samogyi, M. (1952). Notes on sugar determination. *J. Biol. Chem.* **195** : 19-23.

Ziller, R. (1960). Etude de quelques facteurs against Sur la teneur en coprah des noix de Coco. *Oleagineux* **15** : 73-81.

Discussions

Pethiyagoda : Did you also study any diurnal fluctuation of leaf carbohydrate levels ? Any comments on export of carbohydrates out of the leaf ?

Kasturi Bai : Yes. On the first questions that we studied was the changes in starch and sugar concentrations in the leaf tissue from 6.00 AM to 9.00 AM. The changes in starch content were considerable

On the second question, I have no comments to make.

Venkateswaran : What is the relationship between the variations in carbohydrate etc. to the variations in yield ?

Kasturi Bai : This was not investigated in the present study as the material is yet to commence bearing.

Observations on Iron and Manganese Nutrition of Coconut Seedlings

M.A.T. DE SILVA
Coconut Research Institute of Sri Lanka, Lunuwile, Sri Lanka

Abstract

The concentration of iron in coconut leaves is generally low. Acidic soil conditions increase the manganese concentration in leaves, but do not consistently increase iron concentration.

Two sand culture experiments were conducted to study possible effects of Mn and Fe uptake by coconut seedlings.

In the first experiment, the uptake of Fe and Mn from EDTA-incorporated nutrient solutions of different reactions were studied. The uptake of both nutrients was high at pH of 5, 7 and 8 but low at pH 4 and 6. These results are discussed in relation to the behaviour of EDTA-cation complexes.

In the second experiment three levels of Fe and Mn were each supplied at pH 4 and 7. The distribution of Mn in roots and leaf components was largely related to the level of supply. Howerer, Fe uptake was affected by pH, but there was no uniformity in the relationship with levels of supply.

Determinations of Fe^{++} and Fe^{+++} in root tips by an EDTA extraction procedure showed that immobilization of Fe occurs through conversion to Fe^{+++}, when the supply of Fe was increased. The formation of Fe^{+++} was not related to nutrient pH, but tended to decrease when the Mn supply increased.

Although evidently the uptake of Fe is severely reduced through immobilization in the roots of coconut seedlings when the supply is high, Mn does not appear to take any part in this process. The inconsistent pattern of foliar Fe levels in coconut palms is discussed in relation to these observations.

Introduction

Acidic conditions in the growth medium generally favour higher availability of Fe and Mn, while neutral and alkaline conditions reduce their availability. Nutritional studies on coconut palms have frequently shown that while Mn uptake increases when the medium pH decreases and *vice versa*, Fe uptake rarely only shows this trend. Thus, in a field experiment, increase of pH from 4.2 to about 7 using lime caused a highly significant decrease in the content of Mn in the kernel, while the Fe content remained unaffected (de Silva, unpublished . More recently, Kamala Devi *et al.*

(1975) found that a decrease of soil pH by the application of NPK fertilizers caused a sharp significant increase of leaf Mn without influencing leaf Fe. These observations indicate that uptake of Fe by coconut palms is presumably hindered causing it to appear unrelated to availability.

The uptake of Fe by plants is also known to be influenced by the availability of Mn, and the subject of their inter-relationships has been widely discussed and reviewed.

The present investigations were initiated to examine under controlled conditions the inter-relationships of Fe, Mn, and pH in the nutrition of coconut seedlings, in order to trace the factors affecting the uptake of Fe.

Experiment 1

Thirty dehusked seedlings of uniform weight and size were planted in enamelled pots, each containing 15 kg of washed silica sand. The application of nutrient solutions buffered to pH values of 4, 5, 6, 7, and 8 constituted the treatments. Ten litres of the normal stock solution was prepared by adding the following reagents and making up the volume with demineralized water (Hewitt, 1966). 100 ml of 20.2% KNO_3 ; 200 ml of 30.1% $Ca(NO_3)_2$; 100 ml of 20.8% $NaH_2PO_4.2H_2O$; 200 ml of 18.4% $MgSO_4.7H_2O$; 100 ml of 6.7% Fe $C_6H_5O_7.5H_2SO_4.5H_2O$ and 10 ml of each of 2.23% $MnSO_4.7H_2O$, 0.25% of $CuSO_4.5H_2O$; 0.29% of $ZnSO_4.7H_2O$; 1.86% of H_3BO_3 ; and 0.035% of $(NH_4)_6\ Mo_7O_{24}.4H_2O$.

Stock solutions for different pH values were made by carrying out suitable adjustments in the stock solutions as described below :

(a) *Stock solution for pH 4.* Added 500 ml 8.1% potassium hydrogen phthalate solution plus 50 ml 34.0% $NaNO_3$ solution instead of 100 ml of 20.2% KNO_3 solution.

(b) *Stock solution for pH 5.* Same as for (a) with the reaction adjusted to pH 5.0 before making up volume to 10 litres.

(c) *Stock solution for pH 6.* Added 600 ml 1.0 *M* disodium hydrogen citrate plus 400 ml 1.0 *N* NaOH to stock solution before making up to mark.

(d) *Stock solution for pH 7.* Added 600 ml 1.0 *M* KH_2PO_4, 100 ml 1.0 *M* Na_2HPO_4, 50 ml 20.2% KNO_3 solution and 25 ml 34.0% $NaNO_3$ solution instead of 100 ml 20.2% KNO_3 solution and 100 ml of 20.8% $NaH_2PO_4.2H_2O$ solution

(e) *Stock solution for pH 8.* Same as for the normal solution except that the pH was adjusted to 8.0 with NaOH before making up to mark.

All solutions were diluted ten times before application and contained the following concentrations of nutrients :

N—170 ppm ;	Mg—36 ppm ;	Cu—0.064 ppm ;
P—41 ppm ;	S—48 ppm ;	Zn—0.065 ppm ;

K—156 ppm ; Fe—5.6 ppm ; B—0.33 ppm ;
Ca—160 ppm ; Mn—0.55 ppm ; and Mo—0.048 ppm.

High dilution of stock solutions caused a slight change of pH, and a net drift of about 0.5 pH units resulted in the substratum on addition of solutions, which then remained constant for at least six hours after application.

The precipitation of phosphates of Ca, Mg, and Fe in stock solutions was effectively prevented by incorporating a calculated quantity (in a molar ratio of 1 : 1) of EDTA in all nutrient solutions and storing them in the dark. The molar concentration of EDTA was several times higher than that of phthalate and citrate radicals used in stock solutions. This made it improbable that the latter would cause any significant overriding effect on the role of EDTA in this investigation.

Each treatment was tested on five plants which costituted the replicates. Plants of the control received a nutrient solution (pH 5.6) devoid of buffering agents and EDTA. The pots were placed in a randomized manner on outdoor stands roofed with transparent perspex. The frequency of application of nutrient solutions was increased with the growth of seedlings, with daily applications during the last five months.

Twelve months after commencement, measurements were taken of height, girth and leaf number. The seedlings were then uprooted and stripped of the youngest fully opened leaf and roots for chemical examination. The procedure for preparation of samples, and analytical methods for Fe and Mn are described elsewhere (de Silva, 1974).

EXPERIMENT 2

Fifty-four dehusked seedlings of uniform weight and sprout size were planted in cylindrical plastic pots containing 30 kg of acid washed silica sand. These plants were treated twice weekly with the normal nutrient solution used in the first experiment, but prepared with the exclusion of iron and manganese.

Three months after planting, the seednuts were amputated from the developing plants and differential treatments were commenced. These consisted of three levels each of Fe (0, 5.0, and 10.0 ppm) and Mn (0, 1.5, and 3.0 ppm) supplied at two levels of pH (4.0 and 7.0). The experimental layout consisted of a randomized block design with the three replicates for the 18 treatment combinations. The experiment was conducted in a glass-house.

Two nutrient stock solutions buffered to pH of 4 and 7 were prepared as described in Exp. 1, but without Fe and Mn. Frequency of application was similar to that in Exp. 1, with added amounts of Fe (as ferric citrate) and Mn.

Growth measurements were taken nine months after the commencement of the experiment, followed by uprooting plants in two replicates for dry-weight determinations. In each plant, the youngest fully opened

leaf was sampled for chemical examination. Fe and Mn were estimated in HCl extracts of dry-ashed plant materials by atomic absorption spectroscopy. In plants of the third replicate, root tips were excised at 7.5 cm length, sliced into small pieces, and a 20 g sample was macerated with 50 ml each 0-4% EDTA solution and a buffer solution (pH 2.0). The extract made upto 200 ml was centrifuged and 50 ml of clear liquid evaporated to dryness and the residue was digested with a $HClO_3$/—HNO_3 (1 : 3) acid mixture. This digest was evaporated to dryness and residue was extracted with 2M HCl solution and the volume made upto 20 ml. The iron was determined by the O-phenanthroline method. Iron determined by the above method is referred here as the "EDTA-extractable Fe^{+++}". The "EDTA-extractable Fe^{++}" in root tips was obtained by difference using the same procedure after oxidizing ferrous to ferric with ammonium persulphate (1.0 g/sample) added during maceration of sample.

Results and Discussion

In the first experiment, the growth of seedlings, as was evident visually and also from measurements of growth (Table 1), was more pronounced in the controls than in the other treatments. The retarded growth of plants receiving EDTA-incorporated nutrient solutions was traced to the reduced uptake of calcium in the presence of the chelating agent. Growth differences were not significant among the other treatments.

TABLE 1. Effect of EDTA-incorporated nutrient solution on growth

Growth factor	pH 4 with EDTA	pH 5 with EDTA	pH 6 with EDTA	pH 7 with EDTA	pH 8 with EDTA	Control	C.D. (P=0.05)
Height (cm)	119.8	120.6	118.2	112.8	131.6	156.6	16.14
Girth (cm)	18.9	17.4	16.7	18.4	19.1	19.7	1.68
Number of leaves	5.15	5.45	5.50	5.55	5.75	6.30	—

Figures 1 and 2 illustrate the uptake patterns of Fe and Mn respectively in young coconut plants under the influence of treatments. Each diagram shows (a) (graphically) the effect of treatments on the *concentration* of the nutrient in a specific plant part, and (b) (by means of histograms) the effect of treatment on the total *content* of nutrient per plant part. The uptake of Fe had become generally low at pH 4 and 6 but high at pH 5, 7 and 8.

Martell (1957), Guinn and Joham (1963), and Norvell and Lindsay (1969) have shown that the stability of Fe-EDTA decreases with increase of pH, and generally indicates that the stability of Fe-EDTA probably

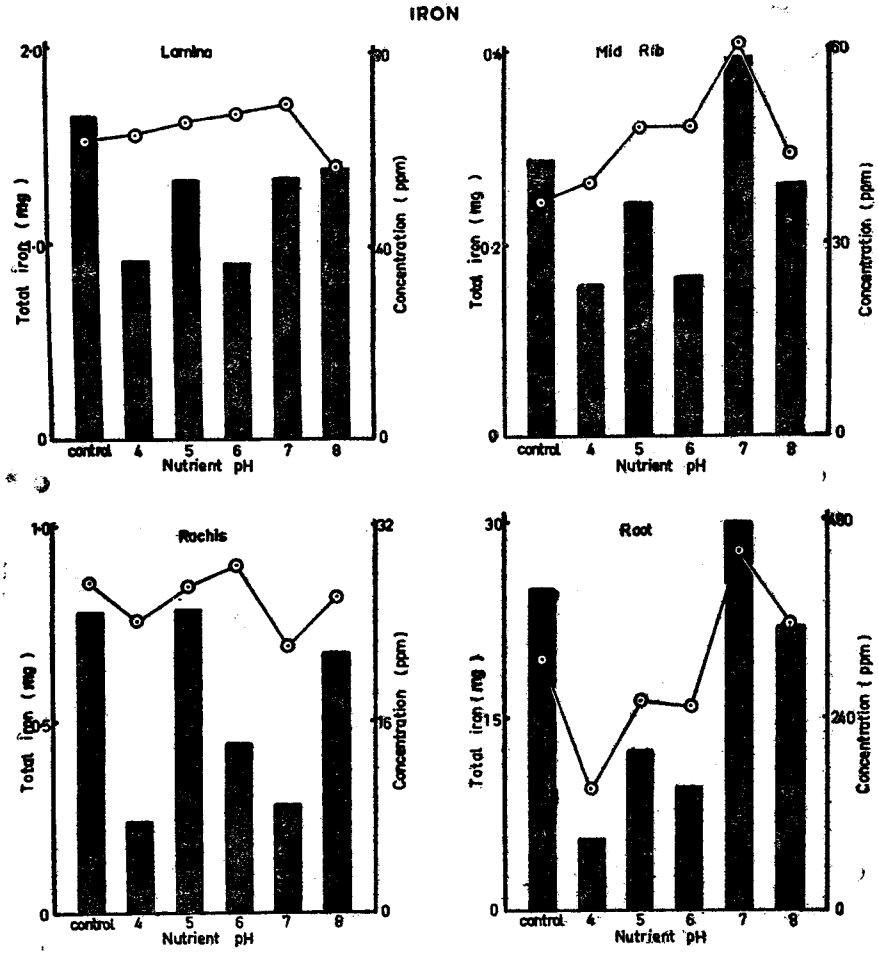


Fig. 1 Uptake patterns of iron in young coconut palms

reaches a peak position between pH 5 and 6. Outside this peak point, a fall in the stability of iron chelate (Norvell and Lindsay, 1969), followed by displacement of Fe from the complex, results in a decline in the uptake of Fe.

It has also been suggested that the presence of an excess of EDTA could reduce the uptake of Fe (Guinn aud Joham, 1962), a condition prevalent in the present study on account of different effects of pH on EDTA complexes. Thus, the higher uptake of Fe at pH 5, followed by a sharp drop at pH 6 observed in this study may probably have resulted from the operation of factors discussed above.

At pH 7 and 8, the uptake of Fe was again high, possibly because the increase in stability of the chelates of Ca and Mg, and the consequent removal of excess EDTA from the medium facilitated the unhindered uptake of Fe. This could also be the reason that a fairly high amount of

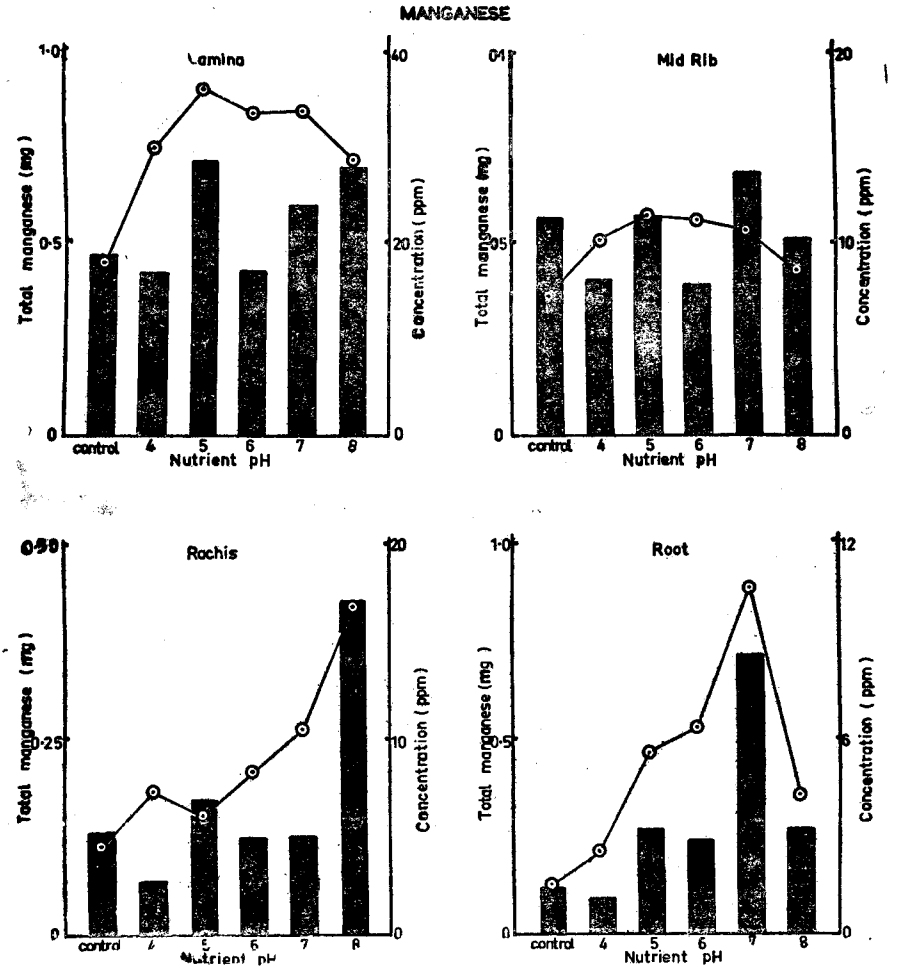


Fig. 2 Uptake pattern of manganese in young coconut palms

EDTA is required to alleviate Fe deficiency chlorosis in calcareous and lime-treated soils (Leonard and Steward, 1953).

Norvell and Lindsay (1969) showed that the chelate of Mn with EDTA was unstable in the pH range 5.70 to 7.85. However, in the present experiment at pH 5, 7, and 8, the uptake has been higher than in controls indicating that at these pH values, the uptake of Mn has been facilitated by the presence of EDTA ; and this had occurred in a manner parallel to that of Fe. This observation obviously is in conflict with the frequently recorded inverse relationship between Fe and Mn, and hence, it appears that EDTA has in fact helped Fe and Mn to side-step the mechanism which promotes their interaction, and facilitated parallel increases in their uptake.

Separation of the linear and quadratic components in the analysis of variance of growth responses in the second experiment showed that some

observations were significant. Interpretation of these results was complicated by the fact that the linear response of one factor was often related to the quadratic effect of the other. However, the height of seedlings increased significantly at pH 4 and decreased at pH 7, when the supply of Fe was increased (Fig.3). Effect of treatments on Fe and Mn concentrations

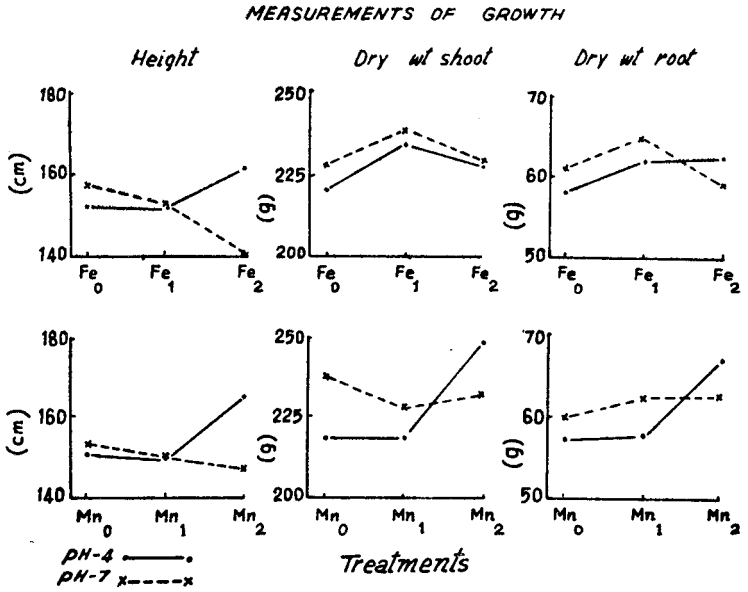


Fig. 3 Effect of pH on plant height and dry weight of shoot and root

in different plant components are illustrated in Fig. 4 and 5. These results show that at pH 4, the root Fe had increased with treatments without affecting lamina Fe concentrations. On the other hand, at the higher pH, root Fe remained virtually unaffected, while lamina Fe responded positively to treatments. It is also significant that in the rachis, Fe concentration increased with the supply level at pH 7, but responded negatively at pH 4. In general, the uptake of Fe was largely related to pH, but showed no uniformity with respect to the supply level of Fe.

On the other hand, in all plant components, the Mn concentration increased almost linearly with level of supply. Although at the higher pH, there was a tendency for leaf Mn to decrease when the supply of Fe increased, the interaction was not statistically significant.

Ferrous and ferric forms of iron extracted with EDTA from root tips of experimental plants (Table 2) clearly show that regardless of the effect of pH, increase in the supply level of Fe facilitated the formation of ferric-Fe. The ferric-Fe appeared to decrease slightly when the supply level of Mn increased.

It is generally recognized that Fe is taken up by plants in the ferrous form even when it is supplied in the ferric state. If this contention is

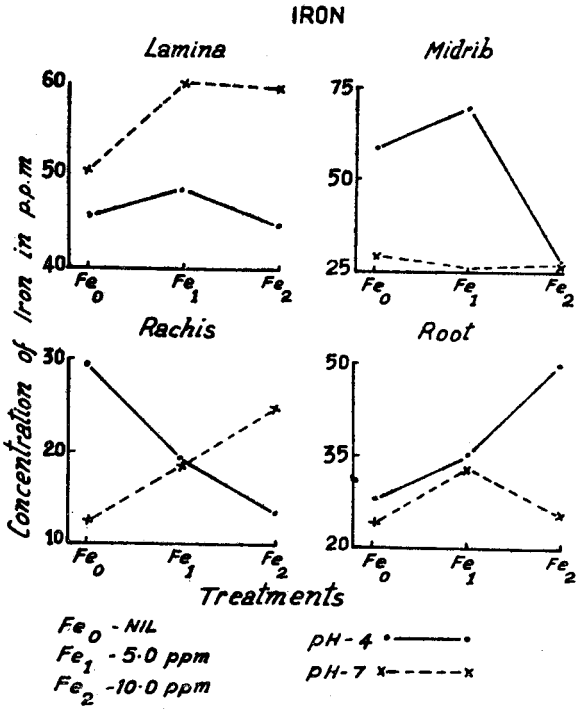


Fig 4 Effect of pH and iron on plant components

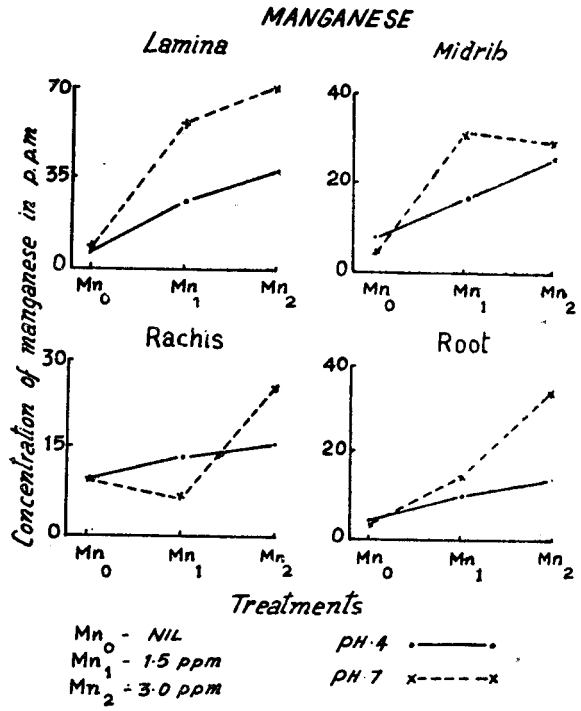


Fig. 5 Effect of pH and manganese on plant components

TABLE 2. Effect of treatments on the EDTA-extractable Fe^{++} and Fe^{+++} forms of iron (in ppm)

Treatment	pH 4		pH 7	
	Ferrous	Ferric	Ferrous	Ferric
Fe_0Mn_0	6.92	6.60	2.56	6.16
Fe_0Mn_1	0.88	9.04	2.30	5.76
Fe_0Mn_2	0.12	6.60	nil	26.80
Fe_1Mn_0	7.08	10.72	1.12	10.32
Fe_1Mn_1	8.80	6.24	0.16	7.76
Fe_1Mn_2	9.12	5.92	nil	10.96
Fe_2Mn_0	nil	17.52	nil	14.80
Fe_2Mn_1	nil	10.88	nil	15.52
Fe_2Mn_2	0.56	9.36	nil	8.96

accepted, then it has to be conceded that at least in the case of coconut palms, when the supply of Fe increases, immobilization of the nutrient occurs through conversion to the ferric state. Since neither the nutrient pH nor the supply level of Mn appear to participate in this transformation, it is possible that either the activity of Fe itself or the operation of some unique mechanism in coconut root tissue is responsible for inactivating Fe in the root. This situation apparently causes an adjustment of Fe levels in foliar components (i.e., in rachis, midrib, and lamina) thus providing an inconsistent or sometime inaccurate picture of the iron status of coconut palms.

Acknowledgement

I thank Messrs P.A.D.G. Appuehamy, B.J.A.F. Mendis, G.D. George and Miss G.M. Anthonypillai for the assistance and cooperation extended to me in carrying out these investigations. I thank also Messrs V. Abeywardena and D.T. Mathes for statistical analysis and interpretation of data.

References

De Silva, M.A.T. (1974). Micronutrients in the nutrition of coconut 1. Methods and preliminary investigation. *Ceylon Cocon. Quart.* **25** : 116-127.

Guinn, G. and Joham, H.E. (1962). Effects of two chelating agents on absorption and translocation of Fe, Cu, Mn and Zn by the cotton plant. *Soil Sci.* **94** : 220-223.

Guinn, G. and Joham, H. E. (1963). Displacement of iron from ferric ethylenediaminetetra-acetic acid and ferric hydroxyethylene-diaminetetra-acetic acid and ferric hydroxyethylethylenediamine-triacetic acid by copper and zinc. *Soil Sci.* **95** : 101-104.

Hewitt, E.J. (1966). *Sand and Water Culture Methods used in the Study of Plant Nutrition.* 2nd Ed. pp. 431-432. Commonwealth Agricultural Bureau, Bucks, England.

Kamala Devi, C.B., Wahid P.A. A. Pillai, N.G. and Sankaranarayanan, M.P. (1975). Effect of NPK fertilizers on trace element nutrition of three coconut genotypes. *J. Plant Crops* **3** : 11-13.

Leonard, C.D. and Steward, I. (1953). An available source of iron for plants. *Proc. Am. Soc. Hort. Sci.* **62** : 103-110.

Martell, E.E. (1957). The chemistry of metal chelates in plant nutrition. *Soil Sci.* **84** : 13-26.

Norvell, W.A. and Lindsay, W.L. (1969). Reaction of EDTA complexes of Fe, Zn, Mn, and Cu with soils. *Proc. Soil Sci. Soc. Amer.* **33** : 86-91.

Foliar Absorption and Distribution of Radioactive Phosphorus in Healthy and Root (Wilt) Diseased Coconut Palms

R. SNEHI DWIVEDI, P.K. RAY and SUNNY NINAN
Central Plantation Crops Research Institute, Regional Station, Kayangulam, Krishnapuram 690533, Kerala, India

Abstract

Radioactive ^{32}P was fed to the coconut leaves in the laboratory and palms in the field. Higher rates of ^{32}P absorption and accumulation were recorded in healthy palms than in diseased ones at early hours of experiment, but during later period the trend of ^{32}P accumulation was reversed. The ^{32}P activity in the stems of healthy palms was lower than that of diseased ones but a reverse pattern was noted in native phosphorus content. Similarly, the outer, middle, and first fully opened leaves of healthy palms did not differ much in phosphorus content, but in the case of diseased ones, wide variations were observed. The autoradiographs and ^{32}P countrigs indicated that P was more in the leaves and less in the roots of diseased palms as compared to those of healthy ones.

Discussions

Pethiyagoda : Have you any views on where the radioactive P is being exported to from the leaves of diseased palms ?

Dwivedi : In any type of palms, either healthy or diseased, radioactive-P from leaf will be transported to nuts, spathe, roots, and trunk.

Ramadasan : You were referring to the healthy palms in Kayangulam. Are they not apparently healthy only?

Dwivedi : Yes, they are all only apparently healthy palms. But there are no concrete physiological, biochemical or morphological evidences to show that they are not completely healthy.

Biochemical Changes in Coconut During Maturation and Germination

K. BALASUBRAMANIAM
Department of Biochemistry, University of Sri Lanka, Colombo, Sri Lanka

Abstract

With increasing maturity of coconuts, the reducing sugars of the liquid endosperm decreased with concomitant increases in the sucrose content and in the insoluble polysaccharides of the solid endosperm. The increase in insoluble polysaccharides followed a sigmoid curve. Galactomannans and cellulose but not mannans formed the polysaccharides of the very immature kernel. The water soluble galactomannans decreased with maturity, whereas the 4% NaOH-soluble galactomannans reached a maximum value at intermediate stages of maturation and then decreased. The 17% NaOH-soluble galactomannans steadily increased with maturity. In mature coconuts, galactomannans, mannans, and cellulose were 61%, 26%, and 13% respectively. In mature fresh kernel, a particulate enzyme requiring GDP-mannose is involved in the biosynthesis of mannans. Using α-galactosidase of kernel and β-mannosidase of haustorium, the presence of α-linked galactose residues and β-linked mannose residues were shown in galactomannans and mannans.

During germination of coconut, the reducing and non-reducing sugars of kernel continued to decrease. In the haustorium, starch increased linearly whereas the reducing and non-reducing sugars initially increased very rapidly and then remained constant. These results suggested that during germination, embryos utilized the stored carbohydrates.

The activities of deoxyribonuclease, ribunuclease, 3'-nucleotidase, pyrophosphatase were the same in the kernels of mature and germinated nuts. In the haustorium, their activities were 2-4 fold higher. Amylase, β-mannosidase, and sucrase were found only in the haustorium. Sucrase activity decreased after an initial rise, whereas the activities of amylase and β-mannosidase remained constant.

Introduction

Biochemical studies on the nature, coconut fruit and biosynthesis and fate of its cellular constituents, namely, fat, proteins, and carbohydrates, have lagged behind agronomical and breeding studies in coconut. This study was therefore initiated with the hope of understanding the various changes in carbohydrate metabolism that are taking place in the nut during its maturation and germination.

Nathanael (1952) reported changes in the amount of reducing and non-reducing sugars of the liquid endosperm during the development of coconut. However, the changes reported in the carbohydrate content of the liquid endosperm had not been correlated with that of the solid endosperm. The presence of galactomannans and mannans in the solid endosperm had been reported by Rao, Choudhury, and Bagchi (1961), Mukherjee and Rao (1962), and Balasubramaniam, Sothary, and Hoover (1969). Subsequently, Balasubramaniam (1976) characterized and quantitated the polysaccharides in the solid kernel of maturing and matured coconuts. Studies on the biosynthesis of mannan using particulate enzyme of mature coconut kernel has also been carried out (Balasubramaniam and Hassid, 1973).

Although, coconut is a seed with a high oil content, the embryo, during its early stages of germination and until the emergence of green leaves, utilizes the stored carbohydrate only, and not fat (Balasubramaniam *et al.*, 1973). Therefore, the significance of the stored triglycerides to the young seedling is still unknown.

Materials and Methods

Analysis of coconuts. From a well-bearing coconut palm (*Cocos nucifera* L.) at the Coconut Research Institute, Lunuwile, all the 18 bunches of coconut were plucked. These bunches, numbered in order of increasing maturity from the top to the bottom, take approximately a year to mature. Three to four coconuts from each bunch were analysed. Coconuts were opened, and noted for their general morphology. The volume of liquid endosperm was measured. The solid kernel was homogenized in a Waring blender (1 g/5 ml water) and centrifuged at 100 g for 10 min. The supernatant was analysed for sugars. The residue was washed with acetone, followed by either-alcohol (3 : 1), and then dried at 80°C overnight.

Determination of reducing sugars and total sugars. Reducing sugars were determined by the Somogyi method (1952) and expressed in terms of mg glucose. The liquid endosperm and supernatants were acid-hydrolysed, neutralized and their total reducing sugars determined as above.

Polysaccharides of coconut kernel. These were extracted with increasing concentrations of NaOH and the non-extractable fraction (α-cellulose) analysed by dissolving it in phosphoric acid (Balasubramaniam, 1976).

Preparation of particulate enzyme (mannan synthetase). Mature coconut kernel (50 g) was homogenized in 150 ml 0.05 M Tris buffer (pH 7.4) containing 0.005 M mercaptoethanol and 0.25% bovine serum albumin in a Waring blender for 4 min at 4°C. The homogenate was strained through cheese cloth and then centrifuged at 1000 g for 10 min at 4°C. The 1000 g supernatant was centrifuged at 30,000 g for 1 hr. The 30,000 g pellet was suspended in 1 ml of the same buffer.

Assay of mannan synthetase. The incubation mixture contained GDP-mannose-^{14}C, 0.7 n mole (1,00,000 cpm ; counts per minute) ; $MgCl_2$, 0.25 μmoles; enzyme 50 μl in a total volume of 62 μl. The mixture was incubated at 25°C for 0 hr and 1 hr and the reaction was stopped by the addition of 50 μl glacial acetic acid. The two samples were separated by descending paper chromatography on Whatman No. 1 using ethyl acetate-*n*-butanol-water:acetic acid mixture (3:4:4.2.5 v/v). The chromatograms were scanned for radioactivity with a Nuclear Chicago Model scanner.

Extraction of labelled mannans. The ^{14}C labelled mannans were extracted from the above incubation mixtures with 1 ml 17% NaOH at 80°C for 1 hr and filtered through glass fibre paper. The residue was washed twice with 0.5 ml 17% NaOH and filtered. The filtrates were pooled. As the concentration of labelled mannans was too small in such a pool for ethanol precipitation, cold mannans were added. This mixture of labelled and cold mannans was then precipitated with ethanol. The precipitate was centrifuged, the pellet suspended in water and re-precipitated with ethanol. This precipitate was taken on an aluminium disc, dried and the activity counted in a Nuclear Chicago gas-flow proportionate counter. The residue left on filter paper was washed with ethanol-acetic acid (100:1 v/v) mixture, dried and counted as above.

Enzyme assays. Acid phosphatase, pyrophosphates, 3'-nucleotidase, ribonuclease, deoxyribonuclease, amylase, β-mannosidasa, and sucrase were assayed as described by Balasubramaniam *et al.* (1973).

Results and Discussion

Changes in carbohydrate during development of coconut. With increasing age of coconuts, the volume of the liquid endosperm increased to a peak of 500 ml and its contents of reducing sugars to 4.1 g per 100 ml in coconuts of the eighth bunch (approximately, 6 months old) (Fig. 1). The liquid endosperm of the first eight bunches contained little or no sucrose. This is in agreement with the results obtained by Nathanael (1952), who showed also that the chief reducing sugar of the liquid endosperm was glucose. As the volume and the reducing sugars of the liquid endosperm decreased in coconuts of the older bunches, the polysaccharides in the residue of the solid endosperm increased and followed a S-shaped curve, as the coconuts matured. The initial lag phase continued until the establishment of the jelly-like endosperm on the entire surface area of the nucellus. This was followed by the logarithmic phase in which the jelly-like endosperm gradually increased in thickness and in hardness. The stationary phase was characterised by the hard solid endosperm in which almost all the cell wall polysaccharides had been laid down.

The solid endosperm appeared in coconuts of the seventh bunch, which is about 5-6 months old. The polysaccharides of this endosperm were mainly 4% NaOH-extractable galactomannans and cellulose. Mannans

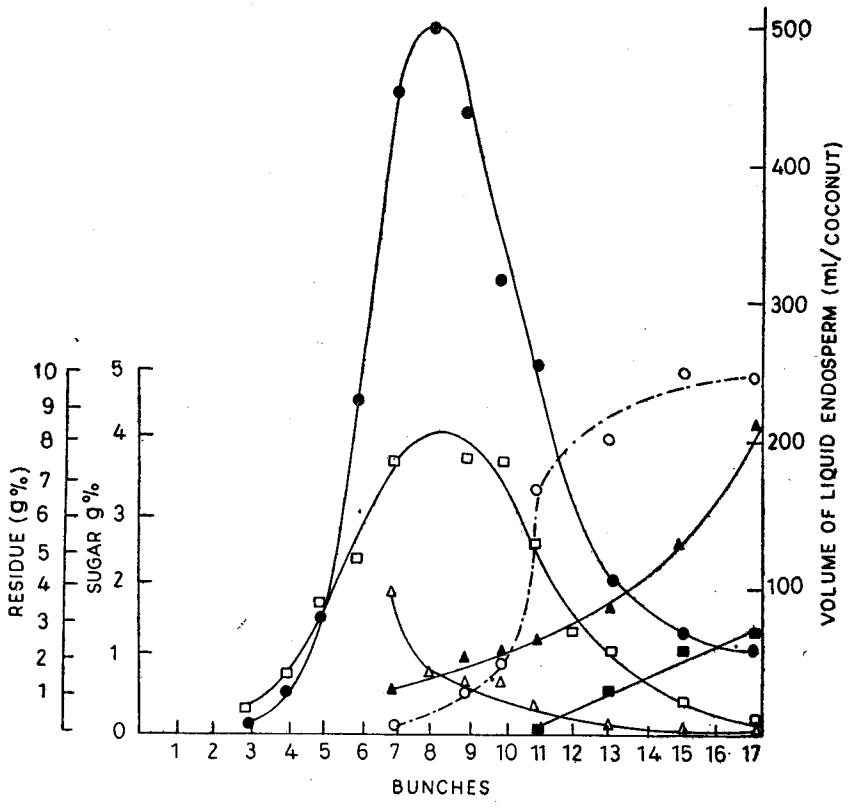


Fig. 1.

were noticeably absent. The water-soluble galactomannans decreased with increasing maturity of the coconuts. In mature nuts, this constituted 0.1%. The 4% NaOH-extractable galactomannans reached maximal values, and then decreased with maturity whereas the 17% NaOH-extractable galactomannans steadily increased. The ratios of galactose to mannose in 4% and in 17% NaOH extractable galactomannans were 1:2 and 1:7, respectively. In mature coconuts, the galactomannans extractable with 4% and 17% NaOH formed 61% and the mannans extractable with 17% NaOH formed 13% of the total polysaccharides. The rest of the polysaccharides (26%) which were non-extractable with NaOH contained mannans and cellulose. These were separated after depolymerization using phosphoric acid. The mannans and the cellulose were found to be in equal amounts. Therefore, in the mature coconut kernel, out of the total polysaccharides, 61% constitute galactomannans, 13% extractable mannans, 13% non-extractable mannans, and 13% cellulose.

Mannan synthesis. Radioactive scans of the paper chromatograms showed that the zero hour sample had only one peak (Fig. 2). This peak corresponds to GDP-mannose-^{14}C. The 1 hr sample showed four peaks. Peak I, at the origin, contained 17% NaOH-extractable mannans and

mannans of α-cellulose (non extractable). Peaks II and III correspond to GDP-mannose-^{14}C and ^{14}C-mannose-1-phosphate, respectively. Peak IV remains to be identified.

The study of incorporation of mannose ^{14}C into mannans as a function of time showed that both forms increased hyperbolically and reached maximal values in two hours (Fig. 3). The donor of mannose for mannan synthesis was GDP-mannose-^{14}C.

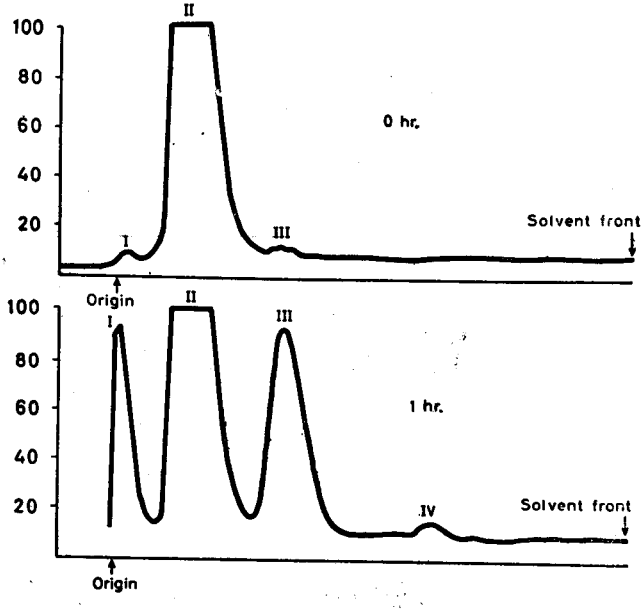


Fig. 2. Biochemical changes during maturation and germination of coconut

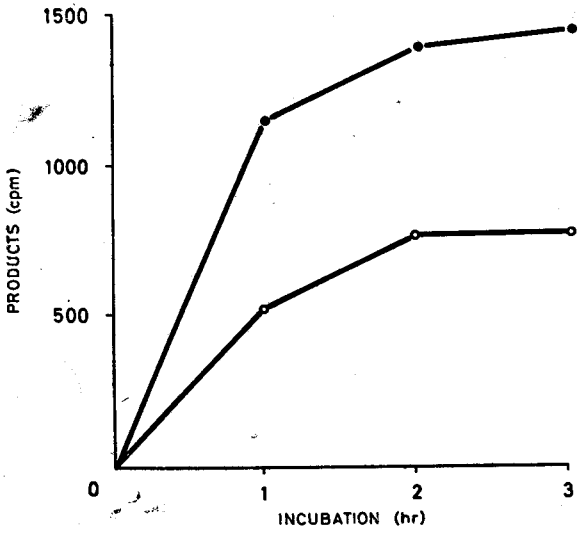


Fig. 3, Biochemical changes during maturation and germination of coconut

The effects of different nucleotide sugar on the biosynthesis of mannans are shown in Table 1. It is clear from the Table that GDP-glucose-^{14}C

TABLE 1. Effect of sugar nucleotides on the biosynthesis of mannans

Nucleotide sugar(s)	CPM in products
GDP-mannose-^{14}C	18,456
UDP-galactose-^{14}C	0
GDP-glucose-^{14}C	0
GDP-mannose-^{14}C+UDP-galactose-^{14}C	2,410
GDP-mannose-^{14}C+GDP-glucose-^{14}C	1,977
UDP-galactose-^{14}C+GDP-glucose-^{14}C	0
GDP-mannose-^{14}C+UDP-galactose-^{14}C+ GDP-glucose-^{14}C	103
GDP-glucose-^{14}C+GDP-mannose	840

Incubation mixture contained 100,000 cpm of each of the indicated sugar nucleotides. After incubation, reaction was stopped with acetic acid, washed with acetic acid and the pellets counted.

and UDP-galactose-^{14}C were not incorporated. In fact, they inhibited the mannan synthesis. The inhibition was greater when both were present in the incubation mixture. An inactive cellulose synthetase might have been present in the particulate enzyme fraction, since the glucose-^{14}C from the GDP-glucose-^{14}C was not incorporated into any of the polysaccharide fractions. However, when cold GDP-mannose was added, the labelled glucose from GDP-glucose-^{14}C-appeared in the polysaccharides.

Germination of coconut. The kernel of the mature and the germinating coconuts did not consume oxygen (Cutter, Wilson, and Dube, 1952 ; Balasubramaniam *et al.*, 1973). Activities of acid phosphatase, pyrophosphatase, 3′-nucleotidase, ribonuclease, and deoxyribonuclease were the same in the kernels of mature and germinating coconuts. In the haustorium, the activities of the above enzymes were two to four fold higher than those in the kernel. Amylase, β-mannosidase and sucrase were found in the haustorium, but not in the kernel. Of these enzymes, sucrase activity decreased after an initial increase as germination proceeded (Balasubramaniam *et al.*, 1973). During the first six months of germination, the reducing sugars and the total soluble sugars of the haustorium increased rapidly to a constant level, while those of the kernel steadily decreased. The starch in the haustorium steadily increased (Balasubramaniam *et al.*, 1973).

The decrease in concentration of the reducing sugars in the liquid endosperm corresponded with the increases in the non-reducing sugars and of the polysaccharides of the solid endosperm. These results appear to indicate that glucose of the liquid endosperm was converted to sucrose and to the polysaccharides of the solid endosperm. With increasing matu-

rity, the 17% NaOH-extractable galactomannans (galactose to mannose 1 : 7) increased, whereas the 4% NaOH-extractable galactomannas (galactose to mannose 1 : 2) decreased. That some of the galactoses in both these galactomannans were α-linked had been shown (Balasubramaniam, 1961) by the action of α-galactosidase of coconut kernel (Balasubramaniam, Dey, and Pridham, 1974) previously. Hence, it is possible that the 17% NaOH-extractable galactomannan is a product of hydrolysis of the precursor galactomannan extractable with 4% NaOH.

The mannans were absent in the kernel of very immature coconuts (seventh bunch). The primary cell wall of the immature kernel cells were formed of cellulose and the matrix polysaccharides, galactomannans. With increasing maturity, mannans were laid down as secondary thickening and the slight increase observed in the weight of the residue, in immature nuts (Fig. 1) could be attributed to the continued synthesis of mannans. This was shown using GDP-mannose-14e and particulate enzyme, mannan synthetase, from mature coconuts. Mannose-1-phosphate was probably formed by the action of the enzyme GDP-mannose pyrophosphorylase present in the particulate enzyme fraction on the substrate GDP-mannose. The involvement of polyisoprenyl phosphate intermediates in the biosynthesis of mannans in *Micrococcus lysodeikticus* was suggested by Scher, Lennarz, and Sweeley (1968) The possibility of mannosyl lipid intermediates taking part in the biosynthesis of mannans in coconut kernel remains to be investigated.

The inability of the kernel to utilize oxygen and the activities of acid phosphatase, pyrophosphatase, 3'-nucleotidase, ribonuclease, and deoxyribonuclease being the same in the kernel of mature and germinating coconuts, indicate that kernel acts only as a storage tissue and is incapable of protein synthesis.

The results presented here contradict the general assumption that the stored oil in coconut is the reserve food for the seedlings during germination. During germination not only that the carbohydrates are utilized but also the excess carbohydrates are stored in the haustorium. The oil content per nut remains unaltered during the first 18 weeks of germination (Nathanael, 1959). Green leaves appear by 22nd week of germination (Child, 1974), and thereafter, the seedling could lead an independent existence. The stored oil has been reported to disappear (Nathanael, 1959) in 6-24 month old seedlings. The significance of this is not known.

Acknowledgements

This study was supported by a research grant of the University of Sri Lanka, Colombo Campus and by the International Atomic Energy Agency. I am very grateful to Dr. W.Z. Hassid (Department of Biochemistry, University of California, Berkeley, California, USA) for providing labo-

ratory facilities to do a part of this work, Dr. W.R.N. Nathanael (Coconut Research Institute, Lunuwile) for supplying coconuts and coconut seedlings, Drs. A.A. Hoover and S. Wijesundera for their helpful discussions, Dr. K. Sihotang for helping to prepare the manuscript, and Messrs R.D. Sothary and G.K.J. Silva for their technical assistance.

References

Balasubramaniam, K. (1976). Polysaccharides of the kernel of maturing and matured coconuts. *J. Food Sci.* "in press".

Balasubramaniam, K., Bey, P.M. and Pridham, J.B.(1974). Association and dissociation of α-galactosidase of coconut. *Trans. Biochem. Soc.* **2** : 1128-1130.

Balasubramaniam, K. and Hassid, W.Z. (1973). Biosynthesis of mannans in coconuts. *Ceylon Assoc. Adv. Sci.* **29** : 155

Balasubramaniam, K., Jayalath, T.M.S., Wijesundera, S., Hoover, A.A. and de Silva, M.A.T. (1973). Biochemical changes during germination of coconut. *Ann. Bot.* **37** : 439-445.

Balasubramaniam, K., Sothary, R.D. and Hoover, A.A. (1969). Hemicellulose in coconut kernel. *Ceylon Assoc. Adv. Sci.* **25** : 95-96.

Child, R. (1974). *Coconuts.* 335 pp. 2nd ed. Longmans, London.

Cutter, V.M., Wilson, K.S. and Dube, J.F. (1952). The endogenous oxygenous oxygen uptake of tissues in the developing fruit of *Cocos nucifera. Am. J. Bot.* **39** : 51-66.

Doudoroff, M. (1962). D-Galactose dehydrogenase of *Pseudomonas saccharophilla.* 339-341. pp. *In* Colowick, S.P. and Kalpan, N.O. (Eds.) *Method in Enzymology,* vol. 5. Academic Press, New York, N.Y.

Mukherjee, A.K. and Rao, C.V.N. (1962). A mannan from the kernel of coconut (*Cocos nucifera*) *J. Indian Chem. Soc.* **39** : 687-692.

Nathanael, W.R.N. (1952). The sugars of coconut water. *Ceylon Coconut Quart.* **3** : 193-199.

Nathanael, W.R.N. (1959). Report of the Chemist. *Ceylon Coconut Quart.* **10** : 27-39.

Rao, C.V.N., Choudhury, D. and Bagchi, P. (1961). A water soluble galactomannan from coconut (*Cocos nucifera*). *Can. J. Chem.* **39** : 375-381.

Scher, M., Lennarz, W.J. and Swelley, C.C. (1968). The biosynthesis of mannosyl-1-phosphoryl polyisoprenol in *Micrococus lysodiekticus* and its role in mannan synthesis. *Proc. Nat. Acad. Sci. U.S.* **59** : 1313-1320.

Somogyi, M. (1952). Notes on sugar determination. *J. Biol. Chem.* **195** : 19-23.

Technology

Chairman : V. SUBRAMANIAM

Rapporteur : M.P. SANKARANARAYANAN

Improvement of Traditional Methods of Wet Milling Fresh Coconut Kernel

J.E. CECIL and W.H. TIMMINS
Industrial Development Department, Tropical Products Institute, Culham, Oxfordshire, United Kingdom

Abstract

The paper reviews recent research into improved methods of wet milling coconuts in both domestic and commercial operations. The results of a world-wide survey on coconut grating tools used currently in the rural and domestic sector in the coconut producing countries are presented, and the results of a practical evaluation to determine optimum blade shape, size, and speed of rotation for simple grating tools, is given. Two prototype grating systems—a stirrup operated grater, and a bicycle grater—have been tested and shown to offer advantages over widely used traditional manual grating systems. Aspects of wet-milling of fresh coconut kernel as practised in the modern processes are discussed, and the TPI wet-milling system is described.

Introduction

During the past two decades, a considerable amount of research has been directed towards developing processes capable of extracting oil and protein from fresh coconuts on a commercial scale These processes have two features in common with traditional domestic methods of processing : (i) the production of an emulsion by comminuting the fresh kernel ; and (ii) the breaking of this emulsion in order to recover the oil and protein. They differ in the techniques and methods used to produce and break the emulsion. This paper discusses the comminution operation, which forms the first stage in all wet processes.

The general motivation of research on wet process has been the increasing need to conserve for human consumption all sources of high quality protein. An addition, by avoiding losses widely experienced in the copra industry an efficient wet process could lead to higher yields of oil.

In many producing countries domestic consumption of fresh coconuts accounts for a large proportion of the total coconuts production. A population growth rate in some of the less developed countries of around 2.5% per annum has meant that increasing quantities of coconuts are being used for domestic consumption. With almost static nut production,

this has left ever decreasing quantities available for industrial purposes. The percentage of total nut production which is used for domestic consumption varies considerably according to the country and area concerned, but on a global basis in 1965, local consumption was estimated at 25% of total production (Thieme, 1969). In 1975, the corresponding figure was around 50% (Thampan, 1975). Faced with these diminishing marketable surpluses, it clearly becomes vital to encourage research aimed at increasing the efficiency of nut utilization in both the commercial and the rural and domestic sectors in the coconut producing countries. An efficient commercial wet process could lead to better utilization of the crop ; so too will more efficient domestic processes. Improving methods in the home is not simply a technical problem ; it also requires acceptance by many people of changes in their traditional methods of preparing foods. It has always been difficult to alter traditional domestic routines, but with the development of new, improved methodology changes could well be beneficial. This paper primarily concentrates on various aspects in the development of machines and tools for the grating of fresh coconut kernel in the rural and domestic sector. The data that have been obtained provides a basis for developing simple, more efficient tools suitable for local manufacture. This in turn should lead to a reduction in the overall quantities of fresh coconuts consumed in this sector.

Review of Traditional Coconut Graters

The TPI carried out a worldwide survey on coconut graters used in rural areas. Information for this survey was received from 16 coconut growing countries, throughout Asia, Africa, Polynesia, and the Caribbean. It showed that there are a number of distinct types of tools used to "grate" the fresh kernel prior to expression of the emulsion. These are as follows :

1. A knife or machete, used to chop the kernel into fine pieces.
2. Nail punch graters. These are either manufactured graters for cheese or carrots, or are made simply by punching nail holes through any convenient piece of metal available, such as biscuit tin lid.
3. Scrapers made from metal or suitable sea-shells.
4. Saw-toothed graters (see Fig. 1, Blades VII and VIII). This type was found to be used throughout most of the major coconut growing countries, and is made by filling saw-teeth in the edge of a flat piece of metal. Tooth sizes may vary from 1.0 mm to 3.0 mm. The grater is either held in the hand, or, more often, is fixed to a large piece of wood, shaped like a cricket bat, and the grating operation is carried out with the person sitting astride the wood, facing the grater. A variant of the saw-tooth design is sometimes produced by using a hack-saw to cut grooves in the metal.
5. Rotary saw toothed grater with upto four blades (Fig. 1, Blades

I-VI). The blades are sized and shaped to fit inside the half-coconut and are rotated by manually turning an attached handle. A treadle operated system has also been proposed (Napitupulu, Fussell, and Quarmby, 1975).

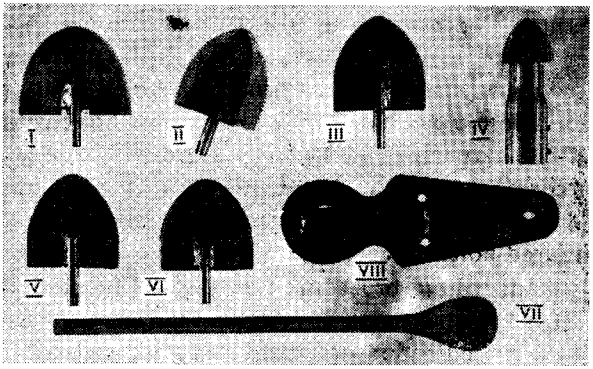


Fig. 1 Coconut graters used in various coconut growing countries

6. Rotary cylindrical metal graters with nail-punch holes. Graters of this type are commonly found in market places and are usually motor driven.
7. In addition to the above tools, a pestle and mortar is sometimes used after the first expression of milk, to improve the oil yield.

In the rural and domestic sector, the grating operation is usually performed manually, and represents the heaviest work in the preparation of oil. The tools used to carry out grating operation differ from country to country and sometimes even between groups within a country. It is clear that traditional methods differ in both the degree of difficulty associated with carrying out the grating operation, and the time taken to complete the operation. These two factors influence to some extent the amount of fresh kernel left attached to the inner shell. Subsequently, this is often discarded as waste. Successful development of new grating tools will depend upon both efficient maceration of the meat, and, more important, the ease with which grating operation can be carried out.

Experimental Methods and Results

The experimental work was carried out in three stages as follows :

A. A preliminary evaluation of various traditional and inexpensive modern graters was conducted for their efficiency in extracting oil from kernel.

The traditional graters were constructed according to information received during the survey and were subsequently evaluated for ease and efficiency of operation. These graters included various designs of blade—numbers II, III, VI, and VII (see Fig. 1) and a grater made from a

biscuit tin lid perforated with a 5 mm diameter nail. Blades II, III, and VI were tested using a prototype pedal powered machine based on bicycle parts.

The modern graters differed in their operation and the design of their perforations. There were graters which included a pressure element by which the kernel was pressed prior to extrusion through the perforations, and others in which the kernel was directly grated. The perforations were either scooped, punctured, or cylindrical holes. The graters tested were a Mouli-Joulienne No. 2 (0.8 mm scoop hole, with pressure) ; a Moulinette self-sharpening mincer (1.6 mm cylindrical hole, with pressure) ; a cheese grater (2.5 mm scoop hole, direct grating) ; cheese grater (5.1 mm scoop hole, direct grating) ; and a cheese grater with 2.5 mm punctured holes.

A carefully standardized procedure was used to prepare coconut emulsions using these tools. A small hand-lever type lemon press was used to press 75 g of the grated endosperm produced with each tool. Use of this press was considered to be less variable than simple hand squeezing. The residue from the first expression was mixed with 150 ml water, soaked for 3 min, and pressed again in the lemon press. The wash/press operation was then repeated. All equipment and materials were maintained at 30°C throughout the procedure and the emulsions and residues obtained were analysed for oil content using standard methods (AOAC, 1970). Although the study is incomplete, the following results have been obtained.

(a) Oil extraction following the first pressing operation lies between 30-50% of available oil. Washing and pressing the expressed residue twice considerably increases the quantity extracted, and in some cases, doubles the yield initially obtained, giving overall extractions of 85-90% of available oil as an oil-in-water emulsion. (b) In general, with scoop holes, the smaller the hole, the higher the yield of oil. (c) Modern graters in which pressure is exerted on the meat during the grating operation give more oil than simple graters. (d) With the nail-punch type of grater, the size of the hole does not appear to correlate with subsequent yields of oil obtained.

B. A series of trials was conducted to determine which blades performed best from the point of view of ease of operation and rate of production of grated kernel. Blades I to VI (see Table 2 and Fig. 1) were attached in turn to the shaft of a variable drive motor. This enabled the output of grated kernel to be measured at differing speeds of rotation. Rates of output from 20 rpm to the speed at which it became too difficult to hold the half-nut were determined in duplicate for each blade at 20 rpm increments. Equations based on linear regression analysis of the results of the experimental trials are shown in Table 1 and are plotted in Fig. 2. Further observations were also made on the influence of the rate of rotation on the quality of the grated product obtained. Table 2 presents information on the characteristics of the tested blades.

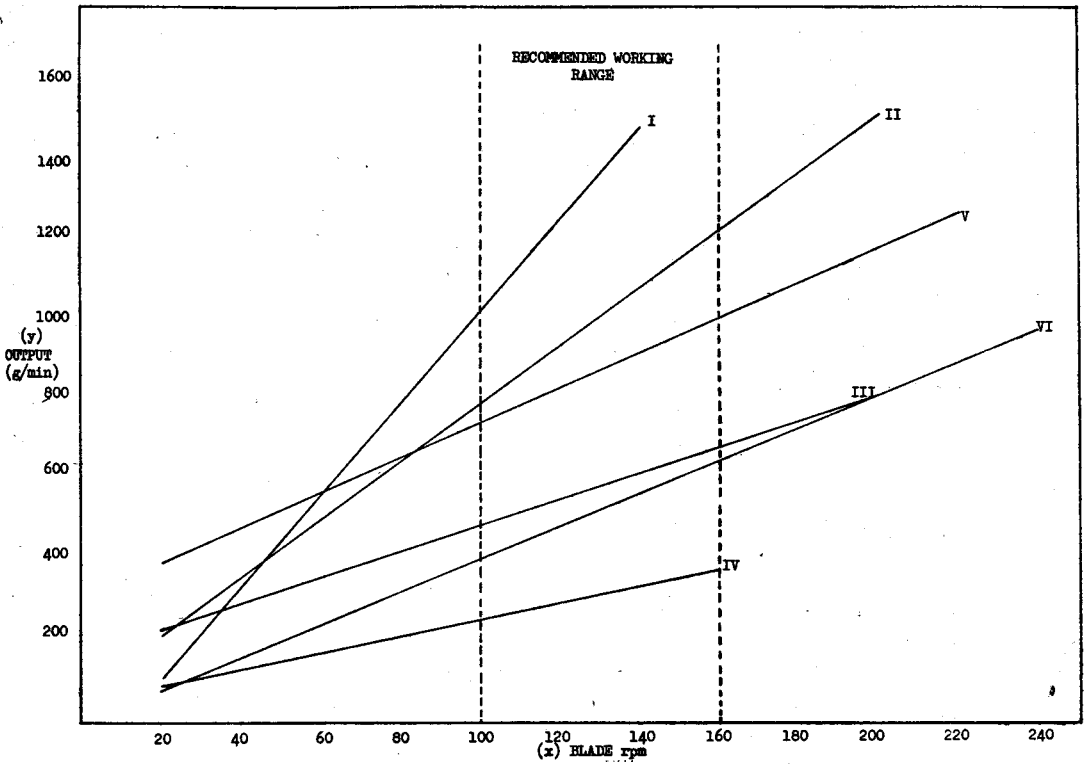


Fig. 2 Performance of different blades in grating kernels at various speeds

Table 1. Linear regression equations (Regression of y upon x)* on differing speeds rotation on output of grated kernal

Blade no.	rpm range	Regression equation	Coefficient of linear correlation (r)
I	20-140	$y=11.6x-128$	0.97
II	20-200	$y=7.3x+66$	0.86
III	20-200	$y=3.3x+163$	0.44
IV	20-160	$y=2.1x+45$	0.93
V	20-220	$y=4.4x+310$	0.88
VI	20-240	$y=4.1x+5$	0.96

x=blade rpm

y=output of grated kernel (g/min)

* These equations are based on analytical results of duplicate tests performed at 20 rpm increments, using each blade within the range indicated.

Table 2. Characteristics of grater blades

Blade no.	Blade description (tooth description)	Theoretical swept surface area/ revolution (cm^2)	Width of base (cm)	Length (cm)	Tooth depth range (mm)	Average no. of teeth/cm
I	Large single (large saw teeth)	357	9.1	7.1	1.7-2.5	3-4
II	Large quadrant (saw teeth)	635	7.4	7.4	1.7-2.5	3-4
III	Large single (hack saw cuts)	317	7.4	7.4	1.8-2.8	4-5
IV	Small quadrant (saw teeth)	191	5.2	3.4	1.3-1.8	4-5
V	Large single (small saw teeth)	317	7.4	7.4	0.9-1.5	4-5
VI	Large scraper (no teeth)	317	7.4	7.4	0	0
VII	Small traditional (saw teeth)	9.8*	4.3	3.3	1.1-1.8	4-5
VIII	Large traditional (saw teeth)	14.6*	6.4	4.8	1.1-1.6	4-5

*Length of cutting edge-cm

C. Experiments were run for comparison purposes in which the time to completely grate a half nut was determined for various blades using different motive systems. The various grating systems tested are listed in Table 3 and include the two prototype systems currently being developed by TPI-a stirrup operated grater (Fig. 3) and a bicycle driven grater (Fig. 4). Apart from these "powered" grating systems, experiments were also carried out on a small and a large traditional grater (Blades VII and VIII, Fig. 1). Ten half-nuts were completely grated in each of the experiments, and the grating time recorded. The results obtained are summarized in Table 3.

Discussion

1. Extraction of Oil Using Traditional and Modern Graters

Graters of the rotary type generally gave higher yields of oil than those

TABLE 3. Time taken to completely grate a half coconut using various different grating systems

Grating system	Blade	Blade no. (Fig. 1)	Average grating time (sec)*	Range (sec)
Motor drive @ 100 rpm	Small quadrant	IV	44.3	6.9
@ 160 rpm	,,	IV	38.0	5.3
Motor drive @ 100 rpm	Large quadrant	II	18.5	3.5
@ 160 rpm	,,	II	13.4	4.7
Stirrup operated	Small quadrant	IV	46.9	15.1
,,	Large quadrant	II	29.8	15.7
Bicycle drive	Small quadrant	IV	38.6	13.0
,,	Large quadrant	I	24.6	10.3
,,	Large quadrant	II	20.6	8.8
Traditional grater	Small blade	VII	56.5	20.4
,,	Large blade	VIII	41.6	12.6

* Notes : 1. Average time to grate a half-coconut (average 156 g of kernel).
2. All grating trials were carried out by the same operator, in order to eliminate the variability expected in performance between individuals.

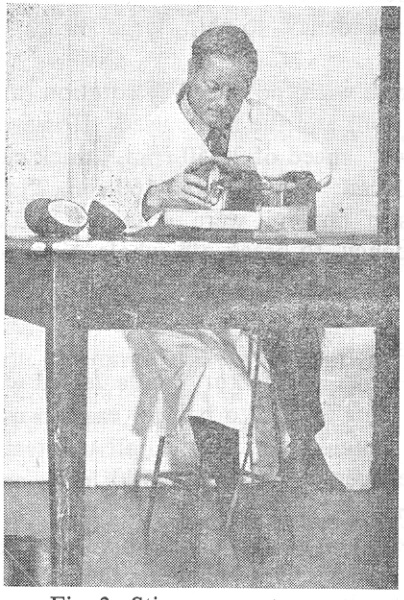


Fig. 3 Stirrup operator grater



Fig. 4 Bycycle grater

which relied on reciprocating actions. A severe drawback encountered with the nail-punch type of grater was the considerable wastage of fresh kernel. This was due to breakage of the kernel into pieces too small to grate without the operator running the risk of lacerating his fingers.

2. Assessment of Grater Blades and Grating Systems

(i) *Variable drive motor experiments.* Varying the speed of rotation of the grater blades had a marked effect on the output of grated kernel, the

ease with which the grating operation could be carried out, and on the appearance of the product obtained.

Output of grated kernel. This varied linearly with the speed of rotation of the blade and increased as the speed increased (Fig. 2 and Table 1). It was shown that the rate of production of grated kernel is also a function of the swept surface area of the blade (Table 2) and that the highest rates are associated with the largest areas. The exception to this rule was found with Blade No. I-a large single blade. The explanation for this probably lies in a consideration of the blade's base width. At 9.1 cm, the base width was considerably greater than those of the other large blades tested (7.4 cm). The coconuts used in the experiments had an average inner shell diameter of 10.1 cm, and an average kernel thickness of 1.4 cm. From this, it can be seen that for much of time, Blade No. I would be using a greater percentage of its cutting surface than any of the other blades, and therefore, would be expected to have a higher rate of production of grated kernel.

(ii) *Ease of operation.* For all blades, the most satisfactory working range lay between 100-160 rpm. At speeds outside this range, it became difficult to hold the coconut and the tendency to chip large pieces of kernel from the nut increased.

(iii) *Appearance of product.* This varied with the speed of rotation (and hence, the degree of difficulty of operation) and the blade used. However, the general pattern was that at the lower speed of 20-50 rpm, "thick curtains" and pieces of kernel were produced; between 100-160 rpm, "lacy curtains", "threads", and small pieces of coconut were obtained; and at speeds greater than 180 rpm, the tendency to break off whole pieces of kernel increased.

3. Assessment of Blade Performance

From an operational viewpoint, the most satisfactory blade tested was Blade No. II, a large quadrant blade. This proved to be very easy to use. Next best was Blade No. V, a large single blade with small saw teeth. Blade I performed reasonably well between 100 rpm and 140 rpm and Blade IV between 100 rpm and 160 rpm. Above these levels (and below 100 rpm) they were both difficult to use. The most difficult blades to use were the large scraper blade (No. VI), and the large blade with hack-saw cuts (No. III).

Practical Grating Trials. The results obtained from these trials are shown in Table 3, and they confirm the importance of sizing the blade to approximate the internal dimensions of the half-nut. In the case of the bicycle grating system, it can be seen that the average grating time for Blade I (24.6 sec) was higher than that obtained with Blade II (20.6 sec). This was unexpected since Blade I had outperformed Blade II during the experiments with the variable drive motor (Fig. 2), and is possibly due to the fact that during the grating operation with Blade I, it was difficult to

maintain a constant speed of rotation due to the tendency of the blade to dig into the kernel. In contrast, no such tendency was experienced with Blade II which was relatively smooth and easy to control during the grating operation.

The equation in Table 1 represent much higher rates of grating than is indicated by apparently comparable figures in Table 3. During the grating trials to determine the time needed to grate a half kernel using different motive systems (Table 3), time was lost in manipulating the nut to present to the revolving blade suitable surfaces for grating. In the trials to compare different blades (equations, Table 1), maximum grating rates were determined.

Finally, it is of interest to compare the grating times obtained with the two prototype systems using Blade II, with that obtained by the traditional grating method using Blade VIII. The stirrup operated and bicycle operated grating systems needed approximately 28% and 50% less time, respectively than the traditional method. In addition, the prototype systems were considerably easier and less tiring to use than the traditional graters. It is, therefore, considered that adoption of these novel graters will help to reduce wastage.

Modern Methods of Wet-milling Fresh Coconut Kernel

In addition to its application in the home, maceration of fresh kernel is also used in processes designed to produce coconut products on a commercial scale. These processes were conceived as ways of avoiding denaturation of the protein, and of reducing losses of oil inherent in the traditional copra process. Wet processes have been reviewed by various authors (Srinivasan, 1963 ; Sreenivasan and Rajasekharan, 1963; Elizabeth and Adair, 1967 ; Dendy and Timmins, 1973 ; Grimwood 1975). The objective of the wet-milling operation is to maximise the extraction of oil and protein from the kernel into an aqueous carrier liquid. (Typically, fresh kernel is mixed with hot water in commercial wet-milling operations). The presence of surface-active constituents from the plant cells, together with the oil and water present, means that extraction by wet-milling normally results in a very stable oil-in-water emulsion. The types of mills which have been used include rod, ball, roller, flaking and high speed disc attrition mills. Batch and continuous milling systems with and without closed loop milling circuits have been tried.

In the continuous closed loop milling circuit, fines are removed and the oversized material returned to the mill for regrinding together with new feed. In general, this type of system will perform more efficiently than 'open loop' systems, and will produce a more uniform particle size distribution in the ground material. The size distribution itself will depend upon the type of classifier, its sharpness of cut, and the recycle ratio employed.

Research on the wet-milling of coconut kernel has indicated the following : (1) Optimal extraction of oil and protein is best achieved by using systems that rupture the maximum number of cells (Timmins, 1970); (2) It is important to wash and press the ground coconut residue in order to obtain high oil extractions (Hagenmaier, Cater, and Mattil, 1972); (3) Varying the temperature (between 30-85°C) and the water to coconut ratio (between 1:1 and 10:1) used in the wet milling operation do not significantly alter extraction of oil and protein (Dendy and Timmins, 1973); and (4) Oil extractions approaching 100% can be obtained by sequentially colloid milling the ground coconut residue (Adair and Timmins, 1974).

The TPI Wet-milling System

Following research on the fundamental aspects of wet-milling fresh coconut kernel, TPI has designed a continuous closed-looped circuit (Fig. 5) which extracts upto 96% of the oil in the kernel. The system combines the shear characteristics of two Wedge Cutter/Die Plate (WCDP) Mills (Foodtech Ltd., Models F9/246 and F10/150) with the attrition characteristics of a colloid mill (Premier Colloid Mills, Model 84, fitted with two 84 mm diameter carborundum grinding discs). The F9/246 WCDP Mill is used to communite the kernel, and has been modified to include a system of blades for precutting the kernel prior to communition. The kernel is fed into this unit with water at 50°C, in the ratio 1:2 (kernel : water). The resulting coconut slurry is then pumped to the F10/150 WCDP Mill for further milling. Following this, the slurry is passed to a two-deck vibratory sieve (William Boulton Ltd , Model 32), fitted with a 12 mesh screen on the upper deck, and a 200 mesh screen on the lower deck. Hot water sprays mounted directly above the top screen ensure that the residue is thoroughly washed during separation into fines and oversize material. Material off the top deck is continuously returned to the F10/150 WCDP Mill for regrinding, together with new feed material. Material of the lower deck passes to the colloid-mill (disc clearance approx. 25 microns) for further milling. The ground residue from the colloid-mill is then pressed, washed, and pressed again. The emulsion obtained from the colloid mill is combined with emulsion which has passed through both screens.

Typical particle size distributions (determined by a wet-sieving method; Adair and Timmins, 1974) of the ground coconut residues arising from the various milling stages can be seen in Fig. 6. The incremental size reduction of the residue at successive milling stages can be clearly seen in this graph. In this particular case, the diameters of the holes on the die-plates of the F9/246 and F10/150 WCDP Mills were 2.0 mm and 1.4 mm, respectively, and the grinding discs on the colloid mill were set at a clearance of 25 microns. This wet-milling system has proved to be an efficient means of producing coconut emulsion. It has been used as

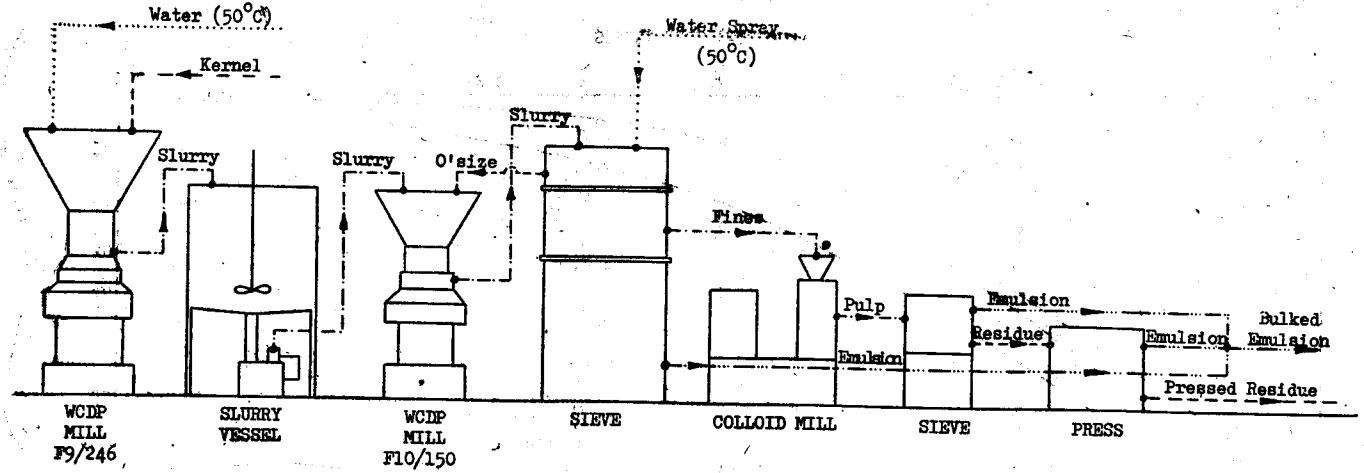


Fig. 5 The TP1 wet milling system

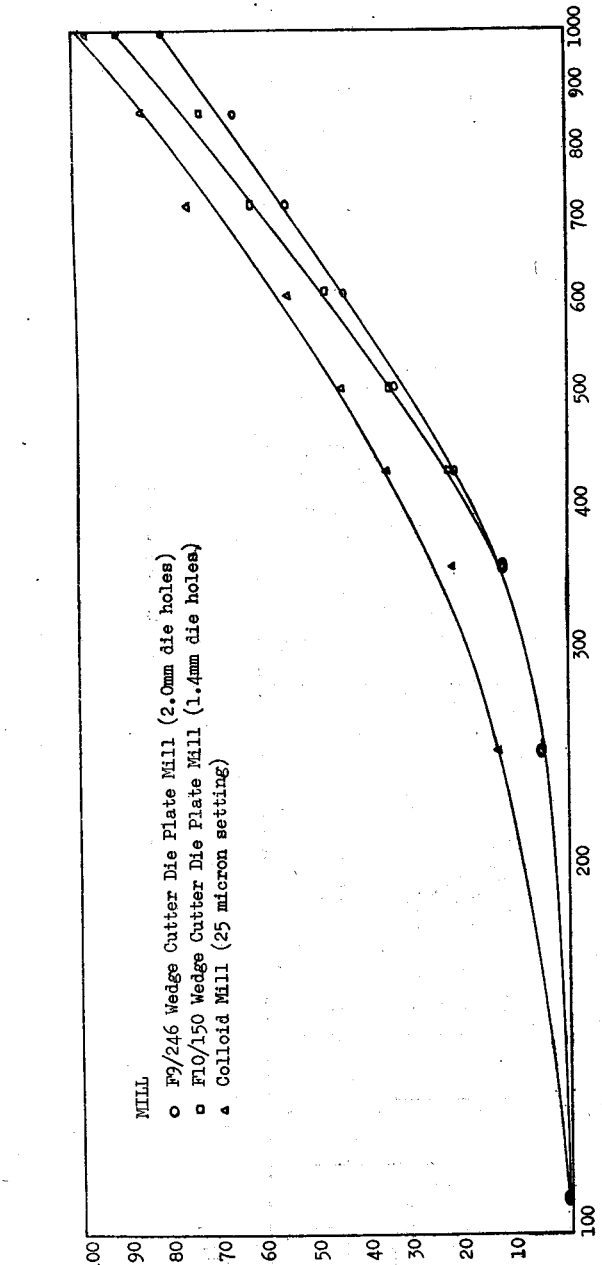


Fig. 6 Size classification of residue

the first stage both in an oil extraction process and in the production of shelf-stable coconut milks and creams.

In conclusion, it is interesting to note the essential similarities which exist between the traditional and modern wet-milling processes for recovering oil from fresh coconuts. Both require an efficient method for size reduction of the kernel, in order to maximize subsequent extraction of the oil. It is important also, in both cases, to efficiently wash and press the ground coconut residue to enhance the overall yield of oil.

Acknowledgement

We thank Mr David Adair for his help and guidance in the preparation of this paper, and Mr R.D. Orme and Mr W.J. Brewer who helped with the experimental work.

References

Adair, D. and Timmins, W.H. (1974). The wet-milling of coconut kernel. Paper presented at the *IVth Int. Cong. of Fd. Sci. and Tech.*, Madrid, Sept. 22-27, 1974.

AOAC. (1970). *Official Methods of Analysis*. 11th ed. AOAC, Washington, D.C.

Dendy, D.A.V. and Timmins, W.H. (1973). Development of a Wet Coconut Process designed to extract Protein and Oil from Fresh Coconut. Report G78. Tropical Products Institute, London.

Grimwood, B.E. (1975). Extraction of oil and protein from fresh coconuts. pp. 193-210 in *Coconut Palm Products. Their Processing in Developing Countries*. 261 pp. Agr. Dev. Paper No. 99, FAO, Rome.

Hagenmaier, R., Cater, C.M. and Mattil, K.F. (1972). Critical unit operations of the aqueous processing of fresh coconuts. *JAOCS*. **49**: 178-181.

Napitupulu, W.P., Fussel, D. and Quarmby, A. (1975). Butsi's Village Technology Unit, Teaching Materials and Methods. Pub. No. 44. Agricultural Development Council, Inc., 630 Fifth Avenue, New York 10020, NY., USA.

Orr, E. and David, A. (1967). The Production of Protein Foods and Concentrates from Oilseeds. Report G 31. Tropical Products Institute, London.

Sreenivasan, A. (1963). Use of coconut preparations as a protein supplement in child feeding : Prospects. Nutrition Document R. 9/Add. 5. PAG, New York.

Sreenivasan, A. and Rajasekharan, W. (1967). The use of coconut preparations as a protein supplement in child feeding. *J. Fd. Sci. Technol.* **4** : 59-65.

Thampan, P.K. (1975). The Coconut Palm and its Products. 302 pp. Green Villa Publishing House, Cochin.

Thieme, J.G. (1968). Coconut Oil Processing. 251 pp. Agr. Dev. Paper No. 89. FAO, Rome.

Timmins, W.H. (1970). The Extraction of Oil and Protein from Fresh Coconut. M. Tech. Thesis. Univ. of Loughborough, London.

Discussions

Sreemulanathan : Will blade II be suitable for different sizes of coconut commercially available, and has the blade to be changed to suit coconut size ?

Timmins : In general, the dimension of the grater blade should be slightly less than that of the nuts handled. It should be possible to cater for the majority of nuts (of the same variety) by sizing the blade to fit the smallest nuts. In the event of gross variation in the sizes between nuts, it may well be advisable to use two differently sized blades.

Thomas : 1. The main difficulty involved in separating oil from water in the wet processing is the presence of an emulsifying agent. Has the TPI made any investigation to identify the chemical composition of the emulsifying agent ?

2. If the chemical composition has been determined it is then possibly only a question of adding some solvents to dissolve the emulsifying agent ?

Timmins : 1. TPI has essentially adopted a practical approach to the problem of emulsion breakage. This has involved evaluating various unit operations and materials used in similar processes.

2. I would agree that an analysis of the membrane constituents may well provide an insight into alternative means of establishing the emulsion. In this respect, the techniques used by researchers, who have attempted to determine the composition and structure of the milk-fat-globule membrane may well be of use. However, in my opinion, the determination is likely to be difficult and costly, requiring very sophisticated analytical equipments. Regarding solvents, aspects relating to food legislation may well prove to be an important constraint, particularly if the protein is intended for human consumption.

Maximizing the Utility of Coconuts by an Integrated Process for Large Scale Production of Proteins, Flour, Coconut Honey, and Oil from Fresh Coconut Kernel and By-Products such as Fibre, Carbon, and Chemicals from Husk and Shell Carbon, Shell Chemicals, Cooking Gas etc. from Shell

T.V.P. NAMBIAR

Chemical Construction Company, North Beach Road, Madras 600 001, India

Abstract

The economics of an integrated process utilizing whole freshly harvested coconuts for the production of proteins, flour, syrup, and oil from fresh coconut kernel and fibre, carbon, various chemicals and cooking gas from husk and shell is given. This process is claimed to yield ten times more profit than the traditional method of processing.

Introduction

Of all the palms, coconut palm is of highest economic value. It is grown over the widest area and has possibly the largest number of uses including in a wide variety of foods. Coconuts are far more important to humanity than the statistics show, because millions of people in several tropical countries depend upon coconut for their livelihood.

In spite of its great economic value, processing of coconuts has remained more or less static till recent times. The usual age old method of drying coconut kernel into copra for subsequent pressing in expellers to produce coconut oil and oil cake is wasteful, cumbersome, and costly. The old process makes copra liable to spoilage, rancidity, and microbial infection. About 25% of all coconuts produced in the world is reported to be wasted or rendered unsuitable for effective utilization because of this. The ECAFE conference held in Manila in 1968 for better utilization of coconuts have recommended as under: "The ideal method of obtaining high quality oil and proteins for human consumption from coconuts would be direct processing of the wet meat out of fresh coconuts, without producing

dried copra first. In view of the fast growing population in south-east Asia and the pre-eminent need for protein-rich food in countries such as India, it would be most worthwhile to start such ventures on a large scale". This is what we are trying to do in a large scale modern integrated coconut processing complex being set up at Ponnani in Kerala (India) and elsewhere in some of the coconut growing countries of the world.

We have developed over the last six years, the 'Solvol' process for integrated processing of fresh coconuts for large scale production of coconut protein, coconut flour, coconut honey, and coconut oil for edible purposes and by-products like shell carbon, shell chemicals, cooking gas, fibre or coir from coconut husk, carbon from coir dust, etc.

Coconut is nature's principal store house of nutrition. It contains in good measure excellent proteins, carbohydrates, minerals and vitamins, besides a good supply of an edible oil. The 'Solvol' process for integrated processing of coconuts shows a way for giving a better price for the coconuts to the farmer who have been exploited by middle men and traders from time immemorial.

The 'Solvol' Process

The integrated *Solvol* process consists of the following operations:

Soon after harvesting and bringing to the factory, the coconuts are defibrated and deshelled to recover the inner kernel. The outer brown cover on the kernel cup (testa) is carefully removed and the kernel is washed, sterilised, and scrapped into a fine meal. The meal is then squeezed in special continuous process to bring out the milk. The milk is filtered and spray-dried under high vacuum and the resulting coconut oil and proteins are separated from each other by filteration or centrifuging. The proteins are solvent-extracted (using an edible grade solvent) to remove and recover the oil adhering to it. The defatted 'coco-proteins' are an excellent material for preparation of baby foods, weaning foods, convalescent food drinks, and other preparations. While splitting the coconuts into halves, the endosperm water is collected. Cocount water contains appreciable quantities of glucose, fructose, levulose, minerals, and growth promoting trace elements. Coconut water is filtered and evaporated under controlled vacuum conditions and blended with a little golden syrup to produce coconut honey which is an excellent breakfast food, bread spread, soft drinks additive, and sweetner.

The fluffy white mass left after squeezing out the milk is dried and solvent-extracted (using an edible grade solvent) to remove and recover the residual oil present in it. The extracted meal is thoroughly desolventized and dried and ground, and graded to a fine mesh and marketed for edible purposes. It is an excellent additive to wheat flour, rice flour, and corn flour for making bread, biscuits, crispies, cookies, and a variety of other food preparations.

In case it is preferred to make high protein coconut flour, the shredded

kernel (without squeezing out the milk) is straightaway dried in a continuous counter current drier and the dried meal is solvent-extracted (using an edible grade solvent) to remove and recover all the oil. The extracted full meal is then powdered and graded to a fine mesh and used for enriching wheat flour, rice flour, cornflour etc. in various kinds of food preparations. The testa removed from the kernel cup is dried and solvent-extracted to recover all the oil. The extracted meal is then utilized in animal feed compositions.

The Oil

The quality of coconut oil produced by this process is much better than the quality of oil produced by the old copra milling process. Practically, no free fatty acids are present in the oil. The entire oil present in the coconut kernel is recovered by this process and no oil is allowed to go to waste through the oil cake or residual meal or water emulsions, thus making this process more efficient and more economical than all other known dry or wet processes.

The Proteins

Coconut proteins contain a high percentage of lysine, cystine, histidine, arginine, methionine and other important essential amino acids. They make 'coconut proteins' extremely important and useful as a constituent of baby foods, convalescent food drinks etc. Coconut proteins have been found to be as good as egg proteins and meat proteins after careful nutritional evaluation.

Coconut Honey

It is easily assimilable and very palatable. It contains many growth promoting trace elements, besides glucose, fructose, and levulose. It is an excellent breakfast food and bread spread, soft drinks additive, and sweetner.

High Protein Coconut Flour

If the shredded kernel is carefully dried in a continuous counter current drier and then solvent-extracted to recover the oil, what is left over is a snow white meal containing about 25% proteins and 65% carbohydrates, together with minerals and and vitamins (Table 1). This high protein coconut flour can be used as an additive for enriching wheat flour, rice flour, corn flour etc. for preparing bread, biscuits, and other kinds of food preparations. Coconut flour has been found to be as good as wheat flour for food preparations.

A sterilizing system has been built into the plant to ensure complete bacterial purity for all the finished products.

TABLE 1. Analysis of coconut flour

Amino acid		Percentage of the total flour weight
Alanine	...	0.99
Valine	...	1.64
Glycine	...	0.76
Isoleucine	...	1.15
Leucine	...	2.26
Proline	...	2.25
Threonine	...	0.91
Serine	...	1.07
Methionine	...	0.54
Hydroxyproline	...	0.00
Phenylalanine	...	1.29
Aspartic acid	...	2.10
Glutamic acid	...	5.43
Tyrosine	...	1.06
Lysine	...	1.87
Histidine	...	0.49
Arginine	...	1.20
Cystine/2	...	0.04
Total		**25.05**

Source: Analytical Biochemistry Laboratories Inc., PO Box 1097, Columbia, USA by Floyd E. Kaiser, Senior Chemist, Lab. No. 14360-2.

By-products

Coconut shell carbon. If coconut shell is destructively distilled, several valuable products can be obtained. They include shell carbon, chemicals like acetic acid, grey acetate of lime, phenols, creosote, etc. from the pyrolygenous liquor and non-condensible gases which can be conveniently used as boiler fuel or compressed in cylinders for use as domestic cooking gas.

Similarly, if coir dust is destructively distilled, carbon, pyrolygenous liquor and fuel gas can be obtained.

Coconut fibre or coir. The coconut husk can be mechanically processed to get good quality coir fibre which has several uses in industry and in the manufacture of household articles.

The *Solvol* process uses at least 1,00,000 coconuts every day in one plant and it is more profitable to process all the by-products under one roof as an integrated industry.

Average minimum yield of protein, honey, oil and other by-products from fresh coconuts. On an average, the following minimum yields of various by-products can be obtained from an average sized nut. Such a nut from Kerala (with husk, shell, kernel, and water) weighs approx. 1.1 kg. In some other countries like the Philippines, Indonesia, Malaysia, and Sri

Lanka, the nuts are bigger and heavier than those of Kerala.

1. Protein-rich flour	...	...	50 g
2. Oil	...	...	110 g
3. Coconut honey	...	...	10 g
4. Coir fibre	...	...	80 g
5. Shell carbon	...	...	30 g
6. Coir dust carbon	...	...	30 g
7. Pyrolygenous liquor	...	...	30 g
8. Cooking gas	...	...	30 g

WORKING ECONOMICS AND PROFITS

A 1,00,000 nuts/day integrated *Solvol* processing plant would register the following approximate working economics :

Debit

Cost of 1,00,000 coconuts @ 80 paise each	Rs. 80,000
Add : all inclusive processing expenditure for processing 1,00,000 nuts (details worked out on 16 and 17)	Rs. 32,000
	Rs. 1,12,000

Credit

Sale value of 5,000 kg high protein flour @ Rs. 8/kg	Rs. 40,000
Sale value of 1000 kg coconut honey @ Rs. 15/kg	15,000
Sale value of 11,000 kg oil @ Rs. 9/kg	99,000
Sale value of 3,000 kg shell carbon @ Rs. 500/ton	Rs. 1,500
Sale value of 3,000 kg coir dust carbon @ Rs. 400/ton	Rs. 1,200
Sale value of 3,000 kg of pyrolygenous liquor and chemicals recovered by destructive distillation of coconut shell at Rs. 1,000/ton	Rs. 3,000
Sale value of 8,000 kg fibre @ Re.1 per kg	Rs. 8,000
Sale value of 3,000 kg cooking gas @ Rs. 500/ ton	Rs. 1,500
Sale value of 500 kg feed stock from testa @ Re. 0 50/kg	Rs. 250
	Rs. 1,69,450
Total	**Rs. 2,81,450**

The plant can work for at least 250 full working days in a year and earn a gross profit of over Rs. 14 million/annum, which works out at over 55% annual returns on a total investment of Rs. 25 million.

Labour charges for dehusking 1,000 nuts ...	15.00	
Labour charges for drying the kernel into copra— one person for 7 days @ Rs. 6.00/day ...	42.00	
Packing, transport and handling charges to take the copra to the market etc.	10.00	
	———	873.00
1,000 average sized nuts give 150 kg (1.5 quintal) copra		
Credit		
Selling price of 150 kg (1.5 quintal) copra @ Rs.550/quintal ...	825.00	
Selling price of 1000 husks ...	40.00	
Selling price of 1000 shells ...	30.00	
	———	895.00
Margin of profit for the village copra maker		22.00

The village copra maker profits Rs. 22.00/1000 nuts or 2.2 paise/nut. By engaging women and children at home during off hours, the villager may be able to make a little more profit, or maximum about 2.5 paise/nut, but this does not change the economics of the business considerably. On the other hand, the village copra maker is at the mercy of the oil miller who purchases the copra for making coconut oil and oil cake. The oil miller in turn is at the mercy of the fluctuating fortunes of the coconut oil market.

B. Let us consider the working economics of the small coconut oil miller.

The sale value of coconut oil meets the purchase price of copra. The profit margin for the village oil miller is the sale value of the oil cake minus his processing cost and tax.

He purchases 150 kg (1.5 quintal) of copra at Rs. 825 from the copra maker and gets a maximum 66% oil, or one quintal of oil valued at Rs. 825.00. His oil milling charges work out at Rs. 12/quintal of copra *plus* tax at Rs. 10/ quintal, i.e., he spends Rs. 18.00 on milling 1.5 quintal copra and pays Rs. 15.00 as taxes, i.e., in all Rs. 33.00.

He gets a sale value of Rs. 58.00 for 0.5 quintal oil cake. His profit, therefore, is Rs. 58.00 — Rs. 33 = Rs. 25.00 for milling 1.5 quintal copra which has come from 1000 coconuts, or, the miller's profit is 2.5 paise/ nut.

Thus, from coconuts to copra and then from copra to oil and cake, the profit margin for one nut is only 2.5+2.5=5 paise.

C. A village copra maker-*cum*-miller on processing 1000 nuts on an average makes Rs. 50.00/day or Rs. 15,000/annum. His total investments on his copra making-*cum*-milling unit is about Rs. 50,000, on which he has to pay an interest of Rs. 7,500 leaving a net profit margin of Rs. 7,500/annum. This profit is again at the mercy of market fluctuation of oil, efficiency of milling, spoilage and rancidity of copra, and several other factors.

As compared to these figures of the village coconut economics, let us

consider the economics of the 'Solvol' process :

Debit

Cost of 1000 nuts	Rs. 800	
All included processing expenses @ Rs. 320/ 1000 nuts (see above)	320	
		1120

Credit

Sale value of one quintal oil	925	
Sale value of 50 kg high protein flour @ Rs. 8/kg	400	
Sale value of 10 kg honey @ Rs. 15/ kg	150	
Sale value of 30 kg shell chemicals @ Re. 1/kg	30	
Sale value of 30 kg carbon @ 50 paise/kg	15	
Sale value of 5 kg feed stock from testa @ 50 paise/kg	2.50	
Sale value of 80 kg coir fibre @ Re. 1/kg	80	
Sale value of 30 kg carbon from coir dust @ 40 paise/1/kg	12	
		1629.50
Margin of profit on processing 1000 nuts		**509.50**
Margin of profit on processing one nut		**0.51**

This works out at over 10 times more profit from the coconut than the old copra process.

As compared to 5 paise profit for the village copra maker and oil miller, the 'Solvol' process gives a profit of 51 paise/nut, or, over ten times more than the traditional copra process.

Thus, considered from all angles (social, economic, utilization, nutritional, and others—the new integrated 'Solvol' process for processing coconuts is at least ten times more profitable and beneficial than the old copra process.

Role of Sodium Dodecyl Sulphate in the Stabilization of Coconut Oil/Water Emulsion

ASHOK K. GOSWAMI
Department of Chemistry, K.R. College, Mathura 281 001, U.P., India

Abstract

The role of sodium dodecyl sulphate (SDS) in the stability of coconut oil in water emulsion has been studied. Flocculation studies were made haemocytometrically in the presence of varying concentrations of different electrolytes, viz., sodium, chromium, lead, and thorium. Zeta potentials were calculated from the mobility data obtained micro-electrophoretically in the presence of electrolytes. The stability of the system has been discussed in the light of the DLVO theory. The high stability of the coconut oil/water emulsion proves its paramount importance in cosmetic industry.

Introduction

Emulsions are widely used in various fields such as the pharmaceutical, agricultural, cosmetic, paint and food industries. An emulsion is a heterogeneous system consisting of at least one immiscible liquid dispersed in another in the form of droplets. From the thermodynamic point of view, such dispersions are essentially unstable, because the large interfacial area indicates a considerable amount of free energy which becomes minimum only when the dispersed droplets have coalesced into one large liquid mass. Hence, coalescence of droplets is a thermodynamically spontaneous process. Accordingly, from a practical point of view, the emulsion droplets must be protected against coalescence. For this purpose, surface active agents are usually added to emulsion ; this is also important in reducing the amount of mechanical work required to effect emulsification, because the interfacial tension is lowered by the absorption of the surface active agents.

The stabilization of vegetable oil emulsion has attracted many workers as they find extensive application in cosmetics. Vold (1975) pioneered this work and stabilized olive oil/water emulsion using sodium dodecyl sulphate as an emulsifier. Emulsion thus obtained had a remarkable stability. Recently Groves (1976) has carried out the study of self emulsifying vegetable oils.

The present paper presents the results of a study of coconut oil/water emulsion stabilized by sodium dodecyl sulphate using haemocytometry and microelectrophoretic techniques.

Experimental

Crude coconut oil was purified by the technique of soxhlet extraction using petroleum spirit (40-60°C). The sodium dodecyl sulphate (SDS) used was obtained from Eastman Kodak Co. All the electrolytes used in the flocculation studies were BDH Analar quality chemicals. The glass apparatus used was made of Pyrex glass, and water was distilled twice before use.

The emulsions were prepared by suspending coconut oil (1% vol) in a solution of SDS (0.005%) in KCl solution (0.01M). The mixture was hand shaken for a few minutes and homogenized with a hand-operated homogenizer (Fischer Scientific Co.). The sampling was always done under identical conditions.

The flocculation of the emulsion with electrolytes was studied by determining the variation in particle concentration with time haemocytometrically, using an improved Neubauer model of a haemocytometer. About 750 particles were counted each time in 80 squares of graticule fitted in the eye-piece (each square corresponding to a volume of 1.22×10^{-7} ml) with a tally counter under a Leitz microscope using 15×95 times magnification.

Measurements of globlue mobility were made microelectrophoretically using Northrup-Kunitz type cell by diluting the emulsion ten times with 0.01M KCl solution. The zeta potentials were calculated using the Helmholtz-Smoluchowski equation (Helmpholtz, 1879; Smoluchowski, 1903). The reproducibility of zeta potential was within $\pm$ 1.0 mv.

Results and Discussion

Effect of Electrolyte Concentration on Flocculation. As expected, from the nature of the emulsifier, the emulsion was negatively charged initially and so different cations were used in flocculation studies. Flocculation of the system was studied in the presence of various concentrations of electrolytes by counting the number of individual droplets present at various time intervals. The initial particle concentration was found to be 1.1×10^8 globules/ml. The number of particles decreased with increase in the concentration of the electrolytes added in the beginning, and attained constancy after some time, indicating the occurrence of reversible flocculation in the system.

Zeta Potentials. Changes in the zeta potentials by the addition of electrolytes have been studied macro-electrophoretically. The zeta

potential in all the cases decreased with the increase in electrolyte concentration, except for $NaNO_3$, where it was apparently constant and only a little variation in zeta potential was seen even at 5×10^{-2} M. Only the trivalent and tetravalent ions were capable of reversing the charge of the oil droplets.

The emulsion has got an initial zeta potential of 145.9mv which in general, falls with increase in the concentration of the electrolyte till the charge reversal takes place. After this, it again increases with the electrolyte concentration. The electrokinetic charge density of the diffused double layer was calculated (Table 1). The charge densities of the system vary in the same way as the zeta potentials.

TABLE 1. Values of zeta potential and charge density for different electrolytes

Electrolyte concentration	Zeta potential	Charge density $\times 106$
$NaNO_3$		
1.0×10^{-4}	53.76	1.11
2.0×10^{-3}	49.60	1.42
5.0×10^{-1}	52.60	3.44
$Pb(NO_3)_2$		
1.0×10^{-5}	62.93	1.54
5.0×10^{-4}	46.90	1.16
1.0×10^{-2}	30.40	1.00
$Cr(NO_3)^3$		
2.0×10^{-5}	57.00	1.19
2.0×10^{-4}	39.10	0.79
1.0×10^{-3}	Charge reverse	
$Th(NO_3)^4$		
1.0×10^{-6}	66.00	0.86
5.0×10^{-6}	34.90	0.76
2.0×10^{-4}	Charge reverse	

Interaction Energy Curves and Emulsion Stability. To have a clear picture of the emulsion stability, interaction energies have been calculated and the curves were plotted as a function of interparticle distance H(Å). Almost all the curves showed a similar trend with very high energy barriers (8000-9000 kT) indicating high stability. The presence of high energy humps depends upon the zeta potential and the Debye-Huckel paramater, which invariably vary with the concentration of the electrolyte added for flocculation.

This study of coconut oil/water emulsion stabilized by SDS reveals that

the time factor does not influence the emulsion stability. It exhibits increased stability and resistance to a break on aging. Such type of stable emulsions may prove of paramount importance in cosmetic industry.

References

Groves, M.J. (1976). Rheological characterization of self-emulsifying oil/surfactant systems. *Acta Pharm. Suecico* **13** : 353-360.

Smoluchowski, M. (1914). p. 366. in Graetz, B. (Ed.) : *Handbuch der Elektrizitat und des Magnetismus*. Vol. 2. Leipzig, G.D.R.

Vold, R.D. (1975). The kinetics and mechanism of ultracentrifugal demulsification. *J. Colloid & Interface Sci.* **51** : 133-142.

Industrial Utilization of Coconut Husk

G. N. PRABHU
Central Coir Research Institute, Kalavoor, Alleppey 688 522, Kerala, India

Abstract

Industrial utilization of coconut husk has so far been confined to extraction of coir of different grades which are preferred for manufacture of coir products of different types. Coir extracted from green husks termed "white/retted fibre" is used in the preparation of yarn, cordage and a wide range of floor furnishing materials such as foot mats, mattings, rugs, carpets and speciality articles such as filters. 'Brown fibre' or coir extracted from dry/semidry husks is used in the manufacture of brushes, curled coir, for filling upholstery, and various types of rubberised coir products which serve as bed mattresses, cushioning blocks, air filters, and packaging materials. Presenting data on the country-wise output of coconuts and production of coir, the extent of untapped potential is protected. Reviewing the methods in coir extraction and further processing of the fibre into yarn and different types of products, the technological improvements contributed to higher productivity entailing reduced physical strain on the part of the operatives in fibre extraction, spinning and weaving, are described. The techniques evolved for improving the feel, texture and appeal of coir by softening, bleaching, dyeing, and finishing treatments have also been dealt with in brief. Elucidating the results arising out of the studies in new uses of coir with particular reference to use of coir panels for improving interior foam acoustics and thermal insulation of buildings, coir mattings for erosion control of soil slopes of highways and railway embankments, coir mattings as a barricading material for sand stowing operations in mines and coir-reinforced partition panels and roofing boards in building construction, the need to further use of coir in these new areas of application is stressed for progressive industrial utilization of the material.

The Fibre from Coconut fruits

J.V. BHAT
Department of Microbiology, Kasturba Medical College, Manipal 576 119, Karnataka, India

Abstract

The fibre from the thick fibrous mesocarp of the fruits of coconut palm, known the world over as coir, is a versatile material which enters the world market as coir fibre spun yarn, rope, woven mats, mattings, rugs and carpets, brooms and brushes, and also as rubberized products. Its method of extraction in India is through the retting (fermentation) of husks, a process unique in that it takes place in brine and requires several weeks to complete and in which a wide variety of microorganisms participate. The reason for the long period required for retting has been explained as due to the presence in the husk of considerable quantities of phenolics which have to be leached out and/or decomposed by microbial activities before the fibre releasing organisms can attack the pectic substances. The two microbiological processes, polyphenolics degradation and breakdown of pectic substances, have been observed to run parallel and take not less than four months to complete even under ideal conditions unlike the retting of other plant fibres which need only few days to get complete.

The microorganisms associated with retting are the predominant gram negative short rods and yeasts. The species that decompose pectic substances are those belonging to the genera *Achromobacter, Alcalingenes, Aerobacter. Escherichia, Pseudomonas, Paracolobactrum, Micrococcus,* and *Bacillus.* Yeast species of *Candida, Cryptococcus,* and *Rhodotorula* have also been reported to possess the ability to attack pectic substances. The successive pattern of microflora in the rets has been followed. *Debaryomyces hansenii,* a yeast, is a powerful species in its ability to degrade phenolics. The *Micrococcus* species isolated likewise, is equally efficient and capable of even forming 3, 4, 3′, 4′– tetradihydroxy diphenyl from catechol.

Several factors influencing retting have been detailed and salt has been proved to be not essential in the process, Pre-crushing of husks before steeping them in water, aeration, and flushing of ret liquor hasten retting. The possibility of reducing retting period by use of cultures and improving the quality of fibre has been suggested.

Introduction

The coconut fibre, also known the world over as coir fibre, is unique in that it is the only commercial fibre derived from any fruit of a plant. What is more, it is produced in a unique manner and has unique properties not shared by other natural fibres. This is no wonder, as the

coconut palm, *Cocoa nucifera* L., itself is a unique tree of great economic importance as no part of it is useless. Hence, the palm is popularly referred to in this country as *kalpa vriksha* or *kalpa taru* (Tree of Heaven).

A good portion of the fruit of the coconut palm is its husk. It is used as a fuel in areas where firewood is expensive or scarce. Undoubtedly, the best way to exploit the husk is to extract coir from it, and in India, this is indeed done to yield a versatile fibre of multiple purposes as yarn, cordage, mattings, carpets, rugs, ropes and a variety of rubberized products. Coir forms 5.6% of the total output of sacking and cordage fibres of the world. More than 50% of it is of Indian origin. It is mostly comprised of the unique retted variety.

According to the method of extraction and use, coir is grouped into three classes. The fine yarn fibre, also called mat-fibre, is the finest and the longest. It is extracted from retted green husks. The other two are the coarser varieties, the bristle fibre and the mattress fibre. These are extracted from the dry husks. Whatever be the manner in which it is extracted, coir has remarkable stretching properties, besides possessing high resistance to attack from microbes, because of its impervious nature. It is particularly resistant to decay in sea water, and thus, happens to be the material of choice for various marine operations. Moreover, it besuits manufacture of fabricated cement articles, roofing boards, hard boards, heat insulating materials, thermo-setting plastics, and other articles. In consequence, the coir industry has become one of the more important of agricultural industries in India. It provides employment for well over half a million people in Kerala state alone.

The retting process. The raw material for the coir industry is the coconut husk which represents the entire fibrous material enveloping the fruit and comprised of both the exocarp and the mesocarp. The yield of fibre from 1000 husks is about 80 kg. Its market price depends on the quality which in its turn depends on the region where it was produced and the manner in which it was extracted. The traditional retting yards, however, are located on the coastal backwaters of Kerala, which is also the area of maximum coconut production.

The usual practice for coir making is to arrange 1000 husks into rope bundles or inside coir nets and keep them afloat on coastal water in the retting yards until the bundles get fully soaked, become heavy, and sink into the floor, the bundles are often also weighed down with mud and slime collected from the floor. In some areas, the husk piles are tied down to bamboo stakes buried into the mud. In any case, the object is to allow the husks to ret in sea water for 6-9 months, the period depending upon the season and the location of the yard. In a few areas, retting is accomplished by steeping the husks in pits dug within the reach of tidal waters, though the quality of this product is relatively poor.

Extraction and processing of fibre. For extraction of fibre, properly

retted husks, washed free of adhering slime and mud and of the exocarp (which gets easily peeled off), are beaten with wooden mallets on a stone —a process which helps to separate the fibre from the cork and pith. Washing once again the fibre in the sea water before drying in the sun, removes the adhering matter and yields a more attractive fibre than that not washed twice. Chemical and other methods so far tried for extracting the fibre have not been found to be as satisfactory or as inexpensive as the biological method, involving retting and manual separation of fibres.

Coir fibre, like other common natural fibres, is amenable to processing on lines applicable to all vegetable fibres, e.g., dry spinning and weaving followed by wet treatments as dyeing and printing. Dyeing can be also carried out on loose fibres, or on yarns, or even on woven materials. Pretreatment of the materials is often resorted to as it tends to impart improved tone and brightness to the dyed products. Coir is a coarse fibre because of its chemical nature, composed as it is of cellulose, cellulosan, lignin, and hemicellulose. Also, it happens to be multicellular in nature and hence measures 12-14 mm in diameter and, interestingly, the fibre surface is occasionally covered with silicized stigmata (Bhat, 1971 ; Bhat and Nambudiri, 1971).

Microbiology of coir retting. Retting may be considered as both an oxidative and fermentative process brought about by the associative activity of several microorganisms, all of which appear to be aerobic. Until recently, the exact manner in which the organisms functioned or the changes they brought about in the chemical constituents of the husk had not been investigated. It was however realized since long that retting brings about loosening of the fibre away from the surrounding non-fibrous tissues, collectively referred to as pectic substances, and that this occurs when the micro-organisms attack and degrade those complex molecules.

Heyn (1952) was the pioneer to isolate from retting husk liquors a few microorganisms which were suspected to have had a role in the retting process. His isolates included *Diplococcus* sp., *Vibrio* sp., *Clostridium* sp., and two unidentified yeasts.

Proximate analysis of 10-11 month old husks, which yield the finest fibre (Bhat, 1966), when retted in their green (not dry) state, revealed that the husks contain 75-76 g/kg of polyphenols and 16–17 g/kg of pectins; on percentage basis, ripe husks contain 7.3% polyphenols and 2.0% pectin approximately. The gradual disappearance of these compounds from the retting husks together with the appearance of heavy populations of microflora, particularly of bacteria and yeasts capable of degrading both these constituents, provided the first clear-cut picture of the biochemical process and the microflora involved in the process (cf. Table 1). As a matter of fact, it was found possible to apply these two criteria to follow the progress of retting itself in that the initial and the residual polyphenols and pectin contents proved to be reliable criteria for the purpose.

Microbiological examination of small laboratory rets and commercial

TABLE 1. Characteristics of different samples of natural rets

Source of sample*	Appearance and dominant flora	pH	Counts per ml	
			Bacteria	Yeasts
Thiruvallam	Somewhat turbid, dull brown colour, predominantly *Bacillus* sp. gram negative rods and gram positive cocci.	6.8	5.8×10^5	1.97×10^3
Kanniyapuram	Turbid, dark brown, predominantly *Bacillus* sp. and gram negative rods	6.5	2.1×10^6	9.7×10^3
Nedumangandu	Clear, yellowish brown predominantly gram positive cocci and gram negative rods	6.5	5.6×10^6	1.63×10^2
Mangad	—do— —do—.	6.7	10.8×10^7	4.7×10^3
Alapat	Somewhat turbid, dark brown, predominantly *Bacillus* sp. gram negative rods and gram positive cocci	6.4	1.92×10^5	5.1×10^3
Ashtamudi	Clear liquid, dark brown, predominantly *Bacillus* sp. and gram positive cocci	6.1	2.93×10^6	1.38×10^3
Vayalar	Slightly turbid, yellowish brown, predominantly *Bacillus* sp. and gram negative rods with yeasts	5.8	6.5×10^6	1.8×10^4

*All locations in south Kerala.

ones revealed the dominant aerobic bacteria of coir rets to be made up of the genera *Escherichia*, *Pseudomonas*, *Micrococcus*, *Bacillus*, *Paracolobactrum*, and *Alcaligenes* and the subsidiary flora belonging to the genera *Achromobacter*, *Aerobacter*, and *Corynebacterium* (Table 2). The predomi-

TABLE 2. Bacterial flora of coir rets

Genera	No. of isolates	% of isolates
Escherichia	129	26
Pseudomonas	92	19
Micrococcus	87	18
Bacillus	68	14
Paracolobactrum	50	10
Alcaligenes	48	10
Achromobacter	7	1
Aerobactor	4	1
Corynebacterium	3	1

nant yeast species of coir rets were *Saccharomyces fructuum, Debaryomyces hansenii, D. kloekeri, Cryptococcus diffluens, Rhodotorula flava,* and *R. glutinis,* and the less dominant were *Debaryomyces nicotianae* and *Hansenula sneggii* (Table 3).

TABLE 3. Yeast flora of coir rets

Species	No. of strains	% of isolates
Saccharomyces fructuum ...	38	24
Debaryomyces hansenii ...	26	16
D. kloeckeri ...	25	16
Cryptococcus diffluens ...	23	14
Rhodotorula flava ...	23	14
R. Glutinis ...	15	9
Debaryomyces nicotianae ...	7	4
Hansenula schneggii ...	3	2

Later investigations, making use of several husks in each containers, but keeping the husk-liquor ratio constant (1 : 10), revealed also the presence in them of yeast belonging to the species *Candida* and *Cryptococcus,* and bacteria belonging to the genera *Archromobacter,* though this may be purely incidental. Among those listed, *Micrococcus* species and *D. hensenii* play important part in the decomposition of phenolics, which is contained in the husk in considerable quantities.

When an attempt was made to follow the pattern of bacterial and yeast populations of coir rets, taking into consideration the two important factors influencing their population as (1) crushing of husks prior to their steeping for retting, and (2) aeration of the retting environment (Bhat, Nambudiri, and Rao, 1972), a picture similar to what was observed during the retting of *Malachra capitata* and *Hibiscus cannabinus* was observed (Betrabet and Bhat, 1959) (Tables 4 and 5). Crushing the husks prior to steeping and aerating the retting environment increased bacterial population of the rets. Maximum number was recorded in the third week of retting after which the number began to gradually diminish. The bacteria were identified to be *Pseudomonas, Achromobacter, Alcaligenes,* and *Bacillus* species. Of these, *Pseudomonas* was the most dominant at all stages (38-48%) and *Bacillus* the least (7-21%), the others being *Achromobacter* (14-31%) and *Alcaligenes* (13-28%). *Pseudomonas* species had previously been demonstrated as an important bacterium involved in the decomposition of pectin and retting of malvaceous plant straws (Betrabet and Bhat, 1958).

The maximum population of yeasts was recorded between the third and the fifth week (Table 5) and the species belonged to the genera *Candida guilliormondii, Cryptococcus diffluens, Candida paraspilosis, Rhodotorula*

TABLE 4. Incidence of bacteria during the progress of retting

Treatment	Number of bacteria/ml of ret liquor × 10^4						
	7 days	14 days	21 days	28 days	35 days	42 days	49 days
Uncrushed (Unaerated)	48	357	540	500	232	25	3
Crushed (Unaerated)	153	1330	5800	1980	173	178	2
Uncrushed (Aerated)	78	550	2980	2380	2030	438	31
Crushed (Aerated)	168	4900	8600	4300	1360	52	5

TABLE 5. Incidence of yeasts during the progress of retting

Treatment	Number of yeasts/ml of ret liquor × 10^3						
	7 days	14 days	21 days	28 days	35 days	42 days	49 days
Uncrushed (Unaerated)	7.4	25.3	58.4	46.4	36.0	36.3	16.2
Crushed (Unaerated)	11.5	67.0	85.0	52.0	15.2	12.5	1.2
Uncrushed (Aerated)	34.3	78.0	485.0	175.0	128.0	75.0	4.5
Crushed (Aerated)	79.0	194.0	990.0	810.0	106.0	12.0	3.3

flava, and *R. glutinis*, *Candida* was the predominant genus (Bhat, 1972). The pattern studied was of the experimental rets set up in the laboratory under controlled conditions in 70 cm^3 concrete cisterns, each with husks derived from 10 husks and steeped in 2% brine, and as such, might not have provided the exact picture of what in fact might be occurring under natural conditions. However, the one conclusion which is of considerable applied interest is that crushing of husks before steeping accelerated the retting process and thereby reduced the retting time. However, retting period varied with different batches of husks, the obvious factors influencing them being their composition, their maturity, temperature of retting, and solubility of oxygen in water. Crushing provides more accessible surface for the microbes to colonize and attack.

Bhat, Kuntala, and Prabhu (1973) studied the succession of microflora associated with the rets under different conditions such as aerobiosis, anaerobiosis, partial anaerobiosis, and with varying quantities of water, slime, inocula of mud from previous rets and presence or absence of NaCl in water was followed (Table 6).

TABLE 6. Nature of the succession of bacterial flora encountered in the different rets.

Date of sampling rets set on 6th July 1972	Cistern no. I	Cistern no. II	Cistern no. III	Cistern no. IV	Cistern no. V	Cistern no. VI
7 July 1972	*Aerobacter aerogenes*		*Alcaligenes metacaligenes*	*Alcaligenes faecalis*	*Paracolobactrum aerogenoides*	*Aerobacter cloacae*
25 July 1972			*Pseudomonas fairmontensis*		*Aerobacter aerogenes*	
1 Sept. 1972					*Pseudomonas*	*Alcaligenes metacaligenes*
4 Sept. 1972	*Alcaligenes faecalis*	*P. fairmontensis P. putida, Aerobacter cloacae*	*P. striata*	*Paracolobactrum intermedium P. striata, A.membranoformis*	*Alcaligenes faecalis, P. fairmontensis, Achromobacter delmarvae*	*P. putida, P. striata, E. freundii*
4 Oct. 1972	*P. putida, P. membrano formis*	*Paracolobactrum aeroginoides, Achromobacter liquifaciens, P. fairmontensis*	*P. putida, Aerobacter cloacae*	*Aerobacter cloacae, P. fairmontesis*		
13 Nov. 1972	*P. aeruginosa*			*Aeromanas liquifaciens*	*Alcaligenes marshalli*	
13 Dec 1972	*P. aeruginosa, Alcaligenes, marshalli, A. hookeri*	*Aeromonas liquifaciens, P. aeruginosa*	*E. freundii*	*Aeromonas liquifaciens*	*Alcaligenes vicolactis*	*Pseudomonas*

The bacteria of the rets, as always, were mostly gram negative short rods. They were identified as *Achromobacter liquifaciens* and *A. delmarvae*, *Aerobacter aerogenes*, and *A. cloacae*, *Alcaligenes faecalis* and *A. metacaligenes*, and *Paracolobactrum aerogenoides* and *P. intermedium*. All of them were dominant during the early stages of retting. *Pseudomonas* isolated at alater stage of retting were represented by *P. aeruginosa*, *P. membranoformis*, *P. fairmontensis*, *P. striata*, and *P. putida ;* a yeast species, not yet identified, was also isolated. The other predominant bacteria encountered in the ecosystem later were *Aeromonas liquifaciens* and *Escherichia freundii*. *Pseudomonas* spp. were conspicuously absent during the first week of retting when many *Aerobacter* and *Alcaligenes* spp. dominated. After 20 weeks, however, two new species of *Alcaligenes*, *A. marshalli*, and *A. vicolactis*, appeared. To conclude, species of the genera *Aerobacter* and *Pseudomonas* appeared to be common to all the rets, whereas the *Paracolobactrum* were present in three of six rets. *Aeromonas* species appeared almost at the end. The presence of salt did not seem to influence the microflora except for the fact that *Paracolobactrum* first appeared in salted rets, while *Aerobacter* and *Alcaligenes* appeared first in fresh water rets. Curiously, *Escherichia* were inconspicuous by their absence, except for one species *E. freundii* at the end. This would seem strange when examined against the observation that 26% of bacteria encountered in the natural rets were *Escherichia* species, but would not be surprising when we take into account that natural rets (unlike the laboratory rets) are subject to cross pollution by human activity. It is equally clear how *Pseudomonas* species, and not *Escherichia*, happen to dominate the scene under artificial retting conditions.

Chemistry of retting. From chemical viewpoint, retting may be defined as the process involving the degradation of pectic substances and polyphenols associated with the husks. Whereas retting of fibres in general, including that of jute, gets completed in the course of a few days, retting of coconut husks takes 6-9 months in most of the areas ; in certain areas, it does not get completed even after 11-12 months of steeping of husks. This was puzzling, until it came to be observed that in the retting of coir, degradation of pectic substances by microorganisms runs almost parallel to leaching away of phenolics irrespective of whether distilled water, 1% NaCl, or brackish water is used for steeping of the husks or not. For the removal of 60 g of the 75 g/kg polyphenols present in the husks, it takes no less than four months, and during the same period, only two-thirds of the pectic substances (12 g of the 17 g/kg present in the husks) get decomposed. This would mean that for retting to get completed (in chemical terms, removal of most of the pectic substances and polyphenolics present in the husks), a longer period than four months is essential, which in fact is the case in most of the natural retting yards as well as for the completion of rets set up in the laboratory.

To gain an insight into the mechanism of the processes involved in the

removal of phenolics and pectic substances from the husks, enrichment culture methodology was exploited using phenol and catechol as representatives of phenolics on one hand, and pure pectin as representatives of the pectic substances on the other (Bhat, 1966). As many as 330 bacterial cultures were isolated from pectin enrichments and 110 from these were examined for their ability to attack pectin and/or to identify them. Those found pectinolytic were *Aerobacter cloacae*, *Arthrobracter pascens pectinolyticus*, *Bacillus subtilis*, *Escherichia coli*, *E. freundii*, *Paracolobactrum aerogenoides*, and *Corynebacterium*. Some of these species have been mentioned earlier as involved in the experimental coir rets. Careful examination of the species clearly showed that whereas some of them possessed pectin polygalacturonase and pectin *trans*-eliminase, others elaborated the depolymerase and pectin methyl esterase. Strangely, none of the *Aerobacter* species were found to be pectionolytic. Of considerable importance was the novel finding that a *Micrococcus* species associated could attack pectin (Jayasankar and Bhat, 1964) due to its ability to elaborate pectin methyl esterase polygalacturonase as well as pectin *trans*-eliminase (also Agate, Jayasankar and Bhat, 1966).

Enrichment with phenol led to the isolation from ret liquors *Pseudomonas demolytica*, *P. fragi*, *P. dacunhae*, and *Micrococcus varians* (Jayasankar and Bhat, 1966 a). Since oxidation of phenol by *Pseudomonas* sp. was only followed, it grew luxuriantly in a medium containing 1.2 mg/ml of phenol and it could tolerate as much as 3.2 mg/ml of this wellknown bactericide. Interestingly, the organism could synthesize in the stationary but not shake cultures from phenol, a melanin-like pigment (Jayasankar and Bhat, 1966 a). The pigment was characterized as 3, 4, 3′, 4′-tetrahydroxydiphenyl (THDP). The formation of pigments from some other agromatic compounds such as by the *Micrococcus* was also demonstrated. An enzyme preparation made from this organism, a metapyrocatechase type, contained a phenol dehydroxylating system (Jayasankar and Bhat, 1966 a).

Equally valuable were the results obtained from catechol enrichments. Though catechol happens to be an important intermediate in the oxidation of phenol and similar other compounds, no organisms were till then shown to either grow in catechol or decompose it in the culture medium containing it, as the sole source of carbon. Significantly, catechol enrichments, unlike the phenol enrichments, which had resulted in the isolation of bacteria, promoted growth exclusively of one species of yeast, identified as *Debaryomyces hansenii*. From 40 enrichments, as many isolates were made of this yeast from different ret-liquor samples. The organism was typically lipolytic, but not pectinolytic, and, during earlier stages of development, formed a ring and smooth sediment. Significantly, the species could tolerate (Table 7) as much as 0.40% and 0.26% phenol. All the strains demanded biotin as accessory growth factor. The presence of catechol-cleaving enzyme was demonstrated in the species (Jayasankar and Bhat, 1966 b).

The detection of β-keto adepic acid in the culture filtrates of *D. hansenii* grown in phenol and catechol together with the finding that *cis-cis* muconic acid was formed in the reaction mixtures made with catechol led to

TABLE 7. Optimum concentration and tolerance limit of phenol and catechol for *D. hensenii* isolates

Substrate added	Concentration, mg/ml	
	Maximum growth	Tolerance limit*
Catechol	2.4	4.0
Phenol	1.5	2.6

*Beyond which no visible growth occurred.

the conclusion that the enzyme cleaving catechol was the pyrocatechase type. This enzyme like the phenol oxidizing enzyme mentioned earlier, was observed to be inducible (Jayasankar and Bhat, 1966 b) and formed only as a result of the adaption by the organism to catechol.

Is coir retting aerobic ? Repeated investigations over the years on coir retting have indicated that retting of this product is indeed an aerobic microbiological process. However, the observation that husks are retted under mud pits, wherein signs of hydrogen sulphide production are evidenced, led to the view that there probably exists anaerobic conditions under which husks undergo retting. Moreover, strictly anaerobic clostridial species have in the past been reported to possess the power to decompose pectic substances. Hence, a fresh attempt was made by collecting pieces of retted husks from retting yards and pits along with ret liquors and mud samples from several evidently anaerobic areas. These were then carefully examined microbiologically for the presence of strict anaerobic species (Bhat *et al.*, 1975).

Growth appeared in plates of solid media and tubes of suitabte liquid media inoculated with the materials incubated under both strict aerobic and anaerobic conditions. Both gave evidence of good growth. However, when the pure cultures of the latter organisms were carefully studied for their oxygen relationship, the cultures which grew "anaerobically" were seen to grow with equal facility under aerobic conditions as well. The bacteria were identified upto their genera but no efforts were made *to identify* yeasts, as they appeared by and large similar to those already identified (Bhat, 1972 ; 1973).

The predominant organisms present in ret liquors, mud, and husk samples were gram-negative rods and a few yeasts. Occasionally, interesting cocci, including a *Diplococcus*, were also encountered. It was not possible to identify this *Diplococcus*. The gram-negative rods belonged to

the genera *Pseudomonas*, *Aerobacter*, *Alcaligenes*, *Paracolobactrum*, and *Bacillus*. No strictly anaerobic species, like *Clostridium* was encountered in either clearly aerobic or apparently anaerobic retting yards anywhere in Kerala.

Often the yeast species were so closely associated with the gram-negative bacteria that the separation of the two organisms was often extremely difficult. Many techniques had to be followed to separate them. It is likely that the aerobic bacteria in association with yeasts function efficiently under anaerobic conditions, and together, these render the retting processes seem "anaerobic" in nature.

An equally interesting finding was that even rets set up anaerobically with a thick layer of paraffin oil on top of water in which husks were steeped failed to enrich growth of clostridia. Cistern nos. IV and VI of experimental rets (cf. Table 6) were set anaerobically (Bhat *et al.*, 1973). But, isolation of bacteria from this was either typically aerobic or facultatively only anaerobic. Thus, there is every reason to believe that retting is by and large an aerobic process, though anaerobic conditions may prevail and facultative anaerobes may function in the process.

Factors influencing retting. Obviously many factors, both major and minor, influence retting process. However, the factors, which were identified from the knowledge gained by retters and from research experience, were put to test (Bhat and Nambudiri, 1973).

Most retters in Kerala believe that retting of husks cannot be done in fresh water. Though, the presence of salt does prevent fouling of rets, fresh water rets complete the retting and yield fibre, comparable in both colour and yield to that obtained from salt water rets. As the result would amply reveal, the decomposition of both pectic substances and polyphenols occur simultaneously and run more or less on similar patterns in distilled water, 1% sodium chloride, or brine. During the first 30 days of retting, a more rapid attack on these substrates evidently occurs in brine. This might explain the lack of fouling in brine and perhaps also acconut for the yield of slightly superior fibre. The view that NaCl is not essential for retting became clear from the finding that the fibres obtained from different rettings were alike in quality (Tables 8 and 9). The effects of salt, crushing, and flushing have all been examined under controlled conditions previously (Bhat and Nambudiri, 1973). Experiments carried out to ascertain if flushing off of ret liquors at intervals and replacement with fresh water to the original volume has any effects revealed that renewal of ret liquor at 10 days interval is indeed beneficial and yields first grade fibre. Too intensive and/or frequent flushings however affected the process adversely as this might presumably be leading to the flushing away of advantageous colonized microbes. The results recorded in the laboratory indeed could be correlated to what is in fact occurring under field conditions. In other words, tides have pronounced effect on retting time and fibre quality.

TABLE 8. Residual pectin* content of the husks during the progress of retting (expressed as percentage)

Days of retting	Flushed				Not flushed				Control
	2% NaCl		3% NaCl		2% NaCl		3% NaCl		
	A	B	A	B	A	B	A	B	
Crushed									
30 days ...	85.00	86.00	83.00	84.00 ...	85.00	86.00	84.00	84.00 ...	85.00
60 days ...	75.00	76.00	71.00	74.00 ...	75.00	76.00	74.00	75.00 ...	75.00
90 days ...	25.00	24.00	28.00	27.00 ...	28.00	26.00	25.00	25.00 ...	27.00
Uncrushed									
30 days ...	91.00	90.00	89.00	91.00 ...	90.00	91.00	89.00	90.00 ...	91.00
60 days ...	80.00	80.00	79.00	78.00 ...	81.00	80.00	79.00	81.00 ...	80.00
90 days ...	60.00	59.00	60.00	58.00 ...	60.00	62.00	61.00	60.00 ...	61.00

A and B are treatments with material : liquor ratios of 1 : 10 and 1 : 20 respectively.
*Ripe coconut husks contained 7.25% polyphenols and 2.00% pectin.

TABLE 9. Residual polyphenol content* of the husks during the progress of retting (expressed as percentage)

Days of retting	Flushed				Not flushed				Control
	2% NaCl		3% NaCl		2% NaCl		3% NaCl		
	A	B	A	B	A	B	A	B	
Crushed									
30 days ...	46.61	47.27	49.03	49.31 ...	84.80	86.90	87.03	88.13 ...	86.56
60 days ...	38.34	34.99	42.74	39.25 ...	63.40	62.03	62.89	60.02 ...	63.72
90 days ...	24.80	21.88	24.80	23.60 ...	24.80	24.11	26.85	26.90 ...	28.12
Uncrushed									
30 days ...	86.90	85.51	86.20	84.82 ...	96.96	96.55	96.55	96.55 ...	95.82
60 days ...	63.72	64.80	60.00	67.66 ...	72.00	74.00	75.00	76.81 ...	76.81
90 days ...	51.72	49.93	54.00	53.09 ...	67.57	66.48	68.00	67.00 ...	68.27

A and B are treatments with material : liquor ratios of 1 : 10 and 1 : 20 respectively.
*Ripe coconut husks contained 7.25% polyphenols and 2.00% pectin.

The husk of a coconut obtained in the market will normalty comprise of four split pieces. Splitting into more pieces, or alternatively, light mechanical crushing, it was thought possible, would provide greater surface exposed to water, air, microbial agencies, and other factors affecting retting. Experiments carried out indeed proved the case to be so. Crushing reduced retting time considerably, but the resultant fibre was somewhat inferior to that derived from uncrushed husks in both colour and uniformity. Apparently, crushing increases exposed surface but the process results in the exudation of polyphenols which get oxidized and deepens the colour– a situation not met with in uncrushed husks. The crushing operation, however, provides more surface accessible for the nicrobes to colonize, and thereby, enhances the breakdown of both pectin and polyphenols (Bhat and Nambudiri, 1973). Washing immediately after crushing, was resorted to for minimizing the oxidation of polyphenols ; this, no doubt, improved the colour, but not uniformily of the fibre. In other words, crushing cannot be recommended from the standpoint of quality, but highly desirable on economic consideration. In some areas like Alempidika, an intermediate crushing is resorted to, and this has been observed to cut down steeping period by about two months.

In the case of other natural fibres, aerating the retting environment has been attempted to accelerate the process. In jute, for example, partial aeration yields better results. Since the microflora associated with coir retting are by and large aerobic, aeration resulted not only in an enormous increase in their number but also in slightly faster degradation of pectin and polyphenols. This is believed to even hasten decomposition of fermentation products of husks constituents, and as such, brings about a favourable effect on the product. In the presence of adequate oxygen (provided by shaking), catechol breakdown by *Micrococcus*, a dominant species, for example, does not lead to the formation of the dark pigment 3, 4, 3′, 4′-tetrahydroxydiphenyl.

References

Agate, A.D., Jayasankar, N.P. and Bhat, J.V. (1966). Pectin *trans*-eleminase. *Curr. Sci.* **35**: 503-505.

Betrabet, S.M. and Bhat, J.V. (1958). Pectin decomposition and the role of *Pseudomonas* in the process. *Appl. Microbiol.* **6** : 89-92.

Betrabet, S.M. and Bhat, J.V. (1959). Microfloral changes occurring in the rets of certain malvaceous plants. *Proc. Golden Jubilee Res.* Vol. pp. 231-239. Indian Institute of Sciences, Bangalore.

Bhat, J.V. (1966). Enrichment culture technique. *J. Sci. & Industr. Res.* **25** : 450-454.

Bhat, J.V. (1971). The coir fibre. *Coir* **16** (Oct.) 37–41.

Bhat, J.V. (1973). Investigations on retting of coconut husks Report submitted to Coir Board, Cochin.

Bhat, J.V. and Nambudiri, A.M.D. (1971). The uniquity of coir retting. *J. Sci. & Industr. Res.* **30** : 720-728.

Bhat, J.V. and Nambudiri, A.M.D. (1973). Effect of some of the environmental factors on quality of coir. *Coir* (Jan.). **17** : 23-25.

Bhat, J.V. Kuntala, K.G. and Prabhu, G.N. (1973). Succession of bacterial species in the experimental rets. *Coir* **17(3)** (Apr.) : 21-23.

Bhat, J.V., Nambudiri, A.M.D. and Rao, B.V. (1972). Pattern of bacterial and yeast populations of coir rets. *Coir* **17** (Oct.) : 13-15.

Bhat, J.V., Jayasankar, N.P., Agate, A.G. and Bilimoria, M.H. (1968). Microbiological degradation of pectic substances. *J. Sci. & Industr. Res.* **27** : 196-203.

Bhat, J.V., Prabhu, G.N., Varadarajan, P., Kuntala, K.G. and Ambuja, R. (1975). Investigations on "anaerobic" retting of coconut husks *Coir* (Jan.) **20** : 27-29.

Heyn, A.N.J. (1952). *Chem. Abstr.* 5322 (original not seen).

Jayasankar, N.P. (1966). Studies on the aerobic microflora associated with the retting of coconut husks. PhD Thesis. Indian Institute of Sciences, Bangalore.

Jayasankar, N.P. and Bhat, J.V. (1964). The role of *Micrococcus* species in coir fermentation. *Curr. Sci.* **33** : 369.

Jayasankar, N.P. and Bhat, J.V. (1966 a). Mode of attack on phenol by a *Micrococcus* sp. isolated from coir rets. *Canad. J. Microbiol.* **12** : 1031-1039.

Jayasankar, N.P. and Bhat, J.V. (1966 b). Isolat on and properties of catechol cleaving yeasts from coir rets. *Antonie van Leuwenhock* **32** : 125-134.

Jayasankar, N.P., Agate, A.D. and Bhat, J.V. (1967). Evidence for the role of *Micrococcus* sp. in the retting of coconut husk. *J. Indian Inst. Sci.* **49** : 10-18.

Discussion

Jeganathan : Does your work apply to the production of white fibre or brown fibre ?

Bhat : If the ratio of water to husk is high and if the husk is not exposed too long to sun and air, then our formation (browning) is minimized and the resultant fibre is of better colour.

Coconut Palm and Palm Kernel Oils—A Comparison

N.C. GANGI REDDY, T. OBI REDDY, D. ATCHYUTA RAMAYYA,
G. AZEEMODDIN and S.D. THIRMALA RAO
Oil Technological Research Institute, Anantapur 575 001, A.P., India

Abstract

Fats from palms are important because of total quantity produced and because they differ in composition from most fats originating in colder climates. In this paper, a comparison of important characteristics and standards in different countries for coconut oil, palm oil, and palm kernel oil is presented. In view of the varied uses of latter oils and their probable commercial availability in future, it has become necessary to lay down standard for those oils.

Introduction

The palms are a family of plants with a pantropical distribution. After grasses (cereals), they are the most useful of plants. Every part of a palm tree is useful in some way or the other. Among the produces of palms are sugar, milk, fat, wax, fibres, wood for building, leaves for thatch, basket, mats, screens, etc. That is why the term '*kalpa vriksha*' is applied to palm trees in general in India.

Palm fruits are generally rich in sugars, starch, and proteins. Fruits of some palm species also contain fat. Among these, coconut palm and oil palm are outstanding as major sources of oil. These oils are by and large of saturated type and are solid at temperate climates. The world production of coconut oil is 17,77,000 tonnes, palm oil 25,00,000 tonnes and palm kernel oil 4,90,000 tonnes ; (Total : 47,67,000 metric tonnes), as against 88,20,000 tonnes soyabean oil, 41,00,000 tonnes sun flower oil, 29,00,000 tonnes cottonseed oil, and 24,00,000 tonnes each of groundnut oil and rapeseed oil. Thus, palm oils constitute the largest source of vegetable fat after soyabean oil.

Coconut plantations are well established in India. Realizing the growing importance of palm oil, efforts are being made to raise oil palms in certain parts of the country (Anonymous, 1976).

In parallel with the development of plantations, exploratory work on the characteristics of palm fruits grown in experimental plantations has

TABLE 1. Specifications for coconut oil in different countries

Sl. No.	Characteristics	International (Standard Codex FAO)	American Oil Chemists Society	British Standards ES : 684	Indian Standards						
					Refined grade	Grade IA(Raw)	Grade IB(Raw)	Grade 2(Raw)	Refined grade	Semi-refined	Grade-1 (Raw)
1.	Moisture and insoluble impurities (per cent by weight, maximum)	...	...	...	0.10	0.25	0.25	0.25	0.10	0.25	1.00
2.	Colour in a 1-in cell on the Lovibond scale expressed as Y+5R	Not deeper than 4 in virgin oil ; 2 in non-virgin oil	...	Colour of the filtered oil shall not be deeper than 5Y+1.2R units (11)	2	4	11	30	2	10	30
3.	Refractive index at 40°C	1.448-1.450	1.448-1.450	1.4485-1.4492	1.4480–1.4490						
4.	Specific gravity 30°C	0.915-0.922	0.917-0.919	...	0.915 –0.920						
5.	Sponification value, Min.	248-264	248-264	248-264	250						
6.	Iodine value (Wijs)	7.0-11.0	7.5-10.5	7.0-11.0	7.5-10.0	7.5-10.0	7.5-10.0	7.5-10.0	7.5-10.0	7.5-10.0	8.0-13.0
7.	Acid value, Max.	1.00-2.81 in virgin oil ; 0.10-.28 in non-virgin oil	...	Not greater than 14.1 : equivalent to 5.0% by mass of FFA	0.5	2.0	6.0	8.0	0.5	1.0	10.0
8.	Unsaponifiable matter per cent by weight, Max.	0.5-0.8	Below 0.5	Not more than 0.8	0.5	0.8	0.8	0.8	0.5	0.8	1.0
9.	Polenske value, Min.	13.0	14.0-18.0	...	13.0	13.0	13.0	...	13.0	...	...
10.	Flash point Pensky Martens (closed) °C Min.	...	...	...	...	...	...	...	225	100	90

TABLE 2. Specifications for palm oil

Sl. no.	Characteristics	Requirements for type		Draft International Standards Codex Committee on Fats and Oils (FAO & WHO)
		Raw	Refined	
1.	Moisture and insoluble impurities, per cent by weight, Max.	1.5	0.1	1.5
2.	Colour in a 25.4 mm cell on the Lovibond scale expressed as Y+5R, not deeper than	—	25	—
3.	Refractive index at 40°C		1.43-1.46	1.45-1.46
4.	Specific gravity at 30°C/ 30°C		0.883-0.925	—
5.	Saponification value	193-200		196-198
6.	Iodine value (Wijs)	52-67		21.0-22.5
7.	Acid value, Max.	20	1	20
8.	Unsaponifiable matter by weight, Max.	1	1	—

TABLE 3. Specifications for palm kernel oil

Sl. no.	Characteristics	Requirements for type		Draft International Standards Codex Committee on Fats & Oils (FAO & WHO)
		Raw	Refined	
1.	Moisture and insoluble purities, per cent by weight, Max.	0.25	0.10	0.35-0.50
2.	Colour in a 25.4 mm cell on the Lovibond scale expressed as Y+5R, not deeper than	30	10	27.5
3.	Refractive index at 40°C		1.44-1.46	1.449-1.451
4.	Specific gravity at 30°C/ 30°C		0.915-0.920	—
5.	Saponification value		228-252	237-252
6.	Iodine value, (Wijs)		14-20	13-23
7.	Acid value, Max.	6	0.5	6
8.	Unsaponifiable matter per cent by weight, Max.	1	1	1.0-1.2

been taken up in Oil Technological Research Institute, Anantpur since 1967. It is now considered an opportune time to suggest specifications for palm oil and palm kernel oil. Standard specifications for coconut oil in different countries are given in Table 1. Specifications for palm oil and palm kernel oil are proposed in Table 2 and 3.

Oil palm fruits, which are botanically drupes, contain broadly two parts, the outer fleshy part or pulp called pericarp, and the inner seed or nut called stone. The stone consists of a hard shell and 1-3 kernels inside. Pulp forms about 40-70% of the fruit. Major portion (about 66-80%) of the pulp yields the famous red palm oil. Kernel constitutes about 6-12% of the whole fruit and contains about 48-50% oil, called palm kernel oil.

Uses

Coconut oil. In western countries, coconutoil is more important as an ingredient of margarine than as a cooking fat. It is also used in confectionery, mainly as a substitute for cacao butter. Coconut oil is used as a cooking oil only along the west coast of India. The first choice of soap manufacturers of fats or oils is invariably coconut oil. It is also used for preparing high grade cosmetics such as face creams, ointments, hair oils, and shampoos. It has some industrial uses in production of plasticizers, manufacture of safety glass for aeroplanes and motor cars, etc. It is used for making synthetic resins, which is used in lining of food containers. It is also used in the making of rubber substitutes such as hospital sheetings. Lauryl alcohol, an important derivative of coconut oil, is used in the manufacture of vulcanized rubber materials such as tyres, pumps, etc. It is also used in dyeing textiles, electroplating, and in insulating materials. Diethanolamides from mixed cacao fatty acids, or from capric/caprylic acids act as efficient desuckering agents in tobacco plant. Lauryl chloride, an oil meal protein extract, condensates from Schotten-Baumann reaction, constitutes an excellent biodegradable detergent.

Palm oil. It has excellent soap-making properties. It is well suited for use as cooking oil and for making margarine and shortening after suitable refining. Considerable quantities of palm oil are being used in hotdip tin plating industry in India. The oil is rich in carotenoid pigments like lycopene, β-carotene, and vitamin E (tocopherol). It is a good source of saturated fatty acids.

Palm kernel oil. The traditional uses of palm kernel oil are in soaps, margarine, and cooking. It is used as a substitute to coconut oil. The non-traditional uses are for making synthetic detergents, confectionery, biscuits, ice cream and bakery products. It is also a source for lower fatty acids like caprylic, capric, and lauric acids.

Palm oil contains glycerides of both saturated and unsaturated fatty acids. Palmitic is the main saturated acid (37-50%) and thus the oil is of

special value in soap making. Oleic and linoleic (45-60%) are the main unsaturated ones. Palm kernel oil contains mainly saturated fatty acids like lauric, myristic, palmitic, etc. (80%). It also contains unsaturated fatty acids, mainly oleic acid (13-20%).

Coconut oil contains mainly saturated fatty acids such as lauric, myristic, palmitic, etc. (85%) and about 15% unsaturated fatty acids. Thus, palm kernel oil resembles coconut oil in many respects (Table 3).

References

Anonymous (1976). Oil palm: New sources of edible oil. *Indian Express*, 8 Sept. issue.

Thirumala Rao, S.D., Ramachander, D. and Krishna Murthy, G. (1968). Colour reaction of red palm oil. *J. Amer. Oil Chem. Soc.* **45** : 480.

Obi Reddy, T. and Thirumala Rao, S.D. (1969). Oil palm of Indian habitat. I. Technology of oil palm of Andhra Pradesh. *J. Oil Techn. Assn. India* **1** : 18-21.

Obi Reddy, T. and Thirumala Rao, S.D. (1969). Oil palm of Indian habitat. II. Technology of oil palm of Kerala. *Indian Oil & Soap J.* **35** : 107-116.

Thirumala Rao, S.D. (1970). Techno-economics of palm oil with special reference to India. East India Oil Millers Association, Calcutta.

Obi Reddy, T. and Thirumala Rao, S.D.(1971).Oil palm of Indian Habitat.*Oleagineux* **26** : 263-266.

Obi Reddy, T., Thirumala Rao, S.D. and Reddy, B.R. (1971). Oil palm of Indian habitat. IV. *Indian Oil & Soap J.* **37** : 75-76.

Gangi Reddy, N.C., Obi Reddy, T., Thirumala Rao, S.D. and Reddy, B.R. (1974). Oil palm of Indian habitat. V. Hybrid palm-1. *Coconut Bull.* **5(6)** : 2-3.

Gangi Reddy, N.C. and Thirumala Rao, S.D. (1975). Oil palm of Indian habitat. VI. Hybrid palm-2. *Coconut Bull.* **6(3)** : 1-2.

Activated Carbons from Coir Fibre Pith

A. ASLAM ALI
Karnataka Carbons Private Limited, 510, V Block Jayanagar, Bangalor, 560 041 India

Abstract

The technological feasibility of producing activated carbons from coir fibre pith obtained from coir factories was studied. The surface areas, adsorptive capacities, and mechanical strength of different samples were determined. Methods by which the adsorptive capacities could be increased are discussed.

Introduction

Activated carbons are produced commercially from various carbonaceous materials. Several industries employ direct physical activation methods, and some others, chemical activation methods to produce various grades of carbons for gaseous and liquid phase adsorption (Bond, 1967; Hassler, 1963). The present investigations were undertaken to study the effect of physical and chemical activation on coir fibre pith at different temperatures.

In India 20-25,000 tonnes of coir fibre pith is available annually from the various coir industries operating in the States of Andhra Pradesh, Karnataka, Kerala and Tamil Nadu (Tendolkar and Thakoor, 1953). This coir fibre pith, when converted into activated carbons, could be successfully utilized for various adsorption processes (Mantell, 1951; Shetty, 1976). Experimental results have shown that coir fibre pith, impregnated with chemicals, and then steam-activated, gives the best activated product.

Experimental Procedure and Discussions

Coir fibre pith from several areas were collected to represent sound coir fibre pith from coir industries heaped and thrown as waste for upto six months. They were sound, with no fibre or shell pieces, but containing water.

Coconut shell coarse powder was also prepared with shells obtained from different places. These shells had also been stored for upto six months.

Briquetting was carried out to obtain materials of uniform size (6.4 sq. cm) with wood tar as binding agent. Briquettes were produced with coir fibre pith and coir fibre pith blended with coconut shell coarse powder in the ratio of 1:1, 1:0.8, 1: 0.4, and 1:0.2.

Carbonization of briquettes was carried out at 325°-600°C in both the horizontal furnace and vertical furnace. The horizontal furnace was found to be more suitable than the vertical one because of the following reasons:

1. The briquettes are dumped down from the top of the vertical furnace. Presumably, it takes some time before it is elevated to the top of the furnace and dumped in. The briquettes that were at 100°C at the top when the lid is kept open for dumping fresh briquettes cool down and thus, some heat is lost during continuous carbonization in vertical furnaces.
2. The heat for carbonization in the vertical furnace is generated by burning some charcoal in the furnace. This lowers the yield of charcoal.
3. In the vertical furnace, the yield of tar is adversely affected, because, as the heat is generated inside, some constituents of tar, more especially, the low boiling ones, will burn away and lower the yield as compared to horizontal furnace.
4. In the case of vertical furnace, the yield of tar is further reduced in another manner. During the burning of charcoal to generate heat, the gases, tar vapours, and droplets travel at high speed, and as the action of the exhaust fan gets changed with static electricity, a part escapes condensation both in the condenser and in the tar separation.
5. In the case of horizontal retorts, the distillate condenses in three layers, tar, pyroligram, and shell oil, whereas in vertical reports, the oil will be lost.
6. Horizontal retorts gives higher yields of distillation products.
7. Uniform quality of charcoal can be produced in horizontal retort by maintaining desired carbonization temperature.
8. In the case of vertical retort, in spite of best efforts and even with the best method of discharge, 10-15% of the charcoal at least becomes power, thereby making it not usable for activation.

The yield of charcoal ranged from 26-34% with an average of 31%. This corresponds to approx. 310 kg of charcoal/tonne of coir fibre pith. In the case of blended material, the charcoal obtained was about 2% more. The average yield of carbonization of two samples of a mixture of coir fibre pith and coconut shell coarse powder (temperature: 350°C) was: charcoal 31.1%; tar 7.3%; pyroligenous liquor 43.7%; and uncondensible gases 17.9%.

The average composition of pyroligenous liquor (including tar) was: methanol 3.0%; acetic acid 7.0%; tar 20.0%; and water 70.0%. The average composition of uncondensable gases was: carbon dioxide 51.0%; carbon monoxide 28.0%; methane 6.0%; hydrogen 2.5% and oxygen

2.5%. A small percentage of air was mixed with the uncondensable gases and fed back to heat the retorts.

The temperature and method of distillation have a marked effect on the composition and properties of charcoal. The charcoal obtained in horizontal retorts by carbonization at 350°C ensured complete carbonization and possessed the best activity. The importance of completing the carbonization is to obtain a charcoal with higher calorific value, higher density, and lesser liability to spontaneous cumbustion.

The blending of coconut shell coarse powder with the coir fibre pith increased the density of charcoal, which ultimately resulted in material of higher structural strength and higher adsorbing capacity per volume of adsorbent.

The charcoal briquettes produced in the horizontal retorts were steam-activated at 800°C, 900°C, 950°C, and 1000°C and the comparative values of these activated carbons were obtained by testing the iodine adsorptive values. The results (Table 1) showed that briquettes carbonized at 350°C and activated at 950°C yielded the best activated products. The optimum

TABLE 1. Direct steam activation of charcoal obtained from coir fibre pith charcoal briquettes and from coir fibre pith blended with coconut shell coarse powder

Temperature of activation	Iodine adsorption value	
	Coir fibre pith charcoal briquettes	Coir fibre pith blended with coconut shell coarse powder
800°C	78.9	82 8
850°C	80.5	83.9
900°C	81.7	85.7
950°C	83.2	87.9
1000°C	82.9	87.6

time of steaming at 950°C was not recorded as it depends on a number of parameters, and with every increment of time, slight increase of activity has been recorded. Steaming for longer periods therefore decreases the yield of carbon considerably.

The briquettes were also tested for mechanical strength. Only the briquettes which had been blended with 1:1 coconut shell coarse powder with coir fibre pith had sufficient mechanical strength to withstand the abrasion incident to continued use. To provide even better mechanical strength, the activation period should not be more than 45 min at 950°C and all the other parameters responsible for activity should be carefully observed and controlled.

Experiments were carried out with coir fibre pith and coir fibre pith blended with coconut shell coarse powder treated with zinc chloride prior to carbonization and activation. The carbonization of impregnated material yielded more charcoal with less percentage of tar. In some of the samples, the tar obtained was almost negligible. The charcoal thus obtained was activated at 800-1000°C. The activity tests revealed that a concentration of 100% zinc chloride yielded the best activity product at 950°C but a concentration beyond 100% zinc chloride decreased the activity.

The results of activation of briquettes obtained at 800-1000°C temperatures (Table 2) showed that the impregnated material gets highly activated by steaming treatment at 950°C. The activity was the highest for charcoal briquettes obtained at 350°C.

TABLE 2. Steam activation of $ZnCl_2$ impregnated coir fibre pith charcoal briquettes and of $ZnCl_2$ impregnated charcoal obtained from coir fibre pith blended with coconut shell coarse powder

Temperature of activation	$ZnCl_2$ impregnated coir fibre pith charcoal briquettes	$ZnCl_2$ impregnated charcoal obtained from coir fibre pith blended with coconut shell coarse powder
800°C	87.5	90.7
850°C	88.9	91.9
900°C	90.1	92.5
950°C	91.2	93.0
1000°C	90.8	92.8

For every 1000 kg of charcoal briquettes obtained at 350°C, approx. 200 kg of highly activated carbon was obtained. In terms of yield based on raw coir fibre pith, for every 1000 kg of coir fibre pith, 65 kg of highly active carbon was obtained. The increase in temperature rate not only turns out the carbon much blacker but also reduces very much the yield of carbon. The porosity of the available source increases only upto 950°C temperature. Beyond this point, the mass of activated carbon per unit of surface falls off so much that the adsorption decreases considerably.

Another point that was considered was the cleanliness of the adsorbing surface. Due care should be given to clean the charcoal surface to increase the adsorbing surfaces. This could be well achieved in horizontal retorts. In case of brick kilns or vertical retorts, we come across too much material handling which ultimately affects the activity. These are the points that should be given prime importance in commercial production programmes.

The studies so far carried out show that spheroidal and cylindrical shapes of active carbon particles give better activity.

Conclusions

Coir fibre pith could be utilized as a raw material for producing activated carbons, which, while different from equivalent commercial products, might find similar applications.

The charcoal obtained in horizontal retorts at 350°C gives the best activated carbon.

The activating temperature should be maintained throughout the process at 950°C.

The raw material impregnated with $ZnCl_2$ gives superior grades of activated carbons than that without any impregnation.

Acknowledgements

I thank Mr Raghavendra Char, Head of the Department of Chemistry, D.R.M. College, Davanagere, for giving me facilities to carry out the work in his laboratory.

References

Aslam Ali, M. (1969). *Feasibility cum Techno-Economic Report :* Manufacture of Wood and Coconut Shell Activated Carbon. 88 pp., Balaji Chemical Industries, Arsikere, Karnataka, India.

Bond, R.L. (1967). *Porous Carbon Solids.* 311 pp. Academic Press, London.

Hassler, J.W. (1963). *Activated Carbon.* 396 pp. Chemical Publishing Co., New York.

Mantell, C.L. (1968). *Carbon and Graphite Hand Book.* 538 pp. Interscience, New York.

Shetye, G.D. (1976). *Activated Carbon as Catalyst Support.* 31-39 pp. *in* Sychem Series No. 4 (Ed. P.V. Kannan), Sychem Organization, Bangalore 560 041, India.

Tendolkar, G.S. and Thakoor, N.R. (1953). Steam activation of coconut shell charcoal. *J. Sci. Industr. Res.* **12B** : 221-223.

Building Materials from Coconut Husk and Its By-Products

JOSEPH GEORGE
Indian Plywoods Industries Research Institute,
Bangalore 560 022, India

Abstract

Coconut husk is a unique raw material. Particles of the husk can be consolidated into boards with little or no adhesive at pressures and temperatures normally employed for particle board manufacture. The boards, which can be made in a wide range of densities, have physical and mechanical properties conforming to the requirements of Indian Standard specifications for article boards. The boards also have moderate resistance to termites, fungi, and fire. They should be suitable for low cost constructions, particularly as roofing panels.

Layered particle boards with coconut husk particle core and wood particle faces can be produced where the characteristic appearance of wood-based boards is combined with the advantages of coconut husk boards.

Retting, leaching, and bacterial action destroy the self-bonding property of coconut husk. By-products of coir industry such as retted pith, baby fibre, and shearing waste therefore require adhesives to convert them into panel materials. Retted pith bonded with portland cement can be made into slabs of high thermal insulation value.

The wood-based particle board industry in the country is operating at a level far below the installed capacity, primarily because of the high cost of synthetic resin adhesives. This points to the need for a detailed investigation of coconut husk as a raw material for particle boards. Out of about two million tonnes of husk produced annually in India, about one million tonnes do not find any industrial use at present.

Introduction

The self bonding ability of "coir dust and shorts" under heat and pressure was first obsesved by Floro (1954) who prepared soft and hard boards from the material without the use of any adhesive. The coir dust and shorts were obtained during the mechanical separation of coir bristles from unretted coconut husk. The boards were strong, durable, water repellent, and fire retarding.

The self bonding ability was made use of in the preparation of particle boards of a wide range of densities from coconut husk by George and co-workers (George, 1964, 1970; George and Joshi, 1959; George and Best, 1962; George and Shirsalkar, 1963), who also carried out explora-

tory work on building materials (Fig. 1) from the by-products of coir industry (George, 1961; George and Joshi, 1960; Jain and George, 1970; Jain, Singh, and George, 1964 ; Shirsalkar, Jain, and George, 1964). A range of products have been made from coconut husk and its by-products (Table 1). The preparation and properties of a few of these products are briefly described below.

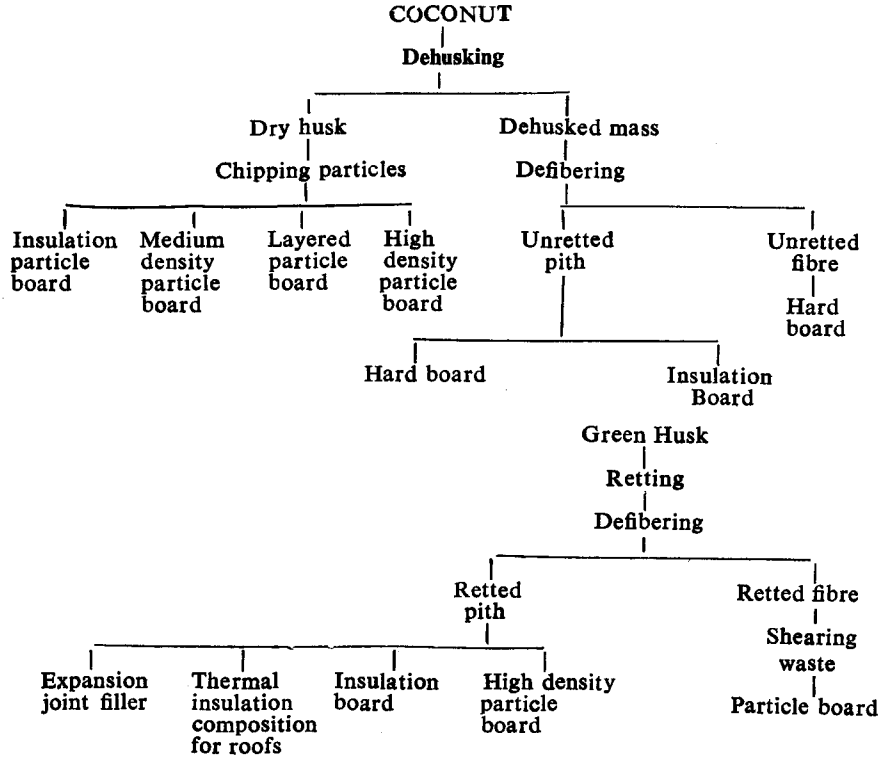


Fig. 1 Building materials from coconut husk and its by-products

Particle Boards From Coconut Husk

The preparation of particle boards from coconut husk follows the same procedure as for the preparation of particle boards from wood which is shown schematically in Fig. 2. Wood is chipped, mixed with a synthetic resin adhesive and a water repellent, and hot-pressed to obtain particle board. Urea-formaldehyde and phenol-formaldehyde resin adhesives are normally employed. They constitute about 8-12% of the weight of the board. The husk of mature coconut was used for laboratory experiments as well as for trial production in a particle board factory. Air-dry husk was chipped into particles of suitable size. This operation was carried out manually because industrial wood chippers were found to be unsatisfactory for chipping coconut husk. The latter caused the separation of fibre in the husk from pith during chipping. Fibre without the pith has poor

bonding characteristics. Fairly satisfactory chippers are now available.

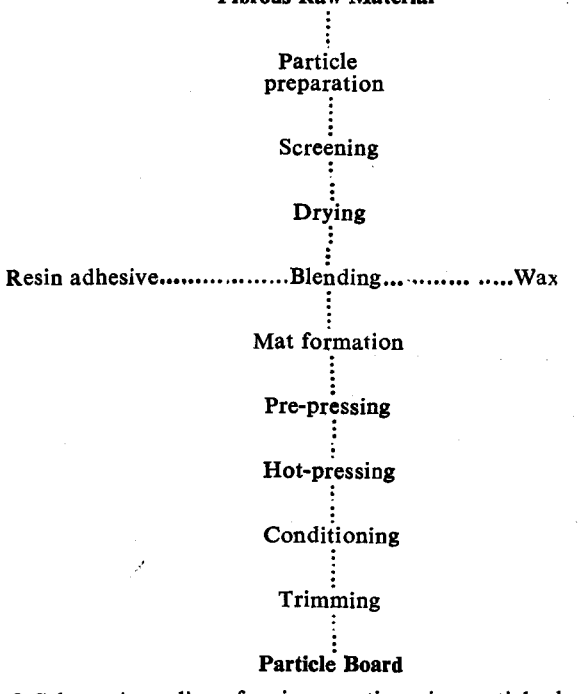


Fig. 2 Schematic outline of main operations in particle board manufacture by the batch process in a flat-platen press

Particle boards are manufactured in different densities for different purposes. Boards of density less than 400 kg/m^3 are produced for thermal insulation. Medium density general purpose boards of 500-900 kg/m^3 density are used in construction and for furniture. High density boards, 900-1200 kg/m^3, are used in engineering industries. Finally, veneered particle boards are made for furniture, building, transportation, and other industries. Coconut husk is a satisfactory raw material for boards in the whole range of densities mentioned above (George, 1964; George and Joshi, 1959; George and Shirsalkar, 1963). These boards can also be veneered in the same manner as boards from wood. Table 1 gives the properties of few boards.

Boards upto 1.3 sq m (14 sq. ft) size were made in the laboratory and larger boards in a particle board factory. The cost of production of coconut husk particle board is estimated to be less than half the cost of production of wood-based particle board (George, 1964).

Coconut husk suitable for coir making is systematically collected from the coconut growing areas of Kerala and brought to the retting areas. The same system of collection could be used to collect husk for making particle boards also. Even if only 10% of the industrially unused husk is collected, the quantity would be about 1,00,000 tonnes, sufficient to manufac-

TABLE 1. Properties of particle boards from coconut husk

Adhesive %	Other additives	Density kg/m³	Modulus of rupture kg/cm²	Water absorption in 24 hr soaking (%)*
Nil	Paraformaldehyde 1%	250	22	113.5
0.5	Nil	510	138	151.0
0.5	Nil	760	233	97.8
0.5	Nil	900	368	88.5
Nil	Paraformaldehyde 1%	1070	373	23.6
Nil	,, ,,	1210	365	16.0
Nil	Nil	1310	254	10.6
Requirements of IS: 3129-1965		Not above 400	15	—
Requirements of IS: 3087-1965		500 to 900	90	70.0
Requirements of IS: 3478-1966		Above 900	225	15.0

*No water repellent was incorporated in the boards.

ture 7.3 million sq. m (79 million sq. ft) of boards of 19 mm (3/4 in) thick ness and having a density of 640 kg/m³ (40 lb/cu. ft).

Wood-coconut husk three layer particle boards were also prepared in which wood particles were coated with the normal proportion of adhesive (George and Bist, 1962). The proportion of adhesive on the board weight was less than normal. Wood chips were used for faces of the board. Table 2 gives the properties of few three layer boards.

TABLE 2. Properties of wood-coconut husk three-layer particle boards

Species of wood	Adhesive in board in per cent	Weight of adhesive on wood particles per cent	Density of board kg/m³	Modulus of rupture kg/cm²	Water absorption in 24 hr soaking* per cent
Toon	PF, 2.8	10.0	740	176	56.3
White cedar	PF, 3.2	7.1	680	210	58.0
Teak	PF, 3.9	8.2	550	715	76.5
Mango	UF, 7.1	12.0	700	165	59.4
Teak	UF, 8.4	11.7	890	324	25.4

PF—Phenol-formaldehyde resin. UF—Urea-formaldehyde resin

*No water repellent was used in these boards

Boards from Unretted Coconut Pith

The reactive nature of the pith obtained by defibering mature coconut husk can be made use of to convert it into dense, strong, highly water resistant

hard board-like boards by hot pressing (George and Joshi, 1959). No additive of any kind is necessary. Properties of such boards are given in Table 3.

TABLE 3. Properties of boards from unretted coconut pith-without any binder or additive

Density kg/m³	Modulus of rupture kg/m²	Water absorption in 24 hr soaking per cent
1210	289	15.6
1300	293	11.2
1390	396	11.3

Building Materials from Retted Pith

Pith from retted coconut husk has a bulk density of about 100 kg/m³ and show good recovery after compression. This property was made use of for the preparation of extension joint filler used between concrete slabs in roofs, roads and runways to accommodate thermal movement (Jain *et al.*, 1964) The joint filler consisted of cashewnut shell liquid resin filled with coconut pith. Properties of joint filler are given in Table 4.

TABLE 4. Properties of expansion joint filler

Pith in filler %	Load for 50% compression kg	Recovery %	Loss in weight %	Extrusion cm³
33	31	90	0.8	3.5
20*	40	83	0.0	1.5
Requirements of IS : 1838-1961	7-53	70	3.0	(6.5)

The pith can be used as a light weight aggregated for low density concrete of thermal insulation of roof slabs. Pith cement concrete of density around 500 kg/m³ is considered best for roof insulation. It has a thermal conductivity value of 0.5 kcal/mhr°C which is quite low as compared to that of foam concrete of equal density and it is only 2.4 times that of expanded polystyrene of 24 kg/m³ density (Jain and George, 1970).

Characteristics of the Panel Materials

The properties of coconut husk and coconut husk-wood particles board are quite good even with little or no adhesive (cf., Tables 1 and 2). Water absorption is low in spite of the fact that no water repellent was employed. The very low absorption of high density particle boards is parti-

cularly noticeable. High density hardboard-like boards from unretted pith also has very low water absorption, although no additive was employed in their preparation (Table 3).

The properties of joint fillers from coconut pith and CNSL resin are very satisfactory (Table 4). Recovery of the filler after compression is as high as 90%. It has good resistance to alternate heating and wetting, and freezing and thawing (Jain *et al.*, 1964). Repeated compression does not result in its disintegration. The material is also resistant to termites.

Test data on fungus resistance of particle board from coconut husk and expansion joint filler from coconut pith show that the particle board may be classified as moderately resistant and the joint filler as resistant to decay on the basis of ratings accepted in decay resistance tests of timbers (Table 5).

TABLE 5. Decay resistance of coconut husk particle board and coconut pith expansion joint filler

Test fungus	Average weight loss % in	
	particle board	joint filler
Polyporus sanguinesu	22.53	3.27
Polyporus palustris	26.26	12.26

Coconut husk particle boards have certain other useful properties also inherent in the material. They are moderately resistant to termites and show considerable resistance to burning (George and Joshi, 1959). Although the board smoulders like the husk itself, it does not show flaming combustion once the igniting source is removed.

Conclusions

The results presented in this paper show the immense possibilities for the commercial utilization of coconut husk and its by-products in the building materials industry. Detailed investigations and development work are necessary to exploit the potentialities of these abundant raw materials.

References

Floro, M. (1954). Complete utilization of coconut husk. *Philipp. Agri. Engg. J.* **5** : 18.

George, J. (1961). Complete utilization of coconut husk. 3. Particle board from by-products of coir industry. *Indian Pulp & Paper.* **15** : 613-616.

George, J. (1964). Production of particle board from coconut husk. *Indocom. J.* 19(2) : 1-5.

George, J. (1970). Building materials from coconut husk and its by-product. *Coir* **14(2)** : 19-44.

George, J. and Bist, J.S. (1962). Complete utilization of coconut husk. Part: IV-Three layer particle boards with coconut husk particle core. *Indian Pulp & Paper* **16** : 437-438.

George, J. and Joshi, H.C. (1959). Complete utilization of coconut husk 1. Building boards from coconut husk. *Indian Coconut J.* **12** : 46-51.

George, J. and Joshi, H.C. (1960). Hardboards from coconut fibre. *Res. & Indus.* **5** : 66-68.

George, J. and Shirsalkar, M.M. (1963). Particle boards from coconut husk. *Res. & Indus.* **8** : 129-131.

Jain, R.K. and George, J. (1970). Utilization of coconut pith for thermal insulating concrete. *Coir.* **14** : (3).

Shirsalkar, M.M., Jain, R.K. and George, J. (1964). Fire-resistant building boards from coconut pith. *Res. & Indus.* **9** ; 359-361.

Basic Studies

Chairman : H.Y. MOHAN RAM

Rapporteur : R.D. IYER

Effect of Cultural Practices, Irrigation, and Manuring on the Development of Root Systems in the Coconut Palm

I. HENRY LOUIS and K. BALASUBRAMANIAN
Tamil Nadu Agricultural University, Coconut Research Station, Veppankulam, Tamil Nadu, India

Introduction

Roots perform more than one function. They anchor the plants in position. They absorb from the soil water and nutrients required by the plant. In the present study, the effect of cultural practices, irrigation, and manuring on the growth and development of roots in the coconut palm was studied.

Materials and Methods

The observations were taken on 8-year old palms planted in an experiment laid out in a split plot design with three replications. The main plot consists of eight palms comprising of four selected and four unselected seedlings (*cf. this* Symposium), and the sub-plots consist of three treatments, cultural practices, irrigation, and manuring, each at two levels. The cultural operation consists of ploughing with an iron plough in July-September and working with a cultivator in January-February, both once annually. The palms were originally planted in pits $1 m^3$ size and at a spacing of 7.5 m^2. Irrigation is given by flooding the basins. The full dose of fertilizer consists of 3 kg ammonium sulphate, 1 kg super phosphate, 1.5 kg muriate of potash/palm annually.

Roots of the palms were exposed in one-quarter of the circumference to a depth of 1.5 m and distance of 3 m by excavating the soil from three sides of the sector. The soil was washed away using water from a pressure pump. The roots were tracked along their length without disturbing the direction and angle of penetration. All the secondary roots were also kept intact. The exposed roots were studied for their angle of penetration and then excised from the base of the bole for further studies. The length and number of secondary roots and respiratory roots on the primary and secondary roots were recorded.

Results and Discussion

The selected and unselected seedlings did not show any consistent differences between them for any of the characters. So this treatment difference was overlooked. The number of primary roots varied highly in different treatments (Table 1). Palms in the plots receiving manure had more than three times roots than those not receiving manure. The next important factor which promoted root growth was irrigation. The effect of various treatments on root length was considerably less (cf. Table 1) and did not show any particular trend ; however, palms of the irrigated plots showed the longest length.

The effect of various treatments on bole length was more distinct. Manuring increased the bole length significantly. And curiously, palms in the plots receiving cultural treatments showed reduced bole length.

Variations on the surface area of the root zone showed the same trend as for root length, except for palms in the plot receiving only cultural treatments (Table 1).

TABLE 1. Effect of cultural practices, irrigation, and manuring on root development

Treatments*	No. of primary roots/palm		Root length in cm		Length of hole in cm		Surface area of root zone in cm	
	Mean	% over control	Mean	% over control	Mean	% over control	Mean	% over control
$C_0I_0M_0$	675	100	299	100	35.0	100	2948	100
$C_0I_1M_0$	1407	208	303	109	36.5	104	6488	220
$C_0I_0M_1$	3910	579	310	111	49.5	141	5679	193
$C_0I_1M_1$	4544	673	402	144	56.0	160	8994	305
$C_1I_0M_0$	1306	194	365	131	30.5	87	3785	128
$C_1I_1M_0$	1646	244	317	114	36.5	104	5877	199
$C_1I_0M_1$	4116	610	291	104	44.0	127	5764	196
$C_1I_1M_1$	4673	692	441	158	49.0	140	8037	273
					CD=10.8			

*For details, see Materials and Methods.

The distribution of roots at different depths of the soil was next observed. Only about 3% of the roots were in the top 15 cm of the soil. As much as 60% of them were in the 31-60 cm depth zone. The distribution of respiratory roots on primary roots was studied. They were considerably less in all the plots receiving cultural treatments.

Observations were taken on some other characters also, but none of them showed any clear-cut trends. The present study gave the impression

that root growth and development are highly variable characters, and that perhaps it would have been better if the study had been carried out on older palms.

Discussions

Nelliat : Shall I conclude from your paper that irrigation is not necessary under Veppankulam conditions ?

Louis : No. Palms show effects of irrigation.
duces significant increase in height of seedlings and number of leaves. (2) Irrigation in combination with manure advanced flowering period by 22 months.

Venkateswaran : What is the number of months by which flowering has been advanced and yield increased as a result of manuring and irrigation separately ?

Louis : By manuring alone, the palms flowered 24 months earlier and gave 272% increase in yield. Irrigation alone failed to contribute to the advancement in flowering and increase in yield.

Asana : Did I understand you correctly that there was an interaction between variety and manurial treatment ? If so, what sort of interaction did you observe ? This is an important question in relation to variability in yield.

Louis : A significant increase in the total number of leaves produced was observed due to the interaction between cultural operation and selections.

Kulkarni : What was the initial fertility status of these soils ?

Louis : The major nutrient content of the soil was 0.364% N, 0.0003% P_2O_5, and 0.0005% K_2O with pH in the range of 5.8–6.8.

Association of Coconut Foliar Asymmetry with Latitude

T. ANTONY DAVIS

Indian Statistical Institute, Barrackpore, West Bengal, India

Abstract

The phyllotaxy of the coconut is alternate and the younger of any two consecutive leaves will be nearer to the older leaf either by its left side or its right. In the former case, the leaves will form a single left-handed (clockwise) spiral, and in the latter case, into one right-handed (counter-clockwise) spiral. Since any two consecutive leaves subtend an angle roughly approximating the Fibonacci angle (137°), the coconut crown displays five clearly visible spirals. In a crown, where the single spiral (formed by consecutive leaves) is clockwise, the direction of the obvious five spirals will be counter-clockwise, and where the single spiral moves counter-clockwise, the direction of the five spirals will be clockwise.

The spirality of 52,960 coconut palms was recorded from 38 countries/regions in both the hemispheres. Of this, 51.159% were left-spiralled. The observations were split into those for northern and southern hemispheres and statistically analysed to see whether foliar was asymmetry associated with latitude. Positive results were obtained.

Introduction

The famed astro-physicist, Grote Reber (CSIRO, Hobart, Tasmania, Australia) did some manipulations with my published data on handedness of coconut Palms (Davis, 1963) and tested for a possible geophysical influence. Since the foliar spiral in the coconut is non-genetic (Davis, 1962), he was inclined to believe that asymmetry in this palm was slightly influenced by earth's magnetic field. He remarked, while forwarding the calculations and graphs he prepared with the data, "I believe you are on to a subject of considerable importance. However, it would be well to secure more data of good quality on (L—R)/(L+R) from higher magnetic latitude near the geographic longitudes of 290° and 110°".

During the past over a decade, much data have been collected from many countries and statistically analysed to see if there is any association between foliar spiral and latitude. The results of analyses are presented in this paper.

Materials and Methods

The leaves of a coconut palm (*Cocos nucifera*) are arranged in five clockwise (left-handed) or counter-clockwise (right-handed) spirals. The two kinds of palms are distributed more or less in equal numbers in any locality. The phyllotaxy of the coconut is alternate, and any two consecutive leaves subtend an angle which is approximately equal to the Fibonacci angle (137°). Such a formation results in the manifestation of foliar spirals. The schematic representation (Fig. 2) depicts a palm crown bearing 43 leaves. When leaves 1, 6, 11, 16 (interval 5 leaves) are joined by a line, a spiral becomes obvious, which corresponds to one of the five spirals of the coconut. All such five spirals veer counter-clockwise from the periphery. The five right-handed spirals become discernible in a crown where the consecutive leaves are in a clockwise spiral, and vice versa, in a clockwise five-spiralled crown (Davis, 1971). In Fig. 2, we can see eight spirals running clockwise, that is, opposite to the five spirals. These eight spirals may be ranged as those of an oil palm (*Elaeis guineensis*). Here the directions of the eight foliar spirals and of the single spiral of consecutive leaves are similar. The numbers 5 and 8 are adjoining terms of the Fibonacci sequence (1, 1, 2, 3, 5, 8, 13, 21, 34.....), and one of the properties of the sequence is that when these terms are continuously numbered, the terms representing odd numbers will tend to move along one direction (from neutral position or equality), while all the even-numbered ones will move along the opposite side.

Several coconut palms from many localities in India and some other countries were examined and their spirality noted. Also, voluminous data were obtained from abroad through coconut research workers who were supplied with elaborate instructions and drawings to distinguish the two kinds of palms. At least, one agency (Andamans) supplied it wrongly, and the data supplied by them and published earlier (Davis, 1963) were rejected. The data were analysed statistically and the results presented below.

Results

The global data have been separated into those for northern and southern hemispheres. A total of 41,857 palms from 25 countries/regions were examined from the northern hemisphere and 11,103 palms from 13 countries from the southern hemisphere (Table 1).

TABLE 1. Distribution of left- and right-spiralled coconut palms

Region	Lefts	Rights	L+R	L−R
Northern hemisphere	21,744	20,113	41,857	1,631
Southern hemisphere	5,350	5,753	11,103	−403
Global data	27,094	25,866	52,960	1,228

In 20 out of 26 countries/regions of northern hemisphere, there were excesses of left-spiralled palms, and in the southern hemisphere, 8 out of 13 countries had excesses of right-spiralled palms. Moreover, the excess of lefts in the North over the rights, was statistically significant, and the X_1^2 value to test the departure from equality turns out to be 63,554. In the southern hemisphere, on the other hand, the rights are in excess of lefts, and the differences again was significant, X_1^2 being 14.627.

Having noticed a significant hemispherical difference in the distribution of left- and right-spiralled coconut palms, we decided to see whether this difference was brought about by abnormal distribution of one kind of palms in one or a few pockets, or if it was due to a regular influence of latitude. A simple and robust test for this problem was the Wilcoxon two-samples rank-sum test (for a complete description, see Lehmann, 1975). The computed value of the test statistic was highly significant statistically at almost any reasonable level of significance.

From this, we conclude that the proportion of left-spiralled palms *does* decrease significantly as we move southwards, establishing thereby an association between latitude and foliar spirality of the coconut palm.

Discussion

The results are surprising as they struck Professor P.T. Mathews (FRS, Imperial College of Science and Technology), London, who remarked in 1963 (personal communication), "It seems to us surprising that you can get a bio-physical distinction between north and south appearing in the tropics where, clearly, the physical differences are very small". But data obtained from regions beyond 20° North and South of the equator contribute largely to this difference. The first five northern-most countries/regions showed that 4,639/7,795 (or 59.511%) palms were left-spiralled, and the last two southern-most countries showed that 353/584 (or 60.442%) were right-spiralled. Charles Darwin (1937) also pointed out such a hemispherical difference in the twinning of stem of *Mikania scandens*, a Composite weed. There are numerous recent works that prove beyond doubt that plants respond to geo-physical and geo-magnetic influences. In the animal world too, apart from the classical work of Ludwig (1932) and D'Arcy Thompson (1961) who tried to give an explanation of the very unique left-hand twist of narwhal tusk (even when two tusks appear in exceptional individuals), there are many recent publications on the question of geo-physical influence on the form and function of animals or their organs. Bonner's (1951) explanation of the twist of the horn of the unicorn is also relevant. The asymmetry of the brow tine in reindeer and caribou is another example (Davis, 1973). In the physical world too, there have been more contributions to demonstrate the physical effects of the hemispheres. Cyclones, anti-cyclones, whirlpools, water spouts, breaches on rivers that flow along the North-South meridian, and bath tub vortex (Shapiro, 1962) highlight the subject.

Acknowledgement

I am indebted to Prof. C.R. Rao, FRS, Director for his special interest in this investigation. It is a pleasure to acknowledge Grote Reber who showed me the way.

References

Bonner, J.T. (1951). The horn of the unicorn. *Sci. Amer.* **184** : 42-44.

Darwin, C. (1876). The Movements and Habits of Climbing Plants. 208 pp , Appleton Co., New York.

Davis, T.A. (1962). The non-inheritance of asymmetry in coconut palms. *J. Genet.* **58** : 42-58.

Davis, T.A. (1963). The dependence of yield on asymmetry in coconut palms. *J. Genet.* **58**: 186-215.

Davis, T.A. (1971). Why Fibonacci sequence for palm leaf spirals ? *The Fibonacci Quart.* **9** : 237-244.

Davis, T.A. (1973). Asymmetry of reindeer antlers. Forma et Functio. **6.** : 373-382.

Lehmann, E.L. (1975). Nonparametrics. Statistical Methods based on Ranks. 451 pp. McGraw Hill, New York.

Ludwig, W. (1932). Das Rechts-Links-Problem. Berlin.

Shapiro, A.H. (1962). Bath tub vortex. Nature. **196** : 1080-1081.

Thompson, D' Arcy. (1961). On Growth and Form. Abridged Ed. (Ed. J.T. Bonner). 345 pp. Cambridge University Press, New York.

Discussion

Panigrahi : Is there any correlation between nut yield and L- and R-spirals in the northern and southern hemispheres ?

Davis : Yes and no. In the northern hemisphere, some association has been observed between L- spiral and higher yield. In the southern hemisphere, no such studies have been made.

Influence of Crop Mixing of Hybrid Napier on the Root Zone Microflora of the Coconut Palm

V.P. POTTY and N.P. JAYASANKAR
CPCRI Regional Station, Kayamkulam, Krishnapuram 690533, Kerala, India

Abstract

Intercropping of fodder hybrid napier with coconut palms resulted in the proliferation of total bacteria and nitrogen fixing organisms in the coconut rhizosphere, irrespective of the condition of the palm. Compared to the palms in the control plot, crop mixing enhanced phosphate solubilizing bacteria in root region of the palm with root (wilt) affected coconut palms harbouring significantly higher numbers. The trend was however reversed after the application of inorganic manures. There was decrease in the nitrogen fixing and phosphate solubilizing microflora in the soil adhering to the coconut roots. The difference between the experimental and control plot was also not significant.

Introduction

Mixed farming initiated at this Station has shown a beneficial influence on the yield of coconut palms. Microbiological analysis of the soil from plots cultivated with coconut palms and fodder crops revealed the presence of cellulolytic, nitrogen-fixing, and denitrifying organisms. Studies made in the past were concerned with the rhizosphere of coconut palms in relation to the root (wilt) disease (Radha and Menon, 1954; Radha and Rawther, 1959). In the present studies, attempts have been made to enumerate the microflora, particularly the nitrogen-fixing and phosphate-solubilizing organisms, in the rhizosphere of coconut palms in close proximity with the fodder grass hybrid napier. Counts were taken before and after the application of inorganic fertilizers and the results are presented in this paper.

Materials and Methods

Samples were collected one meter away from the bole of the palm from a depth of 50 cm from four sectors, from three apparently healthy and three diseased palms crop-mixed with napier grass. The soil adhering to the roots were gently shaken in sterile water and counts were made by

soil dilution technique. Soil extract agar (Lochhead and Taxton, 1952) was used for bacteria and Martin's Rose Bengal agar (Martin 1950) for fungi. Phosphate-solubilizing organisms were estimated using the medium of Pikoviskaya (Pikoviskaya, 1948) and nitrogen-fixing organisms were counted in nitrogen-free mannitol agar. The normal fertilizer dose for coconut is 0.5 kg N, 0.32 kg P and 1.2 kg K/palm/year and for grass 150 kg N, 50 kg K and 100 kg K/ha. Except N, others were applied once before and once after the monsoon for the coconut palm. The sampling was done twice, before and after the application of fertilizers.

Results

The relative incidence of rhizosphere microflora in the experimental and control plots is furnished in Table 1. In general, the samples of rhizosphere before the application of fertilizers gave an increase in the number of different microflora in experimental samples as compared to those from control plots. Both total bacteria and nitrogen fixing bacteria were higher in experimental palms as compared to control irrespective of the condition of the palm. The phosphate-solubilizing bacteria were significantly higher in the crop-mixed area with diseased palms harbouring significantly higher numbers. The incidence of phosphate solubilizing fungi on the other hand was more in the rhizosphere of healthy palms of the experimental plot. The trend however differed subsequent to the application of fertilizers. Except the fungal flora, all the other compo-

TABLE 1. Influence of crop mixing hybrid napier grass on the coconut rhizosphere microflora, before and after fertilizer application

Organisms	Coconut+Napier grass				Coconut alone			
	Pre-application		Post-application		Pre-application		Post-application	
	Healthy	Diseased	Healthy	Diseased	Healthy	Diseased	Healthy	Diseased
Bacteria	51.84	21.25	21.83	10.28	27.00	5.51	5.15	7.81
Fungi	37.62	29.46	28.67	206.71	6.76	76.11	1.05	20.48
Nitrogen fixing bacteria	84.20	35.86	9.92	8.25	35.86	8.71	3.47	7.88
Phosphate solubilizing								
Actinomycete	4.95	2.33	0.83	1.30	1.45	3.04	0.33	0.55
Bacteria	8.15	130.78	0.61	0.87	8.85	3.95	0.63	0.93
Fungi	6.58	5.26	1.12	1.21	2.40	2.40	1.52	1.46

nents of the microflora showed a lower population in the rhizosphere of palms of the experimental plot, irrespective of the condition of the palm. The fungal population recorded an increase in the rhizosphere of wilt-affected palms in the experimental as well as the check plots. In the case of phosphate-solubilizing flora, the fall in population in the crop-mixed plot was significant.

Discussion

The rhizosphere microflora in general is influenced by age of the plant, nutritional status of the soil, the zone of sampling, and cultural practices (Walksman, 1932). Due to non-availability of desired criteria, it was not possible to collect samples from palms of identical age group. This was also the reason for collecting samples from the four sectors of each palm. But, samples from each sector were treated as separate entities. Samples were collected from a distance of one meter from the bole because the roots are dense in this region under normal cultivation. The depth of collection was kept to 0-50 cm on the basis of our earlier observations. The very objective of present investigation was to see how best inter-cropping of coconut with hybrid napier would influence the rhizosphere of the main crop in a beneficial manner. The method followed for the enumeration in the present investigation might not as well hold appropriate for the fungi.

The abundance of phosphate solubilizers in the rhizosphere had been observed by other investigators also (Sperber and Rovira, 1959; Sperber, 1958a; Katznelson and Bose, 1959). Higher incidence of phosphate-solubilizing flora will make possible the conversion of the organic phosphorus available in the soil into a form assimilable to crops. This increased availability of P in the root region can as well help in the proliferation of nitrogen fixing organisms.

The differences in the quantitative distribution of different components of coconut rhizosphere microflora changed with the application of fertilizers. Venkatesan (1962) had also observed a retarding effect of N, P, and K on the rhizosphere bacteria and fungi of rice. Shetty and Rangaswamy (1969) has observed that an inhibition of the phosphate-solubilizing microflora in the rhizosphere of pearl millet was inhibited by the application of phosphate fertilizers.

Acknowledgement

We thank Dr. G. Rangaswami, Vice Chancellor, Tamil Nadu Agricultural University, for his valuable suggestions on this fascinating area of the microbiology of the coconut root region way back in 1972.

References

Katznelson, H. and Bose, B. (1959). Metabolic activity and phosphate dissolving capacity of bacteria isolates from wheat rhizosphere. *Can. J. Microbiol.* **5** : 79-83.

Lochhead, A.G. and Taxton, R. H. (1952). Quantitative studies of soil microorganisms. X. Bacteria requiring vitamin B_{12} as growth factor. *J. Bact.* **63** : 219-225.

Martin, A. (1950). Use of acid, Rose bengal and streptomycin in the plate method for estimating soil fungi. *Soil Sci.* **69** : 215-233.

Pikovskaya, R.I. (1948). Mineralization of phosphates in soils in connection with the vital activity of certain micro-organisms. *Microbiology.* **17** : 362-370.

Radha, K. and Rawther, T.S.S. (1959). Observations on the seasonal variation in the rhizosphere microflora of coconut with special reference to fungi. 298-305 pp. in *Proc. First Conf. Coconut Res. Workers of India*, CPCRI, Kasaragod.

Radha, K. and Menon, K.P.V. (1954). Studies on the wilt (root) disease of the coconut palm : A comparative study of the rhizosphere microflora of coconut from diseased and healthy areas. *Indian Coconut J.* **7** : 99-106.

Shetty, K.S. and Rangaswami, G. (1969). Studies on the influence of the phosphate build up of the soil and rhizosphere of ragi (*Eleusine coracana* Gaertn.) *Mysore J. Agri. Sci.* **4** : 425-428.

Sperber, J.I. (1958). The incidence of apatite-solubilizing organisms in the rhizosphere and soil. *Australian J. Agri. Res.* **9** : 778-781.

Sperber, J.I. and Rovira, A.D. (1959). A study of the bacteria associated with the roots of subterranean clover and wimmera rye grass. *J. Appl. Bacteriol.* **22** : 85-88.

Venkatesan, R. (1962). Studies on the actinomycete population of paddy soil. PhD thesis. Anamalai University, Annamalainagar, India.

Walksman, S.A. (1932). *Principles of soil microbiology*, 2nd ed. Bailliere, Tindall and Cox, London.

Attempts at Vegetative Propagation of Coconut Palm

W.W. SCHWABE
Department of Horticulture, Wye College, Nr. Ashford, Kent, United Kingdom

Abstract

Experiments have been carried out to obtain vegetative propagation of coconut palm from explants of a variety of tissues, including apical meristem tissue, leaf, inflorescence, and root tissue. A mineral salt medium has been defined specifically suitable for coconut and perhaps other palm tissue and the organic constituents have been optimized for maximum callus growth. Experiments with callus tissue and organized inflorescence explants will be described. Brief mention will also be made of experiments to obtain branching in intact palms.

Introduction

This paper represents the work of the tissue culture group in the Horticulture Department at Wye College consisting of Dr. Jennet Blake and Dr. J. Eeuwens, and temporarily Dr. Pimchai Apavatjrut, now at Chieng Mai University. I would also like to refer briefly to work carried out at East Malling Research Station by Dr. R. Fulford and Mr. S. Justin, which is mainly concerned with root culture (See also Blake *et al.*, 1975). In addition, I wish to describe some experiments of my own on complete palms carried out with the help of the Coconut Industry Board in Jamaica, involving originally Mr. Roger Smith, and latterly Mr. D. Romney and Dr. C. Barrant. All this work has been most generously supported by the British Ministry of Overseas Development (M.O.D.) as part of their overseas aid programmes.

The aim of vegetative propagation of the coconut is the obvious one of obtaining uniform clones of elite material. Elite material in this sense are palms exhibiting high yield, disease resistance, adaptability to different cultural practices, etc. That is, the sort of material desired as an ideal, but never completely attained (Schwabe, 1973). Since the coconut palm does not sucker, the only possibility of making cuttings would be by rooting branches such as are produced in the rare aberrant palm. Apart from this rather remote method, there is one other technique of

obtaining clonal material, that is, by one or other technique of sterile culture of tissues or organs.

The two routes by which plantlets in other species have been obtained by tissue culture are : (a) Explant tissue can be induced to multiply into relatively undifferentiated callus, which may then regenerate shoots and roots to form complete new plants. This also includes regeneration from single cells or isolated protoplasts; (b) Use organized apices from lateral or terminal axes which reform roots and grow into new plants. Branching of such explants may be used for further multiplication; inversely, roots might be induced to regenerate shoot apices.

In this resume of the work we have done on vegetative propagation, the information will be presented in the following order : first the types of tissue used for explants will be described; next, culture media and conditions will be discussed including macro and micro elements, organic and inorganic constituents, as well as the external physical environment; then, the efforts made to obtain special objectives and the kind of growth of tissues and explants that we have obtained will be described. Finally, a rather different aspect, the possible induction of vegetative branching of palms growing in the field will be considered.

Types of tissue used

In tissue culture we have the choice of using explants from relatively unorganized tissue, such as is found in or close to the apical meristem (Apavatjrut and Blake, in press), or from young rachis of early stage inflorescences, or from the petiole tissue of young leaves In the case of organized tissue, it is possible to use the terminal apex itself, but this has only resulted in the recovery of a single plant—and clearly, a 1 : 1 ratio of recovery is useless. Other organized tissue that can be used are young leaves, and parts of the young inflorescences which carry apices destined to become inflorescence branches or the flowers themselves, which may be induced to revert to the vegetative condition as shoots. Finally, there is the possibility of using young roots, either large primary or smaller secondary roots.

One of the inherent dangers of this type of cultivation is the occurrence in the callus of somatic mutations or changes in ploidy of the chromosome complements. Generally, the longer the plants are held in culture as callus, the greater is the likelihood of this happening. If it occurs, it would, of course, amount to a reintroduction of variability, that means, defeating the whole object of such work. Hence, the utility of these different types of tissue may depend on the period required over which culture in sterile conditions is needed before plantlet development is achieved. Organ cultures appear to be rather less subject to this occurring, and, therefore, may be preferrable. Also, the re-establishment of a complete plant in such a case would only require the neoformation of one type of organ, i.e., roots on shoot-lets, or shoot-buds on roots.

One of the major problems is represented by the initial variation between different palms. The regenerative potential of tissues is at least as variable as the performance and yield of the palm in the field, a factor which has led to difficulties in experiments exploring relatively slight differences between treatments. It has become clear recently that the conditions under which the palm has been growing has a large effect on the subsequent behaviour of the tissue in culture. Thus, palms grown under drought conditions in the field yield rather unresponsive cultures, quite apart from the fact that the inflorescences normally used in our experiments may themselves wholly or partly abort under such conditions. No work has as yet been carried out on the possible preconditioning of palms before utilization, but some of the hormone experiments in the field, referred to later, might well be useful in this respect.

At East Malling Research Station, Fulford and Justin have been using roots as explant material and have found surprizingly large differences between the behaviour of primary roots and secondary or tertiary roots. Initially, they attempted to use near apical tissue of large primary roots with the object of obtaining callus material, but sections of tissue excised from such primary root tips were very unresponsive, usually turning black without giving regular callus production. Since then, surface-sterilized, primary root tips and secondary roots have been used as explants with much better results.

The Culture Media

The initial study has been concerned with the development of culture media giving the optimum type of growth. Optimum media for organized tissue, as well as callus growth, do not appear to differ from each other, but media suitable for root growth appear to be optimal at a lower salt concentration. A considerable amount of effort has gone into studies on the inorganic constituents of the medium compared with the most commonly used media which have been described in the literature, namely White's (1943), Heller's (1953), and Murashige and Skoog's (1962) ; the last of these includes both nitrate and reduced nitrogen. The medium developed at Wye (designated Y3) by Dr. Eeuwens (1976) includes a number of major changes from Murashige and Skoog's (Table 1). Thus, potassium concentration has been increased to twice the highest value used in the Murashige and Skoog medium, while nitrogen level has been reduced to half. The difference in growth due to these changes is seen in Table 2.

Nitrogen nutrition has been studied in some detail, and it has been found that coconut tissue has a specific requirement for both nitrate and reduced nitrogen, and there is a clear interaction between the two, the best formulation being a combination of ammonium nitrogen of about 10 mM combined with 20 mM of nitrate. The reason for this dual require-

TABLE 1. Composition of the Y3 mineral formulation, specially developed for the culture of *Cocos nucifera* tissues

Macro-elements		Micro-elements	
Component	Concentration mg/l	Component	Concentration mg/l
KNO_3	2020	Fe-EDTA	32.5
KCl	1492	$MnSO_4.4H_2O$	11.2
NH_4Cl	535	KI	8.3
$NaH_2PO_4.2H_2O$	312	$ZnSO_4.7H_2O$	7.2
$CaCl_2.2H_2O$	294	H_3BO_3	3.1
$MgSO_4.7H_2O$	247	$CoCl_2.6H_2O$	0.24
		$Na_2MoO_4.2H_2O$	0.24
		$CuSO_4.5H_2O$	0.16
		$NiCl_2.5H_2O$	0.024

TABLE 2. Growth of stem, leaf, and inflorescence explants on four mineral salt formulations

Source of explants	Mean initial fresh weight	Mean final fresh weight mg+SE			
	(mg)	Y3	MS	H	W
Stem	11.8	279 ± 25	194 ± 15	77 ± 3	65 ± 4
Leaf	9.3	329 ± 37	184 ± 13	41 ± 4	44 ± 4
Inflorescence					
Rachis	8.1	401 ± 27	261 ± 23	75 ± 8	62 ± 4
Rachilla	4.5	486 ± 22	349 ± 32	70 ± 17	35 ± 3

ment is not fully clear, but it seems unlikely that the tissue explants that we have used so far contain adequate nitrate reductases to cope with NO_3 as the sole source. However, it is also possible that pH effects may play a role in this dual requirement. When other sources of reduced nitrogen were tested, ammonium nitrogen proved to be the best sole source and amino acid mixtures were not as good, and the amounts now included in the standard mineral composition seem to be optimal for most types of tissue tested. But the addition of an amino-acid mixture comprising l-glutamine, l-arginine, and l-asparagine to the ammonium nitrogen gives even better growth than ammonium alone.

When the micro-elements were looked at, exclusion of these from the

medium caused substantial reductions in growth. One of the most significant, and perhaps somewhat unexpected, factors was the relatively high demand of coconut tissue for iodine, and even 50 μm did not seem supra-optimal. In fact, this demand for iodine probably also explains some beneficial effects on growth found in other experiments with triiodobenzoic acid additions to the medium.

Of the organic constituents, sugar level is important, and relatively high amounts (4.5-6.5%) proved beneficial, and have, in fact, been used for most of the experiments in coconut tissue culture. It has also been found that many other constituents, such as amino acids and other more complex organic materials, could be replaced by simpler chemicals and the tissue was clearly able to synthesize more complex organic molecules. Initially, coconut water was found to be considerably beneficial for the growth of explants, and it was thought that perhaps the combination of coconut water, the freshly part of the endosperm (the copra), and the embryonic tissue of the 'apple' derived from young seedlings, might constitute the optimum medium for growing coconut tissue. In fact, combining these three constituents gave very good growth. However, this would not be suitable as a general method because of the difficulties in obtaining all three constituents in sterile conditions. It should be stated here that our media are not usually autoclaved, but sterilized by 'Millipore' filtration, something which obviously could not be done with coconut tissue, and in any case, autoclaving the 'apple' tissues would destroy its enzymic activities. In the event, the major benefit of coconut water in the presence of adequate sugar and reduced nitrogen supply seems to be in its hormonal constituents, and when these are replaced by added hormones, growth, as good as with coconut water, can be obtained on a purely synthetic medium. A factor of major importance is the supply of some auxin for which we have used 2, 4-D and IBA, in preference to IAA because of the instability of the latter. Cytokinins also have beneficial effects upto a concentration of about 5×10^{-6} M. Other hormonal constituents such as gibberellin, abscisin, etc. do not seem to have major beneficial effects; the pH of the medium is another factor which appears to have relatively less importance, and the effect appears to be linked with the mineral constituents. A pH of about 6.5 is generally optimal. The maintenance of this level does, of course, depend on the buffering capacity of the medium itself and the uptake of particular nutrients such as nitrate and ammonium nitrogen.

In general, we have found that, at least in the early stages, static cultures give better growth than shake cultures. The support of the cultures on the medium has also been studied. Filter paper bridges are often beneficial in the early stages, and always so, when compared with Oxoid No. 3 solid agar media at 0.6% or above. However, weak agar (0.4%) has been found to be very useful for larger explants, and liquid culture in gently shaken flasks has also proved to be successful for really large explants.

The choice is therefore conditioned by the material. The important factor involved may be the surface area of contact between the explant and the medium, facilitating exchange of constituents of the medium and replacement from the solution.

Physical Factors of the Environment

The most important of these is clearly temperature, and cultures from the above-ground parts of the palm held in a temperature is optimal from root cultures. At about 36°C, growth is largely curtailed. The optimum for stem tissues would seem to lie at approx. 30°-32°C, and all experiments carried out subsequent to this discovery have been done at these temperatures. In the early stages of culture, light is inhibitory and cultures tend to grow better in darkness, but in later stages cultures grow equally well in light and dark. We have not yet investigated the effects of spectral composition and intensity in detail.

The gaseous atmosphere of the medium may also be of importance considering how tightly packed the apical tissue of the coconut palm is and how excess of oxygen and loss of carbon dioxide may be inhibited in such thick tissues. However, no experiments on this aspect have at present been carried out.

Specific Explant Requirements

The nutrient and other conditions described apply largely to the undifferentiated tissue from the rachis axis, petioles, etc. and have been satisfactory for cell multiplication, callus formation, etc. The increases in fresh and dry matter which have been obtained in culture are very substantial, and probably exceed those that would have been made by these tissues *in vivo* on the trees, e.g., a hundred-fold increase may be obtained in 40 days and a thousand-fold increase in twice that time. So far, we have not yet succeeded in obtaining plantlets nor *de novo* shoot or root formation from such cultures. However, in a number of instances, batches of tissue have shown the kind of organization associated with embryoid formation in other species. Unfortunately, we have not normally kept tissues for very prolonged periods, and possibly these incipient embryoids might have developed if the cultures had been maintained for several more months. This aspect is now being studied.

It has also been found that in shake culture of callus, single cells detached in a manner probably analogous to the single cell cultures obtained by F.C. Steward with carrots, can be obtained. Again, so far we have not had any differentiation from such cultures, but it is possible that this may happen in due course. Dr. Eeuwens has also succeeded in preparing free and viable protoplasts from coconut tissue, and further work on these may perhaps, again via single cell culture, lead to embryoid formation.

Perhaps the most promising type of tissue for the regeneration of plantlets is still the inflorescence explant. Starting with explants of no more than 0.5 mg fresh weight, or 0.05 mg dry weight, similar rapid growth rates to those of callus type tissue have been obtained. Here Dr. Blake has found that the flower meristems grow out to produce range of different types of shootlets. Thus, these shootlets can range from what seems bare spikes with no lateral primordia, to spikes with leaf-like primordia and a clearly defined shoot apex, to spikes with clearly differentiated floral primordia. The object of our experiments must clearly be to enhance the vegetative characteristics and, if possible, to obtain repeated branching for subculturing and multiplication and, most of all, to devise a technique for producing roots on these shootlets so that entire plants can be produced. These shootlets have one other possible major advantage, the probability that there is less likelihood of somatic mutations which would upset the overall performance and negate successful cloning.

In the case of roots, the larger explants have been much more successful, and substantial amounts of callus growth have been obtained, upto ten times that from smaller explants, but the period of growth is still limited. Addition of auxin lengthens the life of the callus though enough seems to be taken up in only one or two days. Interestingly, the best growth is made by meristems from which the root cap has been removed with only about 3 mm of root tissue attached. In longer and larger explants, renewed roots growth occurred and secondary roots developed. Secondary roots frequently continue growth, and branching and lateral meristem growth also occurs. Such tertiary roots treated relatively high levels of auxin (about 2 ppm) appear to form callus both from the apical meristem and along the cortex, and this callus sometimes forms nodules. Such callus from the differentiated tissue may still show some degree of organisation and is quite different in potential from the callus developed directly on primary roots. It seems that roots which develop from such tertiary root callus have actually arisen *de novo* and this raises the hope that shoots or plantlets may ultimately be derived from such cultures.

Finally, a few brief comments may be made on a rather different approach. There are a few well-authenticated instances of coconut palms deviating from the normal patterns in which every lateral growing point is clearly differentiated as an inflorescence axis, and where vegetative shoots have been produced in place of lateral branches or floral organs. This has been reported a number of times, for example, by Dr. T.A. Davis in 1969 in India, and other records I have seen describe such palms from the Philippines and Miami, U.S.A. The hope is, therefore, that such branches could be detached and rooted, giving a degree of clonal propagation, albeit on a much reduced scale compared with the potentialities of tissue culture. However, nothing is as yet known as to the cause of this aberrant vegetative branch formation. The probability would seem high, however, that hormonal treatment may bring about such modification. This we

have tried to achieve in young seedling palms at Wye, and clearly hormones can have marked effects on the morphology of the young palm. Unfortunately, at the early stages, these palms grown at Wye have no detectable development of lateral apices and thus no modification of these has yet been achieved. Clearly the young palm must have passed the juvenile stage and must be reproductive before this technique is likely to be operative. In view of this we have also tried to feed hormones into mature palms in Jamaica, initially in collaboration with Mr. R.W. Smith and Mr. D.H. Romney, and more recently with the help of Dr. C. Barrant.

The technique for feeding the bromone into the plant that has so far been most successful has been to cut across the leaflets of the youngest leaf (spear leaf) which are then immersed in special plastic bottles sealed with Parafilm. Such leaves have taken up the hormone solutions quite readily and in the space of a few weeks two or three litres of concentrated hormone solution have thus been put into the mature plant. Regretably, the results of these experiments have so far been negative, and the reason for this may well be that mature palms have so much tissue in which the hormone can be dispersed (a crown weighing approximately a ton). In all probability, the system has not been saturated adequately to bring about morphogenetic responses. Equally, it must be remembered that any modification of the young axillary apex may not show for about three years when the inflorescence emerges. Hence, it is still possible that effects may show up which have so far not been detected. I would regard this technique of cloning as much less efficient, but until tissue culture has been shown to yield plantlet production, anything should be tried.

Assuming that all techniques lead eventually to success, tissue culturing of roots would be the ideal method since this does not involve destruction of the elite material. Next, I would rate the production of plantlets from inflorescence shootlets, and this at present would still seem the most probable method, but might possibly yield rather fewer plantlets than other methods. Finally, single cell or callus-produced plantlets would be another highly desirable technique, but one which has the attendant risk of a higher probability of somatic mutations re-introducing variation.

References

Apavatjrut, P. and Blake, J. (1977). Tissue culture of stem explants of coconut (*Cocos nucifera* L.). *Oleagineux* (in press).

Blake, J. Eeuwens, C.J., Schwabe, W.W., Apavatjrut, P., Fulford, R.M., Justin, S. and Smith, R.W. (1975). Progress in the vegetative propagation of coconut, using tissue culture techniques. *F.A.O. 4th Technical Commission on Coconut Production, Protection and Processing, Jamaica.*

Eeuwens, C.J. (1976). Mineral requirements for growth and callus initiation of tissue explants excised from mature coconut palms (*Cocos nucifera*) and cultured *in vitro*. *Physiol. Plant.* 36: 23-28.

Heller, R. (1953). Recherches sur la nutrition minerale des tissus vegetaux cultives *in vitro*. *Ann. Sci. Natur.* (*Botan. Biol. et Veget.*) **14**: 1-223.

Murashige, T. and Skoog, F. (1962). A revised medium for rapid growth and bioassays with tobacco tissue cultures. *Physiol. Plant.* **15**: 473-497.

Schwabe, W.W. (1973). The long slow road to better coconut palms. *Spectrum* **103**: 9-10.

White, P.R. (1943). A Handbook of Plant Tissue Culture. pp. J. Cattell, Lancaster, Pa.

Discussions

Ninan: I would like to know whether you have been keeping your culture tubes stationary or shaking?

Schwabe: We have used both shake-cultures and stationary cultures. Large explants in liquid culture benefits from agitation; also shaking is needed to produce single cell suspensions.

De Lamothe: Did you try pollen cultures?

Schwabe: Yes, Pollen culture has been tried. Dr. Norman Sunderland at the John Innes Institute as well as ourselves have tried to raise haploid plants from pollen, but all attempts in this direction have failed.

A Coconut Palm Producing Pigmy-Size Barren Fruits

R.B. NAIR
Central Plantation Crops Research Institute, Regional Station, Sipighat 744 101, Andamans, India

Abstract

One palm in Car Nicobar Island was found to produce only sterile male and female flowers with no button shedding. The pigmy-size barren fruits attained a maximum size of 9×5 cm, and a volume of 115 cc after 12 months of growth. All the fruits possessed two internal supernumerary whorls of three alternating carpels each, and the embryo sac was under-developed. The male flowers also had three whorls of alternating supernumerary boat-like fleshy sepals, the anthers dehisced normally, but were mostly devoid of pollen.

Introduction

Several abnormalities on vegetative parts, inflorescence, flowers, fruits, and sex of the coconut palm have been reported from 1901 (Kupfer, 1901). Menon and Pandalai (1960) and Davis (1966) have summarized these. Production of barren fruits in bunches is a common feature in all coconut growing areas. The barrenness may be partial or complete. It is estimated to be about 3% of the gross annual yield (Gangolly and Nambiar, 1953; Mathew, 1976). At the same time, the occurrence of sterile palms is a rare phenomenon.

During a survey of coconut plantations in Andaman and Nicobar Islands, one sterile palm was seen in Car Nicobar. The tree was normal in all respects, excepting for the production of sterile flowers which produced only pigmy-size fruits.

Materials and Methods

Observations were taken on the nature of different plant parts including emergence of inflorescences, behaviour of male and female flowers, etc. Morphological and anatomical observations were conducted on freshly collected flowers and fruits in different stages of maturity.

TABLE 1. Characteristics of the fruit of the sterile coconut palm

Whorl of carpels	Size at the respective stage (L×B; cm)	Size on maturity (L×B; cm)	Shape	Volume on maturity (cc)	Thickness at maturity (cc)	Description
I. Outer	3.4×2.7	7.5×5.0	Boat-like	88.0	1.6	Carpels hard and differentiated into layers of exocarp, mesocarp, and endocarp, endocarp at the stigmatic and slightly lignified and extending towards the stalk and (as opposed to normal ones); this whorl encircling fully the middle and inner whorls.
II. Middle	1.5×1.0	5.5×1.7	Elongated spire-like and 3-edged tapering (towards the stigma)	5.0	0.8	Carpels free during early stages of development and later adhering together, hard and fibrous and differentiated into three layers; endocarp lignified from stigmatic end, extending downwards; this whorl enclosing fully the inner whorl.
III. Inner	0.6×0.35	1.7×0.6	Conical tapering towards the stigma	0.8	0.3	Carpels free in early stages and pressed together later on freshly and less hard and fibrous than the other whorls; differentiation of tissues into different layers not prominent : this whorls arches embryo sac.

Results and Discussion

Female flowers. The juvenile flowers appeared normal. One peculiarity noticed in the development of the ovary was that the outer three carpels were completely free during the early stages of development, but later on, they united together at the base and remained more or less free beyond the three pores of the septal nectaries alternating with the stigma. The growth of the fruit appeared normal during the first 3-4 months and was slow there after. After full maturity, the fruits shed as usual. By this time, the maximum size of the fruit was only 9 cm × 5 cm with a volume of 115 cc. The number of fruits per bunch varied from 20 to 50. The palm did not show shedding of buttons or immature fruits. The pericarp of mature fruits was hard and stony.

All the female flowers and fruits in a bunch were barren and possessed two internal super-numerary whorls of three carpels each. The whorls alternated each other; the outer whorl, which constituted the ovary, was the largest of the lot, and enclosed the other two smaller supernumerary whorls one after the other; the embryo sac was under-developed. Some of the other details recorded from the fruits are given in Table 1.

Male flowers. They were conspicuous (average size 12 mm × 7 mm) and appeared normal. The six anthers dehisced normally, but were mostly devoid of pollen. An abnormality noticed was the presence of three whorls of three alternating supernumerary boat-like fleshy petals in the centre of the flower. The outer whorl of petals had a mean length of 9 mm while the inner ones measured 7, 6, and 5 mm in a few cases; the petals were formed into one or two stamens in the outer whorl.

These findings have shown that this palm is unique in respect of (1) total spirality of male and female flowers; (2) possession of supernumerary carpels and petals in female and male flowers; (3) absence of shedding of buttons and fruits. It does not come within any of the five groups of barrenness and other abnormalities described by earlier workers.

References

Gangolly, S.R. and Nambiar, M.C. (1953). Studies on the occurrence of barren nuts in the coconut. *Indian Coconut J.* **7** : 5-19.

Kupfer, E. M. (1901). Imperfect coconuts. *Ann. New York Bot. Gard.* **11** : 67-71.

Mathew, C. (1976). Barren nut production in coconut. *Coconut Bull.* **6** : 1-2.

Menon, K.P.V. and Pandalai, K.M. (1960). The Coconut Palm, A Monograph. pp. 384. Indian Central Coconut Committee, Ernakulam, India.

Discussion

Venkateswaran : You have said that the female flowers are sterile. What, according to you, could be the mechanism of fruit development in this situation ?

Nair : Vivipary or parthenogenesis.

Preliminary Observations on Floral Biology and Fruiting of *in vitro* Coconut Palms

E.V. DE GUZMAN, A.G. RAFOLS and A.G. DEL ROSARIO
University of the Philippines
Department of Horticulture, College, Laguna, Philippines

Abstract

Fifteen trees, 13 Makapuno and 2 non-Makapuno, which were propagated by embryo culture constituted the experimental palms. They were regularly observed since the commencement of flowering, which occurred 39-62 months after transplanting to the ground. The flowering age (from embryo) of the palms varied from 68 to 95 months.

Flowering habits and floral structure in both types of *in vitro* palms were comparable to those described for the species, especially the Tall variety. However, both types exhibited intra- and inter-inflorescence overlapping of the male and female phases. In Makapuno, the average duration was 2.17 days for intra-overlap, and 0.95 days for inter-overlap. The corresponding values were 0.30 and 1.65 days, respectively for the non-Makapuno.

Within the first 19 months of flowering, the first palm to become reproductive had already produced 30 inflorescences. Pollen viability was high; fruit setting per bunch varied 5-80%; 74 nuts were harvested within 8 months, and based on the 58 nuts (excluding one barren) actually opened, the yield of Makapuno nuts was 84%. From one non-Makapuno palm, all the four harvested nuts were non-Makapuno.

The observations showed that the Makapuno embryo is capable of completing its life cycle, provided the initial problem of non-germination is overcome. Despite the initial growth lag, the total duration of the vegetative phase was not overly prolonged by *in vitro* method of propagation. The observed yield of Makapuno nuts favour the hypothesis that the palm propagated from Makapuno nut is potentially pure Makapuno-bearing.

Introduction

Production of "homozygous" Makapuno coconut palms is of both scientific and economic significance. A hypothesis about the inheritance of the trait predicts that the palm propagated from a Makapuno nut could be pure breeding (Torres, 1937; Zuniga, 1953). However, prior to the development of embryo culture technique for coconut, such Makapuno palms are not known to have been in existence.

The Makapuno palms look very similar to non-Makapuno palms, whether propagated by *in vitro* techniques or by seed (de Guzman and del

Rosario, 1974). Perhaps some features of the reproductive stage might turn out to be diagnostic. In the classification of varieties and forms by Narayana and John, some aspects of floral biology and nut characters were among the criteria used (Menon and Pandalai, 1958). Rognon (1976) showed that varieties could be grouped based on the duration of the male and female phases.

The Experimental Palms

Observations were taken on four palms transplanted on 28 May, 1971 at 20-28 months age, a second group of three palms (aged 25-27 months) planted on 2 October, 1971, and a third group of eight palms transplanted on 21 January, 1972. Two of them, I-38N and I-39N, were non-Makapuno, but had been propagated *in vitro*. Some initial observations on the palms are given in Table 1. Palms in the third batch are much older compared to those in the other two groups.

The onset of flowering. Flowering was first noticed on 26 April, 1975 in a Makapuno palm (I-26) belonging to the third group of transplants. Flowering occurred 39 months after transplanting and 70 months from inoculation of embryo. Data on the onset of flowering are given in Table 1. At the time of preparation of this report, only one palm was still in the vegetative condition. The duration of the vegetative phase varied considerably from 68 to 95 months. Nine out of the 15 experimental palms attained reproductive stage before the seventh year.

Floral biology. In their first year of flowering in most palms, both Makapuno and non-Makapuno, an inflorescence emerged about every three weeks. Opening of the spathe also occurred almost every three weeks. Duration of inflorescence development from emergence to splitting was about two months (Table 2).

With the exception of two palms, I-26 and I-36, all produced both male and female flowers starting with their first inflorescence. In I-26, the first inflorescence was underdeveloped and produced only male flowers. All the three opened inflorescence of I-36 were without buttons. Average button production was around 20 in an inflorescence (Table 2). Floral structures of both male and female flowers were normal.

The male phase lasted an average of two weeks in both Makapuno and non-Makapuno palms. Likewise, in both types, about 20 days elapsed from splitting before the buttons turned receptive. The duration of the female phase also did not show much variation. In the Makapuno, duration of intra-spadix overlap averaged 2.2 days, whereas the average value for inter-overlap ranged 1.1-3.0 days. In non-Makapuno palms, the period of intra-overlap was shorter (average of 0.3 days) than the inter-overlap (1.7 days).

Leaf production was recorded starting from the first scale leaf for the palms in Group 3. In the youngest palm to flower, the first inflorescence

TABLE 1. Observations on *in vitro* coconut palms at transplanting and onset of flowering

	Age in months (range and mean)		Age in months at flowering (range and mean)		Height (cm) (range and mean)		No. of leaves (range and mean)	
	In November 1976	At transplanting	From embryo	From transplanting	At transplanting	At flowering	At transplanting	At flowering
I Group Planted : 2 Oct. 1971; 3 palms	86—88 (88)	25—27 (25)	75—82 (80)	50—58 (54)	159—188 (170)	85—112 (96)	—	—
II Group Planted : 28 May, 1976; 2 palms	90—93 (92)	24—28 (26)	83—86 (85)	55—62 (59)	107—147 (127)	85—102 (94)	—	—
III Group Planted : 21 Jan. 1972; 8 palms	86—99 (91)	28—42 (34)	70—95 (82)	39—54 (48)	172—407 (316)	54—137 (104)	19—28 (24)	52—71 (62)
Control Planted : 28 May, 1976 ; 2 palms	86	20	68—77 (73)	48—57 (53)	93—138 (116)	80—11 (95)	—	—

TABLE 2. Floral biology of Makapuno and Non-Makapuno palms

	Nature of palms and number observed	
	Makapuno—5 nos	Non-Makapuno 2 nos
Interval of emergence of inflorescence (*in days*)	20.5—23.8 (12-30)	17.7—22.8 (15-19)
Dehiscence of spathe — Time from emergence (*in days*)	57.8—65.6	54.1—68.6
Dehiscence of spathe — Interval (*in days*)	19.3—24.8	18.2—22.4
Start of receptivity from splitting (*in days*)	16.4—22.1	20.7—22.6
Average no. of buttons	18.0—22.5	13.2—25.6
No. of inflorescence with 2 or more buttons per rachilla	2—8	2—6
Highest no. of buttons/rachilla	2—9	2—3
Duration of male phase (*in days*)	20.3—23.6	21.2—23.2
Duration of female phase (*in days*)	3.9—5.3	3.5—4.3
Duration of intra overlap	1.3—3.2	0.1—0.5
Duration of inter overlap	1.0—3.9	1.3—2.0

was subtended by the 52nd leaf. The comparable subtended leaf in the palm which took the longest to flower was leaf no. 71. For the period under observation, I-26 proved itself to be a regular bearer (Table 3). In I-15, the next 16 open leaves after leaf no. 71. were without any visible inflorescence. Interruption of flower emergence was noted in both Makapuno and non-Makapuno palms.

Degree of fruit set per bunch based on harvestable nuts from I-26 was very variable, ranging 5-80%. It was not necessarily determined by the number of buttons in a bunch.

Where buttons are produced, fruit set occurred starting with the first inflorescence. Viability of pollen grains was tested in a medium containing sucrose and inorganic salts. Average germination observed 2 hr after pollen was collected from I-26 was 83.2%.

Nut production. Nuts have been harvested from only two palms, one Makapuno (I-26) and one non-Makapuno (I-38N). From the former, 74 nuts were harvested within 8 months. Nuts were harvested at the green ripe stage to avoid possible loss by pilferage.

Most exciting was the outcome of the first harvest. The sole nut picked from the first bunch on 30 May, 1976 turnd out to be a Makapuno. In 12 harvests, the percentage of Makapuno nuts was 84.5 (49 Makapuno *vs.* 9 non-Makapuno). Only 4 nuts have been harvested from I-38N and, as expected, all were non-Makapuno.

Observations on nut characters showed that in the non-Makapuno nuts harvested from I-26, the average kernel thickness was 11.1 mm and volume of water was 226.8 ml. For the Makapuno nuts, the average values were 14.6 mm and 136.1 ml, respectively. The weight of a Makapuno nut was 493.8 g. and that of a non-Makapuno nut was 437.2 g. In two nuts, the condition of the endosperm corresponded to one of the types noted by Adriano and Manahan (1937), that is, the meat had a consistency of hard boiled rice and it filled the whole shell.

Embryos extracted from Makapuno nuts taken from I-26 have been compared with an embryo taken from one of the Makapuno nuts being processed into sweets in a local factory. This factory is the source of embryos used in propagating the Makapuno nuts referred to in this paper.

Conclusions

The Makapuno embryo is capable of completing its life cycle provided the initial problem of non-germination is overcome. Despite the initial growth lag, the total duration of the vegetative phase was not overly prolonged by the *in vitro* method of propagation. Flowering habits and floral structure of both types of *in vitro* palms were comparable with those described for the species, especially the Tall variety. The observed yield of Makapuno nuts tends to favour the hypothesis that the palm propagated from the Makapuno nut is potentially pure Makapuno-bearing. The different types of Makapuno nuts, based on degree of fullness and consistency of the meat can be produced by one palm. Further observations will be made to determine if the duration of the intra-spadix overlap can be used to differentiate the Makapuno palms from the non-Makapuno ones.

Acknowledgement

The paper presents partial results of a project supported by a grant from the National Research Council of the Philippines. Participation of

the senior author in the Symposium was sponsored by the Philippine Council for Agriculture and Resources Research (PCARR). The authors thank Mrs. Eden A. Perez for conducting the pollen germination test.

References

Adriano, F.T. and Manahan, M. (1937). The nutritive value of green, ripe, and sport coconuts (Buko, Niyog, and Makapuno). *Phil. Agric.* **20** : 195-198.

De Guzman, E.V. and del Rosario, A.G. (1974). The growth and development in soil of Makapuno seedlings cultured *in vitro*. *Philippines Res. Bull.* **21** : 1-16.

Menon, K.P.V. and Pandalai, K.M. (1958). *The Coconut Palm.* 384 pp. Indian Central Coconut Committee, Ernakulam, India.

Rognon, F. (1976). Biologie florale du cocotier. *Oleagineux* **31** : 13-18.

Torres, J.P. (1937). Some notes on Makapuno coconut and its inheritance. *Phil. J. Agric* **8** : 27-37.

Zuniga, L.C. (1953). The probable inheritance of the Makapuno character of coconut. *Phil. Agric.* **36** : 402-413.

Diseases

Chairman : G. RANGASWAMY

Rapporteur : P. SHANTA

Biology of *Ganoderma Lucidum* (Leys) Karst. and Control of *Anabe Roga* of Coconut

H.C. GOVINDU, A.N.S. RAO and K.V. KESHAVA MURTHY

Department of Plant Pathology, University of Agricultural Sciences, Hebbal, Bangalore 560 006, Karnataka, India

Abstract

Ganoderma lucidum (Leys) Karst. causes *anabe roga* (mushroom disease) in Karnataka state. It is widely present in the *maidan* parts especially in sandy soils of the southern region of the State. This disease seems to affect older palms in neglected gardens more than the young palms. The pathogen has a wide host range. Some of the important hosts are *Areca catechu, Mangifera indica, Artocarpus integrifolia, Cassia siamea, Pongamia glabra, Dalbergia sissoo, Morus alba, Acacia* sp., *Delonix regia* and *Citrus* sp. (especially acid lime).

The disease manifests itself in various forms presenting different symptoms at various stages of growth of the coconut palm. The three characteristic symptoms are : the outer whorl of leaves droop down, become yellowish and reduced in size, and ultimately dry up ; the stem shows a characteristic oozing of brownish gummy substance through cracks and wounds on the lower parts ; later in disease symptomatology, fructifications occur in the form of corky brackets of the pore fungus at the lower part of the trunk. The ultimate result is the death of the palm.

The seat of infection is the base of trunk and roots. The interior of the affected stems become dark brown 50-70 cm from the base and emits musty smell.

The *anabe roga* in coconut is controlled by biological, cultural, and chemical methods. The present studies include the results of research with a new coded antibiotic which gave good control at a concentration of 7.5 g/10 litre water, when applied at the basal portion of the palm through a bore.

Introduction

Ganoderma lucidum (Leys.) Karst. is ubiquitous in its distribution and causes *anabe roga* (mushroom disease) on several hosts in temperate and

tropical countries. It was first recognized as a pathogen on coconut palm in 1846 (Petch, 1916). The disease has since been reported from several coconut growing countries of the world. In India, it has been known to cause considerable damage to coconut, especially in the States of Karnataka, Tamil Nadu, Kerala, and Andhra Pradesh. Butler (1906) referred to a disease "betelnut plague" in Sylhet, apparently caused by *Fomes lucidus* (Leys.) Fr. The disease was first reported on areca palm in Mysore (now Karnataka) by Coleman in 1911. In 1913, Butler also referred to the occurrence of *Polyporus* (Fomes) *lucidus* on diseased areca and coconut palms in Mysore.

The disease is more prevalent in old palms of neglected gardens than on young palms. It is more severe in lighter soils. The fungus occurs in India, Pakistan, Burma, Sri Lanka, and Malaysia, and also in the tropical and temperate regions of Europe and USA It has a wide host range attacking a variety of palms and several forest, avenue, and fruit trees. According to Naidu *et al.* (1966) hosts belonging to 19 families, 36 genera, and 48 species have been recorded. Some of these hosts are : *Areca catechu, Cocos nucifera, Cassia siamea, Pongamia glabra* (Venkatarayan, 1936), *Eucalyptus* (Bagchee, 1953 ; Bakshi, 1974), *Delonix regia, Azadirachta indica, Morus alba, Acrtocarpus fraxinifolius, Cassia javanica* (Bagchee and Bakshi, 1950), *Acacia catechu* (Bakshi, 1957), *Casuarina equisetifolia* (Bakshi, 1951), *Dalbergia sissoo* (Bakshi, 1974), *Fraximus pennsylvanica, Quercus nuttllii, Platinus occidentalis, Populine* spp., *Platinus orientalis, Melia,* spp. (Mahmood, 1971) and *Elaeis guineensis,* (Koonlin Tan, 1968) and *Mangifera indica* (Govindu, Murthy, and Rao, unpublished). Several other species like *Artocarpus integrifolia* and *Citrus* sp. (acid lime) are also known to be susceptible to it.

The fungus *Ganoderma lucidum* was first described under the name *Fomes lucidus* (Leys) Fr. Butler (1909) described the fungus in detail. Butler and Bisby (1931) cited the following as synonyms : *Fomes lucidus* (Leys) Fr. ; *Polyporus lucidus* Fr. ; *Ganoderma resinaceum* (Boud.) ; *Polystictus egregius* Masse n. sp. (?) ; *Ganoderma amboinensis* (Lam.) Pat. ; *Fomes amboinensis* (Lam.) ; and *Polyporus amboinensis* Fr.

According to van Overem (1926), the following are also synonyms: *G. sessile* Murrill ; *Polyporus fulvellus* Bres. ; *P. resinosus* Schraeder ; *P. curtisii* (Berk.) Merrill ; and *Ganoderma mangiferae* (Lev.)

The disease manifests in various forms on the palm presenting different symptoms at various stages of growth. The three characteristic symptoms expressed on the crown, trunk, base and root zone are as follows : Crown symptoms are the first to be noticed ; they consist of a slight discoloration of leaflets in the outer whorl ; the discoloration later spreads to the whole leaf ; within 2-2½ months, the entire crown progressively becomes yellow with outer whorls drooping down and covering the stem, and ultimatety drying up. Sometimes, there is a reduction in size of the crown. Later, it dries up completely and is easily broken during

heavy winds. The affected palms continue to bear nuts for some years, but in lesser quantity than the normal. Late in disease symptomatology, fructifications occur in the form of corky brackets of the pore fungus at the lower parts of the trunk. The ultimate result is the death of the palm.

The disease generally affects heavy bearing palms of 20-60 years age, and rarely, 16-25 years old palms. It is not noticed in palms below 15 years old (Papa Rao and Govinda Rao, 1966).

On arecanut, the fungus attacks palms of 20-40 years age. But, incidence on palms less than 10 years old and above 40 years old is also some times noticed (Naidu *et al.*, 1966). According to Bagchee and Bakshi (1950), palms from about 18 years of age and above are attacked. The seat of infection is the base of the trunk and roots. Affected roots lose their colour, become dry and brittle. The interior of the affected stem becomes dark brown from 50-75 cm above ground level. Affected tissues emit a musty smell. On the outer border of the brownish zone is an yellowish zone separating the healthy zone. The brownish discoloration extends down to the central thickened portion of the root system. The fungus affects only the xylem vessels and xylem parenchyma, and not phloem. Affected vessels show tyloses.

The fungus is a soil dweller inhabiting dead as well as living plant material in the soil. It is root parasite. It enters the host plant through wounds. The spread of the disease takes place mainly through the soil. In the forests, the fungus is known to build up in the residual stumps, which serve as infection centres (Bakshi *et al.*, 1968). According to Naidu *et al.* (1966), the infection in arecanut is usually present on only one side of the root system, while the rest of the roots remains healthy. The first formed sporophores are directly above the healthy root zone opposite to the area of first infection.

Sporophore. The fruit body is perennial, stipitate, usually lateral, rarely central, sometimes sessile, corky becoming woody later, usually 10-12 × 10-12 × 3-4 cm, but may grow upto 30 cm or more. Upper surface is shining, laccate crust, ox blood in colour, smooth, crust of vertical solid thick walled. The palisade hyphae is about 40μ long and is impregnated with a dark orange varnishing substance which they secrete. Hyphae in the context are pale yellow, thick walled, hyaline, and branched with clamp connections (Bose, 1934), 1.7-3.0μ broad and 10.0-12.5 mm thick, and present only in hymenium. Hymenial surface is whitish or creamish, turning brown later, pores small, round, 90-250μ in diameter. Pore tubes are about 6-7mm long. Basidiospores are brown as thick walled, minutely verrucose, truncate at one end, and 8.3-10.0 × 5.8-6.7μ (average 8.8 × 6.4μ) in size.

Fungus in Culture

(*i*) *Growth characters.* Grows 1.5-2.0 cm in 7 days at 24°C in dark;

growth optimum at 34°C, inhibiting at 46°C; mat appressed felty with parallel longitudinal hyphae in the advancing zone, white with shades of straw yellow, naples yellow, deepening to colonial buff; reverse ferruginous darkening to Kaiser brown; on agar containing gentian violet, growth vigorous, medium discolored; on tannic acid agar, diffusion zones strong, growth 2 mm in 7 days; on gallic acid agar, diffusion zone weak, growth nil.

(ii) *Hyphal characters.* Aerial mycelium hyaline, thin walled, branched with clamped connections, 2.5-4.0μ in breadth; chlamydospores formed abundantly, terminal or intercalary, round to oval, hyaline, slightly thick walled, 10.0-15.6μ × 7.5-12.3μ in size; submerged mycelium thin walled with chlamydospores as in aerial mycelium.

According to Banerjee and Sarkar (1959), besides normal basidiospores, two other spore types also occur in the fructifications of the fungus collected from nature or produced in artificial culture. These are secondary spores and gasterospores. All three types of spores are more or less identical to each other in appearance. But, the secondary spores have endospores less verrucose than the endospores of other two types, whereas gasterospores are characterized by two opposite notches in their exospores.

Venkatarayan (1936), who proved by controlled inoculation the slow but active pathogenicity of the fungus on palms, cultured the fungus by transferring aseptic pieces of the tissues from near the margin of affected tissues on prune juice agar and malt agar. According to him, the hyphae growth was thick and flocculent with abundant clamp connection in thicker growth and mycelium was hyaline becoming brownish on growth on stems. The fungus produces both intercalary and terminal chlamydospores. The strain from coconut forms a poriferous layer containing spores both on agar and sterile pieces of coconut. Sporophores are also produced in pieces of areca stems in the laboratory. The sporophores are of bracket type and smaller. Best growth of the fungus is obtained at pH 6.5, but the fungus is capable of growth between pH 3.0-7.0. In month-old inoculations, drops of colourless liquid appear on the mycelial mat covering pieces of stem. Spore germination is not observed either on material from field or artificial culture (Venkatarayan, 1936).

Ganoderma lucidum is known to secrete several enzymes. They are diastase, laccase, protease, invertase, coagulase, endopolygalacturonase, rennetase, and oxidase. Lalitha Kumari and Sirsi (1971) purified the enzyme endopolygalacturonase and found that the enzyme had a peak activity at pH 5.4 with two temperature optima, 50°C and 70°C. They also partially purified and characterized the enzyme laccase. It was inactivated above 60°C and was inhibited by enzyme inhibitors and metal chelating agents like azide cyanide.

Parasitism. The fungus is a wound parasite. Venkatarayan (1936) found that inoculations of living trees was not successful, but inoculations

to the injured roots after digging the soil gave successful infection of the palm while inoculations made into the trunk (by boring the trunk) produced stem bleeding symptoms.

Ceratocystis paradoxa is often associated with stem bleeding symptoms. This disease often occurs *in situ* along with the *Ganoderma* wilt disease. The main symptoms of the stem bleeding disease are sparse to profuse bleeding through cracks developed on the trunk at varying heights, but progressing upwards. This symptom is often mistaken for the bleeding of the stem caused by the *Ganoderma* wilt which occurs at lower heights mainly near the basal portion of the trunk.

A wilt disease of coconut having similar symptoms and locally called as Tanjavur wilt, is known from the districts of Tanjavur, Thirunelveli, Kanyakumari, Ramnad, South Arcot, Coimbatore, Salem and Madurai in Tamil Nadu. The fungi isolated from this include *Ganoderma* sp., *Rhizoctonia* sp., *Fusarium* sp., *Ceratocystis* sp., *Diplodia* sp., and *Trichoderma* sp.

Control

The control of anabe roga of coconut is based on cultural, chemical, antibiotic, and possibly biological, principles.

Cultural. (i) Field sanitation of the gardens, uprooting and burning of the diseased tree stumps in the pit before the formation of dangerous brackets ; (ii) Isolation of affected palms by digging out trenches 50×50 cm around the palm and application of sulphur ; (iii) Providing good drainage and application of balanced fertilizers preferably after soil testing.

Chemical. Earlier recommendations were : (i) application of iron sulphate (Mysore Agriculture Department, 1919); (ii) disinfection of soil with carbon disulphide emulsion and formalin (Narasimhan, 1920-21); (iii) application of 1.0-1.3 kg sulphur dust in trenches (Venkatarayan, 1935).

Recently, several fungicides including systemics and antibiotics, have been tested. Application of aureofungin sol, 1.5 g in 5.0 l water along with 1.0 g of finely ground copper sulphate to the root zone has been reported to be quite satisfactory (Anonymous, 1975). Among systemic fungicides, vitavax (750 ppm) has been found to be promising both *in vitro* and *in vivo* experiments.

The present studies include the results of field experiments with a coded antibiotic No. 8972 obtained from Dr. M. J. Thirumalachar (then Superintendent of Research, Hindustan Antibiotics Ltd., Pimpri, Poona). The antibiotic was applied both to the trunk and roots at a concentration of 7.5g/10 1 (750 ppm). Holes of 1-2 cm diameter and 5-8 cm depth were made at 3-4 places around the stem about 1 m above the bleeding zone. After pouring the antibiotic solution (5-10 ml/bore), the bores

were plugged with sand and saw dust. The antibiotic was also applied to the root zone after removing the soil round the palm to expose the roots. Five litres of the antibiotic were applied to each palm in both the methods. The antibiotic was used at various stages of disease development as described earlier. It was most effective, when applied prior to the development of sporophores. The recovery was seen after three months with 3 applications at fortnightly intervals.

Even though several fungicides, including some systemics and antibiotics have been reported to give varying degrees of success in controlling the disease, no absolutely satisfactory method has yet been developed. This disease is perhaps one of the most difficult ones to control. One of the major aspects in the control of this disease is to prevent the healthy palms in a diseased garden from getting infected. Another important aspect is to develop suitable techniques to detect the disease in its initial stage. Since the disease is known to be serious in neglected gardens, all efforts should be directed towards maintenance of gardens in healthy conditions through cultural practices such as providing suitable drainage, application of balanced fertilizers, and plant protection measures. Prospects of minimizing damage through biological control cannot be overruled since several workers have reported a close association and possible antagonism of *Trichoderma viridae* with the pathogen.

The future approach should therefore be an integrated one aimed not merely at chemical control, but also through cultural and biological measures since the disease is soil-borne and infection takes place mainly through roots. However, the possibility of controlling the disease with antibiotics, as reported here, appears to be the most promising method of control at the present time. It should be coupled with cultural practices such as application of fertilizers, providing drainage, and isolation of infected palms.

References

Anonymous. (1917). Mycology Division report (1916-1917) *Ann. Rept., Agric. Dept., Mysore.*

Anonymous. (1975). The Ganoderma Wilt Disease of Coconut and Control. Information Pamphlet No. 32. Directorate of Extension, A.P.A.U., Hyderabad, A.P.

Bagchee, K. (1953). New and noteworthy diseases of trees in India. *Ind. Forester* **79** : 341-343.

Bagchee, K. and Bakshi, B.K. (1950). Some fungi as wound parasites on Indian trees. *Ind. Forester* **76** : 244-253.

Bakshi, B.K. (1951). Mortality of *Casuarina equisetifolia Forst. Ind. Forester* **77** : 269-276.

Bakshi, B.K. (1957). Fungal disease of *khair* (*Acacia catechu* Willd.) and their prevention. *Ind. Forester* **83** : 41-46.

Bakshi, B. K. (1974). Control of root disease in plantations in reforested stands (with special reference to *khair, sisso*, eucalyptus, etc.). *Ind. Forester* **100** : 77-80.

Bakshi, B.K., Reddy, M.A.R., Singh, S., Pandey, P.C., and Mukherjee, S.N. (1968). Khair (*Acacia catechu*) seedlings mortality in plantations. *Ind. Forester* **94** : 695-661.

Banerjee, S. and Sarkar, A. (1959). Spore forms in sporophores of *Ganoderma lucidum* (Leys.) Karst. *Proc Ind. Acad. Sci.* **B 49** : 94-98.

Butler, E.J. (1906). *Fomes lucidus* (Leys.) Fr., a suspected parasite. *Ind. Forester* **35** : 514-518.

Butler, E.J. (1913). *Rept. Imperial Mycologist, Rept. Agr. Res. Inst. Coll., Pusa,* **60**: 1911-1912.

Butler, E.J. and Bisby, G.R. (1931). The Fungi of India. Sci. Mono. No. 1. 237 pp. Imperial Council of Agricultural Research, New Delhi.

Coleman, L.C. (1911). Anabe roga of *supari. Ann. Rept. Agri. Chemist,* Mysore 6 : 1919-1920.

Tan, K. (1968). Oil palm diseases in Malaya. *PANS* **14** : 46-52.

Lalitha Kumari, H. and Sirsi, M. (1971). Purification and properties of endopolygalacturonase from *Ganoderma lucidum. J. Gen. Microbiol.* **65** : 285-290.

Lalitha Kumari, H. and Sirsi. M. (1972). Purification and properties of laccase from *Ganoderma lucidum. Arch. Mikrobiol.* **84** : 350-357.

Mahmood, T. (1971). *Ganoderma lucidum,* a virulent incitant of basal stem rot, a malady of hard woods in West Pakistan. *Plant Dis. Reptr.* **55** : 1130-1131.

Naidu, G.V.B., Kumar, S.N.S., and Sannamarappa, M. (1966). *Anabe roga, Ganoderma lucidum* (Leys.) Karst on arecanut palm : a review and further observations. *J. Mysore Hort. Soc.* **11 (3)** : 14-20.

Narasimhan, M.J. (1920-21). Report of work done in the Mycological Section. *Admin. Rept. Agric. Dept., Mysore.*

Papa Rao, A. and Govinda Rao, P. (1966). A survey of coconut diseases in Andhra Pradesh. *Andhra Agric. J.* **13** : 208-217.

Venkatarayan, S.V. (1935). Control of *anabe roga* of areca and coconut palms. *Mysore Agric. Calendar for 1935.* Mysore Agri. Dept. Bangalore.

Venkatarayan, S.V. (1936). The biology of *Ganoderma lucidum* on areca and coconut palms. *Phytopathology* **26** : 153-175.

Discussions

Thomas : 1. Since the disease is soil borne, has any attempt been made to correlate the soil characteristics with the incidence of the disease ?

2. Has any variety been found to be tolerant or resistant ?

Govindu : 1. The disease is mostly prevalent and severe in lighter soils than in heavy soils.

2. So far, all the tested varieties are susceptible.

Jeganathan : Under *in vitro* conditions, the fungus *Ganoderma* grows even at a concentration of 1000 ppm under Muthupet conditions. Hence, the efficacy of aureofungin at the proposed level has to be further explored.

Govindu : This is not true. *In vitro* studies cannot be taken as final especially when working with soil borne pathogens. We do not know the natural conditions, and just making conclusions after carrying out *in vitro* studies about efficacy of aureofungin is not correct. It has been proved beyond doubt by the work done in Karnataka and Andhra Pradesh that aureofungin in the concentrations mentioned in the paper gives excellent control.

Dwivedi : What confirmatory test have you made to make sure that browning of root tissue is not an after-effect of auto-oxidation and enzyme activity, resulting from cutting root sections, but is due to the pathogen ?

Govindu : The seat of infection of *Ganoderma* is the base of the trunk and roots. Affected roots become discoloured, dry, and brittle. Cultures of fungus can be easily obtained by surface sterilizing such roots and planting them on agar. Browning of root tissues due to physiological changes like auto-oxidation etc. does not arise in this case, since we are dealing with infected roots from which successful cultures of the fungus are obtained.

Rangaswami : 1. Have you made any studies to compare the pathogens from coconut, arecanut, and other hosts ?

2. What is the concentration of aureofungin which is effective against the pathogen ?

Govindu : 1. It is extremely difficult to get successful infection even on coconut from pathogen collected from the same host. Inoculating injured roots gave successful infection of the palms in the form of stem bleeding symptoms. So far, we have not compared the pathogens from other hosts. There are, however, instances when a strain from coconut containing spores on sterile pieces of coconut produced sporophores in pieces of stems of area in the laboratory.

As regards question 2, Aureofungin-sol 1.5 g/5 lit. of water along with 1.0 g of finely ground copper sulphate to the root zone have controlled the disease and this has been found to be quite satisfactory in the control of the disease.

Bud Rot Disease of Coconut—A Reappraisal of Associated Factors

K. RADHA and THOMAS JOSEPH

Central Plantation Crops Research Institute, Regional Station, Kayamkulam, Krishnapuram 690 533, Kerala, India

Abstract

Bud rot disease of coconut caused by *Phytophthora palmivora* (Butl.) Butl. often tends to be fatal. None of the environmental factors associated with the disease was found to be solely responsible for its development. Manifestation of the disease requires a combination of favourable factors, of which high relative humidity and low temperature are the most important factors. Number of "favourable days" determined the incidence and severity of the disease, which in turn was dependent on the monsoon rains. Palms aged 3-20 years exposed to suitable microclimate were the most susceptible.

The role of *Phytophthora palmivora* in the incidence of the disease, the nature of damage, and the possible implication of secondary invaders, such as bacteria in aggravating symptoms have been assessed. Production of oospores in infected tissues suggests the mode of survival of the pathogen in the cabbage of affected palms. Under favourable conditions an infection cycle could be completed in about a week by the pathogen.

Introduction

Bud rot disease of coconut was first observed in Grand Cayman (West Indies) in 1834 (Tucker, 1926). Since then, it has been reported from several coconut growing countries. Intensive work on the etiology of the disease has been carried out from 1902. (Busck, 1902 ; Earle, 1903 ; Butler, 1906 ; Petch, 1906 ; Stockdale, 1907 ; Fredholm, 1909 ; Johnston, 1910, 1911 ; Shaw and Sundararaman, 1914 ; McRae, 1923 ; Sharples, 1925 ; Tucker, 1926 ; Gadd, 1927 ; Ashby, 1929). In India, Butler attributed the disease to *Phytophthora palmivora* which was later confirmed by Shaw and Sundararaman (1914) and McRae (1923). Comparative morphological and pathological studies on *Phytophthora* from coconut, arecanut, cocoa, rubber, and colocasia revealed that they are all *P. palmivora* Butl. (Reinking, 1919 ; Gadd, 1927 ; Ashby, 1929 ; Thomas *et al.*, 1947).

Butler (1910) reported that the disease was closely associated with weather conditions particularly relative humidity. Menon and Pandalai (1959) observed that the disease was more common during the monsoon period and in young and middle aged palms upto 40 years. Thorold (1955), working on black pod of cacao, reported that the activity of *P. palmivora* was dependent on relative humidity ; 95-98% R. H. was required for oospore germination. Short periods of high humidity followed by low temperature and free moisture are conducive to formation of swarmspores, their further development and infectivity of *P. infestans* (Crosier, 1934).

Although sporadic in nature, the disease often tends to be fatal. The seasonal development of the disease and the influence of environmental conditions of *P. palmivora* suggest the need for a closer examination of microclimatic factors contributing to the development of disease. A reappraisal of the etiology of bud rot was also felt necessary to explain the extensive wet rot associated with the disease.

Proceedure

1. Studies on the Meteorological and Microclimatic Factors

Data on rainfall, temperature, and humidity were recorded from meteorological observatories on the west coast and east coast of peninsular India, *i.e.*, Kerala and Tamil Nadu. Data on temperature and relative humidity at the leaf axil level of palms of different ages, 3-5 years, 11-15 yrs, and 16-20 yrs were recorded five times a day using an Assman psychrometer. Since the observations recorded till 1970 indicated that the late forenoon and afternoon readings had no bearing on disease development, subsequent observations were confined to early forenoon only, during 07.30-09.30 hr. Occurrence of the disease was also recorded during the same period.

2. Laboratory Studies

Glucose nitrate medium (Hendrix, 1965) with thiamine HCl (2 ml of 1000 ppm solution/1) was the most favourable medium for isolation of *Phytophthora* among a number of other media tried using antibiotics, rose bengal, gallic acid, cholesterol, etc.

Sporangial suspension prepared from 4-day old cultures of *P. palmivora* isolated from coconut, arecanut, palmyra, oil palm, and rubber in tap water having approximately 1200 sporangia/ml and 3-day old broth cultures of the bacteria *Pseudomonas* sp., *Xanthomonas* sp., and *Erwinia* sp. were used for inoculations. Ten ml inoculum was applied at the leaf axil, as axillary infection was found to exist in nature. Experiments on the pathogen were carried out under controlled conditions at 22-24°C and 95-100% R. H.

Results

Meteorological and Microclimatic Factors

The "favourable days", i.e , days having temperature below 24°C and R. H. above 95% were seen to be related to the total precipitation received and the incidence of disease was directly related to the frequency of "favourable days" (Table 1).

TABLE 1. Rainfall and disease incidence at Kayangulam and Kasaragod (May-August in 1968 and 1969)

Variable	Kayangulam		Kasaragod	
	1968	1969	1968	1969
Rainfall in mm	1955	1118	3561	2053
No. of rainy days	68	55	72	61
No. of favourable days*	84	66	41	33
Disease%	1.8	0.5	1.2	0.1

* See text for explanation

The correlation between meteorological factors, microclimate, and disease incidence was further indicated in the studies (Tables 2 and 3). The influence of favourable environment on the development of disease as related to the age of palms is represented in Tables 4 and 5.

TABLE 2. Meteorological factors and microclimate (May-September) at Kayangulam

Variable	1968	1969	1970	1971	1972
Rainfall in mm	2234	1502	1379	1619	1022
No. of rainy days	89	81	77	63	56
No. of favourable days	13–20	3–6	3–4	7–13	—
Disease incidence %	1.6–5.4	0 3–1.2	Trace	Nil	Nil

TABLE 3. Weather factors, microclimate, and disease incidence at Kayangulam and Kasaragod (1970-71)

Variable	Kayangulam	Kasaragod
Rainfall in mm (SW monsoon)	1379	3568
No. of rainy days	77	89
Minimum temperature	22.5–24.8°C	21.1–21.6°C
Maximum temperature	31.3–33.3°C	29.6–33.6°C
No. of favourable days*	4	15
No. of palms diseased	1	24

* See text for explanation

TABLE 4. No. of favourable days and disease incidence in relation to age of palms (Kayangulam : June, August, 1968-1969)

Age of palms	1968		1969	
	No. of favourable days	% disease incidence	No. of favourable days	% disease incidence
Below 5 years	13	0	3	0
6–10 years	16	1.6	6	1.0
11–15 years	20	3.9	3	1.2
16–20 years	18	5.4	4	0.3
21 years and above	—	—	4	0

TABLE 5. Disease incidence and microclimate in relation to age of palms (1970-71)

Age of palms	Kayangulam		Kasaragod	
	No. of favourable days	Disease incidence (no. of palms)	No. of favourable days	Disease incidence (no. of palms)
3–5 years	3	0	15	0
6–10 years	4	1	13	13
11–15 years	4	0	15	2
16–20 years	3	0	13	4
Above 20 years	4	0	11	5

The data collected at Muthupet (Tamil Nadu in 1970) showed that the microclimatic parameters hardly touch the favourable level during the period. Disease incidence was not also recorded there.

Field observations revealed the incidence of disease at Ratnagiri (Maharashtra) in 31 out of 3000 young palms, where the annual precipitation was 3400 mm. On the contrary, in Saurashtra, the plantations of young palms were free of disease. Here, total pecipitation was about 75 mm.

2. Laboratory Studies

P. palmivora could be isolated from the cabbage of bud rot affected coconuts. The pathogen produces a dry rot, which primarily damages the cabbage. Under favourable environment, secondary wet rot sets in and hastens the deterioration of the cabbage. *Fusarium* sp. and species of bacteria belonging to *Pseudomonas*, *Xanthomonas*, and *Erwinia* were associated with the wet rot. The failure often met with in isolating *P. palmivora* from affected crown is attributed to possible collection of

samples having the wet rot, because *P. palmivora* grows ahead of the wet rot. *P. palmivora* can be easily isolated from tissues affected by dry rot.

In laboratory trials, *P. palmivora* was able to penetrate uninjured tender tissues establishing primary infection. Neither the fungus *Fusarium* sp. nor the bacterial species could do this. However, rotting progressed faster when *P. palmivora* inoculation was followed by bacteria and wet rot.

Under favourable environments in the laboratory, *P. palmivora* infected varieties and hybrids of coconut and young arecanut and oil palm. Similarly, the five isolates of *P. palmivora* infected young coconut palms responded to artificial inoculation (Table 6). Seedlings of Malayan

TABLE 6. Infectivity of *P. palmivora* isolates

Isolate	Coconut		Arecanut		Oil palm	
	Inoculated	Infected	Inoculated	Infected	Inoculated	Infected
Coconut	59	33	4	4	5	3
Rubber	6	4	4	4	3	1
Oil palm	10	6	4	4	3	1
Palmyra	10	8	4	4	5	4
Arecanut	7	6	4	4	3	1

Dwarf and the four hybrids tested, Tall × Dwarf, Dwarf × Tall, Tall × Gangabondam, and Dwarf × Gangabondam, were susceptible.

P. palmivora survives as mycelium or as oospores in infected soil as well as tissues. In trials, it survived for eight weeks as mycelium in steamed soil and tender petiole of coconut which were inoculated with sporangial suspension. Infected petiole was kept buried in steamed soil after inoculation.

Development of oospore has been observed in culture medium as well as infected tissues. Oospores appear within two weeks in the vicinity of tissues cultured for isolation. *P. palmivora* produced oospores when the cultures were contaminated with *Thielaviopsis* sp. Oospores development occurred also in the tissues of tender petiole inoculated by the fungus.

P. palmivora requires six days to complete an infection cycle. On uninjured tender petiole, it produces primary infection within 72 hr. Secondary sporangia are produced in 48 hr and further rotting develops after another 24 hr.

Discussion

The controversial problems of bud rot disease of palms and the identity of the casual agent as *P. palmivora* (Butl.) were accepted at international level in 1924. In India, following the report of Butler in 1906 on this

disease, Shaw and Sundararaman (1914), McRae (1923), and Sundararaman (1924) proved the pathogenicity of *P. palmivora* on coconut, arecanut, and palmyra palms. Yet, the many unsuccessful efforts to isolate the pathogen from coconut and the occurrence of wet rot associated with the disease suggested the need for determining the role of *P. palmivora* and that of other pathogens in the incidence of disease. The fact that isolations from the basal parts of naturally infected palms exhibiting only dry rot yield *P. palmivora*, whereas tissues affected by wet rot harbour mainly bacteria and *Fusarium* sp. indicates that *P. palmivora* plays the primary role in bud rot with bacteria occurring as secondary invader in the injured and weakened tissue. Failure of bacteria to initiate rotting and its effect on aggravating rotting initiated by *P. palmivora* are considered suggestive of the secondary role of bacteria in contributing towards the final breakdown of the host.

Bud rot disease of coconut is season-bound and can be classified as a rain-favoured disease. Its outbreaks can be well correlated with periods of rain (Keitt and Jones, 1926). The observations made on the influence of microclimate in the development of bud rot are in line with those of Crosier (1934) and Kyron (1967) in the case of potato blight and of Hicks (1967) in pod rot of cacao, both caused by *Phytophthora* sp. Crosier (1934) showed that relative humidity and temperature are the two cardinal factors that determine sporulation, germination, and infection in the potato late blight. Laboratory trials with *P. palmivora* have shown that it requires neary a week from the time of inoculation as sporangial suspension to complete one cycle, i.e., for the production of secondary sporangia. Several such cycles are required for the onset of the disease to enable the pathogen to penetrate the thickly set whorls of leaves and reach the bud region from the foci of infection. The disease has been seen to develop in a minimum period of five weeks after inoculation under controlled conditions, and in the field, after the break of south-west monsoon. Under field conditions, inoculation of 5—7 years old palms caused infection which penetrated to the upper and lower parts of the crown. However, this failed to cause the disease as the post inoculation period was not favourable for the activity of the pathogen.

Production of oospores in single spore culture of *P. palmivora* in synthetic culture when contaminated with *Thielaviopsis* sp. has its parallel in the observation of Brasier (1971, 1972) that sexual reproduction could be induced in *P. palmivora* in the presence of *Trichoderma viridae*. Development of oospores in artificially inoculated and infected palm tissues perhaps suggests the bisexual nature of the organism, due to the involvement of secondary invaders and possible chemical stimulation. Nevertheless, the occurrence of oospores can serve as potential inoculum for a pathogen which is highly dependent on weather factors.

References

Ashby, S. F. (1929). Strains and taxonomy of *Phytophthora* Butl. (*P. faberi* Maubl.). *Trans. Br. Mycol. Soc.* **14** : 18-38.

Brasier, C.M. (1971). Induction of sexual reproduction in single A^2 isolates of *Phytophthora* species by *Trichoderma viridae*. *Nature New Biol.* **231** : 283.

Brasier, C. M. (1972) Observations on the sexual mechanism in *Phytophthora Palmivora* and related species. *Trans. Br. Mycol. Soc.* **58** : 237-251.

Busck, A. (1902). Report of an investigation of diseased coconut palm in Cuba. *New Ser. Bul.* **38** : 20-24.

Butler, E.J. (1906). Some diseases of palms. *Agric. J. India* **1** : 299-310.

Butler, E.J. (1910). The bud rot of palms in India. *Mem. Dept. Agric. India Bot. Ser.* **3** : 221-278.

Crosier, W. (1934). Studies on the biology of *Phytophthora infestans* (Mont.) DeBary. 40 pp. Memoirs No. 155. Agr. Exp. Sta., Cornell University, Ithaca, NY.

Earle, E.S. (1903). Report on trip to Jamaica. *J. New York Bot. Gdn.* **4** : 00-00 (cited by Butler.)

Fredholm, A. (1909). Diplodia disease of the coconut palm. *Proc. Soc. Trinidad and Tobago* **9** : 159-172.

Gadd, C.H. (1927). The relationship between the *Phytophthora* associated with the bud rot disease of palms. *Ann. Bot.* **61** : 253-280.

Hendrix, J.W. (1965). Influence of sterols on growth and reproduction of *Pythium* and *Phytophthora* spp. *Phytophthology* **55** : 790-797.

Hicks, P.G (1967). Observations on the diseases and conditions of cacao pods in Papua and New Guinea. *Papua New Guinea Agric. J.* **19** : 5-9.

Johnston, J.R (1910). The serious coconut palm disease in Trinidad. *Bull. Dept. Agric. Trinidad* **9** : 25-39.

Johnston, J.R. (1911.) *Is Bacillus coli* ever a parasite ? *Phytopathology* **1** : 97.

Keitt, G.W. and Jones, L.K. (1926). Studies of the epidemiology and control of apple scab. *Wisconsin State Univ. Agric. Expr. Sta. Res. Bull.* **9** : 209-225.

Kyrou, N.C. (1967). The relation of rainfall, relative humidity, and temperature to late blight of potato in seeds. *Pl. Dis. Reptr.* **51** : 936-941.

McRae, W. (1923). History of the operations against bud rot of palms in South India. 11. Inoculation experiments with *P. palmivora* Butl. on *Borassus flabblifer* Linn. *Mem. Dept. Agric. India Bot. Ser.* **12** : 21-70.

Menon, K.P.V. and Pandalai, K.M. (1959). The Coconut Palm. A Monograph. 208 pp. Indian Central Coconut Committee, Ernakulam.

Petch, T. (1906.) Diseases of the coconut palm. *Trop. Agriculturist* **27** : 489-491.

Reinking, O.A. (1919). *Phytophthora faberi Maubl.*, the cause of coconut bud rot in Philippines. *Philipp. J. Sci.* **14** : 131-151.

Sharples, A. (1925). Observations on the bud rot of palms. *Rep. Imp. Bot. Conf. London, 1924. Trop. Agric.* **64** : 257-277.

Shaw, F.J. and Sundararaman, S. (1914). The bud rot of coconut palms in Malabar. *Ann. Mycol.* **12** : 241-262.

Stockdale, F.A. (1907). Coconut palm disease in Trinidad. *Bull. Dept. Agric. Jamaica* **5** : 111-139.

Sundararaman, S. (1924). Bud rot of coconuts caused by *Phytophthora palmivora*. *Agric. J. India* **19** : 84-85.

Thomas, K.M., Ramakrishnan, T.S., Soumini, C.K. and Balakrishnan, M.S. 1947. Studies on the genus *Phytophthora*. I. Oospore formation and taxonomy of *P. palmivora* Butl. *Proc. Indian Acad. Sci.* **B 26** : 147-163.

Thorold, C.A. (1955). Observations on black-pod disease (*Phytophthora palmivora*) of cacao in Nigeria. *Trans. Br. Mycol. Soc.* **38** : 435-452.

Tucker, C.M. (1926). *Phytophthora* bud rot of coconut palms in Puerto Rico. *J. Agric. Res.* 32 : 471-498.

Discussions

Thomas : You have suggested that microclimate plays a great role in the incidence of bud rot. If so, will wider spacing be of any help to counter this condition ?

Radha : Premonsoon spraying will provide protection.

Sarma Y.R. : 1. Is there any correlation between sporangial production at the crown region on the so called 'conducive microclimate' for disease development ?

2. Is there any spatial separation of fungal and bacterial infection at crown region (wet rot and dry rot) ?

Radha : 1. Yes

2. Again yes. Bacterial infection follows the fungal and causes wet rot resulting in collapse of tissue and inhibition of the fungus.

Pattanshetti : If the incidence of the disease bud rot of coconut, is high during monsoon, is it possible to forecast the occurrence of the disease after taking into consideration important factors of weather ? Are there effective preventive measures for the disease ? If the preventive measures are adopted timely, is it possible to induce cent per cent protection to the palms ?

Radha : More extensive studies are to be made for forecasting the disease. With the existing facilities in our methodological observations it is possible to forecast the weather factors for only 48 hrs and this period is not sufficient for adopting prophylactic treatments.

Ninan : Dr. Radha, have you observed any varietal difference in the incidence of infection by this pathogen ?

Radha : No, but only WCT, Dwarfs, any hybrids have been tested.

Rangaswami : 1. What are the bacteria involved and do they act as secondary pathogens causing spot rot ?

2. What is the percentage incidence of the disease ? Is there any information available on the endemic occurrence of the disease in different parts of India ?

Radha : 1. *Erdisina*, *Pseudomonas*, and *Xanthomonas*.

2. Survey has been conducted in only Kerala. The incidence varies from 2 to 40% and the average is 2-3% only. A high incidence (of upto 40%) has been observed only in rare instances and is confined to one or two gardens.

Red Ring Disease of the Coconut Palm

B. P. BLAIR

Red Ring Research Division, Central Experiment Station, Centeno, Trinidad

Red ring disease of coconut palm is incited by the nematode, *Rhadinaphelenchus cocophilus*, which enters trees through cracks in the stems near leaf bases. It then moves downward and simultaneously around the stem in the sub-peripheral region to which it is attracted by the high CO_2 content of that area.

Eggs, larvae, and adults are then found throughout the invaded tissue ; and with a life cycle of only 9 days, the nematode produces two generation before the reddened tissue, the main internal symptom, is fully developed 25 days after inoculation.

The first external symptom, yellowing of leaves, becomes visible 35 days after inoculation, by which time, xylem vessels in the discolored zone are occluded by tyloses thereby impending water movement and the dependent exhaustion of CO_2, which in healthy trees, is transported in the transpiration stream via xylem vessels to leaves.

CO_2 then builds up to concentrations which prolong the life of larvae, but prevent them from maturing or migrating inwards and eventually induce anabiosis. Adults and eggs are then found only at the upper extremity, while larvae only are found throughout the rest of the discolored zone in the stem.

The disease is fatal and control was attempted by injecting poison into stems and spraying crowns with insecticides. Bitumen has been tried as a mechanical barrier in leaf axils, and complete cantrol has been achieved in field plots by placing a granular nematocidal preparation in leaf axils.

A Terminology for the Coconut Root (Wilt) Disease

K. MATHEN, N. GOPINATHAN PILLAI and K. RADHA

Central Plantation Crops Research Institute
Regional Station, Kayangulam,
Krishnapuram 690 533, Kerala, India

Abstract

Coconut root (wilt) disease has been referred to by various authors under different names. The variations in the name have created confusion among readers and reviewers to mistake the disease for other disorders in the coconut palm. A list of all such names used in the literature hitherto is given in alphabetical order. A chronological order of the variations is cited. Suitability of each name is discussed. From among the available names, coconut root (wilt) disease is chosen and recommended for use by all workers for the sake of uniformity, until such time as a new name can justifiably replace it.

Coconut root (wilt) disease has been referred to by various authors by different names. There are instances of the same author (s) having used different names to denote the disease on different occasions. The confusion that is likely to arise in the minds of readers as a result of this is sought to be remedied in this note through a citation and discussion on the suitability of the various names hitherto used in the publications.

Maramarosch (1964) listed the synonyms, which were, however, not exhaustive.

1. Coconut palm disease in Travancore: Butler (1908).
2. Coconut wilt disease in India : Holmes, Lal, and Shanta (1965).
3. Coconut (wilt) disease : Summanwar *et al.* (1969).
4. Indian root (wilt) : Davis (1966).
5. *Kattu* (meaning wind) : Verghese (1934).
6. *Kattuveezhcha* (Malayalam term meaning wind-borne) : Sreedharan (1941).
7. Kerala wilt : Pieris (1960, Personal communication).
8. Kerala wilt : Maramarosch (1964).
9. Kerala root (wilt) disease of coconut : Weischer (1967).

10. New Disease of coconut : Kunjan Pillai (1911).
11. Root disease of coconut : Verghese (1934) (translated in Malayalam as *Verucheeyal* and *Verurogam*)
12. "Root" disease of coconut : Sankarasubramoney, Pandalai, and Menon (1954)
13. Root rot : Maramarosch (1964)
14. Root (wilt) of coconut : Srivastava, Shekhawat, and Rao (1969)
15. "Root" (wilt) disease of coconut in Travancore—Cochin : Verghese, Sankarasubramoney, and Menon (1957)
16. Root (wilt) disease of coconut in Kerala : Lal (1966; 1969)
17. Root (wilt) disease of South India : Menon (1961)
18. Root—wilt in Kerala : Davis (1970)
19. (Root) wilt of Kerala : Vijayan, Natarajan, and Krishnamurthy (1973)
20. *Thengurogam* (=coconut palm disease) : Anonymous (1914)
21. Travancore disease : Butler (1908)
22. *Vasantha* (=plague) : Verghese (1934)
23. *Verucheeyal* (=root rot) : (Malayalam translation of root disease) Menon (1947)
24. *Verurogam* (Malayalam equivalent of root disease) : Menon (1953)
25. Wilt disease (root disease) of coconut : Verghese (1934)
26. Wilt (root disease) disease of coconut in Travancore and Cochin : Menon and Nair (1949).
27. "Wilt" disease of coconut : Menon and Nair (1951)
28. Wilt or root disease of coconut : Menon and Nair (1951)
29. 'Wilt' or 'root' disease : Davis (1953)
30. Wilt (root) disease of coconut palm : Radha and Menon (1954)
31. (Wilt) disease of coconut palm : Ramadasan (1967)

Most of these names have been employed by several workers but the earliest available record of each name alone has been cited here. The chronology and suitability of each name are discussed below:

Butler (1908) reported on the coconut palm disease in Travancore (now part of Kerala) and referred to it in the text of his report as Travancore disease. Kunjan Pilllai (1911) reported on a "new disease" of coconut which appeared in isolated pockets of the then Travancore state between 1874 and 1884 and was perhaps justified in calling it so, as the disease was unfamiliar then. Today, it is a century old and the term may not be any more appropriate. Verghese (1934) pointed out that the coconut palm disease of Travancore was not a specific disease, but consisted of different diseases like bud rot, leaf rot, leaf blight, etc. and discussed how investigations of Butler had led to the disease being called the root disease, under which name similar diseases were then known in Sri Lanka and West Indies. He concluded that later research had thrown doubt on the correctness of this appellation. He also

listed the names under which the disease was known till then both in the local language (Malayalam) and in English, viz., *vasantha* (=plague) in the northern and *kattu* (=wind) in the southern parts of the state; coconut palm disease (translated in Malayalam as *thengurogam*, Anonymous, 1914) and root disease; and indicated his preference for the term wilt disease as a more appropriate one under the then available knowledge on the nature of the disease. He had adopted the name as early as 1930 from Nowell, a West Indies worker, who had suggested it in 1924 for a similar affliction in his country.

It appears that the different diseases of coconut were not clearly distinguished from one another especially in the early days of investigations, least so the relation between leaf rot and root (wilt) disease, as is known today. Sreedharan (1941) explained how *kattuveezhcha*, a Malayalam term meaning wind–borne, came to be used to denote leaf rot. The term is quite apt for that disease as the spores of the causal fungus *Helmlnthosporium halodes Bipolaris hqlodes* (Drechs) are carried through wind (Menon and Nair, 1948). But later, *kattuveezha* came to be used for coconut root (wilt) disease, obviously because leaf rot and coconut root (wilt) diseases were then not considered separate entities. Verghese (1934) differentiated leaf rot which was prevalent generally in all localities where root disease of coconut occurred. Menon and Nair (1948) pointed out the confusion among early investigators about the symptoms of leaf rot and root disease of coconut (translated in Malayalam as *verucheeyal*, Menon, 1947 and *verurogam*, Menon, 1953). Rotting of roots and drooping and yellowing of leaves, among others, have been pointed out as the more common symptoms of coconut root (wilt) disease, while rotting of leaves characterized leaf rot. Symptomatology later brought out that, of the three foliar symptoms of the disease, viz., flaccidity, yellowing, and marginal necrosis of leaflets, flaccidity is the initial and diagnostic symptom of coconut root (wilt) disease (Radha and Lal, 1972). Radha and Lal (1969) pointed out that in a significantly higher percentage, leaf rot was superimposed on coconut root (wilt) diseased palms. Root rot has been described as a symptom of coconut root (wilt) disease but not used to designate the disease, as quoted by Maramarosch (1964). John (1950) used the term root rot to denote 'anabe roga' (*Ganoderma lucidum*).

The name of a disease is very often associated with the place of its occurrence. Since the name of the State changed as a result of political reorganization of the states in India, the name of the disease also got a wide range of variations. The erstwhile Travancore and Cochin states first got amalgamated as Travancore-Cochin state, and then reorganized as the present Kerala state. Hence, references to the disease as of Travancore (Butler, 1908), Travancore and Cochin (Menon and Nair, 1949), Travancore-Cochin (Menon and Nair, 1951) etc., cannot hold good any longer. Even a reference to Kerala (Maramarosch, 1964 ; Lal, 1966,

1969 ; Weischer, 1967 ; Vijayan *et al.*, 1973) cannot stand now since Gopinathan Pillai *et al.* (1972) had located gardens in Tamil Nadu having this disease. Naming the disease by terms like root (wilt) disease of southern India (Menon, 1961), Indian root (wilt) (Davis, 1966), coconut wilt disease in India (Holmes *et al.*, 1965) is also inappropriate since a wilt disease of coconut dissimilar to coconut root (wilt) disease has been reported from Tamil Nadu (India) by Vijayan *et al.* (1973). Mentioning the places of occurrence of the disease after its name can, however, be meaningful when different diseases are referred to under identical names like coconut wilt of Esswquibo and Pomiroon ; coconut wilt of Sarawak, Malaysia ; and coconut wilt of Tamil Nadu.

All the names so far used can be grouped into three major suggestions, root disease ; wilt disease ; and root (wilt) /wilt (root) disease. Among these groups, minor variations have caused apparent differences in the name of the disease by different workers emphasising the symptom which appeared to them to be most important.

The name of a disease becomes very meaningful if it can bring out either the etiology or symptoms. The name *Kera* wilt (Pieris, 1960, personal discussion) is suggestive of the type.

References

Anonymous. (1914). In *Karshaka thrimasika* **1** : 67.

Butler, E.J. (1908). Report on Coconut Palm Disease in Travancore. Bull. No. 9. 23 pp. *Agric. Res. Inst., Pusa.*

Davis, T.A. (1953). Breeding in coconut for disease resistance. *Indian Coconut J.* **6** : 95-100.

Davis, T.A. (1966). Coconut withering disease of Ceylon and the Indian root (wilt), a comparison of symptoms. *Proc. Second FAO Technical Working Party (1964)* on *Coconut Production, Protection, and Processing, Colombo, Sri Lanka* (1964). pp. 289-298. FAO, Rome.

Davis, T.A. (1970). The Malayan Dwarf, a probable answer to root wilt in Kerala. *Coconut Bull.* **1** : 3-7.

Gopinathan Pillai, N., Lal, S.B., and Shantha, P. (1973). Distribution and intensity of root wilt disease of coconut in Kerala. *J. Plant. Crops* **1** (Suppl.) 107-112.

Holmes, F.O., Lal, S.B. and Shanta, P. (1965). Cow pea inoculation test for diagnosis of coconut wilt disease in India. *FAO Plant Prot. Bull.* **13** : 3-7.

Indira, P. and Ramadasan, A. (1968). A note on the anatomical derangement in the root tissue of root (wilt) diseased coconut palms. *Curr. Sci.* **37** : 290-291.

John, C.M. (1950). *Coconut cultivation.* 44 pp. Indian Central Coconut Committee, Cochin.

Kunjan Pillai, N. (1911). Coconut (In Malayalam). 112 pp. Vidyabhivardhini Press, Quilon.

Lal, S.B. (1966). Advances in research on the root (wilt) disease problem of Kerala, India. *Proc. Second FAO Technical Working Party on Coconut Production, Protection, and Processing, Colombo, Sri Lanka* (1964). pp. 273-288.

Lal, S.B. (1969). Root (wilt) disease—Resume of work done since 1964. *Proc. Third FAO Technical Working Party on Coconut Production, Protection, and Processing. Jogjakarta, Indonesia* (1968). Paper No. 40.

Maramarosch, K. (1964). A Survey of Coconut Diseases of Unknown Etiology. 39 pp. FAO, Rome.

Menon, K.P.V. (1947). Diseases of coconut and how to control them. *Naleekara Bull.* **1** : 1-2.

Menon, K.P.V. and Nair, U.K. (1948) The 'leaf rot' disease of coconuts in Travancore and Cochin-1. Symptoms, incidence and cause of the disease. *Indian Coconut J.* **1** : 33-39.

Menon, K.P.V. and Nair, U.K. (1949). The wilt (root) disease of coconut in Travancore and Cochin. *Indian Coconut J.* **3** : 5-10.

Control of Ganoderma Wilt of Coconut

A. PAPA RAO, B. SATYANARAYANA, K. SUBRAMANYAM and S.V. PANDIT

Department of Plant Pathology,
Andhra Pradesh Agricultural University,
Hyderabad 500 030, AP, India

Abstract

Sulphur arrests the spread of Ganoderma wilt of coconut temporarily. Later, the disease spreads faster than in check plots due to annihilation of antagonistic soil microflora by sulphur. Vitavax (750 ppm) and aureofungin sol+copper sulphate (100 ppm) checked the spread of the disease through soil and also its progress within an affected palm. Depending upon the age of the palm, type of soil, and the extent of initial bleeding zone, certain limitations on the efficacy of fungicides have been identified.

Introduction

In Andhra Pradesh, India, the incidence of *Ganoderma lucidum* on coconut is severe causing 100% deaths among affected palms (Papa Rao and Govinda Rao, 1966). Venkatarayan (1935) reported that isolation of affected palms and application of 1.00-1.25 kg sulphur dust/palm controlled the disease. Most coconut cultivators, however, prefer to burn the affected trunks in brick kilns to eliminate the source of inoculum and contain this disease, rather than dusting with sulphur. Therefore, a series of studies were made to find out the reasons for this preference and to see if any of the latest fungicides and antibiotics could check this disease better than the existing methods. The results are discussed in this paper.

Materials and Methods

The efficacy of sulphur dust was tested in two gardens having sandy and sandy loam soils. Dividing each garden into two halves, sulphur was sprinkled around the diseased palms (@ 1.0 kg/palm) in one half of the plot. The other half plot was left as control. In both the half-plots, the spread of the disease and the mortality percentage among affected palms were recorded.

Another field experiment was laid out with seven chemicals in a randomized block design, replicated seven times, to see which of them was the most effective both as a prophylactic and as a curative. One plot consisted of one diseased palm in the centre surrounded by healthy palms. In the prophylactic studies, all the healthy palms were treated, while the diseased palm in the centre was left untouched to serve as a source of inoculum. In the curative studies, the central diseased palm alone was treated, leaving the healthy palms untreated. In the control plot in both the cases, none of the palms was treated. All the systemic fungicides and ziride were applied at the rate of 1000 ml/palm/half year, by feeding them to the trunks through a bore 3.0 cm long and 1.0 cm diameter made at a height of 1.0 m above the top of external bleeding zone. Aureofungin sol+copper sulphate sol was poured on intact cut ends of healthy roots on hole at the rate of 5.0 l/palm. The roots were then covered with soil. This treatment was repeated after a fortnight as a second dose. These two doses formed one treatment given within a half year. All the chemicals were thus administered throughout the 5-year period of study. Sulphur was dusted in isolation trenches in two split doses of 1.0 kg/palm/half-year in the first year only.

Every half-year, all the surrounding healthy palms were examined to see how far each treatment checked the spread of the disease. In the curative studies, the mortality percentage was also recorded among affected palms. The results are presented in Table 1.

TABLE 1. Efficacy of seven fungicides in controlling *Ganoderma* wilt of coconut

Sl. No.	Treatment	Percent spread of disease						Curative
		Preventive treatment			Curative treatment			Percent deaths among affected palms
		1 Year	2 Years	5 Years	1 Year	2 Years	5 Years	
1.	Check	90-100% of healthy palms got infection during the first 6-12 months, and most of them were dead by 5th year						83.2
2.	Plantvax (1000 ppm)	15.0	40.0	58.0	17.0	43.0	68.0	59.2
3.	Benlate (250 ppm)	2.0	29.0	48.0	25.0	42.0	59.0	59.2
4.	Ziride (1000 ppm)	Nil	20.0	30.0	100.0	100.0	100.0	53.1
5.	Aureofungin sol+copper sulphate	15.0	19.0	21.0	15.0	22.0	35.0	21.4
6.	Vitavax (750 ppm)	Nil	5.0	28.0	25.0	27.0	30.0	14.3
7.	Sulphur (two doses of 1.0 kg/palm/half year)	22.0	41.0	69.0	100.0	100.0	100.0	81.6
	CD (p=0.01)	N.S	14.09	17.26	N.S.	5.86	16.69	21.34

N.S=Not significant

In preliminary trials, it was observed that the extent of initial external bleeding zone, age of palms, and type of soil limited the efficacy of fungicides in controlling the disease. To check this the palms were divided into four categories based on their age and the extent of initial external bleeding zone. Within each category, three palms situated in different types of soils were administered the most effective fungicide, viz., vitavax (750 ppm) or aureofungin sol+copper sulphate (100 ppm). The results are presented in Table 2.

Results and Discussion

1. Effect of Sulphur Dust

In both sandy and sandy loam soils, the disease did not spread in the first four months in the half-plots dusted with sulphur, as against continous spread noticed in check plots. However, in the subsequent six months, the spread of the disease was more rapid in the former than in the latter (Table 1). The rate of spread was higher in the replanted field suggesting that the pathogen hybernates in dead tissues. All affected palms died in treated and untreated plots. It appears that sulphur fumes inhibit *G. lucidum* in soil to arrest its spread, but this may not be diffusing deeper into affected tissues to check the development of the disease within an affected palm. *Bacillus coagulans*, *Streptomyces* sp. (Menon, 1963), and *Trichoderma viridae* (Garrett, 1955) have been reported to be antagonistic to *G.lucidum*. Papa Rao and Subramanyam (1976) observed that sulphur not only inhibited *G. lucidum*, but also the soil microflora. The absence of antagonostic soil microflora in sulphur-treated plots may account for the augmented rate of spread of disease in the last six months.

2. Preventive and Curative Control Treatments

In the preventive trials, vitavax in the first two years and aureofungin sol+copper sulphate in the next three years were the best (Table 1). In curative trials, the latter in the first two years and the former in the next three years were the best. Both were at par with each other at the end of five years in their efficacy for both preventive and curative control.

The overall superiority of aureofungin sol and vitavax over sulphur may be ascribed to their systemic properties. In spite of administering these chemicals regularly at half-yearly intervals, the disease spread steadily. It indicates that either the pathogen might be overcoming the inhibitory effects of these chemicals, or that all these chemicals are only fungistatic rather than fungicidal in action. Even their limited success was ensured only in the absence of the borer *Xyloborus* sp.

3. Limitations Involved in Chemical Control

It was easier to control the disease in its earliest stages (Table 2) Papa Rao, Satyanarayanan, and Subramanyam (Unpublished) reported

that the infection progressed along the length and also around the collar of the trunk. If the infection completes the entire girth of collar, the life line between the roots and foliar parts is cut off. This may account for the ineffectiveness of chemical treatments at advanced stages of the disease.

TABLE 2. Limitations involved in chemical control of Ganoderma wilt of coconut

	Age group of palms	Type of soil	Height of bleeding zone			
			I (0-10 cm)	II (1-50 cm)	III (5-100 cm)	IV (Above 100 cm)
1.	5-15 years	Black sandyloam (SL) or red laterite	+	+	—	—
		(RL)	+	+	—	—
		Sandy	+	—	—	—
2.	15-30 years	Black	+	+	+	—
		SL or RL	+	+	—	—
		Sandy	+	(+)	—	—
3.	30-50 years	Black	+	+	+	(+) (Upto 150 cm only)
		SL or RL	+	+	(+)	—
		Sandy	+	+	—	—
4.	Above 50 years	Black	+	+	+	+ (Upto 150 cm only)
		SL or RL	+	+	+	(+) (Upto 150 cm only)
		Sandy	+	+	(+)	—

\+ Almost all treated palms can be saved
(+) Effectiveness was observed only in one-third palms
— Impossible to save even a single palm

Remarks : The above limits hold good only in the absence of the borer *Xyloborus* sp.

In adult palms, the disease can be checked even if it is slightly advanced over the earliest stages, as the development of the disease in such palms is slow, probably due to the presence of more lignified cells in them than in younger palms. Rishbeth's (1955) observation that pine trees aged 25 years and above possessed more resistance to *Fomes annosus* due to more resin production supports this view.

Thus, there appears to exist several limitations in controlling the disease chemically. Papa Rao and Subramanyam (Unpublished) observed that application of organic manure increased soil microbial population and it reduced the disease incidence. Bakshi (1951) reported that manuring not only increased the vigour of plants and gave better yields, but also resisted parasitism by *G. lucidum*. Rishbeth (1955) found conspicuously greater incidence of root disease, when forest sites were burnt. From these, it appears that this menace occurs due to lack of maintenance of equilibrium of natural biological forces in soil microflora. Therefore, a better method to control this disease appears to rest "in hastening natural recolonization by the soil microflora" (Garrett, 1955), rather than resorting to dusting of sulphur or burning diseased palms in brick kilns in endemic gardens. To save the life of palms at the earliest stages of the disease, we recommend the use of vitavax or aureofungin sol + copper sulphate.

Acknowledgements

We thank Indian Council of Agricultural Research and Andhra Pradesh Agricultural University for financial help; Drs A. Appa Rao, J. Subbaiah, and M.J. Thirumalachar for their encouragement and M/s Uniroyal Agricultural Chemicals for supplying vitavax and plantvax.

References

Bakshi, B.K. (1951). Mortality of *Casuarina equisetifolia* Forst. *Indian Forester* **77** : 269-276.

Garrett, S.D. (1955). A century of root disease investigation. *Ann. Appl. Biol.* **42** : 211-219.

Menon, R. (1963). Studies on *in vitro* of *Ganoderma lucidum*. *Phytopath. Z.* **48** : 434-438.

Papa Rao, A. and Govinda Rao, P. (1966). A survey of coconut diseases in ndhra Pradesh. *Andhra Agric. J.* **13** : 208-217.

Rishbeth, J. (1955). Root diseases in plantations with special reference to tropical crops. *Ann. Appl. Biol.* **42** : 220-227.

Venkatarayan, S.V. (1935). Control of *anabe roga* of areca and coconut palm. *Mysore Agric. Calendar* : 33-37.

Pests

Chairman : K.K. NIRULA

Rapporteur : CHANDY KURIAN

Studies on Integrated Control of Coconut Black Headed Caterpillar *Nephantis serinopa* Meyrick (Lepidoptera : Cryptophasidae)

L. Nadarajan and G. P. Channa Basavanna

Department of Entomology, University of Agricultural Sciences, Hebbal, Bangalore 560 024, Kanrataka, India

Investigations were conducted for integrating the existing parasite release for controlling *Nephantis serinopa* with new approaches like sterile male release and stem injection of systemic insecticides. Fumigation of adult males with chemosterilants, thiotepa at 100 mg and hempa at 1 ml for 3 hr at 30 C produced sterility of 100 and 89% respectively. Irradiation and adult emergence were not satisfactory. When pupae were irradiated with 40 krads one day prior to adult emergence, 80% sterility and 0% hatchability were noticed. Stem injection of a systemic insecticide monocrotophos at 7 ml per palm was found to be effective with 90 to 100% mortality of larvae in trees of 9 to 10 years age, and 60 to 70% mortality in taller trees about 50 years old.

Release of Predators for the Control of the Coconut Scale *Aspidiotus destructor* in Sri Lanka

P.R. DHARMADHIKARI, P.A.C.R. PEREIRA,
T.M.F. HASSEN and S.V. SINNATHAMBY

Food and Agriculture Organisation of the United Nations, UNDP, Sri Lanka (PRD), and Coconut Research Institute, Lunuwila, Sri Lanka

Abstract

The coconut scale *Aspidiotus destructor* Sign. is a moderately serious pest of coconut in Sri Lanka. It is normally kept in check by the two prevailing monsoons and an indigenous Coccinellid predator *Chilochorus nigritus* L. Recent outbreaks of the pest, however, prompted the search for more effective methods of controlling the pest. Cocount scale occurs throughout the coconut growing areas of the Island, but is more pronounced under conditions producing luxuriant growth with thick intermingling foliage. Four predators have been recorded. Of these, *C. nigritus* and a parasite *Aphytes* sp. predominate.

Cryptognatha nodiceps Mshl., *Lindorus lophantae* L., *Azya trinitatis* Mshl., *Chilochorus cacti* Mshl. and *Coccidiphilus* sp. were recently introduced into Sri Lanka in an attempt to control the pest. The predators were mass-multiplied in the laboratory on coconut scale bred on pumpkins for subsequent mass-releases in affected areas. Approximately, 30,000 predators were released at 18 localities in three major provinces so far.

Introduction

The coconut scale *Aspidiotus destructor* Sign. (Hemiptera : Diaspididae) is a serious pest of several tropical crops including coconuts, bananas, black pepper, baringtonias, and papaya in several countries. It is a somewhat serious pest of coconut in Sri Lanka. No great effort has been made in the past to control the coconut scale in Sri Lanka, mainly because the two major monsoons, which are fairly regular and the indigenous Coccinellid predator, *Chilocorus nigritus* L., have been exerting appreciable controlling effects on the scale insect. However, during 1974 and 1975, outbreaks of the scale occurred, especially in the drier areas of Southern Province, though the Eastern Province which receives a lower average rainfall and is subject to longer periods of drought, has so far been fairly free from serious outbreaks of *Aspidiotus*.

The control measures adopted to date in Sri Lanka include a preliminary inspection and assessment of the indigenous predator populations. Where predator populations are high, invariably, the pest is soon brought under control. Where predator populations are low, spraying of a soap/kerosene oil emulsion is recommended.

The recent resurgence of localized scale outbreaks, and the fact that *Aspidiotus* in Sri Lanka has never been adequately checked, prompted the search for more effective methods of keeping this insect under control.

Distribution of Coconut Scale

The cocount scale in Sri Lanka is distributed throughout the coconut growing areas of the Island. Normally, a few attacked leaflets may be seen on an occasional palm. However, in some localities in the North Western Province, where a good and even distribution of rainfall coupled with a rich soil, have produced palms with thick, heavy foliage, and the leaves of adjoining palms very often intermingle with each other, the coconut scale occurs frequently and often develops into outbreaks. A similar situation may also be created in areas from where jungles have been cleared and planted with coconuts and the rich virgin soil produces a luxuriant growth of palms. These conditions provide also good protection to the pest from the ill effects of wind and rain also favour dispersal from palm to palm through the crawler stage, either by themselves or with the aid of other animals moving through the foliage. Thus, the distribution of the pest is more or less island-wide, but prevalence of the scale is largely governed by growth conditions.

Host Plant and Damage

In Sri Lanka, *A. destructor* occurs as a serious pest only on coconut, although it may subsist on a variety of other plants. The damage to the plant is consistent with the sucking habits of the insect, causing a loss of chlorophyll tissue and consequent yellowing and eventual withering and death of attacked portions of the leaf.

Endemic Natural Enemies

The most important endemic natural enemy is *Chilocorus nigritus* L. (Coleoptera: Coccinellidae). It is widely distributed and has been capable at times of controlling the pest by itself in certain localities. Other important predators recorded are *Scymunus* sp., the adult of which is reddish brown with a varying black spot design on its elytra, and *Pullus xerampelinus*, another smaller Coccinellid. *Aleurodothrips fasciapennis* has been reported as attacking *Aspidiotus* in Sri Lanka (Taylor, 1935). A species of *Aphytis* has also been recorded as a parasite of *Aspidiotus*.

Introduction of Exotic Natural Enemies

The exotic natural enemies selected for introduction into Sri Lanka were *Cryptognatha nodiceps*, *Lindorus lophantae*, *Azya trinitatis* and *Chilocorus cacti* initially, and *Coccidiphilus* sp. near *citricola*, subsequently. These consignments of insects were imported from the West Indies, through the Commonwealth Institute of Biological Control.

The first consignment of predators arrived in Sri Lanka in January 1974 and consisted of 440 adults of *Azya trinitatis*, 474 adults of *Cryptognatha nodiceps*, 20 adults of *Lindorus lophantae* and 35 adults of *Nephus aeneipennis*. Unfortunately, due to delay in transit, all the insects except 3 adults of *Lindorus* were dead on arrival. The second cosignment, consisting of 213 adults of *A. trinitatis* and 385 adults of *C. nodiceps*, were received in February 1974. All insects were alive and active on receipt, and 100 *Azya* and 210 *Cryptognatha* were released on the following day at Anamaduwa, in the North Western Province, the balance being retained in the laboratory for breeding. The third consignment, consisting of 162 adults of *Azya*, 100 adults of *Lindorus*, and 85 adults of *Cryptognatha*, was received also in February, 1974, and were used for laboratory breeding. Three consignments of the Coccinellid *Chilocorus cacti* comprising 98, 114, and 225 adults, respectively, were received in June/July 1975. The first two consignments were retained in the laboratory for breeding, while the third consignment of *C. cacti* was released immediately on *Aspidiotus* infested coconut palms at Kuliyapitiya in the North Western Province.

Laboratory Breeding of Aspidiotus

Aspidiotus can be conveniently bred on *Cucurbita maxima* fruits. Ahmad and Ghani (1972) has studied the life history of scale bred on cucurbits.

The pumpkin to be infested is washed with 0.1% formalin and then with distilled water. Infested leaflets having mature scale with eggs and crawlers are selected and they are cut into pieces of suitable length and placed against the pumpkin and held in position by rubber bands or twine in such a way that the scale surface is in close contact with that of the pumpkin. The pumpkin is then placed on props and kept inside a dark room or in a darkened cage. The leaflets are removed after 15 days and the scale allowed to develop on the pumpkin. If the selection of leaflets and infestation have been properly done, the pumpkin should be ready for use for feeding and egg laying for the predators after a further 10-15 days. Satisfactory results were obtained with wooden breeding cages $45 \times 45 \times 30$ cm in size.

Laboratory Breeding of Exotic Predators

Exotic predators were bred in the laboratory on *Aspidiotus* infested

Cucurbita maxima fruits using wooden cages of 45×45×30 cm with glass sides and muslin cloth top (with a cloth sleeve). The life-history and behaviour of these predators have been studied by Taylor (1935) and others. In Sri Lanka, approximately 20 adult beetles per cage were used. They were allowed 14 days for egg laying on a well-infested pumpkin.

On the 15th day, the beetles were transferred to another scale infested pumpkin for further egg laying. Pupae were collected in glass petri-dishes lined with filter paper.

C. nodiceps, L. lophantae, and C. cacti were conveniently bred in large numbers in the laboratory using the above methods, but *A. trinitatis* could not be bred, even though a number of modification including the provision of scale infested caged seedlings were tried out.

Releases and Recoveries

Releases of the predators were made in all stages of development, viz., small larvae, full-grown larvae, pupae, and adults, but the majority of releases were carried out in the adult stage. Approximately, 20,000 *C. nodiceps*, 10,000 *L. lophantae*, 500 *C. cacti*, and 100 *A. trinitatis* were released in 18 localities in the North Western, Western, and Southern Provinces of Sri Lanka (Tables 1 and 2).

TABLE 1. Release of coccinellid predators for control of *A. destructor*

Sl. No.	Locality	Number of predators released				Total
		C. nodiceps	*L. lophantae*	*C. cacti*	*A. trinitatis*	
1.	Anamaduwa	210	—	—	100	310
2.	Negombo	2424	—	—	—	2424
3.	Giriulla	960	—	—	—	960
4.	Madampe	3946	1419	—	—	5365
5.	Chilaw	1542	—	25	—	1567
6.	Ambakelle	4755	—	90	—	4845
7.	Hettipola	654	—	—	—	654
8.	Tissamaharama	321	—	—	—	321
9.	Badalgama	400	300	—	—	700
10.	Kuliyapitiya	1000	2344	210	—	3554
11.	Narammala	466	—	—	—	466
12.	Wariyapola	1342	1665	208	—	3215
13.	Nattandiya	300	619	—	—	919
14.	Matara	1275	902	—	—	2177
15.	Ambalantota	—	687	—	—	687
16.	Kelaniya	—	958	—	—	958
17.	Kandana	—	702	—	—	702
18.	Piliyandala	—	373	—	—	373
	Total	19,595	9969	533	100	30,197

TABLE 2. Distribution of exotic predators released

Predator	Number released			
	NWP	WP	SP	Total
C. nodiceps	17999	—	1596	19595
L. lophantae	6347	2033	1589	9969
C. cacti	533	—	—	533
A. trinitatis	100	—	—	100
Total:	24,979	2033	3185	30,197

Although regular observations and a meticulous search have been carried out in all the areas of release, none of the predators has so far been observed as established on *Aspidiotus*. A few larvae of *Cryptognatha* were observed feeding on *Aspidiotus* at Ambakelle after series of quick releases, but these also disappeared along with the pest after some time.

Acknowledgements

We thank the authorities of the Cocount Research Institute, specially the staff of the Crop Protection Division, for assistance and cooperation both in the breeding and release of the predators. Assistance of the United Nations under FAO/UNDP Project SRL/72/038 and SRL/75/041 is deeply appreciated.

References

Ahmad, R. and Ghani, M.A. (1972). Studies on *Aspidiotus destructor* Sign. (Hem: Diaspididae) and its parasites, *Apytis melinus* De Bach (Hym: Aphelinidae) and *Pakenoyrtus pakistanensis* Ahmad (Hym: Encyrtidae) in Pakistan. *C.I.B.C. Tech. Bull.* 15: 51-57.

Anonymous (1965). The coconut scale insect and its control. Adv. Leaflet No. 18. 4 pp. Coc. Res. Inst., Lunuwile.

Taylor, T.H.C. (1935). The campaign against *Aspidiotus destructor* Sign. in Fiji. *Bull. Ent. Res.* 26: 1-102.

Biological Control of Insect Pests of Coconut—A Review

CHANDY KURIAN, G.B. PILLAI, J. ANTONY, V.A. ABRAHAM and P. NATARAJAN

Central Plantation Crops Research Institute, Regional Station, Kayamkulam, Krishnapuram 690 533, Kerala, India

Abstract

Oryctes rhinoceros L , *Nephantis serinopa* M., *Rhynchophorus ferrugineus* F., and *Leucopholis coneophora* B. are the major pests of coconut in India. These insects are attacked by a number of parasites, predators, and microorganisms including nematodes. The most important biological control agents for the control of the black beetle are the indigenous predators *Sntalus parallelus* P.,*Agrypnus* (near *bifoveatus* C.), and the exotic reduviid bug *Platymeris laevicollis* G. The pathogens *Metarrhizium anisopliae* (M.) S., *Rhabdionvirus oryctes* and a nematode *Neoaplectana carpocapsae* D. (DD-136) also show promise. The establishment of the above agents depends very much on the ecological conditions and biotic factors.

No biological agent other than *Chelisoches moris* F. has been reported on red palm weevil in India. The scope of utilizing parasites, predators, and pathogens for the control of the cockchafer is also discussed. The leaf eating slug caterpillars *Contheyla rotunda* H., *Macroplectra nararia* M., and *Parasa lepida* C. are attacked by bacterial, fungal and insect parasites. *Stephanitis typicus* D., the suspected vector of the root (wilt) disease of coconut, has a predator in *Stethoconus paraefectus* D.

Mention is made also of parasites obtained on these pests from other countries. A few such examples of *Aspidiotus destructor* S. (found in India as well), *Artona catoscantha* H., *Levuana irridiscens* B-B, and *Promecotheca reichii* B. are given. Some of the main problems encountered in their utilization are also pointed out.

The phenomenon of an insect preying upon another and being dependent upon it for food was known ever since the early days of entomology. Almost all insects are subject to this natural restraint placed on their increase in population by parasites and predators. By taking measures calculated to favour the parasites and predators, we can help to sway the balance between the pest and their natural enemies in a direction favourable to man. The organisms responsible for insect control, while common in the field and occurring sporadically and causing natural controls have so far proved to be rather unreliable and generally not very effective when artificially introduced. The vertebrate predaotrs, the most important of

which are birds and rodents, destroy large number of noxious insects. But opinion is divided on their efficacy. The chief enemies of insect pests are insects themselves, because their number and rate of reproduction are not less than that of the pest itself and also their extreme specificity.

Two methods are used in biological control. One is the artificial increase of the natural enemies that already exist in the locality and the other is the introduction of a new species into the existing natural enemy complex. The latter is done mostly in cases where effective indigenous parasites or predators are not observed, as in the case of the rhinceros beetle of coconut where effective biological control agents had to be imported from abroad. The introduced parasite/predator should not only be able to survive in the new environment, but must also adapt itself advantageously to the stages in the life-history of the pest, i.e., the correct host stage must be available at the appropriate time.

Coconut palm is attacked by a number of insect pests at all stages of its growth. In India, more than 100 species of insect pests have been reported to damage the coconut palms. These pests get an abundant supply of food and multiply uninterruptedly all the year round with the result that the coconut plantations are often seriously damaged. The major pests are the rhinoceros beetle, *Oryctes rhinoceros* Linn., the leaf eating caterpillar, *Nephantis serinopa* Meyr., the red palm weevil, *Rhynchophorus ferrugineus* Fab., and the cockchafer beetle, *Leucopholis coneophora* Burm. Among the less serious enemies, the important ones are the slug caterpillars, *Contheyla rotunda* H., *Macroplectra nararia* Moore and *Parasa lepida* Cram., the coconut scale *Aspidiotus destructor* Sign., the lace wing bug *Stephantis typicus* Dist., and the nut crinkler *Paradasynus* sp. near *rostratus* Dist.

The Rhinoceros Beetle (*Oryctes rhinoceros* L.) (Coleoptera : Scarabaeidae)

This is the most ubiquitous pest of the coconut palm. The adult beetle bores through into the unopened fronds and spathes. The infestation damages the leaves and quite often, attacked inflorescence is totally destroyed.

The pest is attacked in nature by certain pathogenic fungi, bacteria, viruses, mites, nematodes, insect parasites and predators and vertebrate predators like the squirrel, mongoose, rats, and pig (Kurian *et al.*, 1969; Kurian and Antony, 1973). The fungus *Metarrhizium anisopliae* (Metch.) Sorokin, which is the causative organism of green muscardine disease, has been under investigation in India for more than forty years now. The fungus infects all stages of the pest except eggs (Nirula, Radha, and Menon, 1955; Nirula, 1957). The practical utility of this fungus in controlling the pest was studied in our Station. The disease is more prevalent during the south-west monsoon period when high relative humidity and low temperature are prevalent. Under such conditions, it can take the

role of a virulent pathogen and cause epidemics particularly in the larval population (Elizabeth and Kurian, 1970, 1971). But considerable variations have been reported in the virulence and efficacy of this fungus as an agent for the biological control of the pest. This fungus was also recorded from Samoa and Fiji (Simmonds, 1941) and Palaus (Steinhaus, 1951). Cumber (1957) reported heavy mortality of the pest in Samoa as a result of natural or artificial infection by *Metarrhizium*. Venkataraman (1956) isolated the fungus *Beauveria bassiana* (Bals.) Vuill. from diseased grubs collected from Trivandrum. The second instar larvae were more susceptible. Steinhaus (1951) carried out experiments in the Palau Islands on *Oryctes* using *Bacillus popilliae* Dutky., *B. lentimorbus* D., and *B. thuringiensis* Berl. with no conclusive results. Cumber (1955, 1957) also tested *B. lentimorbus* var. *australis* Beard and *B. eulomarahae* B. Neither of these showed marked pathogenicity. Several types of Rickettsiae are known to be associated with insects. Surany (1960) reported that rickettsial diseases might play an important role in the biological control of *Oryctes*. In majority of cases the rickettsial infections have been found in association with other diseases. He also recorded Heidenreiche' disease, Mayas' disease and a combination of both. It was presumed that these diseases were caused possibly by viruses. A high percentage of mortality of late last instar larvae and prepupae was observed, due to the combined effect of the two diseases.

A virus disease that appears to have great potentialities of practical utility is caused by *Rhabdionvirus oryctes*. Investigations on *R. oryctes* are in progress in Fiji, W. Samoa, and India. The virus appears highly specific to *Oryctes* and has not proved infectious in laboratory tests to any of the Coleoptera introduced earlier into Samoa as biological control agents. In field tests, the virus disease has spread and there was a marked improvement of coconut plantations (Huger, 1969a). Beetles visiting breeding sites containing larvae freshly killed by virus infection can become infected (Zelazny, 1972; 1973a; 1976) In Fiji, a marked reduction in the incidence of the beetle on palms was obtained 12-18 months after introduction of the virus in the beetle population (Bedford, 1976).

Nematode infections in Oryctes seem to be rather common in Africa. Surany (1960) reported that the genus of nematode commonly met with on *Oryctes* larvae is *Rhabdites*. Attempts have been made to rear and infest these nematodes on *Oryctes* larvae in Fiji and Seychelles with limited success. All stages of the pest from egg to adult are prone to the attack of nematodes. Isolations of nematodes were made from the third instar grubs of Oryctes collected from Agathi Island in the Lakshadweep. Suspensions made from the material, when injected into healthy grubs, produced mortality (Kurian *et al.*, 1969). The nematode *cum* bacterium culture DD-136 (*Neoaplectana carpocapsae* and *Achromobacter nematophilus*) was effective against the larval stages of *Oryctes*.

Surany (1960) observed mortality among eggs and freshly hatched first instar grubs as a result of the feeding activities of certain mites. In India, Mesostigmata : Ascidae are found associated with the eggs and early instar grubs of *Oryctes* in the breeding materials. During latter part of summer with the onset of monsoon, they are found to congregate on the eggs and just hatched grubs of *Oryctes* and in August-September, nearly 60% of eggs are damaged by mites (Kurian *et al.*, 1969).

Several species of Scoliid wasps parasitise different species of *Oryctes* in Zanzibar, Malagasay, and Mauritius. They are *Scolia azurea* Chr., *S. oryctophaga* Cog., *S. ruficornis* F., *S. ruficeps* Smith, *S. erratica* Smith, and *S. patricialis* Burm. Biology of all these parasites is known (Gressitt, 1953). Consideration has been given to the control of *Oryctes* by employing some of the scoliid wasps. One instance of satisfactory biological control of an *Oryctes* sp. is that of *Oryctes tarandus* ol. in Mauritius by *S. oryctophaga* introduced from Madagascar. Simmonds (1949) observes that *S. ruficornis* may be playing an important role in keeping *Oryctes bosa* Fe. and *O. monoceros* ol. under control in Zanzibar and neighbouring parts of eastern Africa. Simmonds introduced *S. oryctophaya* Cog. into Western Samoa from Madagascar in 1939, but it failed to establish. However, with *S. ruficornis* it was more successful in 1945. In Western Samoa, *S. ruficornis* has established and spread at least 40 km in one direction. In India, attempts were made without success to establish *S. ruficornis* and *S. oryctophaga* (Kurian and Antony, 1973). More than 100 species of Scoliidae are present in India, including *S. procer* III., which is stated to be a parasite of *Oryctes*. But so far, no evidence is available to prove their efficacy. In general, the results of introductions of scoliid wasps have been disappointing. It is too early however to attempt a final assessment of them (Lever, 1969).

Gater (1924) mentions two cases of Sarcophagid flies reared from *Oryctes larvae*, but indicated that parasitism was uncertain. Venkataraman *et al.* (1954) have also reported a Sarcophagid fly infesting rhinoceros beetle. Since these Sarcophagids are generally seen on dead grubs, they are to be considered saprophytic forms.

Scorpions and the centipede *Scolopendra* sp. are also reported to attack *Oryctes* grubs. There are several indigenous predators of *Oryctes* belonging to families Carabidae, Elateridae, Cetonidae and Histeridae among Coleoptera and Reduviidae among Hemiptera (Kurian *et al.*, 1965). Some of the important predatory insects of *Oryctes* reported from various countries are *Mecodema spinifer* Brown, *Neochryopus sauvagei* Hope, *Catascopus whithilli* Hope, *Morion cucujoides* Walk. and *Pheropsophus* sp. (Carabidae), *Agrypnus fuscipes* Fabs. and *Alaus speciosus* Linn. (Elateridae), *Oxycetonia versicolor* Fab. (Cetonidae), *Pachylister chinensis* Quensel (Histeridae), and *Platymeris laevicollis* Distant. (Reduviidae). (Venkataraman, 1958.) In India, the promising species are *Santalus parallelus* Payk., *Agrypnus* sp. near *bifoveatus* Candeze, *Scarites* spp. and

Harpalus spp. *S. parallelus* is frequently found in Kerala and Tamil Nadu. Larvae and adults predate on eggs and grubs of *Oryctes* singly or collectively (Antony and Kurian, 1966; Kurian *et al.*, 1969). In *Agrypnus*, only grubs are predaceious. *Scarites* sp., during its larval and adult stages, feed on the eggs and early instar grubs of the pest. *Harpalus* spp., which are very common in the breeding material of *Oryctes*, are also predaceous on eggs and early instar grubs.

The reduviid bug *P. laevicollis* Distant., an efficient predator on the adults of *Oryctes monoceros* ol., was imported from Zanzibar through CIBC, Bangalore and tried against *Oryctes* at CPCRI. This is being mass bred and liberated at two centres.

Among the vertebrate predators, the giant toad *Bufo marinus*, the tree lizard, *Hemidactylus brooki* (Geckonidae), the monitor lizard, *Veranus monitor*, the large Geoko, *Gekko* sp. the Pacific Iguanid *Brachylophus fasciatus*, owls kingfishers, chickens, ducks, the Indian crow, the bulbul *Molpastes bengalensis*, the golden backed woodpecker *Brachypternus aurantius*, the Indian hoopy *Upupa epops indica*, the hawk-cuckoo *Hierococcyx varius*, the tree sprew *Tupaia* sp., palm squirrels, rats, pigs, lemurs, the mongoose *Herpestes* sq., some marsupials etc. have also been reported preying upon the various stages of *Oryctes* in different coconut growing tracts of the world.

The Leaf-eating caterpillar (*Nephantis serinopa* M.) (Lepidoptera : Cryptophasidae)

The leaf-eating caterpillar is another serious pest of the coconut palm in India, Sri Lanka, and Burma. It is distributed along the coastal and backwater areas. The larvae live on the under surface of leaves in galleries and feed on green tissues. Infestation results in reduced yield.

The larvae and pupae of *Nephantis* are often killed by fungal and bacterial parasites during the monsoons. The bacterium causing septicaemia is *Serratia marcescens* Bizio. (Antony and Kurian, 1961). According to Steinhaus (1949), the silk worms and a number of other insects are susceptible to *S. marcescens.*

Several brands of microbial "Insecticides" like *Bacillus thuringiensis* preparations have been tested for the control of the pest. These meet to a considerable degree of criteria like consistent virulence, persistence, speed of action, specificity, safety of use, and ease of production. To the present, there is no evidence to indicate that the toxin adversely affects any of the beneficial insects. *B. thuringiensis* HD strain along with surfactant fundal was successfully tried against the caterpillar.

The mite *Pyemotes venticosus* Newport is parasitic on caterpillars during rainy season. It is amenable to laboratory breeding and capable of quick dispersal (Mathen *et al.*, 1968).

The most important parasites of *Nephantis* belong to Hymenoptera and

Diptera. The indigenous parasites are the Vipionid, *Apanteles taragamae* Vier., the Braconid *Bracon brevicornis* Wesm., the Bethylid *Perisierola nephantidis* Mues., the Elasmid *Elasmus nephantidis* Roh., the Eulophid *Trichospilus pupivora* Ferr., the Chalcids *Brachymeria nephantidis* Gahan, *B. nosatoi Habu* and *Antrocephalus* (*Stomatoceras*) *sulcatiscutellum* (Girault), the Ichneumonids, *Xanthopimpla punctata* F. and *Goryphus nursei* Cameroon, and the Tachinid *Winthemia* sp. (Kurian, 1964). Joy (1975) added *Brachymeria lasus* Walker, *B. excarinata* Gahan, *B. himeattevae* J. N.N.J., *B. hearseyi* var. *Xanthosterus* W., *Antrocephalus* sp. near *denticollis* C., *A. phaeosoma* W., and *Anastatoidea brachartonae* G. to the list. A Tachinid, *Spoggosia bezzinna* Bar. and an Ichneumonid, *Erioborus trochanteratus*, introduced from Sri Lanka, are also under trial in India.

Apanteles taragamae V. is an internal parasite of early instar larvae. Only one parasite emerges from each host and duration of life cycle is 10-14 days. This is distributed on the coastal regions of Tamil Nadu, Andhra Pradesh, and Orissa. *Bracon brevicornis* W. is an external larval parasite with a life cycle of 8-11 days on the West Coast and 7-9 days on the East Coast (Nirula, 1956). *Perisierola nephantidis* M. is an effective ectoparasite on larvae with a life-cycle of 8-14 days on full grown caterpillars (Antony and Kurian, 1960). Kurian and Antony (1961) studied its systematic position, host preference, and distribution. In nature, this is hyperparasitised by certain Chalcids. *Elasmus nephantidis* R. is another ectoparasite on full grown *Nephantis larvae* (prepupae). The female lays 20-70 eggs on the host. Life cycle is completed in 9-12 days. The pupae of *Elasmus* are also subject to attacks of certain hyperparasites. *Trichospilus pupivora* is an important internal pupal parasite which is quite amenable to laboratory breeding (Ananthanarayanan, 1934). The life cycle is completed in about 14 days and 45-250 parasites emerge from each host pupa (Nirula, 1956). For *Brachymeria nephantidis* G., the total life cycle lasts 10-14 days during summer. It is slightly prolonged during rainy season. The combined parasitism by various species of *Brachymeria* is 22% with parasitism by *B. nosatoi* reaching 19.3% in southern Kerala and 2.2% in northern Kerala. The absence of *B. nosatoi* is noted in all areas with heavy incidence of the pest. The desirable qualities that make *Brachymeria* important are their long life span and adaptability to hot season and short developmental period as compared to the pest. However, mass multiplication of *Brachymeria* is difficult (Joy, 1975).

The Ichenumonid, *Xanthopimpla punctala* F. is another pupal parasite (Kurian, 1964) Only a single parasite emerges from each host pupa. It has a life cycle of about 20 days. *Goryphus nursei* C. is yet another Ichneumonid. Only one parasite matures from each hot pupa. It has a life cycle of 12-16 days (Nirula *et al.*, 1954). The Tachinid *Winthemia* sp. infests the grown up caterpillar at the time of pupation. It has a life-cycle of 16-25 days. Generally, one or two parasites emerge from each host.

A comprehensive programme for establishing *Spoggosia bezziana*, the exotic tachinid parasite of *Nephantis* is under way in India (Annual Report, 1974, 1976; Kurian, 1976). Jayaratnam (1941) reported that *Trichospilus pupivora* F. acts as a hyperparasite on *S. bezziana* in eastern Sri Lanka, the natural home of the fly. In spite of this adverse interaction, this Tachinid could be of benefit during summer months, when the *T. pupivora* population will be very low. *Erioborus trochanteratus* is under trial at the Tamil Nadu Agricultural University, Coimbatore (Jayaraj, Unpublished, 1976).

Attempts have been made from time to time to multiply some of the parasites of *Nephantis* and liberate them in pest infested tracts. In 1924-25 25, the then Madras Government set up parasite breeding laboratories at Mangalore, Kozhikode, and Ponnani, all on the west-coast of India. At a later stage, a boat laboratory was set up to reach the interior parts by canals. During 1947, parasite breeding laboratories were set up in East and West Godavari to fight the pest. The intensive colonization of the parasites for over two years saved the palms in the worst affected tracts (Rao *et al.*, 1948). During 1950, heavy infestation of *Nephantis* was observed along the coastal area of Quilon District in Kerala. Parasites liberated in large numbers controlled the incidence (Nirula, 1956). There was an epidemic outbreak of the pest in and around Badagara, Kozhikode district, Kerala in 1970. The outbreak was brought under control by employing parasites. The pest population before parasite liberation was 2-3 pests per infested leaflet with a natural parasitization of 3-5%. Two months later, the pest population was reduced by 99.97% with a field parasitization of 37-68% (Annual Report, 1972).

For mass rearing of the parasites, certain alternate host materials are used. *T. pupivora* is considered to be effective because of its short life cycle, prolific breeding habits, and ability to parasitize more than one pupae. Its host range is also very wide. It has little tendency to super-parasitism. It is not observed to be attacked by any hyperparasite, whereas Elasmids and Bethylids are heavily hyperparasitised in nature (Dharmaraju, 1952, 1962). The wasp has active habits and is capable of wide dispersal. But the greatest drawback is its susceptibility to heat. During the hot months of March-June on the West Coast, the parasite almost disappears (Kurian and Pillai, 1964). With a view to supplementing the popluation of beneficial parasites in nature, zonal parasite breeding stations are functioning in major coconut growing tracts where *Nephantis* is a problem. However some workers hold different views as to the utilization of indigenous parasites. They point out the limitations of the present efforts of the biological control of *Nephantis* and emphasize implementation of a pest management programme in line with modern concepts (Nagarkatti, 1973).

The main insect predators of *Nephantis* are the carabid beetle *Parena laticincta* Bates. and *Phalaeodromius nigrolinatus*, the Reduviid bug

Sphedanolestes aurescens, and species of ants (Kurian and Pillai, 1964). The Reduviid *P. laevicollis* D. is found to be feeding on *Nephantis* caterpillars, particularly in the nymphal stages. The Anthocorid bug *Triphleps* sp. and certain species of spiders also feed on various stages of the pest. The house lizard, garded lizard, and some birds are the common vertebrate predators.

Red Palm Weevil (*Rhynchophorus ferrugineus* F.) (Coleoptera: Curculionidae)

Red palm weevil is the most destructive pest of young coconut palms. The damage caused by the grubs is often fatal.

In India, the pupae are often killed by mites. In the western tropics *Rhynchophorus palmarus* has been reported to be attacked by *Tetrapolypus rhynchophori* Ewing, a mite belonging to a family allied to Pyemotidae (Nirula, 1956).

Friderichs (1919) described *Scolia erratica* Smith as parasitizing the larvae of red palm weevil. Burkill (1912) also has recorded *S. erratica* S. as a parasite of red weevil grubs in Singapore. According to Clausen 1940), Scoliids have host preference to grubs of Curculionids, particularly *Rhynchophorus*. In India, a calliphorid fly *Sarcophaga fuscicauda* Botcher has been observed (Lepesme, 1947). Leefmans (1920) in Indonesia, Hutson (1933) in Sri Lanka, and Copeland (1931) in the Philippines could not detect any parasite on the pest.

Abraham and Kurian (1973) observed an earwig *Chelisoches moris* F. feeding on the eggs and early instar grubs of the weevil in Kerala. They found it to be a very effective predator. Recently, a species of predatory thrips has been observed in the cocoon fibres of the pupae at Kayangulam. Some mammalian predators like the mongoose and squirrels have also been observed predating on the various stages of the pest, particularly the grubs. Man is also a predator. Red weevil grub is said to be considered as a delicacy in some parts of Burma.

Cockchafer Beetle (*Leucopholisd coneophora* Burm.) (Coleoptera: Melolonthidae)

Leucopholis and other related species of cockchafers attack roots of coconut and other intercrops adversely affecting the vigour of the palms and yields.

The milky disease, *Bacillus popilliae* Dutky, developed by Dutky (White and Dutky, 1940; Dutky, 1942) is still sold and effectively used to control cockchafer grubs in lawns and golf greens under various trade names including Japidemic or Doom. *B. popilliae* D., isolated from *Holotrichia serrata* and other cockchafers in India, could be used against the species that attack coconut.

Sekhar (1958) reported mortality among the prepupae of *L. coneophora*. Dissected specimen revealed the presence of nematodes. Nematodes have been reported to cause mortality among grubs of the Japanese beetle in the USA. No further work on the relationship of this nematode with the pest appears to have been done.

In Kerala, a scoliid wasp *Campsomeriella collaris* is common and parasitises cockchafer grubs. Its biology has also been studied. This can be introduced into areas where it does not exist (Annual Report, 1969). Some Tachinid and Tiphiid parasites have been recorded on European chafers. *Harpalus pennsylvanicus* (Carabidae) is a predator on grubs (Tashiro *et al.*, 1969).

Birds are an important predator of this pest. The common crow is the most useful bird in this respect. The striped squirrel also predates on grubs. During the peak period of emergence of adults, dogs, cats, and bats are also found feeding on beetles (Menon and Pandalai, 1960). Mammals listed as predators in the USA are skunk, mole, and short tailed shrew and birds, starling, robin, crow, black birds, sparrow, grackle, and pheasant (Tashiro *et al.*, 1969).

Contheyla rotunda H. (Lepidoptera: Eucleidae)

This slug caterpillar, though generally considered a minor pest, is capable of assuming serious proportions. The defoliation caused by it can cause reductions in yield.

During the rainy season, quite often, severe outbreaks are brought under control by bacterial and fungus pathogens. The pest is heavily parasitized by some natural enemies. They are the Braconid, *Rogas* sp., Ichneunonid *Goryphus* sp., Chalcidid, *Antrocephalus* sp., and Chrysidid *Chrysis* sp. (Lever, 1969). The incidence of attack by this Chrysidid reaches as high as 20% (Nirula *et al.*, 1954).

Macroplectra nararia Moore (Lepidoptera: Eucleidae)

On the east coast of India, this "spiny slug caterpillar" occasionally attacks the coconut palms and causes extensive damage to leaves.

During the rainy season, this pest is attacked in nature by fungi like *Aspergillus flavus* Link. and *A. niger* Tieg. (Kurian, 1963). In Sri Lanka, a suspension of a granulosis virus has been applied in an attempt to suppress the pest (Lever, 1969). Gadd *et al.* (1948) have recorded few species of Euplectrine Eulophids on it in Sri Lanka. Of these, the commonest and most effective is *Neoplectrus maculatus* Ferr. Kurian (1954) has recorded four new species of chalcid parasites from this pest from Tatipaka, Andhra Pradesh. They are *Eurytoma tatipakensis* Kurian, *Euplectromorpha natadae* Kurian, *Secodes narariae* Kurian, and *Euderus natadae* Kurian. Their potentialities for control of the pest are yet to be studied.

Parasa lepida **Cram. (Lepidoptera: Eucleidae)**

The larvae defoliate the palms and severe infestations occur sporadically.

The larvae are heavily parasitized. The parasites involved are *Clinocentrus* sp., *Stomatoceras ayyari* G., and *Pediobius* sp. (Chalcididae), *Eupelmus catoxanthae* Ferriere (Eupelmidae), *Stilbum splendidum* Fab. and *Chrysis shanghaiensis* Smith (Chrysididae), *Eurytoma monema* Ruschka (Eurytomidae), *Goryphus oxymorus* Tosquinet (Ichneumonidae), *Apanteles parasae* Rohwer (Vipionidae), *Chaetexorista javana* Brawer and *Bergenstamm* (Tachinidae) and *Sarcophaga antilope* Botcher (Calliphoridae). Studies on their utilization are yet to be made. An interesting predatory caterpillar *Phycita dentilinella* Hps. (Phycitidae) has been recorded inside the cocoon of the pest destroying the pupae (Lepesme, 1947; Menon and Pandalai, 1960; and Lever, 1969).

Stephanitis typicus **Dist. (Heteroptera : Tingidae)**

This lace wing bug is important because of its dual role as a pest of coconut and as a possible carrier of the pathogenic principle involved in the root (wilt) disease of coconut in Kerala.

A Mirid bug *Stethocomes praefectus* (Dist.) is predaceous on the nymphs and adults of *Stephanitis*. Its life history has been worked out (Mathen and Kurian, 1972).

Paradasynus **sp. near** *rostratus* **(Dist.) (Heteroptera: Coreidae)**

It sucks sap from the female flowers and immature nuts and causes their shedding. In an identical species recorded as a pest of cashew, eggs are heavily parasitized in the field by *Hadrophanurus* sp. (Scelionidae) and *Anastatus* sp. (Eupelmidae) (Nair and Remamony, 1964).

Successful Examples of Biological Control Work done Outside India

Outstanding successes refer to biological control projects against a major pest of a major crop over a fairly extensive area, so that other control measures become rarely necessary.

Aspidiotus destructor Sign. (Hemiptera : Coccidae). The coconut scale is a well known pest of several crops in the Tropics. Attempts have been made outside India for controlling this pest by the introduction of Coccinellid beetles. Successful control was obtained in Fiji by the introduction of *Cryptognatha nodiceps* Mohl. from Trinidad (Taylor, 1935). In Mauritius, several parasites and predators were introduced from Java (Indonesia) and Sri Lanka to control it. Of these, the most successful have been the Coccinellid *Chilocorus politus* Mulsant and *C. nigritus* Fabricius. *C. nodiceps* gave successful control within two years in Principle Island in the Gulf of Guinea, where it was released in 1955

(Simmonds, 1960). In Efate Island, in the new Hebrides, another Coccinellid *Lindorus lophanthae* Blaisdell was used with immediate success (Cochereau, 1965).

Levuena iridisuns B-Bak. (Lepidoptera : Zygaenidae). Caterpillars feed on the foliage of the coconut palm and cause heavy damage in Fiji. In 1925, there was a very severe incidence. Tothill *et al.* (1930) reported on a regular compaign made for the control of the pest. The Tachinid *Bessa remota* Ald. was introduced from Malaysia and effective control was obtained (Lever, 1969). This is regarded as one of the classic examples of successful biological control.

Promecotheca cocruleipennis Blanchard (Coleoptera : Hispidae). The larvae feed by mining the tissues of the basal half of the leaflets, whereas the adults feed by making narrow grooves on the lower surface of the distal half of the leaflets. Severe infestations result in the reduction of upto 75% of the functional leaf surface.

Taylor (1937) studied the natural enemies already present in Fiji prior to 1933. Some indigenous parasites seem to have kept the pest under control until the unintentional introduction into Fiji of the mite *P. ventricosus.* The mite reaches the pest to "one stage condition" at a time (Evans, 1952). In this condition, the indigenous parasites are ineffective. Taylor (1937) introduced the Entedontid *Pediobius parvulus* Ferr. from Java. It soon established in Fiji and the pest was brought under control.

Promecotheca cumingi Baly. This is one of the most important pests in the Philippines and neighbouring countries. The damage is greater because of the involvement of a fungus. In 1970, the pest was reported from Sri Lanka. Many egg and larval parasites were introduced and it is reported that *Dimmockia javanica* is responsible for the control (Bannerjee, S.N., Personal communication, 1976).

Problems of Biological Control

The ability of a parasite to control the pest depends mostly on the higher rate of reproductive capacity of the parasite as compared to that of the pest (Taylor, 1937). So also the stages of the pest at which they are attacked by the parasite must be present all through the year lest the parasite should miss them and be consequently displaced. The ideal parasite is one which attacks most of the stages of the pest and which can live on alternate hosts to ensure its uniform distribution. Competitions among parasites and hyperparasitism are also problems which hamper the efficacy of parasites.

A fully effective parasite is always easily and quickly established, ideally even from a single pair. A parasite which takes long to get established may not be very effective later on For this reason, the colonization of an imported parasite or predator may well be discontinued after three or four years of unsuccessful attempts.

Extensive use of modern synthetic insecticides also causes serious problems. Some of them are more toxic to beneficial insects than to the pests. The phytophagous mites appearing in enormous proportions subsequent to insecticidal application is an example. This should be avoided.

For a realistic understanding of the problem, work has to be based on actual observation and experiments on the changes of population in nature. Work should be directed along lines which appear to be most suitable both biologically and ecologically. On a careful scrutiny it may be seen that the number of success attained will be proportional to the amount of research and importation of suitable exotic material.

References

Abraham, V.A. and Kurian, C. (1973). *Chelisoches moris* F., a predator on eggs and early instar grubs of red palm weevil *Rynchophorus ferrugineus* F. *J. Plant. Crops* 1 (Suppl.) : 147-152.

Ananthanarayanan, K.P. (1934). On the bionomics of an Eulophid *Trichospilus pupivora*, a natural enemy of the coconut caterpillar, *N. serinopa*. *Bull. Ent. Res.* 25 : 55-61.

Annual Report (1969). Annual Report for 1968. Central Coconut Research Station, Kayangulam.

Annual Report (1972). Annual Report for 1971. Central Plantation Crops Research Institute, Kasaragod. pp. 100-102.

Annual Report (1974). Annual Report for 1973. Central Plantation Crops Research Institute, Kasaragod. pp. 68-69.

Annual Report (1976). Annual Report for 1975. Central Plantation Crops Research Institute, Kasaragod. pp. 57-59.

Antony, J. and Kurian, C. (1960). Studies on the habits and life history of *Perisierola nephantidis* Muescbeck. *Indian Coconut J.* 13 : 145-153.

Antony, J. and Kurian, C.(1961). A note on the bacterial disease of *Nephantis serinopa* Meyrick, a lepidopterous pest of the coconut palm. *Indian Coconut J.* 14 : 82-84.

Antony, J. and Kurian, C. (1966). Biology of the histerid beetle, *Hister* (*Santalus*) *orientalis* Payk. *Proc. Fiftythird Indian Science Congress, Part III Abstracts* : 362-363.

Bedford, G.O. (1976). Use of a virus against the coconut palm rhinoceros beetle in Fiji. *Pans* 22 : 11-25.

Clausen, C.P. (1940). pp. 612 in *Entomophagous Insects*. McGraw-Hill, New York.

Cochereau, P. (1965). Control, biologique d'*Aspidiotus destruetor* Sign. dans l'ile vate, Nouvelles—Hebrides, au moyess de *Lindorus lophanthae Blaisd. C.R. Acad. Agric. France* 51 : 318-321.

Copeland, E.B. (1931). pp. 68-113 in *The Coconut*. MacMillan and Co., London.

Cumber, R.A. (1955). Quarterly Report for the period ending 28.2.1955 S. Pacific Commission, Noumea.

Cumber, R.A. (1957). The rhinoceros beetle in Western Samoa. *S. Pacific Commission Tech. Paper* No. 106-132.

Dharmaraju, E. (1952). The biological control of the black headed caterpillar *Nephantis serinopa* Meyr., in the East Godavari district of Madras State. *Indian Coconut J.* 5 : 171-176.

Dharmaraju, E. (1962). A check list of parasites, the hyper-parasites, predators, and pathogens of the coconut leaf caterpillar *Nephantis serinopa* Meyrick, recorded

in Ceylon and in India and their distribution in these coconut growing countries. *Ceylon Coconut J.* **13** : 102-111.

Dutky, S.R. (1942). Method for the preparation of spore dust mixtures of Type A milk disease of Japanese larvae for field inoculation. *U.S. D.A. Bur. Ent. Plant Quarant.* **ET-192**, 15 pp.

Elizabeth, G. and Kurian, C. (1970). Fungus to fight the black beetle. *Cocon. Bull.* **1**(1) : 10-11 and 17.

Elizabeth, G. and Kurian, C. (1971). Studies on green muscardine fungus : Influence of meteorological factors and inoculum potential on the infection of *Metarrhizium anisopliae* on *Oryctes rhinoceros* L. *Mysore J. Agric. Sci.* **5** : 423-430.

Evans, J.W. (1952). The Injurious Insects of the British Commonwealth. Commonwealth Inst. Entomology, London.

Friederichs, K. (1919). Schadlishe Insekten durch parasitische pilze-bekampft werden. *Naturwissen. Mitteil. Bern.* 15-16.

Gadd, C.H., Foneska, W.T. and Ranaweera, D.J.W. (1948). Parasites of nettlegrubs with special reference to *Platyplectrus natadae* Ferr. and *Autoplectrus. Ceylon J. Sci.* **B23** : 81-94.

Gater, B.A.R. (1924). Insect pests of Labuan and adjacent islands. *Malayan Agric. J.* **12**(11) : 00-00.

Gressitt, J.L. (1953). The coconut rhinoceros beetle. *Bernice P. Bishop Museum Bull.* **212**. 157 pp.

Huger, A.M. (1969 a). Diagnostic proof for successful introduction of *Rhabdionvirus oryctes* into the *Oryctes* ecosystem in areas of Western Samoa. *South Pacific Commission UNDP (SF)/SPC Rhinoceros Beetle Project, Semi-Annual Report*, Nov. 1968—May 1969, pp. 34.38. Noumea, New Caledonia.

Hutson, J.C. (1933). The red weevil of coconut. *Dept. Agric. Ceylon Leaflet No.* 22.

Jayaratnam, T.J., (1941). A study of the control of coconut caterpillar *Nephantis serinopa* Meyr. in Ceylon with special reference to its Eulophid parasite *Trichospilus pupivora Ferr. Trop. Agriculturist* **96** : 1-19.

Joy, P.J. (1975). Biology and morphology of *Brachymeria nephantidis* G. and its comparative efficacy in the control of *N. serinopa* Meyr. PhD Thesis. pp. 198. University of Calicut, Calicut.

Kurian, C. (1954). Description of some new chalcides (Parasitic Hymenopters) from India. *Agra Univ. J. Res.* **3** : 119-134.

Kurian, C. (1963). Biological control of insects pests of coconut. pp. 157-166 in *Proc. First FAO Technical Working Party on Coconut Production, Protection and Processing, Trivandrum.*

Kurian, C. and Pillai, G.B. (1964). Pests of coconut and how to fight them. pp. 49-54 *Souvenir, Plant Protection Seminar, Trivandrum, Kerala.*

Kurian, C. (1976). Modern trends in biological control of pests. Paper presented at K.K.Nayar Commemoration Symposium, Trivandrum. Abstract of Papers. pp.2-3.

Kurian, C. and Antony, J. (1961). Systematic position, host preference and distribution of *Perisierola rephantidis* Mueseback (Superfamily : Bethyloidea Family : Bethylidae), a larval parasite of *Nephantis serinopa* Meyr.) and its allied species. *Indian Coconut J.* **14** : 123-126.

Kurian, C. and Antony, J. (1973). Attempts at the biological control of *Oryctes rhinoceros. Cocon. Bull.* **1**(1) : 10-11 and 17.

Kurian, C., Antony, J. and Thommen, K.J. (1965). Biological Control of *Oryctes rhinoceros* L. pp. 366-370 in *Proc. Second Session of FAO Technical Working Party on Coconut Production, Protection & Processing, Colombo.*

Kurian, C., Antony, J., Pillai, G.B., and Elizabeth, G. (1969). Methods of control of the coconut rhinoceros beetle *Oryctes rhinoceros.* pp. 15-43. in Final Report, PL 480 Project.

Kurian, C. and Pillai, G.B. (1964). Biological control of coconut pests—a resume. Paper presented at the Entomological Research Workers Conference, IARI, New Delhi.

Kurian, C. and Mathen, K.(1965). Insects of major importance other than rhinoceros beetle. pp. 331-334. in *Proc. of Second Session. FAO Technical Working Party on Coconut Production, Protection & Processing, Colombo.*

Leefmans, S. (1920). De Palmsruitkever *Rynchophorus ferrugineus* F. *Meded. Inst. Plantenziekten,* Nr. **43** : 90 pp. Wageningen.

Lepesme, P. (1947). Les Insects des Palmiers. LC Chevalier, Paris.

Lever, R.J.A.W. (1969). *Pests of Coconut Palm.* FAO Agri. Series, Rome. 190 pp.

Mathen, K. and Kurian, C. (197.). Description, life history and habits of *Stethoconus praefectus* (D). predacious on *Stephanitis typicus* D., a pest of coconut palm. *Indian J. Agric. Sci.* **43** : 255-262.

Mathen, K., Sathiamma, B., and Kurian, C. (1968). A mite to combat coconut caterpillar. *Indian Fmg.* **18**(5) : 32-33.

Menon, K.P.V. and Pandalai, K.M. (1960). The *Coconut Palm*—a *Monograph.* Indian Central Coconut Committee, Ernakulam.

Nair, M.R.G.K. and Remamony, K.S. (1964). *Paradasynus* sp. as a pest of cashewnut in Kerala. *Indian J. Ent.* **26** : 461-462.

Nirula, K.K. (1955). Investigations on the pests of the coconut palm. Part II: *Oryctes rhinoceros. Indian Coconut J.* **9** : 30-79.

Nirula, K.K. (1956). Investigations on the pests of the coconut palm. Part III. *Nephantis serinopa. Indian Coconut J.* **9** : 101-131, and 174-201.

Nirula, K.K. (1956). Investigations on the pests of the coconut palm. Part IV. *Rynchophorus ferrugineus F. Indian Coconut J.* **9** : 229-247.

Nirula, K.K. (1957). Observations on the green muscardine fungus in population of *Oryctes rhinoceros L. J. Econ. Ent.* **50** : 767-770.

Nagarkatti, S. (1973). Biological control campaign aga inst *Nephantis serinopa* Meyr in India in the light of modern concepts. *J. Plant. Crops* **1** : 28-31.

Nirula, K.K., Antony, J., Sahasranaman, K.N., and Menon, K.P.V. (1954). Observations on the biology and control of the slug caterpillar *Contheyla rotunda H. Indian Coconut J.* **7** : 142-155.

Nirula, K.K., Antony, J., Sahasranaman, K.N., and Menon, K. (1954). A new pupal. parasite of *Nephantis serinopa* Meyr. *Indian Coconut J.* **8** : 58-61.

Nirula, K.K., Radha, K., and Menon,K.P.V.(1955). The green muscardine disease of *Oryctes rhinoceros* L. 1. Symptomatology, epizootology and economic importance. *Indian Coconut J.* **9** : 3-10.

Rao, Y.R., Cherian, M.C., and Ananthanarayan, K.P. (1948). Infestations of *Nephantis serinopa* Meyr. in South India and their control by the biological methods. *Indian J. Ent.* **10** : 205-247.

Reyne, A. (1948). Studies on a serious outbreak of *Aspidiotus destructor rigidus* in the coconut palm of Sangi (North Celebes). *Tijdschr. Ent.* **89** : 83-120.

Shekhar, P.S. (1958). Studies on the cockchafer *Leucopholis coneophora* Burm., a pest of coconut palm and other intercultivated crops. *Indian Coconut J.* **11** : 67-80.

Simmonds, H.W. (1941). Biological control of the rhinoceros beetle *Oryctes rhinoceros* L. *Bull. Ent. Res.* **40** : 445-446.

Simmonds, F.J. (1960). Biological control of coconut scale (*Aspidiotus destructor*) in Principe, Portuguese West Africa. *Bull. Ent. Res.* **51** : 223-237.

Steinhaus, E.A. (1949). *Principles of Insect Pathology.* McGraw Hill Book Company, New York.

Steinhaus, E.A. (1951). Report on tests of the susceptibility of the rhinoceros beetle to certain entomogenous micro-organisms. 15 pp. *Invertebr. Consultants Committee, Pac. Sci. Board, Honolulu.*

Surany, P. (1960). Diseases and biological control in rhinoceros beetle. *Tech. Paper No. 128.* 62 pp. South Pacific Commission, Noumea.

Tashiro, H., Gyrisco, G.G., Gambrell, F.L., Fiori, B.G., and Breitfeld, H. (1969). Biology of the European chafer in North-Eastern United States. Bull. No. 828. 71 pp. New York State Agri. Exp. Sta., Geneva, N.Y.

Taylor, T.H.C. (1935). The campaign against *Aspidiotus destructor* Sign. in Fiji. *Bull. Ent. Res.* 26 : 1-102.

Taylor, T.H.C. (1937). *The biological control of an insect in Fiji.* Imperial Bureau of Entomology, London.

Tothill, J.D., Taylor, T.H.C. and Paine, R.W. (1930). *The Coconut Moth in Fiji.* Imperial Bureau of Entomology, London.

Venkataraman, T.V. (1954). Quarterly Report for the period ending 30.11.1954. 6 pp. South Pacific Commission, Noumea.

Venkataraman, T.V. (1956). Quarterly Report for the period ending 29-2-1956. 4 pp. South Pacific Commission, Noumea,

Venkataraman, T.V. (1958). A preliminary report of an investigation on the possibilities of biological control of the coconut rhinoceros beetle, *Oryctes rhinoceros.* 8 pp. South Pacific Commission, Noumea.

Venkataraman, T.V., Venkita Subban, C.S. and Selvaraj, S.C.J. (1954). An interesting Dipterous parasite of the rhinoceros palm beetle *Oryctes rhinoceros* L. in India. *Indian J. Ent.* 16 : 297.

White, R.T. and Dutky, S.R. (1940). Effect of introduction of milky diseases on population of Japanese beetle larvae. *J. Econ. Entomol.* 33 : 306-309.

Zelazny, B. (1972). Studies on *Rhabdionvirus oryctes* I. Effect of larvae of *Oryctes rhinoceros* and inactivation of the virus. *J. Invert. Pathol.* **20** : 235-241.

Zelazny, B.(1973a). Studies on *Rhabdionvirus oryctes.* II. Effect on adults of *Oryctes rhinoceros. J. Invert. Pathol.* 22 : 122-126.

Zelazny, B.(1976). Transmission of a Baculovirus in populations of *Oryctes rhinoceros. J. Invert. Pathol.* **27** : 221-227.

Discussion

Sane : In your talk you gave the impression that in the sterile male technique programme, almost 75% of the males were only partially sterile. This conclusion was based on the observation that about 75% of the eggs hatched in the area where the sterile males were released. This conclusion is not correct. Another possibility could be that the number of sterile males released was too few in numbers. Possibly, the number of females present in the area was far more than predicted from the samples. The methods for sterilizing males have been worked out. It is most likely that all the males released were induced sterile, but the number was inadequate as compared to the population of insects (weevils) present.

Kurian : I said only that 75%of eggs collected from the area hatched. The possibility suggested by you about the inadequacy of the number of sterile males released in the area may be the main reason for this. It was our collaborators from BARC, Trombay, who decided on the numbers and supplied them to us for liberation.

Ananthakrishnan : I would add to the list of predators mentioned by the speaker, the predatory thrips, *Aleurodothrips fasciapennis.* In view of the fact that this species has contributed to the control of the scale *Aspidiotus destructor,* its role as a useful predator in this country may also be looked into.

Kurian : This will be done.

M.R.G.K. Nair : I suggest that attempts may be made to develop biological control methods for the nut bug *Paradesymes rostriatus* to minimise the use of insecticides for controlling the pest.

Kurian : This will be done.

New Developments in the Control of Pests and Weeds of Coconut in Sri Lanka

P. KANAGARATNAM

Coconut Research Institute, Lunuwila, Sri Lanka

Abstract

The management and control of pests and weeds of coconut in Sri Lanka have sought to exploit a variety of methods. These include field sanitation, trapping, use of parasites, predators, bacterial, and viral pathogens, and conventional chemical methods. The nature of pest has determined the particular methods of choice.

Outstanding success has been achieved in the control of *Promecotheca cumingi*, while at the other extreme, two decades of sustained mass releases of parasites have failed to bring *Nephantis serinopa* under effective control. While the indigenous predator *Chilocorus nigritus* appears to be an effective agent for the control of *Aspidiotus destructor*, several exotic predators have failed to establish. The paper examines some of the special factors that may have determined the success or failure of attempted control measures.

The more recent approaches and the results of preliminary investigations on the use of bacterial and viral pathogens and systemic insecticids for the control of selected pests and of the leaf eating caterpillar *Ammalo insulata* for the management of *Eupatorium odoratum* are presented and discussed.

Introduction

Methods employed in Sri Lanka for the control of coconut pests and weeds include field sanitation, use of traps, insecticides, parasites, predators, insect pathogens and insects that selectively feed on leaves and flowers of weeds. The emphasis has been strongly in favour of biological control methods.

This presents newer control measures that have been introduced, the problems that have surfaced, and the programmes that are contemplated. It does not assemble together the recommendations made for the management of pests and weeds of coconut, but presents an insight into certain phenomena of entomological interest and provokes some suggestions on the likely causes that may account for some of the observed phenomena.

Results

Field Sanitation

Mounds of coir fibre dust that accumulate in the vicinity of fibre mills constitute a heavy breeding ground for *Oryctes rhinoceros*. Acceptable leaves of field sanitation to offset the build up of other pests and diseases are generally attainable. Coir fibre dust has hitherto defied attempts to evolve some economic use for this waste product.

Insect Traps

Baited traps designed by Maharaj (1973) have proved effective in trapping adults of *Rhynchophorus ferrugineus* in intensive field tests over the past few years. Use of sex pheromones may improve the efficiency of the traps (Ethyl chrysanthemunate is used as an attractant of *Oryctes rhinoceros* in traps. Turner, 1973).

Systemic Insecticides

As neither biological nor chemical control methods appear to be effective on their own in controlling *Nephantis serinopa*, we were interested in evolving programmes that could make possible the simultaneous use of both. Properly chosen chemical control can selectively diminish pest populations to levels within the controlling capacity of natural enemies.

Further, systemic insecticides, being effective only on pests that directly feed on plant tissues, would have no effect on the adult parasites and only affect parasitic larvae feeding on caterpillars that have ingested the insecticide. These obviate the need to spray tall palms as the application can be made at a convenient height above ground level. Also pollution of the environment could be avoided by properly choosen application techniques. Only one systemic insecticide, metasystox, has been used for the control of only one pest in the past. Preliminary studies carried out recently have indicated that three more systemic insecticides, monocrotophos, dicrotophos, and methamidophos, could also be used effectively for the control of the three pests, *N. serinopa*, *R. ferrugineus*, and *Aspidiotus destructor*.

Six millilitre of monocrotophos (Azodrin 60)‡ when diluted with water and injected into the trunks of coconut palms, was effective in killing larvae of *N. serinopa* for at least four months, and therefore, a succession of generations may be destroyed (Table 1). Also, 12 out of 17 palms infested with larvae of *R. ferrugineus* feeding inside the crown or trunk recovered when treated with monocrotophos at the same dosage as given earlier. Similar results were obtained when dicrotophos and methamidophos were used. In one palm, which died despite treatment with monocrotophos, 75 larvae, one pupa, and five adults of *R. ferrugineus* were found dead when the trunk was split open, indicating that the palm could have survived if treated at an early stage of pest infestation. However, convenient methods of applications which will avoid permanent

TABLE 1. Effect of palm injection of Azodrin 60 on *N. serinopa*. (6 ml diluted with water injected per palm)

Laboratory			Field		
(Samples from a palm injected on 19 Nov. 1975 were fed)			(100 leaflets from 5 treated palms and 100 from 5 control palms were examined)		
Date fed	Percentage larval mortality on 14th day		Date observed after injection	No. of live larvae and pupae	
	Control	Treated		Control	Treated
24 Nov. 1975	—	100.0	5 Dec. 1975	87	87
10 Dec. 1975	—	73.3	16 Dec. 1975	45	33*
20 Jan. 1976	—	86.1	8 Jan. 1976	67	13**
30 Jan. 1976	5.0	80.0	21 Jan. 1976	251	00
4 Feb. 1976	4.0	95.0	6 Feb. 1976	75	00
12 Feb. 1976	26.7	93.2	20 Feb. 1976	23	00
19 Feb. 1976	15.0	65.0	27 Feb. 1976	00	00
19 Mar. 1976	10.0	96.7	4 Mar. 1976	00	00
7 May 1976	59.2	79.3	11 Mar. 1976	00	00
12 May 1976	50.0	30.0	5 Apr. 1976	20	00
19 May 1976	29.1	43.3	19 Apr. 1976	4	00
18 Jun. 1976	22.7	10.7	4 May 1976	14	00
			19 May 1976	7	12
			1 Jun. 1976	58	21
			8 Jun. 1976	50	29
			22 Jun. 1976	8	12

* Pupae only

** 6 first instar larvae and 7 pupae

damage to tissues of the palm have to be evolved. Pouring of diluted insecticide into the crowns of young palms gave satisfactory results, but this may not be practicable for tall palms. Application to soil of suitable formulations of systemic insecticides may be effective but needs to be investigated.

Parasites

Parasites are being employed with different degrees of successes for the control of three major pests, *Promecotheca cumingi*, *N. serinopa*, and *A. destructor*. Excellent control was obtained by means of *Dimmockia javanica* an introduced larval parasite, which was not considered to be an important parasite against *P. cumingi* in other countries. On the other hand, *Pediobius parvulus* which was an important parasite in other countries, has not established well in Sri Lanka (Fernando, 1972). As the parasites used were host-specific and effective, *P. cumingi*, which was threatening the entire coconut industry in Sri Lanka with extremely severe damage, was brought under excellent control, within two to three years. Subsequently, only small pockets of infestations occurred and the parasites brought the pest under control. An outbreak occurred during the last quarter of 1975 near the international airport, an area which was far away from previous pest infestations. This was probably due to a new introduction through air traffic. There, the parasites appeared unaided, moving in naturally from an affected area and bringing the pest under control.

At the other extreme, decades of sustained mass releases of parasites have failed to bring *N. serinopa* under effective control. The parasites bring the pest under control only temporarily. They do not establish and multiply in the field on their own. Thus, continuous mass breeding and release has become necessary. Nine types including three pupal, one prepupal, four larval, and one egg parasite, were used in the control programme. Out of these, four were exotic and five indigenous. Two exotic parasites were never recovered, probably due to climatic conditions being unfavourable for their survival. Eight out of nine-parasites used are not host-specific. Many parasites are attacked by hyperparasites (Dharmaraju, 1964) in the field. Therefore, an exotic larval parasite, *Ptychomyia remota*, was introduced in 1976 with the expectation that it would not have natural enemies. Recently, it has been observed that the puparia of it were heavily parasitized by *Exoristobia philippinensis* Ashmead (Encyridae), a hyperparasite already recorded as attacking *Spoggosia bezziana*, another parasite of *N. serinopa*. Therefore, we may infer that more releases of the above parasites will not bring *N. serinopa* under effective control.

The infestation of *N. serinopa* in Sri Lanka is peculiar in that it is only in certain particular locations that the pest incidence is high, persists for a few years, then disappears, to reappear in the same area, sometimes after several years. Long-term ecological studies would be necessary to

determine the causes underlying these special features of population fluctuation.

Aphytis chrysomphali is a widely distributed indigenous parasite of *A. destructor* in Sri Lanka, but its full exploitation as a control agent emains to be evaluated.

Predators

Predators are used for the control of *A. destructor*. Two indigenous predators were very efficient control agents. They are commonly found in large numbers, while a few others are only occasionally encountered. Three exotic predators were mass-bred and released in large numbers since 1974, but no recoveries has been made at any of the release points. Their evidently high mortality in the field may be due to some inhospitable climatic factors.

The efficiency of the indigenous predators is partly reduced by the following parasites attacking their immature stages. *Homalotylus flaminius* Dalman is a common larval parasite of *Chilocorus nigritus*. *Syntomosphyrum* sp.nr. *obscuriceps* Ferr. is also a common parasite of larvae and pupae of *C. nigritus*. *Aminellus indicus* Kerrich is a common pupal parasite of *Pullus xerampelinus* Muls. found widely distributed. These are new records of parasites attacking predators of *A. destructor* in Sri Lanka.

Insect Pathogens

The possibility of using insect pathogens in pest control is being tested out on two pests. *Bacillus thuringiensis* Berliner, a spore forming bacterium, was observed to cause high mortality of larvae of *N. serinopa* in the laboratory. The formulations of *B. thuringiensis* used were : Dipel (said to contain 15.97 billion viable spores/kg); Thuricide (said to contain 12.32 billion viable spores/kg); Biotrol (said to contain 7.40 billion viable spore/kg); and Bactospeine W.P. 6000. (Wettable powder containing 6000 U.A.A.K./mg of the spore crystal complex of *B. thuringiensis* serotype; 1 U.A.A.K.=Unit of Activity *Anagasta Kuhniella*). Concentrations of the four formulations used are given in Table 2.

TABLE 2. Concentrations of the four bacterial formulations tested (in g/125 ml water)

Dipel	Thuricide	Biotrol	Bactospeine
0.15	0.20	0.33	0.25
0.30	0.40	0.65	0.50
0.45	0.60	0.98	0.75
0.60	0.80	1.30	1.00
0.75	1.00	1.63	1.25
0.90	1.20	1.95	1.50
1.05	1.40	2.28	1.75
—	—	—	2.00

Percentage cumulative mortality of caterpillars for various concentrations of the four formulations at different intervals after feeding with sprayed leaves are given in Tables 3-6.

TABLE 3. Percentage cumulative mortality vs. concentration at different intervals after spraying Dipel

Dosage in g/125 ml water	5th day	8th day	12th day	16th day
0.15	7.3	17.8	22.8	34.9
0.30	15.9	36.1	48.3	62.3
0.45	26.4	57.5	68.0	81.2
0.60	40.0	67.7	76.9	86.4
0.75	52.8	81.3	88.1	94.5
0.90	65.4	87.3	91.7	96.3
1.05	81.1	92.7	95.3	97.4

TABLE 4. Percentage cumulative mortality vs. concentration at different intervals after spraying Thuricide

Dosage in g/125 ml water	4th day	8th day	12th day	16th day
0.2	8.3	13.9	25.4	42.5
0.4	15.3	28.0	46.2	65.5
0.6	25.6	42.0	59.8	76.3
0.8	33.3	51.7	69.2	82.4
1.0	41.4	60.3	77.9	87.6
1.2	53.9	71.7	84.5	92.9
1.4	77.3	92.1	95.9	97.7

TABLE 5. Percentage cumulative mortality vs. concentration at different intervals after spraying Biotrol

Dosage in g/125 ml water	4th day	8th day	12th day	16th day
0.33	4.2	13.8	42.1	64.0
0.65	10.9	24.7	68.0	84.1
0.98	19.7	40.7	82.3	91.8
1.30	29.9	55.0	90.0	97.5
1.63	41.7	71.0	95.0	98.0
1.95	60.0	82.9	97.6	99.2
2.28	76.8	93.0	100.0	100.0

TABLE 6. Percentage cumulative mortality vs. concentration at different intervals after spraying Bactospeine

Dosage in g/125 ml water	5th day	9th day	15th day
0.25	1.1	2.4	10.0
0.50	5.9	10.6	29.1
0.75	8.4	18.5	51.5
1.00	12.7	27.8	62.7
1.25	18.6	43.2	78.6
1.50	26.9	62.0	86.5
1.75	39.2	75.0	93.5
2.00	58.9	91.2	97.6

The LD-50 concentration for the four formulations at different intervals after feeding with sprayed leaves is given in Table 7.

TABLE 7. LD-50 concentration at different dates after spraying with the four formulations. For each dosage 125 ml of water was used for dilution

Formulation	LD-50 concentration			
	4th day	8th day	12th day	16th day
Dipel	0.714 g	0.3904 g	0.3101 g	0.2199 g
Thuricide	1.134 g	0.7629 g	0.4485 g	0.2507 g
Biotrol	1.768 g	1.279 g	0.4057 g	— at the lowest concentration used (0.33 g/125 ml water) 64% cumulative mortality was obtained.
Bactospeine	1.882 g*	1.335 g**	0.7303 g†	

* 5th day
**9th day
† 15th day

Percentage cumulative mortality increased with postspray duration and concentrations. LD-50 values decreased with increase of post-spray duration. The larval populations not exposed to *B. thuringiensis* remained healthy and they caused severe damage to leaflets, while the caterpillars which had ingested the bacterium caused only slight feeding damage.

This bacterium is short-lived, non-persistent, and non-spreading, and consequently, repeated applications are necessary. The commercial formulations containing this bacterium are handled and applied in a manner similar to chemical insecticides. Spraying tall coconut palms is a cumbersome and expensive task. Further, these formulations have to be imported. Hence, there is no special advantage on this account. However, with the current interest in preventing environmental contamination and the need to develop integrated control and pest management programmes, *B. thuringiensis* is one of the few available and ecologically safe insect control agents. Also, formulations of *B. thuringiensis* are compatible with a wide range of chemical pesticides and supplements. *B. thuringiensis* formulations are neither phytotoxic nor harmful to mammals and so can be applied for pest control right upto the harvest without risk.

Rhabdionvirus oryctes Huger, a viral pathogen, is being tested out against *O. rhinoceros* under field conditions. It is being mass propagated and released in various parts of Sri Lanka. It is yet too early to arrive at any conclusion on the effectiveness of this pathogen in controlling the pest under field conditions. It will be a great advantage, if this virus gets established as the other control measures for *O. rhinoceros* need continuous attention and are somewhat expensive.

Weed Control by Insects

Eupatorium odoratum is a common and serious weed of coconut plantations. Chemical control is very expensive and dependent upon imports. Mechanical weeding too is expensive and has to be repeated regularly. Biocontrol agents, if they establish and persist in the field, would be a very valuable means of control.

Attempts to attack the weed by using its insect pests were started in Sri Lanka in 1973. The Arctiid, *Ammalo insulata*, which was fully investigated and tested by the Commonwealth Institute of Biological Control was introduced, bred in large numbers, and released. It has become established. Hundreds of hectares have been completely defoliated by *Ammalo*. All the leaves and buds with tender stems have been eaten by the larvae, leaving only the hard stem in several release points. However, it has not become established in all the release points. In the defoliated areas, the populations of this insect do not persist to bring about repeated defoliations that could keep this weed under control. As a result, the defoliated plants produce new flushes and grow well with the onset of rains. However, in a few localities, there have been resurgence of the larvae at former release sites, but a few months after the initial defoliation. The cause underlying this pattern of population fluctuation remains to be studied.

The efficiency of *A. insulata* is also partly reduced by some newly-recorded natural enemies in the field. These are the parasites, *Apanteles creatonoti* Vier. (Braconidae) and *Exorista* sp. (Tachinidae), and the pre-

dators *Sycanus* sp. (Reduviidae).

In the laboratory, *Trichospilus pupivora* readily parasitised pupae of *A. insulata*. It is an indigenous parasite of *N. serinopa* and is commonly found in the Western Province, which is climatically favourable for the luxuriant growth of this weed.

Alternate Host for *A. insulata*

The larvae of *A. insulata* leave almost all the other plants in the field unattacked except *E. odoratum* and *Ageratum conyzoides* (Compositae). The latter weed is completely defoliated in the field by this insect. In the laboratory, it completes its life cycle when fed with leaves of *A. conyzoides* alone. It is a new record of an alternate host for *A. insulata*.

Apion brunneonigrum an exotic flower eating weevil, was also imported and released. Two months after release, they were seen on flower heads at the same release points. Whether these will establish and control this weed is under study.

Acknowledgements

I thank Dr U. Pethiyagoda, Director for his valuable encouragement and guidance given and the British Museum for identifying the insect specimens.

References

Dharmaraju, E. (1963). Biological control of cocount leaf caterpillar (*Nephantis serinopa* Meyrick) in Ceylon. Bull. No. 21, Coconut Res. Inst. of Sri Lanka, Lunuwila.

Fernando, H.E. (1972). The coconut leaf beetle *Promecotheca cumingi* and its control. *Ceylon Coconut Plant. Rev.* 6: 152-156.

Maharaj, S. (1973). A new design of trap for collecting the palm weevil *Rhynchophorus palmarum* (L.). *Ceylon Coconut Plant. Rev.* 7: 5-7.

Turner, P.D. (1973). An effective trap for *Oryctes* beetle in oil palm. *The Planter* (Kuala Lumpur) 49: 488-490.

Discussion

G.B. Pillai: What is the efficacy of *Ammalo insulata* in the control of *Eupatorium*? As it is a foliage feeder, the insect attack may have only a "pruning effect" and these could bring about a luxuriant growth of the weed. What is the result of the trials in Sri Lanka?

Kanakaratnam: This is under trial. No absolute control has been obtained so far.

Coconut Root Grubs and Their Control in Karnataka, India

G. K. VEERESH

Department of Entomology, University of Agricultural Sciences, Hebbal, Bangalore 560 024 India

Abstract

Three species of white grubs (Melolonthine beetles) damage coconut in Karnataka. While *Leucopholis coneophora* Burmeister and *L. lepidophora* Blanchard confine themselves to heavy rainfall areas of coastal Karnataka and Malnad, *Holotrichia serrata* Fabricius is endemic to the plains.

Ecology and chemical control of *H. serrata* were studied. Five soil insecticides including chlordane 20 EC, dursban 200 EC, phorate 10 G, counter 5 G, and temik 10 G, were tried under irrigated and unirrigated conditions at two levels each. Dursban 200 EC at 10 ml, and counter 5 G and phorate 10 G @ 20g/palm with irrigation after insecticide treatment gave good control of grubs.

Introduction

In recent years, root grubs belonging to the subfamily Melolonthinae and Rutelinae of Scarabaeidae (Coleoptera) have become major pests of cultivated crops in India. Coconut too is attacked by these pests particularly in the young stages.

Three species of white grubs damage coconuts in Karnataka. While *Leucopholis coneophora* Burmeister and *L. lepidophora* Blanchard confine themselves to heavy rainfall areas of coastal Karnataka and Malnad, *Holotrichia serrata* Fabricius is endemic to the plains.

Both the *Leucopholis* spp. occur together in the districts of North and South Kanara, Shimoga, and Chikmagalur. They feed on both areca and coconut roots. They have not been noticed to occur in plains so far.

The occurrence of *L. coneophora* on coconut in Kerala has been reported by several authors (Nirula, Antony, and Menon, 1952; Sekhar, 1958; Mathen, Kurian, and Mathew, 1964; Abraham and Kurian, 1970). They also have worked out control measures.

In the plains, *Holotrichia serrata* is the main root feeder of coconut. It is widely distributed all over India. It is one of the major crop pests in the country (Raodeo *et al.*, 1976; Majumdar and Teotia, 1965; David and Kalra, 1966; Avasthy, 1967; Veeresh, 1973, 1974, 1975, 1976).

Majumdar and Teotia (1965) have worked out its biology under north Indian conditions and Veeresh (1973b) under south Indian conditions. Its morphology, distribution, host range, ecology, behaviour, and control measures have also been studied (Veeresh, 1976).

Biology. Adults emerge after the first rains in April-May. More than 90% of adults emerge during the first 3-4 days after the first rains. The emergence occurs between 7.00 and 9.00 PM. The adults most prefer neem *Azadiracta indica* and acacia *Acacia arabica* over nearly 30 host plants recorded.

After mating and feeding, the adults get back to the soil before dawn and the females begin to lay eggs singly in earthen cells at 6-10 cm depth. A female lays 30-40 eggs during the three weeks' life after emergence. The eggs hatch after 10-12 days. The three larval instars occupy about 30, 36, and 103 days. The first instar larvae normally feed on organic matter, but the second and third stages require live roots for normal development. The larvae undergo a quiescent period of 2-6 weeks before pupation. Pupal period lasts 11-12 days. Pupation takes place during September-February, but the maximum pupation occurs during December-January. Adults, though formed from September, normally emerge only after the first summer rains in April-May, irrespective of the moisture condition of the soil.

Natural enemies. Among the natural enemies, crow (*Corvus splendens*) and Indian mynah (*Acridotheres tristis*) are very effective in reducing the population during tillage operations. A carabid predator *Pheropsophus sobrinus* has also been found feeding both on adults and grubs during night. A fungal parasite *Beauveria bronounierlii* has also been found to be effective against the grubs in the transitional belt of Karnataka (Ranganathaiah, Veeresh, and Govindu, 1973).

Control. Hand collection is both a practicable and cheap method, as this species has some weak links in its biology such as its emergence during specific hours in the evening and its attraction to neem and acacia (Veeresh, 1971; Raodeo *et al.*, 1976). Repeated ploughings once a week, for 4-5 times, after the first rains in summer reduce the population to non-pest level (Veeresh, 1975a). Light traps do not help in the control, though adults are attracted to light (Veeresh, 1974b).

The success of control by chemical methods depends largely on the method of application and time of application (Veeresh, 1973a). Chlorinated hydrocarbons including aldrin, BHC, heptachlor, and chlordane have been used with success to control coconut root grubs (Abraham and Kurian, 1970). However, recent reports show that white grubs develop resistance to chlordane and other persistant chlorinated cyclodiene insecticides (Tashiro *et al.*, 1971; Niemxzyk and Lawrence, 1973; Tashiro and Newhauser, 1973). We have found that these chlorinated hydrocarbons are also slow to act on grubs. Because of these, some attempts were made to control grubs with other chemicals.

Materials and Methods

Five soil insecticides including chlordane 20 EC, phorate 10 G, counter 5 G, chlorphyritos 200 EC, and temik 10 G were tried on six year old coconut palms. The palms were not irrigated for two weeks before treatment. The insecticides were tried under two conditions, one with irrigation immediately after treatment and another with no irrigation after treatment. Under irrigated conditions, the insecticides were tried at two levels. Before the experiments were laid out, the population of grubs in the base of the palms was ascertained by random sampling of six 1.5 m^2 areas upto a depth of 30 cm. The experimental plots were 1.5 m^2 in size and replicated four times. The granular formulations were mixed with moist sand and sprinkled uniformly over the surface. The liquid formulations were mixed in 13 l. water in a rose can and spread over the surface. The surface soil was worked with spade to mix the insecticides with the soil. No irrigation was given to the first experiment. In the second and third experiments, the plots were irrigated immediately after treatment and water was made to stand for some time to ensure percolation to 30 cm depth. Grubs were in 3rd instar at the time of treatment (July, 1976). Five weeks after the first observation, the effectiveness of the treatments were determined by counting the surviving grubs in each treatment upto a depth of 30 cm. To stabilize the variance more effectively, the counts were transformed into square root $(\sqrt{x+1})$ for analysing the data. Per cent kill was determined by Abbott's formula.

Results and Discussion

In the first experiment, none of the chemicals was effective against the grub. The ineffectiveness of the chemicals appeared to be mainy because no irrigation was given after the treatment (Table 1), which prevented the chemicals from acting on the grubs.

In the second experiment, with irrigation given after the treatments, dursban 200 EC at 10 ml/plot, and phorate 10 G and counter 5 G at 20 gm/plot gave significant control (Table 1).

When the chemicals were applied at half the dosage of 2nd experiment (Table 1) under irrigated conditions, phorate and dursban gave significant control over check at 5% level of probability. Phorate gave 83% control and dursban 60%.

Van der Schof and Tashiro (1975) found that efficacy of soil insecticides against white grubs depended upon pre and post-treatment irrigation moisture levels at the time of their application. The difference in the efficacy of the same chemicals in the first and second experiments could be attributed only to the absence and presence of moisture after the treatment.

In the second observations taken five weeks after the first observation,

TABLE 1. Comparative efficacy of five soil insecticides against coconut root grub *Holotrichia serrata* F* (Bangalore, 1976)

Treatment	Not irrigated			Irrigated after treatment							
	Experiment No. 1			Experiment No. 2				Experiment No. 3			
	Dossage**	No. of grubs/ plot	% Control	Dossage**	No. of grubs/ plot	% Control	Transferred value mean	Dossage**	No. of grubs/ plot	% Control	Transferred value mean
Chlordane 20 EC	20 ml	5.00	31.0	20 ml	3.75	53.1	2.14	10 ml	6.25	16.6	2.65
Dursban 200 EC	10 ml	5.50	24.1	10 ml	0.50	93.7	1.18	5 ml	3.00	60.0	1.78
Temic 10 G	20 g	5.25	27.5	20 g	8.00	00.0	2.95	10 g	8.20	00.0	3.02
Counter 5 G	20 g	4.50	37.9	20 g	0.85	90.6	1.25	10 g	6.20	17.3	2.71
Phorate 10 G	20 g	5.00	31.0	20 g	1.25	84.3	1.41	10 g	1.25	83.3	1.48
Untreated	...	7.25	...	...	8.00	...	2.88	...	7.50	...	2.81
		NS		Mean=1.97				Mean=2.40			
				SE of mean difference			0.357	SE of mean difference			0.382
				CD at 5% level			0.917	CD at 5% level			0.991
				CD at 1% level			1.439	CD at 1% level			1.540

* Observations taken a week after treatment

** Dose applied is in a plot 1.5×1.5 m size

some grubs (upto five) were recorded from all the treatments in all the experiments. These grubs appeared to have migrated from untreated sides. This indicates that a single basal treatment alone will not be adequate to get complete control, unless the entire area is treated. Incidentally, many of the newer phosphatic and carbamate soil insecticide do not have long residual effects.

Earlier work has shown that if insecticides can be applied at the time of oviposition or when the grubs are in the first stage, the quantity could be reduced to half of that required to control the third instar grubs (Tashiro and Fiori, 1964; Veeresh, 1973), the reason being that in addition to their small size, the eggs and first stage grubs confine themselves to the top 8-10 cm of soil.

Conclusions

The studies have shown that phorate 10 G, and counter 5 G at 20g/1.5m^2 area and dursban 200 EC at 10 ml/1.5 m^2 area gave good control of root grubs in coconuts, even when applied to 3rd stage larvae, provided the plots are irrigated after treatment. Complete control can be obtained with an integrated approach involving collection of adults, ploughing 3-4 times after first summer rains, and basal application of the above insecticides four weeks after the first rains.

Acknowledgements

I acknowledge the assistance rendered by Dr. G.P. Channa Basavanna, Professor and Head, Department of Entomology. The field experiments were laid out in the gardens of Mr. G. Doddegowda, Mahadeswarapura, Pandavapura Taluk, Mandya District and Mr. K.K. Ghorpade, Bujangatara, Doddagubbi, Bangalore. I thank them for their co-operation.

References

Avasthi, P.N. (1965). The problem of white grubs of sugarcane in India. *Proc. Int. Soc. Sug. Cane Technol.* **12** : 1321-1333.

Abraham, V.A. and Kurian, C. (1970). Save your coconut palm from the ravages of white grubs. *Coconut Bull.* **1** : 3-4.

David, H. and Kalra, A.N. (1966). Observation on *Holotrichia serrata* F., a beetle pest of sugarcane in Hospet area of Mysore State. *Indian Sugar* **16** : 195-198.

Majumdar, N. and Teotia, T.P.S. (1965). Biology of *Holotrichia serrata* F., a serious pest of palas (*Butea monosperma*). *Indian J. Ent.* **27**: 153-159.

Mathen, K., Kurian, C., and Mathen, J. (1964). Field studies on insecticidal control of coconut white grubs *Leucopholis coneophora* B. *Indian Coconut J.* **18** : 101-108.

Nirula, K.K., Antony, J. and Menon, K.P.V. (1952.) A new pest of coconut palm in India. *Indian Coconut J.* **18**: 101-108.

Niemczyk, H.D. and Lawrence, K.O. (1973). Japanese Beetle: Evidence of resistance to cyclodiene insecticides in larvae and adults in Chio. *J. Econ. Entomol.* **66**: 220-221.

Ranganathaiah, K.G., Veeresh, G.K., and Govindu, H.C. (1973). A new entomogenous fungus on the root grub *Holotrichia serrata* F. from Mysore. *Curr. Sci.* **42**: 432-433.

Raodeo, A.K., Deshpande, S.V., Deshpande, A.D., Puri, S.N., and Bilapete, G.G. (1976.) A large scale campaign for the control of white grubs (*Holotrichia serrata* F.) in Maharashtra state. *PANS* **22** : 223-226.

Sekhar, P.S. (1958). Studies on the cockchafer *Leucopholis coneophora* B., a pest of coconut palm and other intercultivated crops *Indian Coconut J.* **11**: 67-80.

Tashiro, N., Personius, K.K., Zinter, D., and Zinter, M. (1971). Resistance of the European chafer to cyclodiene insecticide. *J. Econ. Entomol.* **64** : 242-245.

Tashiro, N. and Newhauser, W. (1973). Chlordane resistance of Japanese beetle in New York. *Search* **3**: 6 p.

Van der Schaf, P. and Tashiro, H. (1975). Control of Japanese beetle and European chafer grub with dursban insecticides *Down to Earth* **31**: 9-13.

Veeresh G.K. (1973a). Preliminary evaluation of insecticides for the control of the root grub *Holotrichia serrata* F. (Melolonthidae: Coleoptera). *Pesticides* **7** : 27-28.

Veeresh, G.K. (1973b). Studies on the Melolonthine beetles of Mysore state with special reference to the biology and control of *Holotrichia serrata* Fabricius. PhD Thesis. University of Agricultural Sciences, Bangalore.

Veeresh, G.K. (1974a). Root grub control campaign in Karnataka. *White Grub Newsletter* **1** : 4-7.

Veeresh, G.K. (1974b). Light attraction to *Holotrichia serrata* F. *White Grub Newsletter* **1** : 39-40.

Veeresh, G.K. (1974c). War against white grubs. *Curr. Res.* **3**: 87-88.

Veeresh, G.K. (1975a). Biology and control of white grubs. *White Grub Newsletter* **1**:, 59-61.

Veeresh, G.K. (1975b). The root grub problem to sugarcane and its control in Karnataka. 72-74 pp. *in* Seminar on Sugarcane Sovenier, U.A.S., R.R.S., Mandya June 1975.

Veeresh, G.K. (1976). Studies on the root grubs of Karnataka with special reference to bionomics and control of *Holotrichia serrata* Fabricius (Coleoptera : Melolonthinae). Res. Bull. No. **2**, UAS, Bangalore.

Discussions

Ail : What is the economics of chemical control of white grubs in coconut ?

Veeresh : This depends on whether the chemical is to be applied all over the garden or only to the bases of coconut. When applied to the bases of coconut a month after the first rains in summer at the rate of 20g of phosphatic or carbamate granular insecticides or 50 ml of chlordane dissolved in 10l of water, it would be economical and effective. These palms must be irrigated immediately after the treatment. When chemicals are applied later in the season, when the grasses are fully grown and have gone deeper (September-October), larger quantities of chemicals will be required, and even with this, one may not get satisfactory control, and then the treatment becomes uneconomical.

Mariau : When the populations are very high, what is the effect of the incidence of the attack on the production of nuts ?

Veeresh : Twenty or more grubs/palm is considered very serious, as palms may then be killed due to the grubs feeding on roots. This is particularly so on young palms of less than five years age. On older palms, the death is gradual and yield also gets progressively reduced during this time.

M.R.G K. Nair : 1. Do you think that organophosphates and carbonates will be more economical in the control of coconut root grubs than the organo-chlorine compounds ?

2. Is there any method of detecting the presence of the grubs in the soil without waiting for the symptoms to appear on the palms ?

Veeresh : 1. Yes, if the chemicals are applied only to the affected palms. Since grubs do not migrate long distance and occur only once in a year after the first summer rains, a basal application of 20g phosphatic or carbonate granular insecticide with a drenching irrigation immediately after treatment, will give cent per cent control with knock-down effect. Organochlorine compounds are slow to act on grubs, specially the dust formations, but when applied early in the season, i.e., about a month after the first summer rains, when the grubs continue to remain in the upper 6-10 cm layer of soil, the organochlorine compounds can be effectively and economically used. Irrespective of chemicals, it is the time and method of application that greatly influences the effectiveness and economics of the insecticide.

2. There is no clear cut symptom of damage due to root grubs on coconut palm except sudden death in young palms, when the grub population is very high. However, one can foresee the root grub problem definitely, if (a) one has noticed grubs in the previous season ; (b) the day after the first rains in summer, one sees round circular holes in the garden (about the diameter of a finger), these are adult emergence holes; and (c) one sees symptoms of adult damage on hosts like *Azadiracta indica*, *Aeucia arabica*, etc. after the first summer rains. Peripheral leaves of such trees are eaten and one can see black pellets, the excreta below such trees. These are the early indications of the root grub problem.

G. B. Pillai : The Sugarcane Breeding Institute, Coimbatore, has recorded the milky disease bacterium from *Holotrichia serrata* Have you come across this pathogen ?

Veeresh : Yes, but the percentage of diseased grubs has been always less than 2% in all the observations. Quite often, healthy grubs and milky diseased grubs occur together. It seems that some physical injury is a prerequisite for the susceptibility of the grub to the disease.

Ananthakrishnan : Is any information available about the flight behaviour of adult *Holotrichia senata ?*

Veeresh : Marked adult release studies have shown that adults can go upto 300 metres if no suitable adult hosts are available in the immediate vicinity of where adults emerge. In some cases, they may go beyond this distance, attracted by light. However, they are more localized and do not migrate long distances. The females, once mated, seldom come out of the soil subsequently, whereas males come out on subsequent days also. Intensity of light during dusk and atmospheric humidity trigger flight activity during adult emergence period.

Aceria (*Eriophyes*) *Guerreronis*, an Important Pest of African and American Coconut Groves

D. MARIAU

Institut de Recherches Huiles et Oleagineux 11 Square Petrarque, 75016 Paris, France

Aceria guerreronis which does not exceed 250 microns in length, lives within the shelter of the floral parts of the coconuts during the first month following pollination. In destroying the young tissues, the mite prevents the nut from developing normally, leading to a decrease in copra which can reach upto 25% and a generally reduced fruit fall. The different varieties of coconut palm do not react in the same way to the attacks, the Yellow Dwarf being more sensitive than the West African Tall and the Cambodia variety being seldom attacked. Chemical methods have proved effective, as for instance with cyhexatin, chinomethionate, and monocrotophos. The application of monocrotophos at 0.04% reduced losses by 90%. But these treatments should be given very frequently (6 treatments per year), and hence it cannot be recommended. The development of more economical control methods has been considered. In this, the points to be considered are : utilization of potential mite diseases which could be identified in the natural state, control with predatory mites, and application of specific planting methods.

Rat Damage and its Control in Coconut Groves

B.K. GURUPRASAD and K. SRIHARI

Department of Zoology University of Agricultural Sciences, GKVK Campus, Bangalore 560 085, India

Abstract

The information available on rat damage to coconut farming is scanty and confined to the genus *Rattus*. The present study revealed that *Bandicota bengalensis* also inhabits coconut plantations along with *R. rattus*. *B. bengalensis* damages coconut seedlings by eating the roots and gnawing into the husk and shells, while *R. rattus* damages the nuts on the palms. Damage to coconut nurseries by *B. bengalensis* is reported here for the first time.

Earlier investigations stressed the efficiency of trunk banding to prevent rat damage in coconut groves. But our observation revealed that trunk banding alone does not control rat damage; on the other hand, it may even confines the rats to particular palms. Such rats cause more damage than the rats on unbanded palms. Isolated rats could be successfully controlled by zinc phosphide treatment. Trunk banding followed by poison baiting proved successful and effectively controlled *R. rattus*. Control of *B. bengalensis* in nurseries with zinc phosphide baiting followed by fumigation with aluminium phosphide proved efficient and profitable.

Introduction

The rodents are a major pest of coconut (Alfonso *et al.*, 1967). Reports of damage due to rats in the coconut plantations (Streeker, 1962; Smith, 1967, 1968; Williams, 1947 a,b; Wodzicki, 1968) are confined to damage caused by the genus *Rattus* only (Williams, 1947a; Smith, 1967, 1968). Streeker (1962), while working in the Pacific Islands, found that rats damaged nuts of sizes ranging from an orange upto those used as tender nuts. Wodzicki (1958) found that the Polynesian rat *Rattus exulans* climb the coconut palms, build nest and damage intact nuts in Tokelau Islands. He reported an intensity range as high as 84% and concluded that rat damage in Tokelau atalls was mainly a question of management (Wodzicki, 1969). Nut damage may be related to factors like season, height of palm, degree of maturity or hardness of husk; and also, large unexplained variations may occur from year to year in the same location

(Williams, 1974 a; Jackson, 1976). Williams (1974 b) found a compensatory increase in female flowers after early nut removal and opined that estimates of loss generally gave exaggerated values of real loss (absolute nuts lost/palm). Hoque (1973) studied the extent of rodent damage and efficiency of trunk banding over a period of four months and concluded that trunk banding proved 100% effective in controlling rat damage.

Reports on rat damage to coconuts and its control aspects are scanty from India. The present study was undertaken in the Regional Coconut Research Station, Arsikere, Karnataka.

Materials and Methods

The Arsikere Station has 15.38 ha under coconuts. There is a nursery of 0.5 ha area made up of beds having 50 seedlings in each bed. Active burrow counts were made in the nursery. Population control of surface active rodents was done by acute poisoning with zinc phosphide for two days using a bait mixture: rice flour—80%; ground nut kernel—10%; groundnut oil—6%; and zinc phosphide (commercial)—4%; after prebaiting for two more days with bait mixture, rice flour—85%; groundnut kernel—10%; and groundnut oil—5%, the mixed bait was kept about 12 cm deep inside the burrows and their openings were closed superficially. The residual population was knocked down by inserting aluminium phosphide tablets (3 g) deep into the burrows and closing the openings air tight. Reduction in rodent activity was assessed by the difference in active burrow counts before and after the treatment.

Two sample areas (0.5 ha each) having of 40 palms each were taken for study. Palms in one area was trunk-banded according to Hoque (1973) and the other area was left with unbanded palms. The palms were inspected for the presence of rat and rat-damaged nuts. Acute poison baiting with zinc phosphide was done with bait mixture as mentioned earlier, after two days of pre-baiting. Empty coconut shells were used as bait containers and the bait was placed at three points in the crowns of rat-infested palms. The day after poison baiting, the crowns were inspected for dead rats. They were then autopsied to collect data on their reproductive status. Rat-damaged nuts in sample areas were counted and classified as given in Table 1.

TABLE 1. Classification of rat-damaged coconuts

Sl. No.	Stages	Approximate age in months
1	Button	2—3
2	Intermediate-I	3—6
3	Tender coconut	6—8
4	Intermediate-II	8—12
5	Mature nut	12—15

Observations

Characteristic heaps of mud in the form of mole hills were noticed in several places resulting in 15 active burrows and they confirmed the presence of *B. bengalensis* in nursery. Out of 2000 seedlings in the nursery 136 seedlings (6.8% of the total) were damaged and died ultimately. Examination of these seedlings showed absence of roots and typical gnawed markings at the region where the seedlings come out of the shells.

Treatment with zinc phosphide followed by aluminium phosphide brought about 80% reduction in rodent activity by knocking down the population from 15 active burrows to 2 active burrows.

Rat damaged nuts had either fallen down, or remained intact on the inflorescence and their number was used to estimate the incidence of rat damage in the sample area. Close inspection showed fecal droppings on the crowns of palms. The incidence of damage in sample areas and the assessment of damage for the entire plantation (taking two-thirds of the palm population as yielding) were done (Table 2). The per centage damage at different stages in sample areas are given in Tables 3 and 4. Rat damage

TABLE 2. Incidence of damage assessed for the entire plantation (15.38 ha) at the Regional Coconut Research Station, Arsikere

Type of sample	No. of coconut palms in sample area	No. of yielding palms	Incidence of damage	Percent incidence of damage in yielding palms	Estimated incidence of damage for 1250 yielding palms
Banded	40	40	3	7.5	93.8
Unbanded	40	32	8	25.0	318.5

TABLE 3. Coconut damage at different ripening stages

Type of sample	Palm no.	No. of nuts damaged	Percent damage in stages				
			Button	Intermediate-I	Tender coconut	Intermediate-II	Matured
Banded	BK 5	34	—	82	8	—	—
	BK135	8	—	100	—	—	—
	BK 4	24	—	100	—	—	—
Unnumbered	Unnumbered	7	—	86	14	—	—
	Rv. Dl A3	12	—	83	17	—	—
	Unnumbered	12	—	100	—	—	—
	Unnumbered	5	—	100	—	—	—
	Unnumbered	6	—	67	33	—	—
	Rv. Dl A3	36	—	100	—	—	—
	Unnumbered	31	—	100	—	—	—
	Unnumbered	6	—	100	—	—	—

to nuts at Intermediate-I and Tender coconut stages were observed with high intensity in both the sample areas (Table 4). Damaged nuts showed basal injury.

The cost benefits of banding was assessed (Table 5). It prevented 54.8% of damage as compared with the unbanded area. The dead rats were identified as *Rattus rattus*. Autopsy of female rats did not reveal the presence of developing embryos or placental scars in uterus indicating that the animals were not sexually active.

TABLE 4. Coconut damage at different ripening stages estimated in two sample areas

Type of sample	No. of nuts damaged	Per cent total nuts damaged				
		Button	Intermediate-I	Tender coconut	Intermediate-II	Matured
Protected (Banded)	66	—	90.9	9.1	—	—
Unprotected (Unbanded)	115	—	95.7	4.3	—	—

TABLE 5. Cost benefits of tree banding

Type of sample	Approx. cost per nut	No. of nuts damaged	Incidence of damage	Mean damage/palm	Estimated loss of nuts/ 1250 palms	Estimated loss in 1250 palms Rs.
Banded	60 paise	66	3	22.00	2062.50	1237.50
Unbanded	60 paise	115	8	14.37	4576.85	2745.60

Discussion

Bandicota bengalensis is an inhabitant of arable and semi-arid zones. It inhabits field edges, particularly the bunds of paddy fields (Wangle, 1927; Urs, 1967; Srivastava *et al.*, 1968; Greaves *et al.*, 1975). Little is known about its food preferences and dietary requirements in fields. One analysis of stomach contents of traped rats revealed mostly about the crops on which the rats were feeding (Sagar, 1972). The presence of roots and tubers of grasses and weeds in stomach has also been observed (Krishna Ayyar, 1931; Sagar, 1972; Wangle, 1972). Burrows excavated in paddy fields showed the presence of subterranean stems and tubers of ginger grass (*Panicum repens*). Occurrence of *B. bengalensis* in coconut nurseries, its

depradation of seedling roots, gnawing of nuts to the shell, and eating the cabbage of transplanted coconut seedlings (Antony *et al.*, 1976) suggests the possibility of *B. bengalensis* getting its dietary requirements from the nursery itself.

Control of *B. bengalensis* has been worked out using various rodenticides (Wangle, 1927; Deoras, 1968; Barnett and Prakash, 1975). Zinc phosphide followed by aluminium phosphide bring down the population to a minimum (DVB/UAS, 1975). This could be recommended for nurseries.

In coconut palms, rat damage was confined to nuts of the size of an orange upto tender nut stage (Streeker, 1962) and the species involved is *Rattus rattus* (Smith, 1967, 1968; William, 1974). Though nests could not be located on the crown (Streeker, 1962; Wodzicki, 1968) fecal droppings were found on crowns. Rat damaged huts fall down within 2-6 days of rat injury (William, 1974a). We have found that rat damaged nuts could be attached to the inflorescence also.

Trunk banding which is reported to be 100% effective in controlling rat damage (Hoque, 1973), does not appear to be a realistic method, as trunk banding has been observed to isolate the populations on the crowns and confine the infestation to particular palms. Incidence of rat infested palm will be less in banded areas (Table 1), but the number of nuts damaged per palm would be higher (Table 4). Working out the cost benefits, trunk banding was only 54.8% effective. However, treatment with an acute poison like zinc phosphide after trunk banding is recommended as rat infestation will be localised to lesser number of palms as compared to unbanded areas.

Acknowledgements

We are grateful to Dr. K. Ramakrishnan, Dean, and Dr. R. Narayana, Director of Instruction (Basic Sciences and Humanities) for encouragement; and Dr. R.V. Krishnamoorthy, Associate Professor and Head, Department of Zoology, for critically going though the manuscript. We gratefully acknowledge the financial grant from Ford Foundation.

Diseases of Uncertain Aetiology

Chairman : K. RAMAKRISHNAN

Rapporteur : K. RADHA

A Serological Test for the Detection of the Root (Wilt) Disease of Coconut

J. J. SOLOMON, M. SASIKALA and P. SHANTA

Central Plantation Crops Research Institute, Regional Station, Kayamkulam, Krishnapuram 690 533, Kerala, India

Abstract

Samples drawn from healthy and diseased palms of varying intensities and growing in different soil types were tested with root (wilt) antiserum by the cross absorption technique. All the 108 healthy samples from various parts of India gave negative reaction, while 157 out of 161 diseased samples gave positive reaction. The 44 of the 150 apparently healthy samples (with no visual symptoms) tested, which gave positive reaction, will be observed for the development of symptoms to assess the sensitivity and diagnostic value of this test.

Introduction

The root (wilt) disease, whose causative agent is yet to be determined, is diagnosed only on the basis of visual symptoms. Radha and Lal (1972) concluded that flaccidity or ribbing of leaves is the best diagnostic visual foliar symptom of the root (wilt) disease. Visual symptoms, be it due to pathogen or nutritional deficiency/imbalances or any other factor, are the culmination of derangement in the host metabolism reflected after the actual disorder has set in. Hence, for evolving a suitable diagnostic test, the changes in the host metabolism consequent to the disease were studied and a colour test was developed (Joseph and Shanta, 1963). However, this colour test, based on the differential dehydrogenase activity of leaf tissue developed after testing a considerable number of palms of all age groups, failed to yield consistent and conclusive results when applied to healthy samples from disease free area. The scope of a sero-diagnostic test was also reduced with the healthy and diseased grindates reacting against normal and root (wilt) antiserum (Shanta *et al.*, 1975).

The present paper deals with the development of a serological test for the early detection of the disease before the visual expression of the symptoms.

Materials and Methods

Purification

Fifty gram tender leaves from unopened spindles (spear) of root (wilt) disease affected coconut palms belonging to the West Coast Tall cultivar was homogenized in 3 volumes of *M*/15 Sorensen's phosphate buffer containing 0.005 *M* EDTA and 1% mercaptoethanol. It was filtered through muslin cloth and the filtrate clarified by low speed centrifugation at 5000g for 10 min. To the supernatant, polyethylene glycol 6000 and sodium chloride were added to give 4% and 0.1 *M* final concentrations, respectively. The sap was left in the refrigerator overnight allowing a precipitate to be formed. The precipitate was collected by centrifuging at 10,000g for 15 min and the pellet dissolved in *M*/15 phosphate buffer containing 1% Triton X-100. The undissolved particles were removed by centrifugation at 5,000g for 10 min and the supernatant was centrifuged at 1,05,000g for 60 min. The pellet dissolved in *M*/15 phosphate buffer was cleared of larger aggregates by low speed centrifugation at 5000 g for 10 min. The resulting suspension was subjected to two cycles of differential centrifugation and the final glossy pellet was dissolved in distilled water. The concentration and purity of the suspension was determined spectrophotometrically before using it as an antigen.

Preparation of Antisera

White female rabbits previously bled for normal serum were injected intramuscularly at weekly intervals with partially purified preparation emulsified with Freund's incomplete adjuvant. Four weekly intramuscular injections were followed by a booster dose with double the concentration of the emulsion given on 50th day from the start of immunization. The bleeding and collection of antisera were started a week after the 4th injection and they were continued at weekly intervals for eight succeeding weeks.

Serological Tests

Double diffusion tests were carried out with microslides (7.5 × 5.0 cm) precoated with 0.5% formvar. They were layered with 2.5 ml of melted oxoid Ionagar No. 2 in phosphate buffered saline (pH 7.4) containing 0.22% sodium azide as preservative. Blocks of agar were removed with a pressure pipette to give a four member well pattern 4 mm in diameter and spaced at 6 mm from the centre well. Extracts of tender leaves from unopened spindle (spear) ground in 0.005 *M* phosphate buffered saline (pH 7.4) (1:1 w/v) were used as antigens in the tests unless otherwise specified.

Results

The partially purified preparation used as antigen for immunization had maximum absorption at 260 nm and minimum at 280 nm. The

260-280 ratio was 1.3. Work on further fractionation and characterization of the above fraction is in progress. The antiserum prepared against this partially purified fraction produced on testing two precipitin lines against diseased and a single precipitin line against healthy extracts indicating the presence of host specific antibodies To have a disease specified antiserum, free from host antibodies, cross absorption was done by direct mixing of healthy sap with the antiserum (cf. Noordam, 1973). Cross absorption was incomplete when healthy sap was mixed in quantities upto four volumes (Table 1). This was evident from a weak non-specific

TABLE 1. Reaction of antiserum at various degrees of cross absorption

Volume of healthy sap added (in ml)	Reaction against		Titer of antiserum
	Healthy palms	Diseased palms	
0	++++	++++	1/1024
3	++	+++	1/128
4	+	++	1/32
5	–	–	1/8

reaction of the cross-absorbed antiserum against healthy samples. A decrease in the titer of the antiserum at various volumes of added healthy sap was also noticed leading to the total absence of reaction against both healthy and diseased at the antigen excess level. Obviously, the disease specific antibodies were lost along with that of host antibodies at this level. This was overcome by adopting the technique of van Regenmortel (1976), by which the centre antiserum well was first charged and equilibrated with healthy sap. The antigen was allowed to diffuse and from a concentration gradient in the gel. The excess undiffused antigen was removed, and the well was recharged with antiserum and the peripheral wells with the antigens to be tested. In the test, the root (wilt) antiserum formed a single precipitin line against the diseased samples midway between the antigen and antiserum reservoir. No precipitin reaction was evident against any of the healthy samples tested from different parts of India. Of the 105 apparently healthy looking palms tested from the diseased tract, 44 reacted to the antiserum. A gradation as to the intensity of reaction with the severity of the disease was also evident, the intensity being highly pronounced in the early stages of the disease followed by a drop with the advancement of the disease. Healthy and diseased palms growing in different soil types—laterite, alluvial, clay, and sandy loam—were also tested against the antiserum. In all the tests, irrespective of the soil type involved, the antiserum reacted only against diseased samples and not against any of the healthy samples (Table 2). Palms of different age groups also could be diagnosed as to their health conditions by this test,

At the same time, none of the 108 healthy palms and as many as 158 samples out of 161 diseased palms sampled reacted to the antiserum.

TABLE 2. Relative precipitin reaction of root (wilt) antiserum against healthy and diseased palms from different soil types

Condition of palm soil type and	No. of samples tested	No. of samples reacted
Healthy – Laterite	40	nil
,, – Alluvial	30	nil
,, – Sandy loam	8	nil
,, – Clay	20	nil
Diseased – Laterite	32	31
,, – Sandy loam	121	118
Diseased – Reclaimed sandy loam	8	8

Discussion

The coconut sap, is an unsuitable medium for tests which involve direct mixing of the reactants because of its high tannin content. Direct addition of sap to antiserum before the removal of host antibodies resulted in non-specific reaction against healthy palms at lower levels of sap added and total absence of reaction against both healthy and diseased at the antigen excess level. This could be due to the non-specific binding and precipitation brought about by the tannins in the clarified sap resulting in a low titered antiserum (Table 1). Such non-specific reactions between serum proteins and leaf and root coconut tissue extracts have been reported earlier also (Shanta *et al.*, 1975). The intra-gel cross absorption plate method of van Regenmortel (1967) was found more suitable, as it was capable of completely cross-absorbing the host antibodies in the gel, permitting only the specific antibodies to diffuse through the barrier and react with disease-specific antigens. The antiserum, being specific in its reaction, react only with the diseased samples irrespective of the age of the tested palm. The versatility of this test was further evident from the fact that diseased and healthy palms growing in different soil types also could be easily identified with certainty. The reaction of some of the apparently healthy palms (in the diseased tract) with the antiserum could be due to the presence of the aetiological agent at a sub-clinical level. However, this can be confirmed only if these palms are observed after a period of incubation.

Acknowledgements

We thank Dr. K.V. Ahmed Bavappa, Director, for his interest and encouragement.

References

Joseph, T. and Shanta, P. (1963). Studies on a colour test for the root (wilt) disease of coconut. *Proc. 50th Session Indian Sci. Congress.*

Noordam, D. (1973). Identification of Plant Viruses : Methods and Experiments (ed. D. Noordam). pp. 117. Centre for Agricultural Publishing and Documentation, Wageningen, The Netherlands.

Radha, K. and Lal, S.B. (1972). Diagnostic symptoms of root (wilt) disease of coconut. *Indian J. Agric. Sci.* **42** : 410-413.

Regenmortel, van, M.H.V. (1967). Serological studies on naturally occurring strains and chemically induced mutants of tobacco mosaic virus. *Virology.* **31** : 467-480.

Shanta, P., Hariharasubramanian, V., and Gopinathan Pillai, N. (1975). Possible association of tobacco mosaic virus with the root (wilt) disease of coconut. *J. Plantation Crops* **3** : 77-80.

Discussions

Ninan : I would like to know if you have extended these studies to the hybrids and Dwarfs ? It would be interesting to study the varietal differences, if any, specially since the Dwarfs in general, and the Green Dwarf in particular, are reported to be resistant to wilt ?

Solomon : The serological studies are mainly done with WCT samples. Of course, we have tested the varieties also, but we do not have enough data to draw conclusions on this aspect at present.

Sane : Your results suggest that in the diseased palms, the intensity of a certain proteins reacting with your antisera is higher. Would it not be possible to examine protein patterns on the gels (gel electrophoresis) and identify the protein associated with the diseased palm ? Knowing the protein, it should be possible to identify the organism responsible for the production of this protein. Gel electrophoresis is a much simpler and quicker procedure.

Solomon : Yes. The protein pattern in healthy and diseased palms could be studied by polyacrylamide gel electrophoresis, but I wonder how far this would help in identifying the causal organism responsible for the disease, as the technique will indicate only the presence or absence of a particular protein.

Chenulu : Have you made any serological tests other than gel diffusion test ? It so, what was the result ?

Solomon : Yes. I have done slide agglutination test, tube precipitin, immun-electrophoresis, and immuno-osmophoresis tests. The first two tests, though simple, gave highly nonspecific reaction, especially in coconuts, as the latter contains large amounts of tannins. The other two tests gave results identical to what we have been getting in double diffusion plate method.

Research on Coconut Yellow Disease of West Africa

JOSEPH GIANNOTTI and MICHEL DOLLET

Station de Recherches Cytopathologiques, INRA, 30380 St. Christol, France
Institut de Recherches pour Huiles et Oleaginux, 11 Square Petrarbue, 75016 Paris, France

Abstract

In West Africa, coconut plantations are found along the coast of the Gulf of Guinea. In the coastal areas of Cameroun, Togo, and Ghana, palms show withering with yellowing, nut dropping, flower abortions, and death of palms. These diseases are known as Kribi, Abwa, Cape St. Paul wilt, and Kaincope. The last disease has been reported from Togo occurring as early as 1932. Since then, new foci have appeared around the original focus along the coast, at least upto 50km inside, and it is spreading slowly in patches. Since 1952, the hypothesis of a contagious disease has been put forward.

Using cytochemical techniques, the phloem cells of diseased plants were seen to contain a lightly dense material similar to DNA. This material is often found in the vicinity of the pores. Roots and inflorescence of the same palm were used for *in vitro* culture of mycoplasma.

Examination of the diseased plant tissues (inflorescence) under the electron microscope from palms showing the first symptoms of the disease showed mycoplasma like objects, but in low concentrations only. Studies are under way to determine the most favourable conditions for its multiplication and for establishing its identity with other coconut diseases reported from the region.

Introduction

Coconut plantations were established in the coastal regions of Togo in Western Africa, between 1885 and 1914. In 1932, a disease was observed in the village 'Kaincope' which remained restricted in the area for a long time. In 1954, it suddenly began spreading to the nearby areas (Bachy and Hoestra, 1958). However, the casual organism could not be determined.

Several hypotheses have been put forward on the cause of the disease. Though various efforts have been made to find out the causal agent *in situ*, actual problems of epidemiology still remain unsolved.

Symptomatology

The disease is characterized by falling off of premature nuts followed by yellowing of fronds, from older to younger leaves and finally reaching the youngest fronds of the crown. All the affected leaves begin to droop down. Unopened inflorescences blacken and rot from the tip downwards. Depending on the age, the palms die within 3-6 months after the appearance of the first symptom. The cause of rapid death, even of the older palms, is probably due to early infection of the vegetative bud in the crown.

The symptoms of all the other West African yellowing diseases of coconut reported from the Gulf of Guinea, such as Cape Saint Paul wilt (Martyn, 1955), Kribi (de Lamothe, 1970), Akwa disease (Bull, 1955) and from Mozambique are similar. The disease is probably comparable to lethal yellowing found in Jamaica, Trinidad, and Florida (USA) (Ollagnier and Weststeijn, 1961).

Epidemiological and Etiological Studies

Early studies on the disease consisted mostly of epidemiological observations. Most of the early hypotheses on the disease are based on its origin and spread. In a plantation, the disease first appears in a small zone with a few attacked palms in an approximately circular patch. It spreads gradually in the areas forming an irregular and elongated patch. The disease has been found to recur on new healthy seedlings replanted in areas which were previously diseased.

The appearance of the disease does not have any relationship with the conditions and the direction of the wind, but the spread is checked during dry seasons. In infected areas, often a few palms remain symptomless. Usually, the spread of the disease is gradual, but due to some unknown factors at times, it may spread rapidly.

All these epidemiological observations were taken into consideration to determine the etiological agent of Kaincope disease. Both inanimate elements and animate organisms have been considered to be etiologic agents. Micronutrient deficiencies have also been considered.

The theory of viral origin was put forward by Nutman and Roberts (1955). Bachy and Hoestra (1958) showed after epidemiological observations during 1955-1957, that Kaincope disease is very contagious. But, all the direct and indirect tests for viral etiology have remained inconclusive. Transmission studies also remain inconclusive and are further complicated due to the occurrence of disease in patches and the persistence of the pathogen in areas from where diseased palms have been removed.

Cytochemical studies with Feulgen reaction showed the presence of DNA in the phloem cells of diseased palms (Giannotti *et. al.*, 1955), indicating the probable presence of some pro-caryotic germ in the phloem.

Mycoplasma has been cultivated from the unopened young inflorescences and roots of infected plants, both in the broth and agar medium Giannotti *et al.*, 1975).

Ultrastructural studies of young inflorescence (Dollet and Giannotti, 1976) showing early symptoms revealed the presence of ovoid bodies of 200-600 nm size in sieve tube elements. These bodies are bound by a single trilaminar unit membrane with diffused fibrillar nuclear material and bacterial ribosomal bodies. These bodies resemble mycoplasmas. They were few in number and could be observed only rarely in transverse sections. Often associated with the mycoplasmal bodies were some mitochondria, plastids with crystalline structures, cuneate inclusions, and fibrillar P-proteins. Mycoplasmal elements were frequently found close to the sieve plates.

Using the direct injecting method of McCoy (1972), Steiner (1975) adminstrated antibiotic solutions to the trunk of diseased palms and he concluded that the causal agent might be pro caryotic in nature.

Discussion and Conclusion

Recent researches throw some light on the etiology of Kaincope disease, but much more careful and multidisciplinary work is necessary to confirm it.

In the first place, it is important to study the exact relationship, if any, between Kaincope disease and similar diseases found in nearby areas. Secondly, ultrastructural comparisons should be made carefully between Kaincope and lethal yellowing disease (Plavsic-Banjac, Hunt, and Maramorosch, 1972 ; Beakbane, Slater, and Posnette, 1972). Differences in the number of germs in the cells of the two diseases do not rule out the possibilities of similarities in the nature of the two organisms.

The actual nature of etiologic agents of all unknown diseases of coconut palms is yet to be understood, except that of lethal yellowing and Kaincope, where recent studies provide strong evidences of mycoplasmal etiology. Flagellated protozoa (Trypanosomatidae) have also been reported to be associated with diseased oil palms (Dollet, Giannotti, and Ollagnier, 1976) and coconut palms (Parthasarathy, Van Slobbe, and Soudant, 1976) but their role in the phytopathogenicity is yet to be determined.

References

Bachy, A. and Hoestra, H. (1958). Contribution a l'etude de la "maladie de Kaincope" du cocotier au Togo. *Oleagineux.* **13** : 721-730.

Beakbane, B.A., Slater, C.H.W. and Posnette, A.F. (1972). Mycoplasmas in the phloem of coconut *Cocos nucifera* L. with lethal yellowing disease. *J. Hort. Sci.* **47** : 265.

Bulla, R.A. (1955). Bronze leaf wilt of coconut palms in Nigeria. *West Afr. Inst. Oil Palm Res.* **3** : 70-72.

Dabek, A.J., Johnson, C.G. and Harries, H.C. (1976). Mycoplasma-like organisms associated with Kaincope and Caps St. Paul wilt disease of coconut palms in West Africa. *Pans* **22** : 354-358.

De Lamothe, De Nuce. (1971). Report on the disease of coconuts at Kribi, Cameroon. Institut Recherches Huiles et Oleagineux--Rapport interne non public.

Dollet, M. and Giannotti, J. (1976). Maladie de Kaincope: presence de mycoplasmes dans le phloeme des cocotiers maladies. *Oleagineux.* **31** : 169-171.

Dollet, M., Giannotti, J. and Ollagnier, M. (1976). Observation de protozaires flagelles dans les tubes cribles de palmiers a huile malades. *C.R. Acad. Sci.*

Giannotti, J., Arnaud, F., Dollet, M., Delattre, and de Taffin, G. (1975). Mise on culture de mycoplasmes a partir de racines et d'inflorescences de cocotiers atteints per la maladie de Kaincope. *Oleagineux* **30** : 13-18.

Giannotti, J., Vago, C., Marchoux, G., and Louis, C. (1975). Les rickettsoides de plantes, une nouvelle orientation en pathologie vegetale. *C.R. Acad. Agri.* 1017-1020.

Martyn, E.B. (1955). Diseases of coconuts. *Trop. Agric.* **32**: 162-169.

McCoy, R.E. (1972). Remission of lethal yellowing in coconut palms treated with tetracycline antibiotics. *Pl. Dis. Rep.* **56**: 1009-1021.

Nutman, F. J. and Roberts, F. M. (1955). Lethal yellowing, the unknown disease of coconut palms in Jamaica. *Emp. J. Exp. Agric.* **23**: 257-267.

Ollagnier, M. and Weststeijn, G. (1961). Les maladies du cocotier aux Iles Caraibes. Comparasion avec la maladie de Kaincope au Togo. *Oleagineux.* **16** : 729-736.

Parthasarathy, M.V. (1973). Mycoplasma-like organisms in the phloem of palms in Florida affected by lethal yellowing. *Plant Dis. Reptr.* **57** : 861-862.

Parthasarathy, M.V., Van Slobbe, W. G. and Soudant, C. (1976). Trypanosomid flagellate in phloem of diseased coconut palms. *Science.* **192** : 1346-1348.

Plavsic-Banjac, B., Hunt, P. and Maramorosch, K. (1972). Mycoplasma-like bodies associated with lethal yellowing disease of coconut palms. *Phytopathlogy* **62** : 298-299.

Steiner, K.G. (1975) Studies on the Kaincope disease of coconut palms in Togo. Fourth Session Tech. Working Party on Coconut Production, Protection, and Processing. Kingston, Jamaica. September, 1975. FAO. Rome.

Whitcomb, R.F. and Davis, R.E. (1971). Mycoplasmas, rickettsiae and chlamydiae : possible relation to yellows diseases and other disorders of plants and insects. *Ann. Rev. Phytopath.* **9** : 119-154.

The Association of Anomalous RNA with Cadang-Cadang Disease of Coconut, and Evidence Towards a Viroid Etiology

J.W. RANDLES, ERLINDA P. RILLO and G. BOCCARDO

Department of Plant Pathology, Waite Agricultural Research Institute, University of Adelaide, Australia; Guinobatan Experiment Station, Guinobatan, Albay, Philippines; and Laboratorio di Fitovirologia Applicata, Via O. Vigliani, Turin, Italy. Australia, Philippines and Italy

Abstract

Cadang-cadang is a coconut disease of unknown etiology. It was first described in the Philippines in 1931 and is apparently still confined to that country. Symptoms and epidemiology are not inconsistent with a virus etiology, but no viral pathogen has been found to be associated with the disease.

A search for unusual nucleic acids in diseased palms led to the discovery of two low molecular weight RNA species (ccRNA-1, ca. 80,000d; ccRNA-2, ca. 200,000d) which were too small to have originated from virus particles. Studies of the properties of ccRNA-1 indicated that it is structurally similar to two of the known viroids (low molecular weight, uncoated RNA pathogens) potato spindle tuber and citrus exocortis viroids, and dissimilar from normal plant RNA. Inoculation of coconut seedlings with a combined unfractionated nucleic acid extract from diseased palms led to the appearance of ccRNA-1 and -2 in 60% of the inoculated seedlings. The transmissibility of the disease associated RNA's, and the size and structure of ccRNA-1 supports a viroid hypothesis for cadang-cadang, but final proof will depend upon demonstrating the pathogenicity of one or other of the isolated RNAs. Failure of tetracycline or penicillin injections to affect either the progress of the disease or the detection of ccRNA-1 and -2 in diseased palms indicate that mycoplasma-like organisms have no role in cadang-cadang disease.

Introduction

Cadang-cadang, or yellow mottle decline of coconut has been recognized as a serious disease in the Philippines since 1926. It has apparently spread within a radius of approximately 300 km from its apparent original source since then (Price, 1971) causing an estimated loss of 12 million palms. The theory that cadang-cadang is an infectious disease is based on its natural spread and symptomatology. Artificial transmis-

sion has not been convincingly demonstrated, and no virus particles, bacteria, fungi, or nematodes have been found to be associated with the disease.

The disease progresses through early, middle, and late stages (Price, 1971). The early stage is when characteristic non-necrotic yellow leaf spots appear on the third or fourth frond down from the unopened spear leaf and nuts start to become smaller and rounded with longitudinal scarifications chiefly around the equator. During the mid-stage, lasting several years, spathe, inflorescence, and nut production decline and finally cease. At the late stage, fronds decline in size and number, pinnae become brittle, leaf spots increase in size and frequency, and the palm eventually dies.

We describe here the results of attempts to define the cause of cadang-cadang based on the use of antibiotics to test whether mycoplasma or rickettsia-like organisms are involved, and nucleic acid characterization and transmission studies in the search for a virus-like pathogen.

Results and Discussion

Chemotherapy with Antibiotics

Tetracycline or penicillin was injected into palms by drilling holes 2×20 cm in the bole, pouring in the antibiotic solution at a concentration of 200-7000 ppm, and stoppering the holes. Between 0.25 g and 1.75 g was injected into each palm at intervals of 3-4 months. Neither antibiotic affected the progress of the disease significantly, nor did they affect the rate of frond, spathe, inflorescence or nut production. Uptake of solutions using this procedure was demonstrated by injecting a dye, and by the production of apparent tetracycline-induced scorching of pinnae in some palms. The tetracycline dosage exceeded that necessary to produce recovery in lethal yellowing diseased palms in Florida (McCoy, 1972, 1975) and we conclude that neither mycoplasmas or rickettsias are the primary cause of cadang-cadang.

The Demonstration of Unusual RNA Species in Diseased Palms

Nucleic acids from diseased palms were analysed in a search for unusual species which might indicate the association of a virus or viroid with cadang-cadang.

Leaf tissue was chopped, then blended with 3 or 4 volumes of cold 0.1*M* Na_2HPO_4, containing 0.1% sodium thioglycollate and 0.1*M* sodium diethyl-dithiocarbamate. Extracts were strained, clarified by low speed centrifugation, and then treated with 5% polyethylene glycol 6000 for 1-2 hr. The resulting precipitate was collected by centrifugation, and subjected to a nucleic acid extraction procedure based on phenol-sodium dodecyl sulphate extraction and protease digestion. The nucleic acids obtained from this polyethylene glycol precipitated material were analysed by electrophoresis on polyacrylamide gels (Randles, 1975a).

Two species of RNA were found in the preparations from diseased palms only. Healthy palms, and palms stressed by other factors showed neither of these RNA species. The major species, ccRNA-1, has a molecular weight of $6.3\text{-}7.3 \times 10^4$ daltons under denaturing conditions, and a sedimentation coefficient of 7.6S. Properties such as solubility in 2*M* LiCl, a thermal denaturation profile with a sharp 11-20% increase in UV absorption at 260 nm at the melting point of 52-54°C in $0.01 \times$ SSC and $0.1 \times$ SSC ($1 \times$ SSC = 0.15*M* NaCl, 0.015*M* Na citrate), partial sensitivity to the single-strand specific S1 nuclease, and some resistance to ribonuclease A, suggest that ccRNA is a partially double-stranded looped molecule, possibly hair-pin shaped, or a closed circle. ccRNA-2 is approximately twice the molecular weight of ccRNA-1, but its structure has not been investigated.

The physico-chemical properties of ccRNA-1 are similar to those known for the potato spindle tuber and citrus exocortis viroids, and appear to be different from those known for normal plant, or plant virus RNAs. The structure of ccRNA-1 therefore appears to resemble closely that of viroid RNA. Nevertheless, ccRNA-1 differs from the viroids in that it is apparently not associated with chromatin, nor any cell organelle fraction. Furthermore, no evidence has been obtained to show that either of the RNA species associated with cadang-cadang disease is infectious, and only such a test of pathogenicity will be proof of a viroid etiology for cadang-cadang. Apart from the possibility that ccRNA-1 and-2 may be components of the causal agent of cadang-cadang, their easy recognition in nucleic acid extracts from diseased palms may have diagnostic value, and so far, such tests have shown ccRNA-1-like RNA in African oil palm as suspected to cause cadang-cadang disease.

Transmission of RNA Associated with Cadang-Cadang Disease

A number of transmission trials are in progress. In view of the reported lack of success of standard mechanical and graft inoculation procedures in previous attempts to transmit cadang-cadang, a high pressure injection procedure (Price, 1971; Mumford, 1972) was used. The instruments were either a "Hypospray" injector (Scherer Corp., U.S.A.) with an electrically operated air compressor, or a hand primed "Panjet" mechanical injector (Schuco International, London, U.K.). Injections were applied to the petiole bases, or to the folded leaflet of the spear leaf of young seedlings, after stripping away the fibrous sheath material. Injections were combined with either a razor-slashing inoculation, or rubbing of the carborundum-dusted petiole base with inoculum wet finger.

The transmission trials were assessed by analysing the extracted nucleic acids for the presence of the disease-associated RNA. In the earliest trials, ccRNA-1 and -2 were found in 2 out of 14 seedlings inoculated with polyethylene glycol-insoluble material resuspended in 0.05*M* phos-

phate buffer, pH 7; and 12 out of 20 seedlings inoculated with unfractionated total nucleic acids combined from a number of diseased palms. Nucleic acids were assayed 19 months after inoculation. Between 19 and 22 months after inoculation, the palms with the ccRNAs were showing bright yellow spots on the first frond down from the spear leaf, and a yellow green mosaic on the second frond down. In uninoculated palms, the ccRNAs were undetectable, and no leaf spotting was observed on the young fronds. It seems likely that the leaf spots and mosaic on the young fronds are the early symptoms of cadang-cadang, but further observations will need to be made to check that later symptoms are characteristic of cadang-cadang. ccRNA-1 inoculations did not induce the appearance of diagnostic RNA or symptoms under the same conditions, and further attempts are in progress to isolate and test individual RNA species for pathogenicity.

Conclusions

Discovering the nature of the causal agent of cadang-cadang disease, and how it spreads, are necessary steps towards developing control measures for the disease. The results presented here indicate that the primary cause of the disease is not a prokaryotic organism, as appears to be the case with lethal yellowing disease in the West Indies and Florida (Plavsic-Banjac *et al.*, 1972), but suggests that a virus or viroid is the cause. A viroid etiology is favoured because of the inability to detect virus-like particles in association with cadang-cadang (Randles, 1975b), and because one of the RNA species which is exclusively associated with cadang-cadang has physico-chemical properties similar to those described for other viroids (Randles *et al.*, 1976), and can be detected prior to symptom development.

The development of a technique which allows the transmission of the cadang-cadang associated RNA, together with symptoms which may be the early signs of the disease, now provides a means of directly testing the viroid hypothesis for cadang-cadang, that is, by testing the infectivity of ccRNA-1 and -2. Assuming that the disease has been transmitted, we conclude that the causal agent is contained in unfractionated nucleic acid extracts of diseased palms, and that the disease has a latent period of 19—22 months. Once the optimum conditions for transmission have been elucidated, a programme to select breeding material with resistance to the cadang-cadang agent could be commenced. The mode of natural spread of the disease is not yet known.

The detection of ccRNA-1-like RNA in African oil palms in the Philippines with cadang-cadang-like symptoms strongly supports Price's earlier suggestion (1971) that this economically important and widely grown crop is also affected by the agent which causes cadang-cadang disease in coconut.

References

McCoy, R.E. (1972). Remission of lethal yellowing in coconut palm treated with tetracycline antibiotics. *Plant Dis. Reptr.* **56**: 1019-1021.

McCoy, R.E. (1975). Effect of oxytetracycline dose and stage of disease development on remission of lethal yellowing in coconut palm. *Plant Dis. Reptr.* **59** : 717-720.

Mumford, D.L. (1972). A new method of mechanically transmitting curly top virus. *Phytopathology* **62** : 1217-1218.

Plavsic-Banjac, B., Hunt, P., and Marmorosch, K. (1972). Mycoplasma-like bodies associated with lethal yellowing disease of coconut palms. *Phytopathology* **62** : 298-299.

Price, W.C. (1971). Cadang-cadang of coconut. *Indian Phytopathology* **24** : 425-436.

Randles, J.W. (1975a). Association of two ribonucleic acid species with cadang-cadang disease of coconut palm. *Phytopathology* **65**: 163-167.

Randles, J.W. (1975b). Detection in coconut of rod-shaped particles which are not associated with disease. *Plant Dis. Reptr.* **59** : 349-352.

Randles, J.W., Rillo, E.P., and Diener, T.O. (1976). The viroid-like structure and cellular location of anomalous RNA associated with the cadang-cadang disease. *Virology* **74**: 128-139.

Attempts to Transmit Lethal Yellowing of Coconut Palms by Suspected Vectors

JAMES H. TSAI

Agricultural Research Centre, University of Florida, 3205 S.W. 70th Ave. Fort Lauderdale, Florida 33314, USA

Abstract

Two approaches, dodder and vector transmission, were used in atte mpts to transmit lethal yellowing disease of coconut palms (*Cocos nucifera* L.). These approaches were based on the premise that pathogen is a mycoplasma-like organism. A parasitic dodder, *Cuscuta campestris* (Yuncker), was bridged from diseased coconut palms to periwinkle (*Catharanthus roseus* Don.) in an attempt to transmit the pathogenic agent. The emphasis in the vector trials was placed on homopteran insects. Besides direct feeding of *Spangbergiella* sp. from diseased palms to healthy palms, partially purified and crude phloem sap from diseased palms were artificially fed and also injected by needle into adults and nymphs of *Oncometopia nigricans* (Walker) and *Macrosteles fascifrons* (Stal.). Other plants, such as aster (*Callistephus chinensis* N.) periwinkle, and celery (*Apium graveolens* L.), were used as possible alternate hosts for the pathogen. No transmission has resulted from these various attempts. Large number of the mite *Tetranychus tumidus* (Banks) were introduced to feed on coconut and *Veitchia* palms in the screenhouses for over eighteen months and failed to induce lethal yellowing.

Introduction

The devastating disease, lethal yellowing (LY) of coconut palms (*Cocos nucifera* L.), was first reported in Jamaica in 1891 (Fawcett, 1891). It has since spread to other islands of the West Indies. LY appeared in Key West, Florida, in 1955 and killed 15,000 of the 20,000 coconut palms in the area during a 7-year period. By 1971, LY had moved northward to the Florida mainland. It is estimated to have killed 80% of the 3,50,000 coconut palms in Dade County, Florida (McCoy, 1976). In addition, several other palm species were suspected to be affected by LY (Parthasarathy, 1974; Thomas, 1974).

Many researchers have theorized that the causal agent of LY is carried by windborne arthropod vectors and most of the earlier transmission studies involved such vectors (Carter, Latta and Suah, 1965; Latta, 1966; Grylls

and Bor, 1968; Grylls and Hunt, 1971; Heinze, Petzold, and Marwitz, 1972; Schuiling and Johnson, 1973). Mycoplasma-like organisms (MLO) were implicated as the causal agents of LY when they were observed in diseased palm tissues (Beakbane, Slater, and Posnette, 1972; Heinze *et al.*, 1972; Plavsic Banjac, Hunt, and Maramorosch, 1972; Parthasarathy, 1974; Thomas, 1974), and symptoms remission occurred following antibiotic treatment (McCoy, 1972; Hunt *et al.*, 1974). Since most plant diseases of mycoplasmal etiology are transmitted by leaf hoppers, this study emphasized homopteran leaf hoppers.

Materials and Methods

Stock colonies of *Macrosteles fascifrons* (Stal.) and *Spangbergiella* sp. (Homoptera: Cicadellidae) were reared on potted oats (*Avena sativa* L.) and on St. Augustine grass (*Stenotophrum secundatum* (Walt.) Kuntze) at 24±2 °C under continuous 'Plant Gro' fluorescent lighting of approx. 5,380 lux. The colonies of *Oncometopia nigricans* (Walker) were maintained as described earlier (Tsai, 1975). Procedures such as preparation of test plants. inoculum source plants, acquisition feeding, inoculation feeding and injection procedures were similar to those reported earlier (Tsai, 1974).

For testing the inflorescence as a vector feeding and LY inoculation site, four blocks of street plantings of *Veitchia* palm (*Veitchia merrillii* (Becc.) Moore), 2.5-3.0 m tall, were selected in a LY epidemic area. The unopened inflorescences of palms in two blocks were periodically removed, the other inflorescences of palms in two blocks were left untouched. After 6 months, the results were compared.

In the toxin study, 42 container-grown coconut palms 2 m in height were isolated in one room (8.4 × 6.0m) covered with 52 mesh saran screen. A similar room contained 66 potted *Veitchia* palms 1m in height. About 2,000 tumid mites (*Tetranychus tumidus* Banks) were introduced into each of these two rooms for over 18 months.

For the vector phototropistic test, one 52 mesh screen light trap (2.2× 0.9×0.9m) was contructed of a wooden frame to house four potted coconut palms approximately 0.9 m tall. On top of the trap, a funnel and a 15-watt ultraviolet lamp were mounted. The trap was placed in LY epidemic areas for a period of 12 months. Each of three sets of palms was exposed to light-trapped insects for four months and then sprayed with malathion and kept in a screen house for symptom observation.

In the dodder transmission test, healthy dodder (*Cuscuta campestris* Yuncker) seedlings were established on 12 healthy potted periwinkles (*Catharanthus roseus* Don.). The periwinkles with dodder were then tied on 12 apparently healthy coconut palms grown in an active LY area. Strands of dodder were constantly trained on to the leaflets of coconut palms. Six to 12 weeks after dodder had established and survived on

coconut alone, the strands of dodder from those trees expressing LY symptoms were bridged to healthy periwinkles, then they were transported back to the greenhouse for observation of symptom development.

Results and Discussion

The leaf hopper *Spangbergiella* sp. is abundant on St. Augustine grass and other grasses under the coconut plantings both in Jamaica and Florida. It is an occasional feeder of coconut palms. Therefore, one experiment was conducted to test the transmissibility of this insect. Five hundred *Spangbergiella* leaf hoppers were collected from the stock colonies and caged over a spear leaf of LY-infected coconut palm for a 48 hr acquisition access period (AAP). At the end of AAP, about 400 leaf hoppers were recovered and released in a screen room containing two 2.2 m tall healthy coconut and two 1.5 m tall healthy *Veitchia* palms. Fourteen 15 cm pots of St. Augustine grass were also provided as breeding host for the test insect. There was no positive transmissiom after five months, even though the estimated incubation period in palms may vary from three to nine months (Heinze *et al.*, 1972; author's observation).

One experiment was designed to test whether the suspected vector of LY is positively phototropistic. Each set of four test palms was exposed to the light-trapped insects in an active LY area for four months. Observations were made throughout the year. None of the 12 test plants was affected by the feeding of the other light-trapped insects.

In the inflorescence removal tests, five out of 28 *Veitchia* palms with removed inflorescences showed LY symptoms and died later. Four of the 21 control palms showed LY symptoms. Another parallel experiment showed that two out of 12 palms in a test group succumbed to LY, whereas four out of 18 palms in the control group were affected. The results suggested that the inflorescences are probably not the feeding and inoculation sites for LY vectors. The frequent inflorescence visitors of *Veitchia* palms are *Apis mellifera* L. (Apidae), *Polistes fuscatus* (Fabricius) (Vespidae), *Agapostemon splendens* (Lepeletier) (Halictidae), *Pachodynerus erynnis* (Lepeletier) (Eumenidae), *Angochlora pura* (Say) (Halictidae), *Dorymyrmex pyramicus* (Roger) (Formicidae), *Allograpta cubana* (Curran) Syrphidae), and *Idioderma virescens* (Van Duzee) (Membracidae) (author's observation). In nature, very often nonflowering coconut palms die of LY. This would further support the theory that the inflorescence is not the inoculation site for the LY causal agent.

To determine if a mite commonly found on the coconut palm would be able to produce a phytotoxic substance causing LY symptoms, an experiment using *T. tumidus* was set up. About 2,000 *T. tumidus* collected from an LY area were established on the coconut and *Veitchia* palms in confinement. The average number of mites/leaflet was 12.5 over a period of 18 months. The damage on the palm leaf as a result of mite feeding

was noticeable, but no LY symptoms were observed on the tested 198 palms. Although this mite is frequently found in palm plantings, it is evident that LY is not caused by the toxin of *T. tumidus*.

In another technique used in this study, 74 nymphs of *Oncometopia nigricans* and 490 of *Macrosteles fascifrons* were allowed to feed on phloem sap from diseased coconut palms through a membrane. At the end of a 16 hr AAP, some mortality was noted. Then, 60 *O.nigricans* nymphs were divided on to two periwinkle plants and 233 *M. fascifrons* nymphs divided into 11 groups, and each group was kept on an aster (*Callistephus chinensis* N.) plant.

Considerable mortality was experienced with the needle injection of crude phloem sap into *M. fascifrons* and 23 of 42 *M. fascifrons* adults survived after injection. They were then placed on an aster plant. The mortality was very low in the *O.nigricans* group. Thirty-five of 42 injected insects were divided into groups of seven and placed onto five periwinkle plants. *Oncometopia* is rather large and hardy, and therefore, better withstood the puncturing injury than the former two species. The results were negative after 10 months.

Another experiment was conducted by feeding and injecting *M. fascifrons* with the supernate of phloem sap from diseased palms centrifuged at 8,000 RPM for 15 min to obtain a clean sap. At the end of 8 hr AAP, 78 of 130 *M. fascifrons* were recovered. *M. fascifrons* were placed on three celery (*Apium graveoleus* L.) and two aster plants. The same inoculum was injected into 36 *M. fascifrons* adults. Twenty-one surviving *M. fascifrons* were kept on one aster, and one celery plant. Negative results were obtained from the above tests during 3-5 months of symptom observation. The last experiment was designed to obtain a higher concentration of pathogen by centrifuging the supernate at 18,000 RPM for 90 min. The pellet was mixed with healthy phloem sap which passed through a 0.45 μ millipore filter. The filtrate was fed and injected into the adults of *M. fascifrons*. After 7 hr AAP, 52 *M. fascifrons* were divided on three aster and two celery plants. The same inoculum was injected into the adult insects. Twenty-eight of 44 injected *M. fascifrons* were divided on two aster and two celery plants. No positive transmission occurred before the death of test plants.

Other workers have been able to transmit MLOs from diseased plants via several species of dodder (Dale and Kim, 1969; Hibban and Wolanski, 1971; Dijkstra and Wolanski, 1972). A similar technique was tried on coconut palms. Although the haustoria were established on the leaflets of coconut palms, constant attention and training of the strands of dodder was required. Eight of 12 source palms showed striking LY symptoms and the connections between the hosts were maintained until the death of the palms. The tested periwinkles showed no sign of yellowing or other disorder after six months in the green house.

While the results of transmission studies outlined in this paper are

inconclusive, the identity of the vectors of LY of coconut palms is still unknown, and remains the most important gap in our knowledge about this disease. Much future effort will be directed at searching and testing other species of suspected vectors. Unless a vector is found and the mode of transmission becomes known, it is unlikely that effective control measures can be developed to reduce the vector populations. Screening programme to find other palm species resistant to LY will rely greatly on the ability to use the vector. Based on their difference in pattern of spread, McCoy (1972) suggested that different vectors may be involved in the transmission of Kaincope disease in West Africa and LY in the Western Hemisphere. The true co-identity in these diseases can only be verified when pathogen characterization is made, and the vector specificity is known. Thus, much effort will be continued to determine the mechanism of transmission of the causal agent for LY.

References

Beakbane, A.B., Slater, C.H.W. and Posnette, A.F. (1972). Mycoplasmas in the phloem of coconut, *Cocos nucifera* L. with lethal yellowing disease. *J. Hort. Sci.* **47** : 265.

Carter, W., Latta, R.K. and Suah, J.R. (1965). The symptoms of lethal yellowing disease of coconut palms. *FAO Plant Prot. Bull.* **13** : 49-55.

Dale, J. L. and Kim, K.S. (1969). Mycoplasma-like bodies in dodder parasitizing aster yellows-infected plants. *Phytopathology* **59** : 1765-1766.

Dijkstra, J. and Lee, P.E. (1972). Transmission by dodder of sandal spike disease and the accompanying mycoplasma-like organisms via *Vinca rosea*. *Neth. J. Pl. Path.* **78** : 218-224.

Fawcett, W. (1891). Report on the coconut disease at Montego Bay. *Bull. Bot. Dep. Jamaica* **23** : 2.

Grylls, N.E. and Bor, N.A. (1968). Investigations on the etiology of lethal yellowing of coconuts in Jamaica. 2. The role of insects as possible vectors. FAO Technical Working Party on Coconut Production, Protection and Processing. 3rd Session, Indonesia.

Grylls, N.E. and Hunt, P. (1971). Studies on the etiology of coconut and lethal yellowing in Jamaica by mechanical bacterial inoculations and by insect vectors. *Oleagineux* **26** : 543-549.

Heinze, K.H., Petzold, H. and Marwitz, R. (1972). Beitrag zur Atiologie der todlichen Vergilbund der Kokospalme. *Phytopathol. Z.* **74** : 230-237.

Hibban, C.R. and Wolanski, B. (1971). Dodder transmission of a mycoplasma from ash witches-broom. *Phytopathology* **61** : 151-156.

Hunt, P., Dabek, A. J. and Schuiling, M. (1974). Remission of symptoms following tetracycline treatment of lethal yellowing-infected coconut palms. *Phytopathology* **64** : 307-312.

Latta, R. (1966). Attempts to relate nematodes to lethal yellowing diseases of coconut palms in Jamaica. *Trop. Agric. (Trin.)* **43** : 59-68.

McCoy, R.E. (1972). Remission of lethal yellowing in coconut palm treated with tetracycline antibiotics. *Plant Dis. Reptr.* **56** : 1019-1021.

McCoy, R.E. (1976). Comparative epidemiology of the lethal yellowing, kaincope and cadang-cadang diseases of coconut palm. *Plant Dis. Reptr.* **60** : 498-502.

Parthasarathy, M.V. (1974). Mycoplasma-like organisms associated with lethal yellowing disease of palms. *Phytopathology* **64** : 667-674

Plavsic-Banjac, B., Hunt, P. and Maramorosch, K. (1972). Mycoplasma-like bodies associated with lethal yellowing disease of coconut palms. *Phytopathology* **62** : 298-299.

Schuiling, M. and Johnson, D.G. (1973). Current attempts to find a vector associated with lethal yellowing disease of coconut palms. *Principes*. **17** : 151-159.

Thomas, D.L. (1974). Possible link between declining palm species and lethal yellowing of coconut palms. *Proc. Fla. State Hort. Soc.* **87** : 502-504.

Tsai, J. H. (1975). Transmission studies of three suspected insect vectors of lethal yellowing of coconut palms. *FAO Plant Prot. Bull.* **23** : 140-145.

Tsai, J.H., Woodiel, N.L. and Kirsch, O.H. (1976). Rearing techniques for *Haplaxius crudus* (Homoptera : Cixiidae). *Florida Entomologist* **59** : 41-43.

Discussions

Govindankutty : Do you come across mycoplasmas in the body tissues of the insects visiting coconut ?

Tsai : No, even though we have not checked enough insect tissues to say no. As we know, when insects feed on the pollen, they are naturally contaminated with other MLOs.

Shantha : 1. Is it true that just one treatment with tetracycline will give remission of symptoms ?

2. What concentration of the antibiotic should be applied to give the minimum concentration required in the host tissues ?

Tsai : 1. It depends on the stage of infection, that is, concentration of the organism. If the stage is early, remission of symptoms after one treatment can be obtained. However, no matter what stage it is, continuous injection is required.

2. 3 g actual tetracycline weight.

Histopathology of Roots of Coconut Palm Affected with Root (wilt) Disease

M.P. GOVINDANKUTTY and K. VELLAICHAMY

Central Plantation Crops Research Institute Regional Station, Kayamkulam, Krishnapuram 690 533, Kerala, India

Abstract

Anatomy of roots from healthy and diseased coconut palms was studied using serial microtome and free-hand sections. Some externally healthy roots from apparently healthy, and obviously diseased trees (naturally infected) from an area of active disease spread showed poorly staining mechanical and vascular tissues. Walls of tracheal elements were thinner and disorganized. Tyloses occurred occasionally in metaxylem vessels. Several roots revealed degenerate phloem. Necrotic effects were shown by abnormally and deeply staining phloem with dense contents. Tissue degeneration was less pronounced in metaphloem. Many healthy-looking roots from apparently healthy and diseased palms had fungal hyphae (?) in metaxylem. Sections of roots with external lesions of the burrowing nematode *Radopholus similis* revealed the presence of nematodes and their eggs in cortical burrows. Such burrows contained deeply staining cells encircled by abnormal sclerenchyma. Degenerative changes in conducting elements could derange the flow of nutrients and thereby contribute to root death due to starvation.

Introduction

The root (wilt) diseased coconut palms exhibit macroscopic symptoms characterized by general drooping, yellowing, and necrosis of leaflets. The number of roots is reduced and a high percentage of the roots show rotting (Anonymous, 1976). External symptoms of diseases are the manifestations of biochemical and histological alterations occurring in the susceptible host caused by or as an effect of pathogenic infection. Association of several microorganisms with the root (wilt) disease affected palms has been reported (Anonymous, 1976).

Anatomical studies on root (wilt) affected coconut palms have been attempted by Joseph and Shanta (1963) and Indira and Ramadasan (1968). The present studies were undertaken to gather additional information on the histological alterations in the roots of coconut.

Materials and Methods

Roots of the coconut cultivar West Coast Tall were collected from the bole regions of healthy palms from a disease-free area (Kasaragod) and apparently healthy and diseased palms from a severely infected area (Kayangulam). Samples with lesions at the burrowing nematode were also collected at Kayangulam.

Roots without obvious external damage were fixed in FAA (formalin-acetic acid-ethanol). For microtomy, materials were dehydrated and infiltrated in a tertiary butanol series. Serial transections (10-15 μ thick) and free-hand preparations were used. Johansen's safranine fast green, resorcinol blue and acid fuchsin-lactophenol were used for staining. Some sections were stained with phloroglucinol-HCI to test for lignification, and Sudan IV to determine suberization (cf., Johansen, 1940). Observations were recorded from at least six roots from each palm.

Results

The structure of the root fits the description of Tomlinson (1961). However, for the sake of comparing the histological alterations in the disease affected palm, the following details are given. The root has no epidermis in a mature differentiated zone. A conspicuous exodermis develops in place of the worn out epidermal layer. The cortex has schizogenous cavities. The inner cortex gets sclerotized as the root matures. An endodermal cell with casparian bands delimits the cortex. This encloses a pericycle having passage cells and cells with reticulate thickenings. Tanniniferous cells are interspersed in cortex, xylem parenchyma, and pith cells.

The xylem and phloem occur in different radial bundles. Some roots have 40-44 protoxylem points and an equal number of phloem. Metaxylem vessels form an inner ring. The metaxylem in a representative sample measures 480×315 μ. Phloem bundles here occupy an area of 315×120 μ. The large metaphloem measures 90×48 μ. The pith in old root is lacunose.

Root damage is quite obvious in disease prevalent areas. There occurs a progressive deterioration in the root system through increased die-back of roots and root rot. Roots are very few in palms at the advanced stages of the disease. This may be because of a reduction in meristematic activity. Certain roots from apparently healthy and obviously diseased palms showed poorly staining mechanical and xylem tissues. The reduced intensity of staining is indicative of poor lignification. However, in some cases, the inner cortical cells were deeply staining.

Walls of metaxylem elements become disorganised and thin. Their wall thickness was much reduced and resulted in uneven walls. The biggest metaxylem in some diseased roots measured 370-440 μ long and 270-285 μ

wide. Tyloses were seen in 18/132 roots examined. They are formed by the invagination of the protoplast from the bordering parenchyma into xylem lumen through pits in the walls of xylem. Some tyloses had undergone reticulate thickenings.

Metaxylem of some roots contained fungal hyphae-like structures. They were noticed in 10% roots of apparently healthy palms, 17% of diseased early palms, and 25% roots of diseased advanced palms. Such structures occurred generally around the septa of adjacent xylem members. In a few cases the bordering parenchyma cells were also found to contain these indicating colonization of xylem vessels by some fungi. We did not attempt to identify them.

Phloem tissues showed degeneration in the roots of palms of all categories from the disease prevalent area. The cells of protophloem and a few members of metaphloem showed necrotic effects. The component cells were smaller in size. They had an unusually intense chromophilic reaction and dense contents. The phloem walls in such specimens were distorted and collapsed. Complete blocking of the phloem was not seen in any specimen. Callose accumulations were found in some sieve plates. Degeneration of phloem was noticed in the roots of apparently healthy (13%), diseased early (19%), and diseased advanced (29%) palms. Some roots had degenerate phloem and abnormal cells in place of metaxylem vessels.

Burrowing nematode lesions are often encountered in the roots. Incipient lesions appear as water soaked areas. The borders of lesions attain a brownish colour and longitudinal cracks appear in the exodermis. Nemas were seen 15-20 cell layers deep in cortex. They however, were not seen to penetrate the steel. Nematodes were seen embedded between and inside cells. Galleries produced by destruction of cell walls were found to contain nematodes and their eggs. Invasion occurs also along the points of lateral root emergence. The cells at the site of lesions take up more fast green stain than the bordering tissues. Suberized tissues develop around the lesions. Nematodes in incipient lesions were encountered in 32% roots of apparently healthy, 27% roots of diseased-early, and 33% roots of diseased-advanced palms.

Discussion

Several microscopic changes were seen in the roots of palms growing in disease affected gardens. The histological alterations seen in the undoubtedly diseased palms were present also in some roots of apparently healthy palms. This suggests that they might have contracted some infection long before visual symptoms are manifest. Tissue breakdown should be a major factor in the weakening of the root system. *Radopholus similis* is known to produce extensive damage to crops like citrus (Du Charme, 1959). The fungi which colonize the vessels were not identified.

Vessel blockage in plants has been attributed to fungus hyphae, spores, bacterial cells, organic substances etc. (Beckman, 1964). Indira and Ramadasan (1968) had reported the presence of tyloses in majority of the roots in an earlier study. They could be produced in vessel members as a result of some infection or as a defence mechanism.

The observation of phloem degeneration was noteworthy. Phloem necrosis has long been recognized as a symptom of virus diseases (Esau, 1938). Incidentally, the mycoplasma-like organisms associated with lethal yellowing and Kaincope diseases of coconut are located in the phloem tissues (Parthasarathy, 1973; Dollet and Giannotti, 1976). Dutch elm disease, possibly caused by a mycoplasma also produces phloem necrosis (Braun and Sinclair, 1976). Phloem necrosis has been observed in the apical meristem of cadang-cadang affected coconut palms (Rasa, 1968). We are tempted to believe that in the case of coconut root (wilt) disease, the degenerative changes observed in the conducting elements would derange the flow of nutrients and thereby contribute to root death following starvation.

References

Anonymous (1976). Coconut Diseases of Uncertain Etiology. 30 pp. *Tech. Bull. I.*, CPCRI, Kasaragod.

Beckman, C.H. (1964). Host response to vascular infection. *Annu. Rev. Phytopathol.* **2** : 231-252.

Braun, E.J. and Sinclair, W.A. (1976). Histopathology of phloem necrosis in *Ulmus americana*. *Phytopathology* **66** : 598-601.

Dollet, M. and Giannotti, J. (1976). Kaincope disease : Presence of mycoplasma in the phloem of diseased coconuts. *Oleagineux* **31** : 169-171.

Du Charme, E.P. (1959). Morphogenesis and histopathology of lesions induced on citrus roots by *Radopholus similis*. *Phytopathology* **49** : 388-395.

Esau, K. (1938). Some anatomical aspects of plant virus disease problems. *Bot. Rev.* **4** : 548-579.

Johansen, D.A. (1940). *Plant Mierotechnique*. 523 pp. McGraw-Hill Book Co., New York.

Joseph, T and Shanta, P. (1963). Anatomical changes in the tissues of the tender leaves of coconut palm affected by the root (wilt) disease. *J. Indian Bot. Soc.* **42** : 61-65.

Indira, P. and Ramadasan, A. (1968). A note on the anatomical derangement in the root (wilt) diseased coconut palm. *Curr. Sci.* **37** : 290-292.

Parthasarathy, M.V. (1974). Mycoplasma-like organisms associated with lethal yellowing disease of palms. *Phytopathology* **64** : 667-674.

Rasa, E.A. (1968). Anatomic effects of cadang-cadang disease on coconuts. *Pl. Dia. Reptr.* **52** : 734-737.

Tomlinson, P.B. (1961). *Anatomy of the Monocotyledons. II.* Palmae. Clarendon Press, Oxford.

Discussions

Asana : In a paper read yesterday, a case was made out for micronutrients being involved in this disease. Micronutrient deficiencies are known to cause several morphological and histological deformities. To what extent, do you think, would micronutrient deficiencies be responsible for the changes described by you ?

Govindankutty : Histological alterations are induced by the application of chemicals like alar, kinetin, and auxins. The role of micronutrients in producing the histological symptoms described here is worth testing.

Nirula : Did you come across necrosis caused by burrowing nematode in roots collected from Kasaragod area ? What was its incidence as compared to those on roots collected from diseased areas ?

Govindankutty : A low population of *Radopholus* is reported to occur in Kasaragod also. *Radopholus* is capable of producing similar histological changes in certain other crops too. The present studies were confined to burrowing nematode infected coconut materials from Kayangulam.

Two New Coconut Diseases in the Nursery and on Young Plantations in Middle Ivory Coast

J.L. RENARD, D. MARIAU, J.P. NORIN and G. QUILLEC

Institut de Recherches pour les Huiles et Oleagineux, 11 Square Petrarque, 75016 Paris,France

Abstract

Two new diseases appeared on coconut palms in 1971 in middle Ivory Coast, dry bud rot and blast. These are found mainly in the nursery and in the first year of planting.

Dry bud rot is found at the base of the spear and in the bulb. The growth of the seedling is slowed down, the spear dries up, the leaves turn yellow, the roots rot slowly, and the seedling dies.

Blast is characterized by a damp rot of roots and spear, browning of the lower leaves, and rapid death of the seedling.

These diseases are related to the insect populations. The diseases do not appear in seedlings kept in a closed cage. The incidence of the disease is low in shaded areas, where there are practically no insects. Treatment with temik also prevented the appearance of dry rot. Varieties show differences in sensitivity.

The effective control methods consist in reducing insect populations (shading, insecticide treatment, and complete weeding of seed beds and nurseries) and in choosing least sensitive varieties.

Introduction

Two new diseases appeared on coconuts in 1971-1972 in the Ivory Coast, simultaneously in the nursery and in the field on seedlings less than one year old. The death rate was particulary heavy in the marginal coconut growing zone, where the rainfall is about 1200 mm, and a very marked dry season prevails for about five months. In certain parts of middle Ivory Coast, more than 50% of the seedlings were killed. These two diseases, which have different and characteristic symptoms, are called blast and dry bud rot.

Description of Symptoms

Dry Bud Rot

The disease causes slackening of the growth of the spear, which tends

to unfurl even before it emerges completely. Small square patches, white, yellow, or sometimes pale green, appear either scattered or close together forming streaks on the still folded leaflets of the spear or those of frond 1. Pink mottlings can be seen in the folds of the spear on its petiole.

The bulb is healthy in the very early stages of the disease. When the small patches on the leaves turn brown, woody-looking concretions of the same colour appear on the bulb close to the meristem. This woody, dry rot spreads and invades the growing point.

Initially, both the root bulb and the roots are healthy. In the petioles of fronds 1 and 2, scattered brown, woody, lentil-shaped patches, more or less hollow, form in the parenchyma; invisible from ou side at first, they sometimes split the epidermis as they spread. The roots are usually healthy, but the same symptoms as those observed in the rachis sometimes manifest themselves on the cortex of the primary roots.

Destruction of the growing point leads to drying of the spear, yellowing of the leaves, and finally, the death of the seedling. The roots rot slowly from the tips upwards. The seedling withers progressively, and the death occurs about two months after the first symptoms appear.

Blast

Wet rot of the spear and a loss of turgor in the leaves are the first visible symptoms. Rapidly, in about eight days, the leaves at the base of the seedlings turn brown, and in less than two weeks, it dies. This sudden death results from decay of the roots, which starts at their apices before or at least at the same time as the first leaf symptoms appear. If the seedlings is pulled out at this stage, the roots are seen to present nothing but fine filaments made up of stelae, cortex, and decayed parts remaining in the soil. On the stelae and the inside walls of the cortex, sclerotia of *Rhizoctonis bataticola* develop.

Method of Study

At first, decay strongly suggested that parasitic fungi could be at the origin of the diseases. Whilst it was easy to isolate *Pythium splendens* and *Rhizoctonia bataticola* from the decayed roots of plants attacked by blast, 90% of the samples taken of the brown parts of seedlings suffering from bud rot remained sterile, 10% of them very belatedly developed a few *Diplodia, Pestalotia, Curvularia, Fusarium solani,* and *F. roseum.* These genera are frequently present in damaged tissue, but their presence was too small for them to be considered as pathogenic agents. It was not possible to reproduce the symptoms of blast by inoculating the two fungi isolated from the roots.

The remarkable efficiency of shade in preventing the disease from appearing, as well as the results of experimentation on oil palm blast disease, indicate that it must be of insect origin.

Experiments were carried out in the nursery and the field on one year old young coconuts.

In the nursery, the influence of different factors on insects was tested: shade: a zone little or not frequented by insects; a cage ensuring complete protection from insects; insecticide treatments with direct action on insects, or indirect, if they are systemic; and the cover, particularly grasses, which shelters large populations of insects.

In the field also, the seedlings were given shade individually with coconut leaves either horizontally held up by four poles, or in a pyramid round it. The influence of soil cover was studied by covering with *Pueraria*. The insecticide treatment consisted of : DDT, dimethoate sprayed on, and temik applied to the soil. The influence of the age of seedlings at planting time and of variety were examined.

Results

The role of shade in the nursery. Shading of seedlings provided very good protection against blast and against dry bud rot (Table 1).

TABLE 1. Incidence of shade on mortality in the nursery (per centage of diseased plants)

Year	Locality	Without shade		With shade	
		Blast	Bud rot	Blast	Bud rot
1974-1975	Yamoussoukro	32.5	29.5	3.5	2.5
1975-1976	Yaora	1.0	11.5	0.5	0.5

The time at which the shade is given is also important. The disease incidence is low, if shade is given from the time the nuts begin to sprout in polythene bags in August (Table 2).

TABLE 2. Effect of length of time between the planting of germinated nuts (August) and providing of shade (per centage of diseased plants in the nursery in February)

Disease	Shade-planted in					
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
Blast	3.0	0.5	6.0	6.5	8.0	5.0
Dry bud rot	10.0	14.5	11.6	17.5	20.0	25.0

In the field. As in the nursery, the shade given to seedlings in the field gives good protection against diseases (Table 3).

TABLE 3. Effect of shading on disease incidence

Treatment	Per centage incidence
Standard shade (the same as in a nursery)	3.4
Pyramidal shade (3 palm fronds planted in the soil)	7.9
Control: without shade	33.3

Only 3.6% of the seedlings of Yellow Dwarf × West African Tall hybrids were attacked under shade, against 20.7% under unshaded conditions.

The role of cages. Cages, which are completely closed, give total protection against the disease; the diseases appear if there is any opening at the top or the bottom.

Time of replanting in the nursery. The highest percentage of diseased plants occurs amongst the germinated nuts pricked out first, i.e., in July and August. To all appearances, contamination in the nursery fell to a very low level after September (Table 4).

TABLE 4. Incidence of diseases as related to the date on which seedlings are planted (percentage diseased plants in February).

Disease	Date of planting					
	July	Aug.	Sept.	Oct.	Nov.	Dec.
Blast	32.5	22.0	6.5	4.5	3.0	0.0
Dry bud rot	29.5	20.5	7.5	4.0	2.5	0.0

Chemical treatments. The most marked effect was obtained in the nursery with temik applied each month at the rate of 4 g/bag. In the field, temik (10g/seedling) proved less efficient; Dimethoate, dieldrin, and DDT were ineffective.

Influence of manuring. The seedlings receiving the heaviest manuring showed the greatest predisposition to the diseases (Table 5).

Influence of the adventitious vegetation. In the nursery, when the germinated nuts were removed belatedly from a very weedy seed bed and planted in bags in the same environment, 11% of the seedlings were attacked by dry bud rot. On the contrary, when they were removed early and replanted in a very clean nursery, no diseases appeared.

In the field, in a plot completely covered by *Pueraria*, 4.8% seedlings died of disease, whereas in a neighbouring plot which had no cover crops, 15.7% seedlings were attacked.

TABLE 5. Role of manuring on predisposition of the seedlings to the diseases

			Yamoussoukro 1974-1975	Yaora 1975-1976	Daloa 1975-1976
With shade	Standard manuring	Blast	7.5	0.5	0
		Bud rot	6.0	4.5	0.5
	Without manuring	Blast	4.5	0	0
		Bud rot	4.0	1.5	1
Without shade	Standard manuring	Blast	13.5	3.5	0
		Bud rot	13.0	19.5	1.5
	Without manuring	Blast	7.5	1.5	0
		Bud rot	6.0	10.5	2.5

Influence of the age of seedling at the time of field planting. In the Abengourou region, a trial showed that 14-months old seedlings were more resistant to diseases after transplanting, than 2-months old seedlings; these showing 8% and 21% infection, respectively.

Influence of variety. In two performance trials set up in 1973, varietal differences were evident in their susceptibility to the diseases as early as in 1974.

At Abengourou, only blast had caused damage, and at Daloa, mortality was due to dry bud rot alone (Table 6).

TABLE 6. Reaction of coconut varieties and hybrids to the diseases (per centage diseased plants)

	WAT× Rennel	Pure Green Dwarf	Red Dwarf ×WAT	Yellow Dwarf ×WAT	Green Dwarf ×WAT	WAT
Abengourou Blast (Trial 1)	55.6	—	35.8	16.2	46.4	26.6
Daloa Dry bud rot	—	75.0	25.5	15.0	14.0	5.0
Abengourou Blast (Trial 2)	12.5	—	8.7	3.4	11.1	—
Dry bud rot	34.4	—	17.4	17.2	25.9	—

At all locations, the Yellow Dwarf×West African Tall hybrid was most resistant to both blast and dry bud rot.

Incidence of diseases as a function of the age of seedlings. Blast and dry bud rot appear most frequently in the first year of planting (Table 7).

In the second and third years, very little damage is caused by dry bud rot. Blast is rare in the second year and disappears completely in the third.

TABLE 7. Per centage of diseased seedlings amongst 1, 2, and 3-year old seedlings in the field

Disease	3-year old	2-year old	1-year old
Dry bud rot	2.2	6.1	18.1
Blast	0	3.3	33.3
Total	2.2	9.4	51.4

Discussion

Observations on sucking insect populations in particular have shown that *Hemoptera* are almost entirely absent under shade and also in closed cages. On the contrary, in seed beds where weeds, especially Gramineae, are not removed, insects of *Jassidae* and *Delphacidae* groups are particulary abundant. No insects are seen on seedlings treated with temik.

Insects are more frequent in the nursery at Abengourou than at Yaora and Daloa and so are cases of diseased plants.

There appears to be a relationship between insects and the two diseases. The differences observed in the number of diseased seedlings in a plot receiving a standard manuring and one without may possibly be explained by the succulence of well manured seedlings.

Entomological observations are more difficult in the field. Twenty-five species of *Hemoptera* were counted. The relationship between insects and diseases is therefore more difficult to establish than in the nursery; nevertheless, certain elements are in favour of such a hypothesis.

A sharp fall in the insect populations was observed at the end of December, mainly due to the disappearance of the *Delphacidae*. The diseases are probably transmitted before December.

Insects were most numerous in the Abengourou region, the highest incidence of disease was also recorded here.

It is difficult to explain the wide variations in the numbers of diseased plants from one field to another, without invoking the action of insect vectors.

The distribution of these diseases and their close link with insect populations lead to the conclusion that the seedlings are infected after the nuts have germinated, and that they have not been transmitted from mother palms.

The marked differences in the symptoms of blast and dry bud rot suggest that these are two different diseases. As both diseases have a close link with insects, at least two species of insects may be involved.

Methods of Control and Conclusions

With the present state of our knowledge and the data presented above, the diseases can be effectively controlled both in the nursery and in the field.

Precautions should start in the seed-bed, where contamination can occur. The seed beds should be free of weeds and covered with *Pueraria* before planting. The nuts should be transplanted soon after germination, as long sprouts can attract insects. Spraying with dimethoate could also be done. The seedlings should remain in the nursery as long as possible (at least 10 months), since the young palms are much more sensitive to diseases once they are in the field. In the nursery, the seedlings should be protected from July to February, either by shade or by a monthly treatment with temik (2 g of pellets) of 10% seedlings. The nursery and its surrounds should be kept very clean. The young seedlings should be shaded particularly from September to March in the first year after planting.

The variety PB 121 (Yellow Dwarf × West African Tall), which has shown some resistance, could be preferred in zones where disease is prevalent.

Investigation on Thanjavur Wilt of Coconut in Tamil Nadu, India

T. JAGANATHAN, S. KOLANDAISAMI* and R. RAMASAMI

Coconut Wilt Disease Scheme, Muthupet 614 764 Tamil Nadu, India

Abstract

The results of experiments conducted at Muthupet on Thanjavur wilt of coconut have been reviewed. The disease is spreading from the coastal areas of Thanjavur district to the interior areas. It appears to be a complex disease in which the fungus *Ganoderma lucidum* is also involved in the final stages. Disease syndrome and epidemiology of the disease have been described. Increased level of N, P and K fertilizers enhanced the disease intensity. The disease was aggravated by the attack of beetles and weevils and these have been reduced by treatment with heptachlor. Summer irrigation was found to be beneficial in reducing the disease. Quarterly application of Bordeaux mixture was effective in controlling the disease. The ameliorative effect of tank silt and green leaves along with Bordeaux mixture has been reported.

Introduction

Tamil Nadu with 0. 105 million hectare under coconut occupies the third place in India in area with a production of 932.2 million nuts per year. Among the diseases of coconut in Tamil Nadu, Thanjavur wilt is a major one limiting production. The severity of the disease was noticed only after the cyclones of 1952 and 1955 in Thanjavur district and hence the name Thanjavur wilt. The disease is prevalent in about one third of the gardens of the coastal areas of Thanjavur district and an estimated loss of Rupees six lakhs has been reported in this area alone. The disease has been gradually spreading to new plantations in interior districts also and hence a scheme was started in 1965 at Muthupet to device suitable control measures. A brief review of the results obtained is presented in this article.

*Presently at Department of Plant Pathology, Tamil Nadu Agricultural University, Coimbatore—641 003, India.

Materials and Methods

Experiments were conducted in private gardens by selecting trees of uniform age, growth and pathological conditions. The intensity of the disease as Disease Index (D.I.) was assessed by following the formula given below in which all the attributes of the disease have been taken into account according to their importance.

D.I. $= A/10+B/10+(C\times 10)+(D\times 100)$ where A is the number of fresh patches produced, B the number of fresh bleeding from old patches, C the height of occurrence of patches and D the total number of trees wilted in that treatment.

Results and Discussion

Occurrence and Distribution

A survey of different coconut growing tracts in the State indicated the prevalence of the disease in 195 gardens out of 650 inspected and the intensity ranged from 0 to 50 per cent. The occurrence of the disease has been reported from all the districts of the State except the Nilgiris.

Epidemiology of the Disease

Lack of soil moisture during summer months, water-logging in rainy weather, presence of old infection in the garden and neglect of cultural and manurial operations were found to be conducive to the spread of the disease (Vijayan and Natarajan, 1972). Maximum disease incidence was observed in sandy soils (27.4%) followed by sandyloam (14.0%). Subsoil in the diseased areas of Thanjavur district consists of a mixture of sand and yellow clay which hardens considerably on drying in summer months and forms hard pan impeding root penetration and predisposes the tree to infection. The disease syndrome was severe in summer, particularly during February to June, which synchronises with a high temperature and low rainfall. Trees in the age group of 10 to 30 years are more susceptible to the disease (43%) than younger(17%) and older trees (20%). The intensity of the disease was aggravated by association of beetles (*Xyleborus* sp.) and weevils (*Diocalandra stigmaticollis*) with the affected palms. In such cases the palms die within a period of six months.

Etiology

The exact cause of the disease is still under investigation, and from the evidence available so far, it appears to be a complex disease in which the fungus *Ganoderma lucidum* (Leyss) Karst. is also involved in the final stage. It is thus probable that the trees are weakened due to adverse soil and environmental factors which result in nonfunctioning and decay of the root system and finally the fungi and insects invade. Pathogenicity tests with an isolate of *G. lucidum* which was frequently associated with the disease using six months old seedlings have not given any posi-

tive results so far. Now attempts are being made to test the pathogenicity by inoculating the trees in the most susceptible age adopting different techniques.

Symptomatology

The earliest expression of the external symptom is the exudation of reddish brown viscous fluid from the basal portions of the stem. The bleeding patches begin from the base and extend upto five metres upwards as the disease progresses. The bleeding generally comes from the inner discoloured core which is usually confined to the height at which active bleeding symptoms appear. Soon after the appearance of bleeding patches the outer one or two whorl of leaves became chlorotic and start drooping along the trunk. If the progress of the disease is rapid, the remaining leaves also droop in quick succession until the spindle alone remains. Generally the spindle remains normal till the death of the tree and it emits a bad odour in the final stages. The spindle gets easily blown off at this stage. Normally the tree dies within a period of six months to three years after infection.

Bracket shaped fructification of the fungus *G. lucidum* has been seldom noticed on the roots and basal portions of the diseased trees. Other associated symptoms of the disease include discolouration of the root system, extensive rotting of bole region, shortening of spindle and shedding of buttons and nuts in large numbers. Heavy bearing just before the death of the tree has also been observed in few cases (Vijayan *et al.*, 1973 b).

Cultural and Manurial Trials

Fertilizer trial. The fertilizers N, P and K were applied at two different levels both on healthy and diseased trees with a control. Fertilizers at N (0.2 kg), P_2O_5(0.2 kg), K_2O (0.5 kg) per tree per year did not produce any significant effect on the disease while double the dose of the above fertilizers aggravated the disease symptoms both on healthy (D.I. in treated : 195; D.I. in control : 6) and diseased trees (D.I. in treated : 1062; control : 134). Higher doses of fertilizers increased the susceptibility of healthy palms also and the effect was fatal on already affected trees. Hence great care has to be taken in advising any fertilizer schedule in the infected localities.

Organic manurial trial. The effect of annual application of organic manures in two combinations, viz., (i) farm yard manure (250 kg) + wood ash (20 kg) and (ii) green leaves (50 kg) + tank silt (1000 kg) was tested on the disease. These treatments did not produce any significant effect on the disease intensity but they indicated some protective action against the disease on healthy trees (Vijayan and Natarajan, 1975).

Manurial cum *irrigation trial.* Two levels of N, P and K fertilizers, viz., 0.2:0.2:0.5 kg and 0.4:0.4:1.0 kg, green leaves (50 kg) + tank silt

(1000 kg), farm yard manure (250 kg) + wood ash (20 kg) and untreated control were included as main treatments and pot watering during summer months as sub-treatment. The main treatments did not seem to influence the intensity of the disease. However in four out of five manurial treatments the irrigated series have shown less infection (Average D.I. 72.2) than the nonirrigated series (Average D.I. 139.4) indicating that summer irrigation may afford some protection to the diseased trees (Vijayan and Natarajan, 1975).

Combined manurial trial. This trial was started to observe the combined effect of chemical fertilizers—N (0.2 kg) + P_2O_5 (0.2 kg) + K_2O (0.5 kg) —and manures— green leaves 50 kg + farm yard manure 250 kg—on seedling trees and on big trees. This treatment exerted very little influence on the disease intensity of treated palms (Vijayan and Natarajan, 1975).

Bulk manurial trial. Combined effect of the following chemicals and manures was tested on 30 diseased trees : copper sulphate (200 g) + lime (800 g) + N, P and K fertilizers (0.2:0.2:0.4 kg) + tank silt (1000 kg) + neem cake (5 kg)+coconut husk (300 numbers)+green leaves (50 kg). Another set of 30 diseased trees were kept as control. The combined treatment did not exert any beneficial effect on the disease.

Pilot project with manures and fungicides. Among the different fungicides tested in the previous experiments, Bordeaux mixture was found to give promising results in controlling the disease (Vijayan *et al.*, 1973a). Hence the ameliorative effects of organic manures and fertilizers in combination with Bordeaux mixture in arresting the disease was tested in this trial. The treatments include : (i) 1% Bordeaux mixture (B.M.) (40 l/tree) + farm yard manure (160 kg) + wood ash (40 kg), (ii) B.M. + coconut husk (300 numbers), (iii) B.M. + palmyrah leaves (20 numbers), (iv) B.M. + N, P and K fertilizers (0.2:0.2:0.4 kg) + farm yard manure (160 kg) + green leaves (50 kg), (v) B.M. + tank silt (1000 kg) + green leaves (50 kg) and (vi) untreated control. Among the treatments, combined application of Bordeaux mixture, tank silt and green leaves was superior to others and a low disease index of 15.0 was observed in the treated palms as compared to a maximum of 75.2 in the control. The ameliorative effects of tank silt and green may be due to their effect on the antagonistic microorganisms in the soil.

Trial with coconut husk. Burial of 500 numbers of coconut husk around the tree was beneficial in reducing the disease intensity in old trees (treated D.I. 56; control D.I. 130) though the effect was not so pronounced in young trees (treated D.I. 105; control D.I. 123).

Soil amendment trial. The ameliorative effects of some soil amendments was studied against the disease. Among the six treatments, viz., gypsum (20 kg), sulphur (1 kg), molasses (10 kg), paddy husk (60 kg), lime (2 kg) and neem cake (5 kg) + green leaves (50 kg) applied annually, lime (D.I. 261) and neem cake + green leaves (D.I. 292) reduced the disease intensity (control D.I. 486) to a considerable extent. The beneficial effect

may be due to the improvement of soil conditions.

Chemical Methods of Control

Fungicidal trial. Among the different chemicals tested by soil drenching method, viz., Bordeaux mixture (1.0%), wet ceresan (0.1%), merculine, (0.1%), wettable sulphur, (0.5%), PCNB (0.6%), Fytolan (0.25%)+BHC (0.1 %) and tar application on the stem, application of Bordeaux mixture was most effective as a curative treatment (Treated D.I. 261; control DI. 813) (Vijayan *et al.*, 1973a). Hence application of Bordeaux mixture can be recommended during the initial stage of disease till a better chemical is evolved.

Fungicidal cum *insecticidal trial.* In a trial using dieldrex (0.1%), Heptachlor (3% dust), chlordane (5%) C.L. dust (0.3%) and sulphur dust (250 g.) applied at quarterly intervals for controlling the *Xyleborus* beetle and wilt disease, minimum disease intensity was recorded in heptachlor treatment (Treated D.I. 288; control D.I. 447) indicating that the beetle may have some role in disease development.

Stem and soil treatment trial. This trial was initiated with the object of studying the curative effects of certain treatments applied to the stem as well as to the soil. In one series, stem treatment with tar followed by drenching with either BHC 0.2% or DDT 0.2% or common salt, application of zinc white or santar A on the stem were attempted. In another series, stem treatment with tar followed by application of either cheshunt compound or magnesium sulphate (0.5 kg) to the soil, injecting the stem with pyrecone E (10 ml), paradichlorobenzene (25 g) and neem oil (25ml), were taken up. All these treatments were found to be ineffective in reducing the disease intensity.

Bulk fungicidal trial. The following fungicides were applied twice in a year in bulk quantities (50 kg/ha) to the soil in the interspace of each plot, ploughed in and a booster dose was also given to individual diseased trees : copper sulphate (200 g) + lime (800 g), Heptachlor (250 g) and sulphur dust (250 g). These chemicals did not produce any significant effect on the disease.

Acknowledgement

We are grateful to Dr. T.K. Kandasamy, Professor and Head of the Department of Plant Pathology, Tamil Nadu Agricultural University, Coimbatore for his valuable guidance in the preparation of this article.

Refereqces

Vijayan, K.M. and Natarajan, S. (1972). Some observations on the coconut wilt disease of Tamil Nadu. *Coconut Bull.* 2:12-13.

Vijayan, K.M. and Natarajan, S. (1975). Influence of fertilizer and manuring on the incidence and progress of coconut wilt disease of Tamil Nadu. *Coconut Bull.* 5 1-5.

Vijayan, K.M., Natarajan, S. and Krishnamoorthi, C.S. (1973a). Some observations on the chemical control of coconut wilt disease of Tamil Nadu. *Madras agric. J.* 60:56-60.

Vijayan, K. M., Natarajan, S. and Krishnamoorthi, C.S. (1973b). Coconut wilt disease of Tamil Nadu. *Madras agric. J.* 60:504-506.

Discussions

Subbayya : What is the method of application of Bordeaux mixture referred to in the article ?

Jaganathan : As a drench in the trench dug around the palm.

Subbayya : The author mentioned that the pathogenicity tests conducted with *Ganoderma lucidum* on the host were not positive. I feel that the reason for this failure may be the very low amount of inoculum used in the tests, since it is known that large amounts of inoculum are necessary for this fungus to produce infection. Hence, I suggest that larger quantities of inoculum raised on large bits of coconut stems may be used as inoculum and they be kept close to the roots of healthy plants.

Jaganathan : We shall try this method of inoculation.

Thomas : From the symptoms of the disease given by you, it appears to be quite similar to those of coconut bole rot disease of East Africa. I would advise that the author may contact Dr. K.R. Bock of EAARO, Nairobi, who identified the causal organism and made other investigations on this disease.

Jaganathan : We shall do it.

M.R.G.K. Nair : What is the type of damage done by the insects associated with the disease ?

Jaganathan : The insects, viz., scolitid beetle (*Xyleborus* sp.) and the weevil (*Diocalandra stigmaticollis*) produce small holes and tunnel deep into the trunk of the palms, mostly at the bottom, and powdery masses of host material come out through the holes. In the diseased palms, the death is accelerated with insect attack. Such affected palms die within six months.

Velayutham : 1. Does the disease index include foliage characteristics also ? If not, manurial effect, as inferred, does not seem to be valid.

Jaganathan : In the disease index, foliar characteristics are not included. However, the death of the palm is taken into account in assessing the disease index. Since the F2 level of fertilizers has brought about quite a large percentage of mortality as well as increased bleeding patches, it is possible that the nutrients may have a role in disease development.

Kulkarni : Your findings show lower incidence of the disease after following better management practices. Will you please clarify whether this is due to resistance brought about by better management and nutrition or if some other factors are associated with this phenomenon ?

Jaganathan : It is possible that reduction in severity of the disease may be due to altered soil conditions such as prevention of the formation of hard pan, increasing the water holding capacity of the soil, etc. However, further studies are needed to confirm these. The nature of resistance also needs further studies.

Uncertain Etiology Diseases of the Coconut Palm

KARL MARAMOROSCH

Waksman Institute of Microbiology, Rutgers University, New Brunswick, N. J. 08903, U.S.A.

The present status of rickettsia-like and mycoplasma-like diseases of plants and their relevance to coconut palm diseases will be discussed. Certain plant diseases, earlier grouped together with virus diseases, are caused by viroids, spiroplasma, mycoplasma, or rickettsia—like agents. Electron microscopy techniques have been used in several instances, including coconut lethal yellowing disease, for the visualization of mycoplasma microorganisms. Tetracycline chemotherapy gave additional support to the mycoplasma etiology of lethal yellowing disease. In other instances, electron microscopy revealed the presence of artifacts, or of particles such as phytoferritin. The etiology of Kerala wilt of coconut palms is still uncertain. Interactions between disease agents, plant hosts, and insect vectors can be manipulated so as to prevent spread of diseases, even if the etiology is uncertain.

Discussions

Carlos : Thank you for suggesting the hypothesis. Rest assured, our colleagues in the Philippines will learn about this. Incidentally, are there known cases indicating that viroids are transmissible ?

Maramorosch : All viroids studied to date have been transmitted mechanically to plants, and none has been transmitted by vectors. For instance, agents of potato spindle tuber and chrysanthemum stunt, both viroids, have no known vectors.

Chenulu : Do you doubt the etiology of Rickettsia as causal agents of plant diseases even after the work of Windsor and Black on clover club leaf ?

Maramorosch : The clover club leaf, as well as several other RLO associated diseases are definitely caused by the microorganisms found (by electron microscopy observatives) in the phloem. However, the name "Rickettsia" or "RLO" is not correct. These are bacteria as far as could be determined, but none has been identified as members of the Rickettsia. The name was given merely on the

basis of the biological association with insects and inability to culture the RLO in bacteriological media. These characteristics, as well as the rippled cell wall are not adequate systematic characteristics of the genus *Rickettsia*.

Nirula : Can you kindly indicate which of the factors responsible for such diseases could be eliminated in case of root (wilt) disease, so that our field of investigation could be narrowed down to fewer factors and we are able to arrive at the conclusion at an early date ?

Maramorosch : If the assumption is correct that the disease is infectious and that it is spreading, all that can be suggested at this stage is to consider all known disease agents of plants, as well as possibly new, as yet unknown, agents. A decade ago we did not suspect mycoplasmas, and we did not know of the existence of spiroplasmas or viroids. This possibility—of as yet unknown disease agents—should be kept in mind.

Mariau : How can one interpret the 'dosage effect' observed in the two diseases—the increased severity related to the increased number of insects ?

Maramorosch : We don't record the insects on a per palm basis, but per 100 seedlings plot. If so happens that insects are more numerous in plots where the incidence of disease is also more. But the number of inspected insects is never very high. For instance, when we count, 50 Delphacidae on 100 coconut palms in two-months period (four records a month), the incidence of dry bud rot is 30%. But, when we record in the same place 10 insects, the incidence is only 20%.

Heart Rot-A Coconut Disease of Surinam Associated with a Trypanosomatid Flagellate

M.V. PARTHASARATHY

Section of Genetics, Development and Physiology, Cornell University, Ithaca, N. Y. 14853, U.S.A.

Heart rot, which has also been called lethal yellowing, bronze leaf wilt, Coronie wilt, and 'unknown disease', was first reported in Surinam in 1906. The disease exhibits many but not all the symptoms of lethal yellowing that has decimated coconut palms in the Caribbean Islands, Western Africa and Southern Florida. None of the coconut varieties including Malayan Dwarf seem to be resistant to heart rot. Electron microscopic observations of the phloem of affected coconut palms have revealed the presence of trypanosomatid flagellates, indentified as the genus *Phytomonas* Donovan, in mature sieve tubes. Since the flagellates were present in large numbers in the expanding inflorescences and leaves of the infected palms, they could be readily smeared on to the glass slides for observations with phase-contrast microscopy. It was possible to keep the flagellates alive for several minutes in sucrose solutions and upto 90 minutes in coconut milk. Effects of antibiotics on the flagellates were studied both under field and laboratory conditions. The absence of organisms other than flagellates in the earliest symptoms of the disease and the correlated increase and spread of the flagellates in sieve tubes as the disease progresses suggest that the flagellates are pathogenic to their hosts and hence the possible causative agents of heart rot. The disease is thus quite distinct from lethal yellowing. The death of an affected palm is presumably caused by the plugging of the sieve tubes by the flagellates.

Use of Oxytetracycline as Prophylactic and Therapeutic Treatment for Lethal Yellowing in Florida, U.S.A.

R.E. McCOY,* G.H.GWIN,** and H.M. DONSELMAN*

*University of Florida Agricultural Research Centre, 3205 SW College Avenue, Fort Lauderdale, Florida 33314, **Florida Department of Agriculture and Consumer Services, Chapman Field, Miami, Florida 33158, U.S.A.

Abstract

Tetracycline antibiotic has been found to give both prophylactic and therapeutic benefit when injected into coconut palms, either threatened or affected by the lethal yellowing disease. Oxytetracycline-hydrochloride was approved for use as a control agent against lethal yellowing by the United States Environmental Protection Agency in June 1974. Since that time, until 1976, some 2.5 million grams of oxytetracycline-HCl have been distributed for lethal yellowing treatment in Florida. The coordinated prophylactic use of oxytetracycline-HCl has prevented new development of lethal yellowing in three Florida Counties. In other areas, where antibiotic use was discontinuous or erratic, lethal yellowing has continued to spread. However, coconut plantings receiving regular prophylactic treatment for 2 1/2 years are still intact in the Miami area, even though all surrounding untreated coconut palms within a 10 km radius are dead. The therapeutic efficacy of oxytetracycline-HCl used at 4-month intervals is 50%. This might be increased if applications are made at monthly intervals in order to maintain high foliar titers of antibiotic until a full remission is evident. Variations in translocation of antibiotic among individual trees may account for the observed responses of diseased coconut palms to oxytetracycline therapy.

Introduction

The lethal yellowing disease of coconut palm was first reported on the Caribbean island of Jamaica by Fawcett in 1891. Since then, this disease has spread northward, affecting coconut production in other islands of the West Indies. Jamaica alone has lost an estimated 7.5 million coconut palms since 1965 (D. Romney, personal communication). Lethal yellowing was first reported in Florida in 1956 on the island of Key West. After killing 75% of the palms in Key West, the disease was found 100 km to the east on Key Largo in 1959 and then appeared on the Florida mainland in Miami in late 1971 (Seymore, Miller, and Roberts, 1972). In the following five years, lethal

yellowing killed an estimated 85% of the coconut population in the greater Miami area (Dade county). The disease spread into Broward county in 1973 and is currently well established in Broward, Dade, and southern Palm Beach counties. In Florida, the rate of spread of lethal yellowing has been such that, in the absence of antibiotic treatment, 100% of the coconut palms present within an area of approx. 1 km^2 will be dead 2-3 years after the appearance of the first case of disease in that area (McCoy, 1976a). In a measured test in Miami 9,672 coconut palms, out of a total of 10,399 (93%), were lost in a 22 km^2 area between June 1973 and June 1975. Initially, only 6 palms per sq. km had been affected.

The destructive potential of lethal yellowing cannot be overemphasized; in addition to the rapid rate of spread, lethal yellowing kills rapidly, taking only four months from appearance of the first symptom until death of the average tree. The symptom syndrome begins with shelling of the immature nuts and necrosis of new inflorescences, and extends to a systemic chlorosis which begins in the lower fronds and moves up through the crown. Eventually, the spear leaf and growing point become necrotic and the crown topples from the trunk.

Shortly after the appearance of lethal yellowing on the Florida mainland, experimental treatment with tetracycline and other type of antibiotics was initiated to help determine whether a mycoplasma-like organism etiology might be involved in the disease, as was suggested by electron microscopic examination of diseased palm tissues (Plavsic-Banjac, Hunt, and Maramorosch, 1972; Beakbane, Slater, and Posnette, 1972; Parthasarathy, 1974; Thomas, 1974). The results of differential chemotherapy indicated that antibiotics of the tetracycline group (excluding penicillin) would suppress symptom development of lethal yellowing in diseased coconut palms when treated prior to the expression of systemic foliar yellowing (McCoy, 1972, 1973, 1975). Experiments done concurrently in Jamaica also proved tetracycline to induce remission of lethal yellowing (Hunt, Dabek, and Schuiling, 1974).

Doses of oxytetracycline-HCl ranging 1-3 g in aqueous solution, injected directly into the trunks of diseased palms completely stopped all symptom development for 4-7 months in 50% of all treated palms in Florida (McCoy, 1974 a, 1975). In the remaining treated palms, systemic yellowing would begin even though obvious signs of remission, such as production of necrosis-free new inflorescences and setting of new fruit, did occur. Some of these trees were brought into a state of full remission with subsequent treatments while the symptom progression in others was so rapid that the trees were lost.

In a second series of tests, spanning a 16 months period, 3,300 healthy coconut palms in areas where lethal yellowing was present were treated with oxytetracycline-HCl at intervals of four months to determine the prophylactic effect of treatment (McCoy *et al.*, 1976). As a result of these treatments, the apparent infection rate of lethal yellowing was slowed by

a factor of three to five times. A second test involved 100 initially healthy palms in an active area of lethal yellowing. Fifty of these trees were treated prophylactically and 50 were untreated. After 12 months, 85% of the untreated palms were lost, while only 6% were lost with treatment (McCoy and Williams, unpublished).

Extensive studies on the translocation of oxytetracycline in coconut palm revealed that most of this material was carried into the actively transpiring foliage in a pattern typical of xylem distribution (McCoy, 1976b). Little antibiotic has been found in the fruit of treatment palms, (McCoy, 1976c). The amount of oxytetracycline-HCl found in foliage averaged 1-3 ppm gram injected into the trunk. Certain treatment methods particularly injection under hydraulic pressure (McCoy, 1974c), resulted in highly variable concentrations of antibiotic in the fronds of different treated trees. Certain trees apparently absorb and translocate the antibiotic readily after trunk injection, while a few do not accumulate any antibiotic in their foliage.

Use of Oxytetracycline in Florida

The coconut palm is grown in Florida almost exclusively for its aesthetic value as a landscape plant. No other tree can generate the tropical atmosphere development by this palm. Because Florida relies heavily on tourist trade for revenue, the maintenance of its tropical appearance is of great importance. As such, lethal yellowing with its potential to eradicate the coconut palm poses a potential detriment to the economy of the area (Fisher, 1975), and has, therefore, created a great deal of public interest.

As a result of this interest and after completion of the field tests just described, a non-restricted pesticide registration was granted for the use of oxytetracycline-HCl (Terramycin,R) Pfizer Inc., New York City) for lethal yellowing control by the United States Environmental Protection Agency, in June 1974. This constituted the first federal registration of an antibiotic to control any disease associated with a mycoplasma-like agent. Oxytetracycline-HCl became commercially available in September 1974 and its use by private individuals and by civic agencies began to develop. The entry of another company into the market with a similar formulation of oxytetracycline-HCl (Uritet,TM Key Pharmaceutical, Miami, Florida) created competition and reduced the price of the antibiotic to the public. In addition, the Florida Department of Agriculture and Consumer Services developed a plan to purchase bulk quantities of antibiotic on a bid basis and distribute it to municipal agencies at an additionally reduced cost. Approximately one million grams of oxytetracycline-HCl have been distributed per year by this programme. Also, it is estimated that 20,000 g/year of antibiotic are being purchased privately. At an average dose of 3 g/palm, three times/year, this amounts to about 1,30,000 palms getting the treatment in southern Florida.

For any lethal yellowing control programme to be initiated, several basic factors must be contemplated. First, whether it be a home owner with only one palm, or a municipality with tens of thousands, a commitment must be made to continue the project for 5-10 years. A decision must be made that the palm to be saved are sufficiently valuable to warrant injections.

The cost of treatment average 25-30 cents (USA) per treatment for antibiotic. Labour and equipment bring the cost of an individual treatment to about $ 1.00, or $ 3.00/palm/year when calculated for a large scale programme. There is no chance for survival of susceptible coconut varieties without treatment, and the costs of tree removal in Florida's urban environment average $ 30.00 per tree, sufficient to treat a tree for 7½ years plus plant a resistant Malayan Dwarf seedling. Clearly, the cost of treatment is feasible, even though it must be repeated at regular intervals and is not 100% effective.

Since its approval, the pattern of use of oxytetracycline-HCl in Florida has varied from area to area. Every municipal agency faced with the loss of coconut palms to lethal yellowing has evaluated the pros and cons of establishing a control programme and come to separate decisions. Some cities or counties have programmes to treat all coconut palms within their boundaries, while others have programmes to treat only public-owned trees. Some have made antibiotic and injection equipment available to the public at little or no expense in the form of do-it yourself kits, and some agencies have done nothing. Most agencies have instituted equally important programmes to replant with the lethal yellowing resistant Malayan Dwarf coconut cultivar. In addition to these programmes, the Florida Department of Agriculture and Consumer Services developed a programme to treat all coconut palms within a 100 metre radius of any new outbreak of lethal yellowing outside Dade and Broward counties in an attempt to reduce or prevent spread of this disease into previously noninfested areas.

After 2½ years, these programmes have met with varied degrees of success. In three counties, Collier, Hendry, and Martin, where treatment programmes were established when lethal yellowing first appeared, there were no further cases of lethal yellowing since the original infestations. In Monroe county, there has been a marked reduction in incidence of lethal yellowing on the islands of Key West, Key Largo, and Little Torch Key during this period. No new cases of lethal yellowing have developed in any of the sites in Martin, Hendry, Collier, or Monroe counties where all palms within 100 m of a new infestation were treated and the affected palms removed. New occurrences of lethal yellowing 2-30 km from the original infestations have occurred in Martin and Monroe counties in the past few months ; however, these are highly unlikely to be secondary spread from the treated sites. This programme has also been successful in northern Palm Beach county.

Disease spread in Palm Beach county has been primarily limited to untreated areas, except in the city of Boca Raton, which already had an extensive disease build-up when the treatment programme began. However, blocks of coconut palms within Boca Raton, which have been under continuous treatment, are still intact. The town of Palm Beach which first experienced lethal yellowing in 1974, lost in 1976 only 15 out of 40,000 palms under treatment. The City of Fort Lauderdale has lost very few municipally-owned palms all of which have been treated; however, untreated privately-owned palms in this area are being lost. The city of Hollywood established a mass treatment programme for one year and then stopped. As a result the rate of spread of lethal yellowing was suppressed for 18 months and then increased dramatically.

Perhaps, the most convincing demonstrations of the protective value of oxytetracycline-HCl treatment are in the cities of Coral Gables, Miami, and Miami Beach where isolated groups of several hundred palms each still remain after 3 years of continuous treatment. The last noninjected coconut palms within 10 km of these treated groups of palms died by June 1975. These remaining palms include several groups described by McCoy *et al.* (1976), for work ending in March, 1975. Other groups described in that paper did not receive additional treatments after March 1975, and most palms in those groups have since died.

Discussion

The patterns of use of oxytetracycline-HCl injected on a prophylactic basis can affect the subsequent success of an area-wide treatment programme. By far, the best results have come from areas such a Naples where all susceptible coconut palms have been treated. In areas where only selected palms have been treated, lethal yellowing has continued to spread among the untreated palms. This, in turn, has increased the inoculum pressure upon the treated palms and increased the infection rate in these. Such theoretical considerations were borne out when the patterns of spread of lethal yellowing under various community treatment programmes were analysed.

Two other factors affecting the efficiency of injection are the timing of application and variations in antibiotic uptake among treated palms. The timing of antibiotic application is particularly important in therapeutic treatment A single therapeutic dose may produce a disease remission lasting 4-7 months (McCoy, 1974a) ; however, the persistence of oxytetracycline in foliage is not more than two months. It is possible that monthly treatments to maintain a high foliar titer of oxytetracycline-HCl in therapeutic treatment might result in a higher ratio of complete remission than the 50% currently obtained with single applications at 4-month intervals (McCoy, 1975). This approach was used by Hunt *et al.* (1974) in Jamaica, but additional study will be necessary to quantitate the response on a large scale basis.

The variation in uptake of antibiotic by coconut palms receiving trunk injections (McCoy, 1974b, 1976b) may be partially responsible for the observed variation in therapeutic response and for the less than 100% efficiency of prophylactic treatment. A greater knowledge of the basic translocation system within the coconut palm may help to achieve consistent uptake of the antibiotic. Presumably, injection during periods of active transpiration will result in a greater uptake and distribution of antibiotic.

In addition to the physical factors attendant to the injection process, a successful lethal yellowing control programme involves several management factors of extreme importance. Persons who have set up successful programmes understand the benefits and problems of such a programme. They have committed themselves for several years to continued funding and supervision. They have knowledge of the latest research developments in lethal yellowing and make sure that all procedures are carried out correctly.

In an unsuccessful programme, one of the three factors is usually involved. The first and most frequently encountered factor is apathy on the part of the city/county management. Perhaps this apathy is due in part to the second factor which is lack of funding due to apathy on the part of the general public. Public interest declines unless a serious effort is made to inform them of the importance of keeping the coconut palm in the Florida landscape and the necessity of an injecting and replanting programme. Without public support, no lethal yellowing control programme can survive.

The third and possibly most damaging factor which can hurt an injection programme is negligence on the part of the workers making the applications. If just one injection is missed, the probability of that palm developing lethal yellowing is increased. In many cases improper injection techniques raise the incidence of lethal yellowing considerably. Proper training is available from the Florida Department of Agriculture. Programme supervisors should be aware of the correct procedures and insist that they be followed.

The results of treatment programme have not been absolute. Even though lethal yellowing has been eliminated for upto two years in areas of low disease incidence with preventive treatment, it has continued to spread in high incidence areas, although at a much lower rate than without treatment. However, persons not understanding this expected response who say "injections do not work" can destroy a treatment programme before it is initiated, create public apathy, and threaten existing successful programmes. The fact is that research has shown, and existing programmes have proved that oxytetracycline-HCl injection does work and, coupled with the replanting of resistant cultivars can maintain the tropical coconut palm in the Florida landscape.

Disclaimer

The use of a trademark name does not constitute a guarantee or warranty of the product by the University of Florida and does not imply its approval to the exclusion of other products that may also be suitable.

References

Beakbane, A., Slater, C.H.W., and Posnette, A.F. (1972). Mycoplasmas in the phloem of coconut, *Cocos nucifera* L., with lethal yellowing disease. *J. Hort. Sci.* **47**: 265.

Fawcett, W. (1891). Report on the coconut disease at Montego Bay. *Bull. Bot. Dept. Jamaica* **23**:2.

Fisher, J.B. (1975). Environmental impact of lethal yellowing disease of coconut palms. *Environmental Conservation* **2**: 299-304.

Hunt, P., Dabek, A.J. and Schuiling, M.(1974). Remission of symptoms following tetracycline treatment of lethal yellowing-infected coconut palms. *Phytopathology* **64**: 307-312.

McCoy, R.E. (1972). Remission of lethal yellowing in coconut palm treated with tetracycline antibiotics. *Plant Dis. Reptr.* **56**: 1019-1021.

McCoy, R.E. (1973). Effect of various antibiotics on development of lethal yellowing in coconut palm. *Proc. Florida State Hort. Soc.* **86**: 503-506.

McCoy, R.E. (1974a). Duration of remission of lethal yellowing in coconut palm treated with tetracycline antibiotics (Abstr.). *Proc. Am. Phytopath. Soc.***1**: 164.

McCoy, R. E. (1974b). Techniques for treatment of palm trees with antibiotics. *Proc. Florida State. Hort. Soc:* **87**: 537-540.

McCoy, R.E. (1974c). How to treat your palm with antibiotic. *Florida Agri. Exp. Stn. Circ.* S-228. 7pp.

McCoy, R.E. (1975). Effect of oxytetracycline dose and stage of disease development on remission of lethal yellowing coconut palm. *Plant Dis. Reptr.* **59**: 717-720.

McCoy, R.E. (1976a). Comparative epidemiology of the lethal yellowing, kaincope, and cadang-cadang diseases of coconut palm. *Plant Dis. Reptr.* **60**: 498-502.

McCoy, R.E. (1976b). Uptake translocation, and persistence of oxytetracycline in coconut palm. *Phytopathology* **66**: 1039-1042.

McCoy, R.E. (1976c). Accumulation of antibiotic residues in the fruit of coconut palms treated with oxytetracycline for control of lethal yellowing. *Oleagineux*: **31**: 215-218.

McCoy, R.E., Carroll, V.J., Poucher, C.P., and Gwin, G.H. (1976). Field control of coconut lethal yellowing with oxytetracycline hydrochloride. *Phytopathology* **66**: 1148-1150.

Parthasarathy, M.V. (1974). Mycoplasma-like organisms associated with lethal yellowing disease of palms. *Phytopathology* **64**: 667-674.

Plavsic-Banjac, B., Hunt, P., and Maramorosch, K. (1972). Mycoplasma-like bodies associated with lethal yellowing disease of coconut palms. *Phytopathology* **62**: 298-299.

Seymore, C.P. Miller, J.W., and Roberts, D.A. (1972). An outbreak of lethal yellowing of coconut palms in Miami, Florida (Abstr.). *Phytopathology* **62**: 788.

Thomas, D.L. (1974). Possible link between declining palm species and lethal yellowing of coconut palms. *Proc. Florida State Hort. Soc.* **87**: 502-504.

Development Programmes

Chairman : A. VENKATARAMAN

Rapporteur : M. K. MULIYAR

Coconut Situation and FAO Assistance

K.J. GUNAWARDENE

Plant Production and Protection Division, FAO, Rome, Italy

FAO assistance in the development of coconut production mainly centres around the small holdings. This is natural since nearly 80% of the total world coconut area of about 6 million hectares consists of small units managed by peasants. Moreover, more than 50% of the area is senile and unproductive and needs replanting. Currently, through several projects in the Far East and Pacific, FAO is engaged in laying the basic foundations for future coconut development schemes.

In Indonesia several hybrid seed gardens are being established with a view to embarking on a large replanting programme in the immediate future.

In Malaysia, coconut is receiving encouraging support from the government and some of the hybrid introductions so far made from the Ivory Coast appear to be very encouraging and prospects for further development are bright.

In Thailand, FAO experts have suggested research and development proposals for this crop with the aid of World Bank/FAO assistance, and these are likely to receive very early attention.

In the Philippines, the project envisages the development of large extents of poor yielding coconut and perhaps the resolution of the problem of the cadang-cadang disease in certain areas. Coconut timber utilization is a very valuable adjunct of this development project.

In Asia, a regional project on hybridization and training has been on the boards since 1974. Unfortunately, due to the UNDP liquidity crisis, the project has been in abeyance but it is expected to be resurrected in the coming year.

The Pacific area has also received considerable assistance, such as Samoa, Fiji, Tonga, and some other islands. New programmes combining coconut, pasture, and root crops are under intensive study, particularly, intercropping of food and cash crops to support the growing tendency among small holders to fully utilize the land under coconut.

Most of these projects involve an important element of plant material,

improvement through the introduction of new breeding techniques, and the overriding influence of germplasm exchange in accentuating all coconut improvement programmes.

Integrated coconut livestock programmes encouraged by the results obtained in the past in Sri Lanka, Samoa, and other places, have also added impetus to coconut development in combination with animal husbandry.

West African, Caribbean, and Latin American regions are also coming to the forefront with new expansion programmes for coconut. Nigeria, Cameroons, Ivory Coast and Liberia have very ambitious programmes in the development plans. The research and large scale estate plantings in the Ivory Coast are largely responsible for this promising activity. The ability to raise 4-6 tons of copra/ha/year and the efficient combination of nucleus plantations and outreach settlement schemes have been good examples for the neighbouring countries.

Latin America made little attempt to develop coconut industries in the respective countries, but now, a number of requests from some of these countries have been received. In view of the shortage of improved plant material in this region, a germplasm/cultivar collection is proposed to be established in Costa Rica to serve the entire region.

Brazil, Mexico, Venezuela, Dominican Republic and a few others have expressed a desire to receive assistance under the new Technical Cooperation Programme of FAO.

FAO's emphasis on germplasm collection and the study of their progenies, hybridization between Talls and Dwarfs, establishment of a considerable number of nurseries to provide high quality seedlings, study of diseases and pests and control measures with special enquiries into diseases of unknown etiology, end-use investigations of coconut trunks, fibres, shells, and coir dust, and the training imparted to a large number of research workers and middle-level officers constitute much needed development assistance. We in FAO are heartened by the abundant measures of support that we have received from the Asian and Pacific Coconut Community, research institutes in Asia, Africa and the Caribbean and the various governments that have an abiding interest in coconut development.

In conclusion, I would like to state that FAO appreciates the very useful contribution made by Kasaragod through its research activities initiated by a group of dedicated staff members with a high sense of duty and service towards the peasantry of this country.

The Coconut Profile of India

P.K. THAMPAN

Coconut Development Board, Ministry of Agriculture, Government of India, Ernakulam, Cochin 682001, Kerala, India

Abstract

India is the third largest coconut producing country in the world. It contributes 15% of the area and 20% of the production of coconut in the world. Despite this, the per capita availability of the commodity in India is a low 11 nuts/year. Owing to ecophysiological restrictions, the cultivation of coconut is not widespread, but is confined to the coastal belts of the country. Though the per hectare productivity of coconut in India is comparable to that of other major producing countries, the per palm productivity and the unit output of copra are comparatively low. To some extent, this is compensated by the quality of copra in terms of oil output. Coir and coir products, milling copra, and coconut oil are the major commercial products produced in the country. The production of coir and coir products constitutes 54% of the world output and the country has a monopoly in the production of white fibre coir products. India's export trade accounts for 27% of the total export trade in the world. The milling industry in India is well organized and the entire quantity of coconut oil produced in the country is absorbed in the domestic market. The present annual production is 300,000 tonnes of milling copra, 25,000 tonnes of edible copra and 2,00,000 tonnes of coconut oil. The end use pattern for coconut oil is in the ratio 40:60 edible-nonedible end uses. Desiccated coconut and shell based industries are yet to develop on commercial lines.

The price behaviour of coconut oil is generally independent of the international markets. The only single factor that influences price is the overall availability of fats and oils in the country. Coconut oil prices normally command a premium over those of other oils and fats.

Coconut development in the country has a recorded history of only less than a century. The Directorate of Coconut Development, Cochin, Ministry of Food and Agriculture, Government of India was the national organization for plan formulation and coordination of programmes covering development, marketing, and processing. A Coconut Development Board has since been established by an Act of Parliament to look after all aspects of coconut production and development.

The coconut growers in India are marginal and small farmers. The average size of coconut holdings in India is less than 0.5 ha, 98% of the holdings are only less than 2 ha. The strategy of coconut development is to accomplish the objectives of increasing production through intensive cultivation and expansion of area and of improving the productivity of coconut holdings through scientific utilization of the interspaces between palms. A large number of development programmes are urrently under implementation. The two major programmes are hybrid produc tion

and the package approach for improving the productive potential of existing palms. The current programme is to produce 525,000 T×D seedlings and 100,000 D×T seedlings every year. Five seed gardens with a combined total area of 670 ha have also been established for the production of D×T hybrids which are expected to produce 4 million hybrids annually from 1985. The package approach is to bring 1,20,000 ha of coconut gardens under scientific management programme encompassing the use of quality planting material, adequate fertilizer inputs, irrigation and improved investment for coconut development in the country. The cost is estimated around Rs. 1000 million over a period of five years.

General

Coconut is a crop of great antiquity in India. It has a recorded history of over 3,000 years and has always been an object of reverence in the local tradition. India is now the third largest coconut producing country in the world, with an area of about 1.1 million hectare and an annual production of 6,000 million nuts (Table 1).

Although India is one of the largest coconut producing countries of the world, the per capita availability is a low 11 nuts/year. It is 215 in the Philippines, 60 in Indonesia, and 161 in Sri Lanka. Unlike in other coconut growing countries, the cultivation of coconut in India is confined only to the coastal states, which ultimately have to meet the requirements of 650 million people. Even among the coastal states, there is regional imbalance in the distribution of the crop. As much as 70% of the total coconut area is concentrated in Kerala, a small state accounting for only 1.18% of the total land area of the country (Table 2).

The restrictions imposed by the ecophysiological factors apply only to the distribution of the crop because the demand for coconut and its products is fairly widespread in the country. The demand is for both edible and inedible end-uses.

Productivity of Coconuts

The data in Table 1 show the productivity and the number of nuts required to make one tonne of copra. While 4,500-5,000 nuts are required to produce one tonne of copra in other countries, the figure for India is 6,800 nuts. This is about 35% higher than the standard level in other countries. The low rate of copra output is also not compensated by a higher per palm yield. While the per palm productivity is 35 nuts in India, it is 62 nuts in western Samoa, 45 nuts in Sri Lanka, 40 nuts in Indonesia, and 35 nuts in the Philippines. However, the per hectare productivity is comparatively high in India, compensating to a large extent the difference in copra output per nut. Similarly, the quality of copra produced in India is only next to that of western Samoa. The average oil content of copra produced in India is 62.5% against the corresponding figures of 65.0% in western Samoa, 62.0% in Thailand, and Philippines, 61.5% in Sri Lanka, 58.0% in Indonesia, and 57.0% in Malaysia.

TABLE 1. Area under cultivation and production of coconuts in the different coconut growing countries of the world

Country	Reference year	Area in thousand ha	Share %	Production in million nuts	Share %	Yield/ ha	No. of nuts/ ton of copra
Philippines	1975	2249	30.4	8625	29.1	3835	4500
Indonesia	1974	1941	26.2	7512	25.4	3870	5000
India	1975	1115	15.1	5961	20.1	5346	6800
Sri Lanka	1974	466	6.3	2131	7.2	4573	5000
Thailand	1975	384	5.2	514	1.7	1339	5000
Malaysia	1974	214	2.9	870	2.9	4065	4700
Papua-New Guinea	1971	248	3.4	728	2.5	2935	5500
Fiji	1973	69	0.9	160	0.6	2319	6000
Zanzibar	1971	49	0.7	154	0.5	3143	NA
Trinidad and Tobago	1971	12	0.2	86	0.3	7167	NA
Western Samoa	1973	32	0.4	162	0.6	5063	4500
Other areas (estimated)	1975	620	8.3	2700	9.1		NA
Total		7399	100.0	29603	100.0		

TABLE 2. Distribution of coconut in India

State	Area in thousand ha	Percentage	Production in million nuts	Percentage
Kerala	748.2	67.1	3718.7	62.4
Tamil Nadu	112.3	10.1	986.6	16.6
Karnataka	140.5	12.6	759.8	12.7
Andhra Pradesh	40.4	3.6	167.2	2.8
Maharashtra	8.7	0.8	50.6	0.8
Orissa	11.4	1.0	43.3	0.7
West Bengal	6.7	0.6	22.0	0.4
Assam	4.4	0.4	10.6	0.2
Goa, Daman, Diu	18.7	1.7	97.5	1.6
Andaman & Nicobar Islands	19.4	1.7	63.6	1.1
Lakshadweep	2.8	0.3	21.0	0.4
Pondicherry	1.6	0.1	19.9	0.3
Tripura	0.4	0.0	0.5	0.0
All India	1115.5	100.0	5961.3	100.0

Utilization of Coconut Products

Of the varied products of coconut, husk, and kernel are perhaps the only ones commercially exploited in India. Coir manufacture and copra

crushing are traditional industries in the country. The manufacture of desiccated coconut and the commercial utilization of shell are yet to be developed.

Coir and Coir Products

The annual production of coir and coir products in India is 1,55,000 tonnes, which form about 54% of the total world production. India has a virtual monopoly in the production of white fibre from retted husks, as it accounts for about 96% of the total world production. Sri Lanka produces 1,30,000 tonnes of brown fibre accounting for 45% of the total production of coir products in the world.

The coir industry in India provides direct employment to about 500,000 people and another one million people are indirectly benefited by it. The internal demand for coir products is also on the increase. At present, it absorbs about 65% of the total output. The fact that India, with only 20% of the world coconut production accounts for 54% of the coir production in the world is definitely an indication of the importance the industry has assumed in this country. But, not more than 40% of the total production of husk is currently utilized for processing mainly for want of retting facilities in the areas of production. The situation is likely to change with further progress in the mechanical extraction of fibre.

Copra

The processing of coconuts into milling copra is concentrated in Kerala and to a small extent in Lakshadweep, Andaman and Nicobar, and Tamil Nadu. The total production of milling copra is about 300,000 tonnes of which 90% is produced in Kerala. India with about 27.5% of the total production of nuts in the Asian region has a share of only 12% of the total copra output. Philippines with 30% of the nut output accounts for 52% of the copra output in Asia. The corresponding figures for Indonesia are 23% and 25% and for Sri Lanka are 5% and 10%. These differences are indicative of the consumption pattern of coconuts in the respective countries for edible purposes. In India, only 50% of the total production of nuts becomes available for further processing, the rest being utilized for edible purposes in the household sector. Apart from milling corpa, a small quantity of edible copra is also produced in the country mainly in Karnataka and Andhra Pradesh. The total production is 25,000 tonnes a year and is mostly consumed in states where fresh nuts are either not readily available or difficult to get.

Sun-drying is the most popular method employed in India for copra making. During rainy weather, direct heating in smoke kilns is adopted. This is often combined with sun-drying. The use of mechanical driers for indirect heating has not become popular in the country, mainly because of the high processing cost and the initial investment.

Coconut Oil and Cake

Though 90% of the supply of milling copra originates from Kerala, only 50% is utilized for crushing within the state leaving the balance for utilization in other states, particularly Maharashtra and West Bengal. Both rotaries and expellers are used for crushing. The recovery of oil is 62.5% in rotaries and 64.0% in expellers. The production of oil in the country is 200,000 tonnes which is 15% of the total production in the Asian region. The contributions of other countries in Asia are 47% Philippines, 25% Indonesia, 5% Sri Lanka, and 6% Malaysia.

The bulk of the oil cake produced in India is utilized for feeding the cattle leaving only a small per centage for further processing in the solvent extraction plants. The cake prices are slightly more than that of compound feeds, but a large section of cattle growers still prefer the cake for direct feeding. Almost the entire quantity of cake produced in the country is consumed for this purpose and the demand matches the supply. Because of the high unit value of coconut protein, compound feed manufacturers do not prefer solvent extracted meal as their raw material. Nor is it preferred by cattle growers for direct feeding. Thus, the meal is confronted with a marketing problem which is the main reason for not utilizing the entire quantity for further processing. There are over 1,000 oil milling units in the country and a dozen solvent extraction plants for processing cake.

Desiccated Coconut

The desiccated coconut industry is only slowly developing in India. The domestic demand is mainly from bulk consumers and is fully met by the present production which is around 4000 tonnes per annum. This is very insignificant when compared with the production levels of the Philippines and Sri Lanka, which are 57,000 tonnes and 43,000 tonnes, respectively. The domestic price of the product is also very high. The demand for the product in the domestic market is also confined to a small number of organized confectionary units. However, there is a scope for developing a market for product in those states where coconut is not grown but is in demand for household uses.

Coconut Protein and other Food Products

Viable technology for the production of coconut protein and other products from the wet kernel is yet to develop in the country. The modified Krauss-Maffei process developed by the Central Food Technological Research Institute, Mysore, though found technically feasible, is still to be pilot-tested for determining its commercial feasibility. A recent development in the field is the 'Modified Solvol Process' which was pilot-tested by the Chemical Construction Company in their unit at Faridabad, near Delhi. This process, though fundamentally the same as that of the KM/CFTRI process, Texas A & M University process, and the TPI

process, combines solvent extraction at different stages for ensuring maximum recovery of oil. The reported recovery of various products on fresh weight of kernel is 38.30% oil, 1.12% protein-sugar mixture, and 5.81% coconut flour.

In the Philippines, coconut water is reported to be utilized for the preparation of varied food products and vinegar. In India, the entire nut water is wasted. The higher cost of sugar in India is a limiting factor in the preparation of sweet products from coconut water. Yet, there is good scope for effectively using coconut water for preparing vinegar by cheaper methods, as is being done in Sri Lanka. The vinegar prepared out of coconut water could compete with synthetic vinegar.

Shell Products

Only a small portion of the total shell output in India is currently used for conversion into flour and also into charcoal. The use of shell charcol for activation is slowly developing in the country. Some shell flour units have come up in Karnataka region where shell is available at cheaper rates from the desiccated coconut units. The technology for preparing shell powder of 300 mesh size or above, which alone is demanded by the industries, has not been commercially developed. There is immense scope in this field.

Consumption Pattern of Coconut Products

Coconuts are used both as tender nuts for drinking purposes and as mature nuts for household culinary purposes. In Kerala, more than 25% of the total production is consumed as mature nuts for edible uses. In other states, except the Island groups, 75% of the production is consumed either as tender nuts or as mature nuts for various household purposes. Thus, about 50% of the total production in the country is consumed as fresh nuts. The rest alone is converted into edible copra, desiccated coconut, and milling copra.

Coconut oil is used for both edible and nonedible end-uses. The consumption pattern is in the ratio of 40:60 of edible : non-edible end-uses. The edible use is mainly in Kerala. The household consumption for toiltetry in both the producing and non-producing regions in the country accounts for bulk of the share in nonedible end-uses. While the small scale soap units consume large quantities of coconut oil, the organized sector uses only about 8% of the total oil output in the country. Small quantities of oil are also used in confectionary and toiletry industries. The demand for coconut oil for industrial uses is price-elastic and is also influenced by the availability and prices of other oils. However, coconut oil is a preferred commodity if its price premium over other oils and fats is not very high. The demand in households for toiletry uses is more or less steady and price-inelastic. The normal price fluctuations do not influence the demand because slight changes in the expenditure on this small item do not disturb the household budget.

Price Behaviour of Coconut Oil

The demand for coconut oil in India is steady over short periods. International prices do not influence the domestic prices. Unusual behaviour in certain years is more related to changes in the overall supply position of oils and fats in the country than to any other single factor. Normally, coconut oil prices command a premium over other oils and fats and are not influenced by the availability and price behaviour of any individual oil in the country.

Since coconut prices are linked directly with the oil prices, the determining factor for farm level prices is the oil price and its demand. In India, the cost of production at farm level is estimated at around Rs. 600 per 1000 nuts and the ruling price in the market is around Rs. 800.00 average. Thus, the coconut grower gets fairly good remuneration for his produce.

Export Trade in Coconut Products

Export trade of India in coconut products is practically restricted to coir products and its share in the world market is 27%. Sri Lanka controls the remaining 70% of the world coir export. In other commodities, India has no export trade, except of course, in oil cake which is also exported to the extent of only 1% of the world exports. The export trade in cake is almost equally shared by Indonesia and the Philippines. In the coconut oil and copra export trade, Philippines has the monopoly position controlling 94% of the market. Similarly, desiccated coconut export is controlled equally by Sri Lanka and the Philippines.

The factors determining the export quantum of any commodity is its abundance and the international prices relative to the domestic prices. India and Indonesia and comparatively larger countries and their domestic demand for oils and fats is more than the supplies. The tendency, therefore, is to consume the entire production within the country itself. The internal prices of coconut products in these countries are surprisingly more or less on the same level and more than double the international prices (Table 3).

TABLE 3. Prices of coconut products in the major producing countries (in Indian rupes)

Country	Copra/tonne	Coconut oil/tonne
India (1975-76)	5080	7850
Indonesia (Java)	4880	7800
Philippines	2100	3350
Sri Lanka	1596	2575
International Price (London market)		
Philippine copra	Rs. 2180/tonne	
Sri Lanka coconut oil	Rs. 4250/tonne	

On the other hand, the internal prices in the major exporting countries, such as the Philippines and Sri Lanka are less than the international prices, and they stand to gain by exports. Because of these, the export trade of India in coconut products is confined to coir and coir products and the annual export earning is around Rs. 150 million.

Institutional Arrangements for Coconut Development

Though the coconut palm has been known to exist in India since 3,000 years ago, organized efforts to develop the crop have a recorded history of only less than one century. It was in 1916 that the first Coconut Research Stations were established in the country. It was only since 1945 that integrated efforts for modernizing coconut culture and industry were promoted. The Indian Central Coconut Committee, which was established in 1945, was vested with statutory powers for the overall development of coconut industry, including research. In the year 1966, the Indian Central Coconut Committee was abolished, and in its place, the Directorate of Coconut Development, with headquarters at Cochin, was constituted under the Ministry of Agriculture & Irrigation, Department of Agriculture, Government of India. The Directorate was vested with the functions of planning and coordinating of programmes relating to development, processing and marketing of coconuts in the country. The Directorate, in association with the agriculture departments of the coconut growing states are now involved in the integrated development of coconut industry in India.

The Government of India decided in 1979 by an Act of Parliament to constitute a Coconut Development Board with headquarters in Cochin to promote an integrated development of coconut production in all its aspects. The Board has representatives of all the major coconut growing States and interested Ministries of the Government of India and functions under a Chairman. The functions of Directorate of Coconut Development have been taken over by the Board.

Progress of Coconut Development in Recent Years

Consequent on the organized efforts put in by the Indian Central Coconut Committee, and subsequently by the Directorate of Coconut Development, significant improvements have become manifest in the field of coconut production (Table 4).

TABLE 4. Changes in area and production of coconut

Year	Area (in thousand ha)	Increase percentage	Yearly average	Production (in million nuts)	Increase percentage	Yearly average
1949-50	620.2	—	—	3251.3	—	—
1959-60	728.4	15.8	1.6	4845.5	49.0	4.90
1969-70	1033.3	41.9	4.2	5858.7	20.9	2.09
1674-75	1115.5	8.0	1.6	5961.3	1.8	0.35
Average 25 years		77.3	3.1		83.4	3.33

Objectives and Strategy of Coconut Development

The present production of coconut falls short of the domestic demand. One of the basic objectives of coconut development in the country is to wipe out this deficit within the shortest possible time. Unlike in other coconut growing countries of the world, the small coconut holders in India are essentially marginal farmers. The average size of cocount holding in the country is only 0.5 ha with 98% of the holdings having an area of less than 2 ha. In Kerala state, where 70% of the coconut area in the country is concentrated, there are about 2.5 million small coconut holdings. Nearly 50% of the rural population of the state derive their main source of livelihood from these holdings. Though general increase in the production of coconut is essential, equally important is improvement in the productivity of small holdings which alone can augment the income of the multitudes of small and marginal growers. The strategy of coconut development has, therefore, been evolved to accomplish the two-fold objectives of increasing the production and productivity of small holdings through scientific management of the palm and intensive utilization of holdings under coconut.

Programmes of Coconut Development

The programmes of coconut development, which are under implementation, have been framed to satisfy both the short term and long term requirements. To ensure sizeable productivity increases within a short period, programmes on scientific management of the existing palm population covering irrigation, manuring and plant protection aspects have been formulated. For developing increased production potential under the long term approach, programmes giv ing priority for the genetic improvment of the palm by the production of hybrid planting material for replanting and new planting within a reasonable short period have been adopted. A brief description of the major programmes being implemented in the country so far is given below.

Package programme. Package programme is the most effective short-term approach adopted for achieving significant increases in productivity in the existing palm population. The programme aims at implementing intensive production-oriented programmes encompassing the use of quality planting material, adequate fertilizers inputs, irrigation and improved plant protection techniques in potential districts in the different states for a continuous period of five years. The objective is to achieve a doubling in production within five years. The programme is implemented in units of 500 ha each with a total coverage of 1,20,000 ha. The growers covered under the programme will receive credit facilities for adopting improved management practices and effective extension education. Field demonstrations have also been established at the rate of 10 demonstration units

of 0.25 ha each for every operational area of 500 ha. The total financial investment for the programme for five years is Rs. 772.34 million, which includes a credit component of Rs. 761.56 million.

Hybrid seed garden. The production of coconut hybrids (T×D and D×T) has been receiving priority in the National Plans since 1966. The programme, which started with the production of 26,000 T×D seedlings annually, is now a major development activity. It will be continued until the D×T hybrid seed farms established in the country start commercial production of hybrids. The present programme is to produce 5,25,000 T×D seedlings and 100,000 D×T seedlings every year of which 4,50,000 T×D seedlings and the entire D×T seedlings will be from Kerala. The annual financial investment for this is about Rs. 3 million.

For commercial production of D×T hybrids, five hybrid seed farms have been established in the country. These gardens, one of 200 ha in Kerala, one of 200 ha and another of 120 ha in Karnataka, one of 100 ha in Tamil Nadu, and one of 50 ha in Orissa, are expected to produce annually about 4 million hybrid seedlings from 1985. The investment stipulated for five years is Rs. 4.0 million.

Elite seed farm and coconut nurseries. The production and distribution of quality planting material of the local cultivars initiated on an organized scale in 1945 has continued as a popular development programme since then. In 1970, a 40 ha elite seed farm was also established in Karnataka with the progenies obtained from controlled pollination of prepotent palms for the production of T×T progenies. The coconut nurseries established in the different states have an annual output of about 4.0 million seedlings and the annual investment is about Rs. 10.0 million.

Expansion of area. Despite the ecological restrictions for area expansion under coconut, the estimated availability of suitable area for new plantings is about 1,30,000 ha. Area expansion programmes initiated in potential centres have achieved a coverage of about 25,000 ha. Credit facilities are extended to the growers for the purpose and the total investment is about Rs. 125 million.

Rejuvenation of diseased coconut gardens. In the absence of cultivars resistant to the root (wilt) disease of coconut, how best the unit productivity could be maintained at a satisfactory level in the presence of disease is a matter of considerable importance to Kerala. The coconut hybrids possessing desirable economic qualities like precocity in bearing and high yield potential, are utilized for underplantings and replantings in a selected unit of 5000 ha after removing all the diseased palms. Even in the absence of differential response to disease incidence, if the high yield potential of hybrids manifest any improvement in the productivity per unit area, an expanded programme of replanting in all the disease-affected gardens in the state could be drawn up with confidence. The present programme was started during 1973-74. The financial investment for five years (1974-79) was Rs. 265,000.

Other programmes. Other programmes currently in operation in the country include protected belt spraying in Kerala against leaf rot parasite, breeding stations in the different states for the biological control of *Nephantis serinopa*, comprehensive coconut development programme in Tamil Nadu, and the demonstration programmes in Pondicherry, Goa, and Maharashtra. The annual investment for these programmes is about Rs. 1 million.

Coconut Research and Development Programmes in the Philippines

JUAN T. CARLOS, JR. and SEVERINO E. CUEVAS

Department of Horticulture, University of Philippines, Los Banos, The Philippines

Abstract

The characteristics of the Philippines coconut industry, including its present status, future plans, and prospects have been discussed. Some details on the economics of the industry, varietal development, replanting programme, nursery practices, fertilization, cropping systems, and pests and diseases are presented. Priority research areas, current and proposed researches, and research needs for industry are also included.

Introduction

Coconut may have originated in the Philippines. As early as 1668, Alzina (Uichanco, 1931) recognized the great usefulness of the palm and described several varieties in the archipelago. Later, Wester (1918) also enumerated more than 100 local cultivars on the basis of his surveys. Copeland studied the physiology of the palm as early as 1911, while Juliano and Quisumbing pioneered studies on the development of the nut in later years. Aldaba studied coconut pollination in 1921, while Eocomo (1917), Espino (1923), David (1953) and their students studied mainly the culture of the crop.

Meanwhile, the coconut industry in the country grew steadily. By 1911, about 11 million palms were bearing (Prudente, 1975). In 1960, about 1.1 million hectares were devoted to coconut (Zafra, 1960) and in 1976, 2.3 million hectares or 21% of the total cropland in the country is planted to coconut. All these developments took place practically with private initiative alone. In recent years, however, government development programmes for the industry have intensified greatly.

Today, the coconut industry supports about one-third of the Philippine population either directly or indirectly About 21% of the external earnings of the country come from coconut exports. Coconut products from the Philippines account for about two-thirds of the coconut products in the world market.

Coconut farming in the Philippines is basically a small-holders' enterprise. The average farm is abour four hectares. Many of these farms are along coastal and interior areas where transportation and market facilities are far from satisfactory. Modern techniques in crop production are not adapted widely and average production is only about 1.1 tons/hectare.

Experiences in Production

Geographical and Climatic Adaptability

The coconut palm performs well along coastal areas and in inland areas where sufficient rainfall or ground water is available throughout the year. Such areas include southern and eastern Mindanao, eastern Visayas, western Mindanao, and Sulu. The Bicol and southern Tagalog regions also have good distribution of precipitation but they are often visited by typhoons which cause premature falling of nuts and consequent low yields.

Varieties and Cultivar Improvement

Commercial cultivars include Laguna and San Ramon, both of which fall under the *Typica* variety (John and Narayana, 1949). Several other forms of varieties exist. Normal cultivation brings the palms to flowering in 6-7 years, but it takes only 3-5 years under modern management.

It takes about 4-5 nuts of the cultivar Laguna to produce a kilogram of copra, while 3-4 nuts only of the San Ramon produce the same amount (Carlos, 1963, 1975). The present national average production is 1.10 tons/ha including the young groves, without which the average production is 1.44 tons.

Several forms of *Bilaka* (Javanica) variety are found in the countryside. The nuts range from medium to large, require 3.7-6.0 nuts to produce a kilogram of copra, depending on the form. Eight distinct Green Dwarf, two Golden King, and one Silver Queen have been known. They flower in 23-27 months after transplanting (6 month-old seedlings) under proper grove management (Balingasa, 1975; Carlos, 1976).

At least five cultivars in the country may be classified under the *Coconino (Nana)* variety. These are Coconino Mangipod, mamareng Yellow Dwarf, and Orange Dwarf.

Two forms of medium-seeded Dwarf *Spicata* palms with closely arranged pinnae (similar to Niu Leka) (Balingasa, 1973) palms which produce upto 1232 buttons/inflorescence and 300 mature nuts/bunch, herein called Pagasa (Carlos, 1976), and several others of botanical interest, are found in the country.

Some hybrids, especially those involving *Bilaka* and *Coconino* cultivars as maternal palms and Laguna as source of pollen have been produced. In general, they perform better than either of the parent palms (Santos, 1973).

A solid plantation of Dwarf mother palms for hybridization was established in 1972. More followed afterwards.

Nursery Management

Well-known nursery practices such as those involving selections of plantations, mother palms, seednuts, and seedlings are recommended. Seedlings raised in ordinary seedbed in the open are healthier than those under shade. Raising seedlings in polyethylene bags has reduced the vegetative period of the palms by three months in the early-bearing Dwarfs (Balingasa *et al.*, 1975) and 9 months in the late-bearing talls.

Grove Management

Cover cropping. Where pure cropping of coconut is envisioned, cover cropping is recommended with a mixture of Centrosema and Colopogonium. The latter is fast growing, but dies out during the dry months, exposing the grove to fire hazards. The former is slow growing, but persistent. Other legumes like Pueraria and Siratro may also be used.

Fertilizer and tillage. Tillage in mature plantations previously subjected to cattle grazing increases yield by about 40% (Felizardo and Galvez, 1961). The addttion of fertilizers based on soil analysis furtherincreases yield to about 65%.

In recent years, the significance of chlorine in coconut nutrition has been realized. Newly transplanted *Typica* palms flowered in 3 years and 7 months with chlorine (Mendoza and Prudente, 1972). An eight-year experiment starting with eight-year old Laguna palms resulted in an annual average copra yield of 4.7 tons/ha. On this basis, the Philippine Coconut Authority now recommends ammonium chloride, where nitrogen is also deficient. The critical level for chlorine appears to be 0.5% (Magat *et al.*, 1976).

Cropping systems with coconut. The current pressure of population growth on limited land resource is forcing a shift in the strategy of agricultural land use from monoculture to mixed or multiple cropping system. This is happening now in the Philippines, especially with rice and coconuts.

Philippine coconut situation is very conducive to the development of intensive cropping systems with coconut, because 90% of the 2.3 million hectares of land planted to coconut are in small land holdings or farm units of less than 10 ha area. However, the average family size of a coconut farmer is relatively large—with 7 members (Cuevas *et al.*, 1974). Intercropping is a common system, with about 68% of coconut farms practising a certain form of intercropping usually on a small portion of the farm (Baker and Nyberg, 1968).

Crop combination with coconuts. As many as 50 different crops are reported to be grown with coconuts by farmers (Nyberg, 1968; Cuevas *et al.*, 1974a). The most important are bananas (*Musa balbisiana* 'Saba'), pineapple (*Ananas comosus*), coffee (*Coffea* sp.), corn (*Zea mays*), cassava (*Mani-*

hot utilissima), lanzones (*Lansium domesticum*), camote (*Ipomea batatas*), abaca (*Musa textilis*), upland rice (*Oryza sativa*), papaya (*Carica papaya*),

TABLE 1. Some of the more successful crop combinations with coconut in southern Luzon, Philippines

Crop combination	Input/Output per ha/year	Remarks
Coconut + lanzones	Net income : $ 1,984 Labour : 18.6 man-days Cash cost : $ 432	Low labour and capital output Delayed income from intercrop, about 15 yrs from planting, suitable for hillside areas in places with short dry season and with good proximity to market centres.
Coconut + coffee + lanzones + banana	Net income : $ 3,282 Labour : 233 man-days Cash cost : $ 895	High labour but low capital input With the same suitability as above, but with better market flexibility and earlier time for getting return
Coconut + papaya + pineapple + banana + gabi	Net income : $ 11,502 Labour : 310 man-days Cash cost : $ 10,147	High labour and capital input, but with high return if market prices of fruits are good. Recommended for rolling and cultivable areas. Income is highly reduced by wind damage. The cropping pattern would be replanted every 3-4 years. Very heavy fertilizer requirement.
Coconut + rice + gabi + ginger	Net income : $ 5,552 Labour : 183 man-days Cash cost : $ 4,707	High labour and capital input. Recommended for relatively flat cultivated area.
Coconut + rice + pechay + mustard + upo	Net income : $ 14,341 Labour : 1361 man-days Cash cost : $ 21,162	Require heavy labour and capital input. Would need good market for the vegetables. Suitable in rolling highlands with area of one ha or less per farm unit
Coconut+ rice + daisy + banana + pineapple +sweet potato+chayote +ginger	Net Income : $ 22,162 Labour : 847 man-days Cash cost : $ 7,584	High requirement for labour and capital. Would need proximity to urban area for market of flowers, fruits and vegetables. Suitable in rolling highlands with an area one hectare or less per farming unit

gabi (*Colocasia esculentum*), peanut (*Arachis hypogea*), ginger (*Zingiber officinale*), sugarcane (*Saccharum officinarum*), mungo (*Phaseolus aureus*), pepper (*Capsicum annum*), eggplant (*Solanum melongena*), and arrowroot (*Marantha arundinacea*). A recent study showed that the performance of grain sorghum (*Sorghum vulgare*) under coconut was better than that of corn (Garrity *et al.*, 1976), gabi was better than sweet potato and cassava, and solanaceous vegetables (pepper, eggplant) were less susceptible to rat damage than legume vegetables (*Vigna* spp.) (Cuevas *et al.*, 1974). There are strong indications that certain varieties of particular intercrop species are better adapted under coconut environment at particular plant population density and season (Empig, 1975; Cuevas *et al.*, 1974).

The soil types climate, market availability, and food habits of people influence the suitability of cropping system. The profitability of different cropping systems is very much dependent on the market of intercrop products, availability of capital and supply inputs, and familiarity of the farmer to properly scheduled work operations and apply appropriate techniques.

The growing of different intercrop combinations does not reduce nut yield of coconut (Mangabat, 1960; Hilario, 1975), nor affect the oil content of copra (Gicana, 1974). Fertilization, however, is a must to have a successful coconut-intercropping system.

Coconut cattle enterprise. While a good number of the smaller farms are intercropped or catch-cropped, the tendency among large plantations is to raise cattle under the coconuts. This has been practised in the Philippines since the turn of the century. De Guzman *et al.*, (1975) estimated that more than 400,000 ha or 18% of the coconut plantations in the country are used for cattle production. A good number of farmers succeeded in this venture although some failed.

TABLE 2. Return on investment

Farm	Pasture	Stocking rate Cattle/ha	Return on investment (Per centage)
A	Improved	1.7	30
B	Natural	1.0	22
C	Natural	4.0	18

Some basic considerations in this type of farming system are sufficiency of feed for the cattle the whole year round, competition for plant nutrients between the pasture species and the coconut, and the depressing effects of grazing on coconut growth and productivity. Successful coconut/cattle farmers look at the coconut and cattle as one enterprise rather than two separate business undertakings.

The pasture species which have been found tolerant to shading, capable of producing sufficient herb, and possessing high quality for feeds

are : *Grasses :* Para grass (*Brachiaria mutica*); Guinea grass (*Panicum maximum*); and Alabang (*Dicanthium aristatum*); and *Legumes;* Centrosema (*Centrosema pubescens*); perennial stylo (*Stylosanthes guyanesis*); and Ipil-ipil (*Leucaena latisiliqua*).

A general evaluation of the economic outlooks for three coconut/cattle farms illustrates the significance of management *vis-a-vis* pasture condition, stocking rate, and return on investment from cattle (de Guzman, 1970).

TABLE 3. Cost and return per hectare of beef cattle-coconut enterprise (average of 103 farms with a total of 11,021 hectares)

		Cattle	Coconut	Common	Total
Income	cash	47.37	760.58	0.88	810.83
	non cash	54.48	—	—	54.48
Expenses	cash	51.58	102.45	150.62	450.67
	non cash	—	—	262.96	262.96
Net cash return		—	—	—	360.16
Total net return		—	—	—	151.68

It is apparent that rate of returns are decent. However, the returns on investment decrease tremendously without improving the natural vegetation under the palms. Further reduction in returns continues when the stocking rate is increased. It is highly possible that coconut yield in farm C may also be lower because of greater soil compaction.

A general picture of the combined enterprise from 103 farms with a total of 11,021 hectares indicated that more of the farm income still comes from the coconut at a ratio of about 1:7 although the expenses for coconut are about twice as much as those for cattle (de Guzman, 1970).

Pest Management

The coconut is sporadically infested with slug caterpillars (*Thosea sinensis, Darna trima,* and gelatine caterpillar), rhinoceros beetle, and Asiatic palm weevil. A bacterium *Serratia marcescens* has been found effective against *D. trima* and gelatine caterpillar but not on *Thosea.* Sanitation and care are about the only preventive measures against the beetle and weevil up to date.

Cadang-cadang, bud rot, and leaf spots have been infecting coconut palms in the country. The cause for cadang-cadang has not been definitely identified, much less its cure. However, farmers in the region where the disease occurs have replanted with seedlings from survivor palms and this has maintained if not increased the regional yields.

Bud rot infects coconut palms in some regions quite seriously. When it occurred in southen Tagalog recently, infected palms were then cut down

and burned, but no preventive measures were feasible to take care of the remaining healthy ones.

Leaf spot is a common problem in the nursery, especially with seedlings beyond eight months of age. It is minimized by transplanting the seedlings before eight months and by KCl rather than N or NP fertilization (Abad *et al.*, 1975).

Primary/Farm Product Processing

Copra making. Drying of the coconut kernel into copra is still basically by the *tapahan* or smoking method utilizing coconut husks with or without the shell. Sun-drying is resorted to especially in areas where there is a distinct dry season. New dryers as the philcoa type and the kukum type of the PCA which use coconut shells have been developed. The former is just a slight modification of the *tapahan*, hence copra quality is not significantly improved. The latter uses hot air and produces goo quality copra. This dryer also involves two to three stages of drying to prevent scorching of the copra (Castro, 1976). It has yet to be used commercially.

The Subramanian me thod of drying using chemicals was adopted during the later part of 1960. High quality copra based on Philippine standards was pro duced but neither the importers nor most of the local processors paid for the quality. Sierra (1972) showed that moldy copra has higher percentage of oil than "good" copra.

Coir extraction. Bristle and coir fibres are extracted commercially by some farmers in southern Tagalog mainly for the mattress and car seat industries.

For this coconut husks are soaked in concrete tanks and passed individually through a rotating drum toothed with nails or pieces of iron.

Development Programmes

Marketing of Products

The Philippine government, based on existing copra standards, maintains a moisture meter law governing the quality of copra in the market. To some extent, this law has encouraged farmers to dry their copra sufficiently.

An oil subsidy law has been enforced to safeguard the local oil users from paying too much price for the indigenous product whenever world prices are high. This step also insures the industry of a strong local market for the product.

Oil mills, as well as other industrial concerns, have been encouraged to disperse from Manila and its suburbs to the provinces. This cuts down high transportation costs and raises the farm price for copra. The number of oil mills in any one region is also regulated.

Credit Facilities

The Development Bank of the Philippines (DBP) is capitalized by the government to lend sufficient loans for the establishment and/or rehabilitation of coconut plantations. Funds are released according to the scheduled needs of the plantation which are identified by the farmers with the assistance of farm technicians of the bank.

A tie-up between the Coconut Producers' Federation and the Central Bank of the Philippines also supports the development of other farm enterprises such as plantings of annual and perennial crops and raising the small livestock under coconuts with the ultimate objective of improving coconut yield and general farm income among small holders. Funds utilized in this project come from the planters but disbursed and collected by the Rural Bank for the Central Bank and Planters' Federation.

Coconut/cattle farming is also financed by an IBRD-DBP loan for large plantations for the Mindanao island. This is also a supervized type of credit funded by the World Bank but managed by the Development Bank of the Philippines with the assistance of the Bureau of Animal Industry.

Fertilizer Project

Coconut fertilization has never been popular among farmers because of slow effects of the technology on the palms. A law sponsored by the leaders of the Planters' Federation which taxes the former for coconut development exists. Funds accumulated with this law have been partly used to purchase fertilizers for distribution to planters, through the local chapters of the Federation.

Replanting Project

Many of the coconut plantations in the country are populated with senescent palms way beyond 60 years old. Some palms are more than 100 years. Yield is low and harvesting cost high. Hence, the need to replant is urgent.

Establishment of Seed garden. Part of the levy from the producers has been loaned by the government for the establishment of a seed garden for the production of hybrid nuts. This seed garden is envisaged to supply planting materials sufficient to cover 60,000 hectares annually. Other private, government, and semi-government entities have also started establishing seed gardens and even producing hybrids. Massive replanting has commenced in 1980.

Trial replanting. A trial replanting will soon commence involving about 5 hectares per region. Technical surveys are currently going on and reports indicate that seed nuts are now available. This step will afford the industry the opportunity to see the loopholes, if any, of the present plans.

Financing. The farmers have been paying a levy intended for the pur-

chase of seednuts for replanting. A coconut planters' bank was recently organized for this and other industry development projects.

Manpower Development Projects

Apart from state scholarships available to needy and highly qualified students in the universities, the Philippine Coconut Producers' Federation (PCPF) also provides scholarships for selected children of coconut farmers who are admitted to universities. For the last two years, six hundred scholarships have been granted. Graduate scholarships are also envisaged by some quarters to train middle and upper level leaders for the industry.

In anticipation of the massive replanting project which has commenced in 1980, the Philippine Coconut Authority has launched an intensive training for extension workers who will implement the project.

Meanwhile, Coconut Farmers Associations have been organized within the village level. These associations are envisioned to serve as the means for adult education in various facets of the industry.

Research manpower needs for the coconut is estimated at about 17 man-years for PhD and 41 man-hours for MSc researchers. The Philippine Council for Agricultural and Resources Research (PCARR) had targeted for the scholarships of 14 PhD and 33 MSc candidates for the commodity during 1976-1980.

Quite recently, the Philippine Coconut Research and Development Foundation was formed. Aside from its commitments to encourage and support research and development projects in the industry, it has decided to grant professorial chairs to distinguished educators and scientists in the country directly involved with coconut.

Research Programmes

The authority and power to monitor and co-ordinate researches in agriculture, including coconut, and other resources are with the Philippine Council for Agriculture and Resources Research (PCARR) which was established in November 1972. The Coconut Research Team of the PCARR, which is composed of leading scientists and research administrators from the various government and private agencies and representing various disciplines, assess the research needs of industry, establish and assess priorities, evaluate proposals and on-going projects, and recommend termination or integration of duplicatory activities. Research budgets for each agency are acted upon by the national budget commission on the basis of research proposals passed by PCARR.

Table 4 lists the research priority areas and recommended projects under each area for the coconut. This has served as the guideline for national research organizations and researchers in recent years. Strict implementation of the priorities are adhered to although some amount of flexibility is exercised with basic problems. Regional priorities have also

been identified in cooperation with regional research and development agencies.

It is apparent that the research priority areas and recommended projects jibe with the development programmes of the industry. Also, cooperation exist between agencies in terms of implementing and funding the activities.

Remarks

The paper covers a wide range of important facets of the industry some of which may not have been given the appropriate prominence they deserve. It is hoped though that a substantive review of the research and development programmes of the country for coconut is presented.

TABLE 4. PCARR priority research areas, coconut commodity 1975

Rank	Priority area/Recommended priority projects	Implementing agency	Funding agency
1.	Primary processing and utilization of coconut products and by-products		
	a. Coconut cottage industry development project		
	Indentification of feasible cocobased handicraft products	VISCA PCA	PCARR PCA
	Food products	VISCA PCA	PCARR PCARR
	b. Coconut timber utilization		
	Design and fabrication of equipment for portable sawmills	FORPRIDECOM	PCA
	Insect and decay resistance	FORPRIDECOM	PCARR
	Sliced veneers for plywood	FORPRIDECOM	PCA
	Utilization of manufacturing wastes	FORPRIDECOM	PCA
	c. Coconut drying systems		
	Comparative studies on coconut drying systems	PCA	PCA
	Design and fabrication of efficient coconut drying systems	PCA/VISCA	PCA
2.	Intercropping and coconut/livestock farming		
	a. Regional adaptability for crops	PCA/BPI/BUCA	
	b. Fertilization	VISCA/UPLB	
	c. Cropping patterns		
	d. Nutrient recycling studies in cattle-coconut-pasture ecosystem		
	e. Productivity of recommended pasture species at different fertilizer and cutting/grazing management	BAI/UPLB/VISCA/MSU	
	f. Effect of different pasture/livestock management on coconut productivity		

	g. Screening and evaluation of pasture species which are adapted to environment under coconuts and which are not too competitive to affect coco yield	PCA-Mindanao BPI-Luzon VISCA-Visayas UPLB-Coordinating Agency
	h. Economic comparison of cattle/coconut integration vs. coconut alone and versus coconut/intercrops	
	i. Coconut pest and disease management	
	j. Intercropping and covercropping in relating to pest and disease incidences	
3.	Fertilization	
	a. Manufacture of organic fertilizer	NSDB/UPLB/VISCA/
	b. Organic fertilizer use	BPI/Private Sector/
	c. Inorganic fertilizer use	PCA/VISCA/
	d. Micro-nutrient studies	UPLB/XU
4.	Population dynamics of pests and mass rearing of parasites	VISCA-Visayas BPI-Luzon
	a. Population dynamics of pests	(TES)
	Development of reliable sampling techniques	PCA-Mindanao
	Monitoring of the incidence of different pests and diseases	UPLB-Coordinating Agency
	Population studies on the natural enemies of pests	
	Assessment of the economic injury level of the various pests and diseases	
	b. Mass rearing studies of pests and their corresponding parasites, predators and pathogens	VISCA-Visayas BPI (TES)-Luzon PCA-Mindanao UPLB-Coordinating Agency
5.	Development and evaluation of hybrids and methods of facilitate breeding work	
	a. Regional testing of local and foreign varieties or hybrids**	UPLB/PCA/VISCA/ BUCA/BPI Tiaong
	b. Combining ability test between promising populations**	
	c. Indentification, classification and nomenclature of local and foreign coconut plantations	UPLB/PCA
	d. Screening for resistance to indigenous pests and diseases**	UPLB/PCAR BPI Guinobatan
	e. Clonal propagation through tissue culture**	UPLB

**Partially on-going research project

6.	Replanting		
	a. Land classification and zoning of coconut areas	PCA/BS/VISCA UPLB	
	Soil characterization and leaf analyses		
	Climatic/hydrologic		
	b. Replanting systems	BPI/PCA	
	c. Financing schemes	MICC/PCRDF	
	d. Replenishment (in relation to maintaining a minimum production level without prejudicing our position in the world market		
7.	Cadang-cadang research**	BPI/UPLB/VISCA	
	Priority 2		
8.	Product development and storage		
	a. Foods : Product development for industry		
	Studies on the maximization of recovery of oil and protein from meat-wet and dry process	UPLB/PCA	PCA
	Coconut-based beverages (Pilot)	PCA/NIST	PCA
	b. Energy		
	Fuels from coconut by-products	PCA	PCA
	Fuels and lubricants from coconut oil	UPLB	PCA
		NIST	NSDB
	c. Non-food		
	Development of derivatives of coconut oil-cosmetics, soaps, detergents	UPLB	PCA
		NIST	NSDB
	Studies on biomedical uses of coconut parts	UPLB	PCARR
	d. Coir fibre		
	Improvement of processing systems for coir fibre	PCA	PCA
		NIST	NIST
	Studies on further utilization of coir fibre	PCA	PCA
	Coir dust		
	Development of tannin glues	FORPRIDECOM	PCARR
	Utilization of coir dust as building materials	FORPRIDECOM	PCARR
	e. Long term storage		
	Comparative studies on methods of long term storage (stockpiling) of coconut products	PCA	PCA
	Economic feasibility of stockpiling coconut	PCA-UCAP-PCRDF	PCRDF
	f. Foods		
	Studies on livestock food formulation utilizing copra meal and other coconut by-products	UPLB/VISCA	PCARR
	g. Coconut water		
	Studies on coconut water utilization	UPLB	PCARR

**Partly on-going research project

9.	Future Market	PCA/UCAP/FTI
10.	Organization and Management	BAEcon
11.	Basic Studies on Coconut Breeding	
	a. Studies on isolation distance of planting coconuts	
	b. Oil and protein content of coconut varieties	UPLB/PCA/BPI Tiaong
	c. Studies on genetic markets	UPLB/PCA
	d. Collection of foreign varieties of coconut	PCA/UPLB
	e. Use of embryo culture to facilitate the introduction of varieties and cultivars	UPLB
	f. Culling rates of seedlings different populations	UPLB/PCA
	g. Studies on flowering habits of dwarf varieties	UPLB/PCA/ BPI Tiaong
	h. Culture of irradiated pollen tissue and college**	UPLB/PCA/ PAEC/BPI Tiaong
12.	Forecasting Production	BAEcon/PCA
13.	Resource allocation, land and labour utilization, problems in selected areas for extension work	BAEX/BPI/PCA

**Partially on-going research project

VISCA—Visayas State Agricultural College
PCA—Philippine Coconut Authority
FORPRIDECOM—Forest Product Industries and Development Commission
BPI—Bureau of Plant Industry
BAI—Bureau of Animal Industry
UPLB—University of the Philippines in Los Banos
NSDB—National Science and Development Board
XU—Xavier University
BUCA—Bicol University College of Agriculture
BS—Bureau of Soils
PCRDF—Philippine Coconut Research and Development Foundation
MICC—Private group
NIST—National Institute of Science and Technology
UCAP—United Coconut Association of the Philippines
BAEcon—Bureau of Agricultural Economics
BAEx—Bureau of Agricultural Extension

Development Programmes of Coconut in Sri Lanka

M.S.S. FERNANDOPULLE

Coconut Research Institute, Lunuwila, Sri Lanka

Abstract

The coconut area comprises about a third of Sri Lanka's cultivated land. The total production of coconut in Sri Lanka in 1974 was 2,044 million nuts. Sri Lanka is the fourth largest producer of copra in the world and coconut is the third largest foreign exchange earner next to tea and rubber. The major coconut products exported from Sri Lanka are copra, coconut oil, desiccated coconut, and fresh nuts. Four independent Boards under the overall control of Coconut Development Authority take care of research, cultivation, processing, and marketing aspects of coconut. The drop in production and the steadily increasing domestic consumption have posed the problem of a continuous decline in future exports. The solution seems to lie in replanting with higher and quicker yield varieties.

Introduction

Area of Coconut in the World and Sri Lanka

The total area under coconut palms in the world is over 6,000,000 hectares. The four largest areas under coconut are in the Philippines, Indonesia, India, and Sri Lanka. The Philippines have 1,800,000 ha, Indonesia ha 1,200,000 ha, India 978,000 ha and Sri Lanka 466,000 ha under coconuts.

Coconut is grown in all the 22 districts of Sri Lanka, but maximum areas are found in Karunegala, Colombo, and Puttalam districts in that order. The coconut area comprises about a third of Sri Lanka's cultivated land. According to the 1962 census, 166,405 hectares or 35.7% of Sri Lanka's coconut lands comprised holdings of 10 ha or more.

Coconut Production in Sri Lanka

The average production of coconut in Sri Lanka during the last ten years was around 2,500 million nuts/annum. The highest production was recorded in 1964 when 2,988 million nuts were produced.

Importance of Coconut for the National Economy of Sri Lanka

Exports and local consumption. Sri Lanka's economy is an open economy. It is largely dependent on foreign trade. The total value of imports and exports constitutes more than 50% of the GNP. Sri Lanka obtains its export income primarily from tea, rubber, and coconut which together contribute about 50% of that income. The average value of coconut exports for the five years 1964-68 was Rs. 231 million/annum, about 16% of Sri Lanka's foreign exchange earnings. Coconut is the third largest foreign exchange earner for Sri Lanka. Her export earnings for 1974 were Rs. 1360 million from tea, Rs. 738 million from rubber, and Rs. 397 million from coconut. An estimated 56% of coconut production is consumed locally.

Sri Lanka's Coconut Products in the Context of World Production

Coconut oil. The United States Department of Agriculture estimated the world's production of copra and coconut oil in terms of oil at around 3.9 million metric tonnes in 1975 and 3.2 million metric tonnes in 1974 and the world's exports in terms of oil at around 1.2 million tonnes in 1975 and 950,000 tonnes in 1974. Sri Lanka's production of coconut oil was 120,000 metric tonnes in 1975 and 65,000 metric tonnes in 1974. Accordingly, the exports of coconut oil was 54,000 metric tonnes in 1975 and 22,000 metric tonnes in 1974.

Desiccated coconut. The Philippines and Sri Lanka are the major exporters of desiccated coconut in the world. In 1969, Sri Lanka exported 1.8 million kg more of desiccated coconut than the Philippines. In 1974, Sri Lanka exported 17.4 million kg less than the Philippines.

Copra. The Philippines usually produces about 40% of the world output of copra. The second largest producer is Indonesia with about 20%. Sri Lanka's production is only around 5% of world's copra output. In 1970, the Philippines produced 1,325,000 tonnes, Indonesia produced 660,000 tonnes, India 280,000 tonnes, and Sri Lanka 183,000 metric tonnes of copra. The production of copra in Sri Lanka in 1975 was 203,000 metric tonnes, which represented a utilization of 39% of the total coconut crop for 1975. Only 1,414 metric tonnes of copra were exported in 1975.

Coir fibre. The production of coir fibre dropped sharply from the high level of 122,000 metric tonnes in 1974 to 71,000 metric tonnes in 1975. Sri Lanka's exports of bristle fibre in 1975 at 19,000 metric tonnes were the lowest recorded since 1963. Exports of mattress fibre in 1975 amounted to 46,000 metric tonnes and was the lowest quantity exported since 1953. Coir yarn production, which has been increasing steadily over the last few years, was estimated at 7,100 metric tonnes in 1975 as compared to 6,600 metric tonnes in 1974, an increase of 8%. Coir yarn exports increased from 2,200 metric tonnes in 1974 to 2,500 metric tonnes in 1975, an increase of 17%. Foreign exchange earnings increased from Rs. 3.7 million in 1974 to Rs. 5.4 million in 1975, an increase of 36%.

Sri Lanka's coir yarn exports constitute about 5% of world coir yarn exports. India is the main exporter of coir yarn. Internal consumption of coir yarn is estimated to be about 4,500 metric tonnes/year, local demand being for use in toddy tapping, transport of tea leaf and vegetables and rope.

The individual shares of four major coconut products in the total export value of all coconut products of Sri Lanka over a five-year period is set out in Table 1.

TABLE 1. Shares of four major coconut products (in value terms) in Sri Lanka

Product	1971	1972	1973	1974	1975
Desiccated coconut	30%	23%	47%	46%	39%
Coconut oil	42%	39%	11%	26%	38%
Copra	7%	15%	2%	0.2%	1%
Coir fibre	16%	18%	33%	21%	16%
Others	4%	5%	7%	6.8%	6%
Total	100%	100%	100%	100%	100%

History of the Coconut Industry in Sri Lanka

Coconut Cultivation

Unlike tea or rubber, coconut was already established in Sri Lanka before western colonization. However, the cultivation of coconuts as a plantation crop in Sri Lanka followed the birth of soap industry in Europe in the middle of the nineteenth century. European enterprise, first laid down commercial plantations during the 1840's, at first in the northern and eastern provinces; thereafter, the Sri Lankans brought many thousands of hectares of jungle under coconut cultivation in the western and north-western provinces. Cultivation extended gradually into other parts of Sri Lanka and coconuts were successfully grown as a plantation crop even in the hill country far from the sea.

Coconut Research Scheme

In Sri Lanka, the beginning of the twentieth century saw the establishment of scientific bodies to look after the interests of plantation crops as tea, rubber, and coconut. The Planters' Association of Ceylon played an important role in setting up organized research on these crops. A few individual and collective attempt had also been made in the first years of the twentieth century to study coconut on scientific lines. A definite proposal for a coconut research scheme was put forward during 1923 and a Joint Committee representing the Planters' Association of Ceylon and the Low Country Products Association of Ceylon together with the Director of Agriculture was appointed to formulate a scheme to lay before the

Government. The Committee submitted a 'Memorandum on the Proposed Coconut Research Scheme'. The proposal however was shelved until the Rt. Hon. W. Ormsby Gore, Under Secretary of State for the Colonies, intervened in favour of the proposal. The Coconut Research Ordinance No. 29 of 1928 came into operation in December 1928, and the first meeting of the Board of Management took place on April 27, 1929.

Twenty-one estates were offered for establishing the headquarters of the Coconut Research Scheme. The choice fell on the 60 ha Bandirippuwa Estate, Lunuwila, which can claim to be located in the heart of Sri Lanka's coconut growing area. It is 20 km north of Colombo, with Kurunegala 27 km to its east and Puttalam 31 km to its north.

Subsequently, more land was required for experimental work, and in 1937 Ratmalagara Estate (109 ha) was established as a substation. The funds for the scheme were obtained by means of a cess on coconut products exported and a grant from Government revenue, which were quite inadequate, and so for 21 years, the scheme struggled against financial difficulties. In 1949, a Planting and Advisory Division was created within the scheme for carrying out advisory service and administering the coconut replanting project.

Coconut Research Institute

The 'Scheme' finally became the Coconut Research Institute of Ceylon in December 1950, when under the Coconut Research Amending Act No. 31, the cess was increased. On April 23, 1955, to enhance the plant breeding programme, the Coconut Research Institute established an isolated seed garden on a jungle land of about 81 hectares at Ambakelle in the Puttalam district. About this time, another sub-station was started at Pottukulama in Puttalam district, about 23 km to the north of the headquarters.

Ceylon Coconut Research Board

In order to develop the coconut products and to the promote the export market, a separate organization called the Ceylon Coconut Board was established in 1935. On May 24, 1935, His Excellency the Governor, Sir Edward Stubbs, gave his assent to the Coconut Products Ordinance No. 13 of 1935 which made "provision for the relief of the coconut industry and for the marketing and exportation of the products of the coconut palm". The Ordinance was proclaimed on October 22, 1935 and came into force on November 1, 1935.

Coconut Fibre Board and Department of Coconut Rehabilitation

In 1968 the Coconut Fibre Board was established to look after the interests of the coconut fibre industry in Sri Lanka. There was also a Department of Coconut Rehabilitation charged with the power and duty of rehabilitating coconut lands.

The First Five-Year Plan and Reorganization

The year 1970, ushered in a new chapter in the history of coconut industry in Sri Lanka. In May, 1970, with the setting up of the Ministry of Plantation Industry, all thegovernment agencies concerned with coconut industry were placed under one Ministry. The Five Year Plan published in November 1971, stated that "the coconut industry which is a key sector of the economy has been allowed to decline for many years", and proposed policies for the development of the coconut industry.

A major step in the implementation of the policies enuntiated in the Five Year Plan was taken by introducing in Parliament the Coconut Development Act No. 46 of 1971. This act provided for the setting up of a Coconut Developmnet Authority as the organization responsible for advising the Minister on policy with regard to coconut industry as a whole, and ensuring the implementation of the policy decisions. Since it was felt that the concentration of all executive power in one single authority would be a hindrance to the execution of the planned programme, it was decided that independent statutory boards would be set up for operational purposes. These boards would be subject to control at the policy level by the Coconut Development Authority, but each board would enjoy a large degree of independence, as regards implementation. The Coconut Development Authority was set up on the November 15, 1971, on which date, the Minister appointed five members inclusive of the Chairman to serve on the Authority. Four boards were set up in terms of the Coconut Development Act in March 1972. They are the Coconut Research Board, the Coconut Cultivation Board, the Coconut Processing Board, and the Coconut Marketing Board. Their names are largely indicative of their fuctions. In May 1972, these four boards took over the functions carried out by the then existing organizations, namely the Coconut Research Institute, the Ceylon Coconut Board, the Coconut Fibre Board, and the Department of Coconut Rehabilitation.

Organization of the New Boards

Finances. The initial capital of the Boards were specified. They were Rs. 18 million for the Coconut Research Board, Rs. 5 million for the Coconut Cultivation Board, Rs. 2.5 million for the Coconut Marketing Board, and Rs. 6 million for the Coconut Processing Board. The activities of the boards are financed by the income of the respective boards plus a Government grant wherever a deficit of expenditure over income is experienced. Practically, the activities of the Coconut Research Board and the Coconut Cultivation Board are financed solely by Government grants. The Coconut Processing Board draws its main income from the fees in respect of desiccated coconut sampling and the registration of desiccated coconut, coconut oil, and fibre millers. The deficit of expenditure over income is met with by a Government grant. The operation of the Coconut Market-

ing Board is usually financed solely by the income derived from its activities, viz.,the issue of export licences, conduct of copra auctions and the registration of shippers, dealers, auctioneers/brokers, and estate owners/shellers.

Staff and headquarters. Each of the four boards has a chairman and six other members appointed by the Minister of Plantation Industries. The Coconut Research Board has its headquarters at Bandirippuwa Estate, Lunuwila, with the Director of the Coconut Research Institute and its research and supporting staff serving under the Coconut Research Board. The other three boards have their headquarters in Colombo and their staff, headed by a General Manager for each board, functions under the respective Boards of Management.

Some of the contributions of the four boards to the coconut industry are summarized below.

The Coconut Research Board

Hybridization and selective breeding. By recourse to controlled pollination, the Coconut Research Board has isolated the following promising varieties based on studies on the first generation progeny : (a) CRIC 60 *Typica* × *Typica*; (b) CRIC 65 *Typica* × *Pumila* and its reciprocal; (c) *San Ramon* × *Pumila* and its reciprocal.

Research nurseries. At the Coconut Research Board's research nurseries, experiments are conducted on all aspects of nursery techniques involving seednuts and seedlings. Earlier experiments were concerned with lay out (vertical and horizontal planting), depth of planting, selection criteria, and forms of seed bed making. Experiments now in progress concern the irrigation of nurseries and the production of seedlings of improved vigour and quality.

Coconut nutrition and management techniques. The results of the Boron-Zinc-Sulphur experiment at Monrovia Estate suggest that sulphur reduced the size of the fruit but increased the overall yield.

Experiments on micronutrient requirements of coconut seedlings. The data show that while zinc and copper increased the rate of germination, an excess of boron decreased the rate of germination.

Subsidy schemes. The Coconut Research Board sells from its 15 nurseries very carefully selected coconut seedlings to growers at 50 cents a seedling, although the cost of production per seedling is Rs. 1.62. The Board also sells hybrid seedlings at Rs. 0.75 for the production of which it incurs an expenditure of Rs. 16.00.

The Coconut Cultivation Board

Advisory and extension services. The Coconut Cultivation Board has about 75 coconut development officers stationed in all the coconut growing areas of the country. They are in the charge of seven Senior Coconut Development Officers who also maintain liaison between the head office

and the field staff in their ranges. The Coconut Development Officers carry out extension and advisory work under the supervision of the Senior Coconut Development Officer of the Region.

Demonstration centres. The Coconut Cultivation Board maintains 10 demonstration centres. In these lands, coconut plantations are maintained to demonstrate correct methods of planting and maintenance. Intercropping is carried out whever possible.

Training centres. An 8-9 months residential training course is given to the youth in batches of 25 at the Board's three training centres.

Subsidy schemes. Under the Coconut Rehabilitation Scheme, cash subsidies are given to owners of coconut small holdings for filling vacancies, removal of excess palms, and the establishment of contour drains and drainage drains for the purpose of conservation of soil and moisture on the land. Under the Pasture Subsidiary Scheme, a cash subsidy is paid for establishing pasture or fodder under coconut.

Seedling and fertilizer distribution. The Coconut Cultivation Board distributes quality coconut seedlings to small land owners in the dry zone districts of Batticola, Polonnruwa, Amparei, and Moneragala. Authorized dealers are registered with the Board for the purpose of distribution of fertilizer, half the cost of which is borne by the Board.

The Coconut Processing Board

Regulatory functions. The main activities relating to this function are the selection of mills for registration, control of the conditions under which coconut products are processed by inspecting and supervising the standards maintained in the operation of mills, ensuring quality control of processed products, granting of export licences for the product.

Research and development. A series of experiments were carried out on the retting of green husks, with a view to reducing the retting period of 8-10 months normally required. It was confirmed that pre-crushing of the husk reduces the retting period by 3-4 months. In collaboration with the Sri Lanka Institute of Scientific and Industrial Research, the Coconut Processing Board has made arrangements to set up a pilot project for the bottling of coconut cream. The Board works in close collaboration with the Bureau of Sri Lanka Standards with a view to establishing national standards for coconut products.

Coconut Marketing Board

Price stabilization scheme for coconut oil. Under this scheme, the Coconut Marketing Board acts as a buffer between world market and the local producer to absorb the variations in the world market prices and ensures a stable and sufficiently attractive price to the coconut producer irrespective of world market fluctuations.

Licensing of exports. An important activity of the Board is the regulation of export trade in coconut products (copra, cocount oil, desiccated

coconut, coir fibre and yarn, and cononut shell products) by functioning as the licensing authority for exports. In the issue of export licences, the Board considers whether the export prices fetched by shippers and the terms and conditions of their foreign sales are fair and reasonable in the national interest.

Regulatory work. Under the Coconut Development Regulations No. 1 of 1972, all shippers, dealers, and others engaged in the marketing of coconut products are required to register with the Coconut Marketing Board. This enables the Board to regulate the activities of such persons by ensuring that they conform to standards laid down by the Coconut Marketing Board.

The Future of Coconut Industry in Sri Lanka

Any scheme for the development of the industry must be based primarily upon the improvement of the productivity of the coconut plantations. The drop in production and the steadily increasing domestic consumption have posed the problem of a continuous decline in future exports and the eventual possibility of Sri Lanka becoming a net importer of coconut products.

The solution seems to lie in replanting with higher and quicker yielding varieties, not merely the so called senile trees, but almost the entire coconut acreage, particularly in those agroclimatic zones of the country which are ideally suited for coconut. Attempt is being made to make available quality seedlings in quantitites adequate to replant about 8000 ha/year.

An Assessment of the Coconut Industry of Malaysia

HARCHARAN SINGH KHERA

Department of Economics, University of Malaysia, Kuala Lumpur, Malaysia

Abstract

Coconuts rank as Malaysia's fourth largest crop in terms of acreage covering about 215,000 ha of 7% of total cultivated land area. About 90% of the total coconut area in Malaysia is under small holdings. Out of an estimated total of 70-80,000 coconut small holders, about 17,000 are in the poverty group.

The problems connected with the Malaysian coconut industry are low productivity due to poor management and cultural practices,the use of unselected varieties, lack of adequate research for the improvement of the crop and the industry, the sociological problems associated with a large number of small holders dependent on a low income crop, uneconomical size of holdings, and the absence of a good marketing system. In the light of these problems the government has taken some measures to improve the industry and raise the income of the small holders.

An assessment of the industry and the government's corrective measures is made to throw greater light on the problems faced by the industry.

Introduction

The coconut palm has been grown in Malaysia* since very ancient times, but as in other coconut growing countries, its development as a commercial crop began only during the latter part of the 19th century. By 1974, the coconut industry in Malaysia was the fourth largest in terms of acreage in the agricultural sector, preceded by only rubber, rice, and oil palm (Table 1). Over half a million people depend directly or indirectly for their living on coconut and copra production. In terms of export earnings, the coconut industry ranked seventh, accounting for about 1.1% (M$ 120.2 million) of the total export earnings.

The overall performance of the coconut industry of Malaysia over the past two decades has not been very encouraging. It has registered a very slow growth rate ; even with government encouragement and assistance, it registered an average of 1.6% annual growth rate only dur-

*Unless otherwise stated, Malaysia in this paper refers to Peninsular Malaysia, and all money values expressed refer to Malaysian dollars.

TABLE 1. Cultivated area under important agricultural crops in peninsular Malaysia during seleeted years (in thousand hectares)

Period	Rubber		Palm oil		Coconut		Rice		Others	
	ha	%	ha	%	ha	%	ha	%	ha	%
1947	1405.6	64.7	31.2	1.5	204.8	9.6	325.6	15.3	161.2	7.6
1950	1420.4	65.3	38.4	1.8	194.0	8.9	372.4	17.1	148.4	6.8
1953	1454.4	66.8	43.2	2.0	194.0	8.9	333.6	15.3	151.2	7.5
1956	1477.6	65.5	46.0	2.0	206.8	9.2	350.4	15.5	175.2	7.9
1959	1513.2	64.2	50.4	2.1	188.0	8.8	369.6	15.7	175.2	7.5
1962	1656.0	67.9	61.2	2.5	204.0	9.3	326.8	13.4	193.2	7.9
1965	1731.2	67.8	83.2	4.3	202.8	7.9	346.0	13.5	190.8	7.5
1968	1703.2	62.6	199.2	7.3	206.8	7.6	473.2	17.8	140.0	5.2
1970	1710.0	59.6	276.8	9.6	210.8	7.3	527.2	18.4	145.6	5.1
1972	1704.4	56.8	354.8	11.8	212.8	7.1	565.6	19.8	160.8	5.4
1973	1674.4	54.6	430.8	14.0	215.2	7.0	584.8	19.1	162.0	5.3
1974	1664.0	52.5	529.6	16.7	215.2	6.8	590.4	18.6	171.2	5.4

Source : Monthly Statistical Bulletin of West Malaysia, Department of Statistics, Kuala Lumpur, Malaysia, Various Issues.

ing the Second Malaysian Plan (1971-75). In view of the significance of the industry to the economy of Malaysia, an attempt is made in this paper to diagnose some of the problems faced by the industry and make some policy recommendations.

Acreage

It is an officially accepted practice to dichotomize arbitrarily coconut holdings into estates and small holdings. The Malaysia Department of Statistics defines a coconut estate as "an area under coconut or alienated for the planting of coconut, contiguous or non-contiguous, and aggregating not less than 100 acres (40 ha) under a single ownership". Of the 2,15,000 ha under coconuts about 1,98,000 or 92% of the total area was under small holdings.

From 1963 to 1974, the area under small holdings increased from 84.4 to 92.0% according to the Malaysia Department of Statistics. At the same time, the total area under coconut has remained more or less stagnant. The decline in the area under the estate sector is mainly attributable to the rapid growth of the oil palm as an alternative and more profitable crop. The developments that have taken place in the oil palm industry over the last decade have resulted in a significant increase in plam oil yields—making the crop profitable even on marginal soils (Khera, 1976). The 1960's witnessed a phenomenal change in the rate of development of the oil palm industry in Malaysia when compared to other crops. The share of oil palm in total acreage increased from 2% in 1965 to over

16% in 1974 (Table 1). Even at the highest level of copra output prevailing in large estates an investment in oil palm is more profitable than an equivalent investment in coconut output (FAMA, 1968). Hence, most coconut land suitable for oil palm on estates has been replanted with oil plam. In the next few years, we do not expect a large decrease of the coconut acreage under estates.

The average size of small holdings vary considerably from State to State The average size of the area under coconut cultivation is estimated to be 3.8 ha in Johore, 1.1 ha in Kelantan, and 4.3ha each in Selangor and Perak.

Productivity

Productivity measured in terms of yield of nuts and output of copra per unit area, and the extraction efficiency of oil mills has shown little tendency to improve over the last decade (Table 2). In the estate sector, through the yield in some of the well-managed estates, particularly the British, is in the range of 1.8-2.3 tonnes/ha/year, the average for this sector as a whole is only 1.4 tonnes.

TABLE 2. Productivity in coconut estates

Year	Nuts harvested/ ha	Copra produced/ ha (m kg)	Oil exported/ tonne copra (tonnes)
1964	5550.09	1062.74	0.58
1965	6046.56	1158.25	0.59
1966	6021.85	1126.93	0.61
1967	6041.62	1171.59	0.62
1968	6624.54	1269.70	0.59
1969	5653.83	1047.29	0.62
1970	5851.43	1099.03	0.61
1971	5806.97	1106.46	0.64
1972	6271.33	1143.52	0.70
1973	7269.21	1149.31	0.63

Source : Department of Statistics, Oil Palm, Coconut and Tea Statistics.

In the small holding sector, the productivity is even lower. It is estimated that the average yield is only 0.9 tonnes. In some areas like Kelantan, it is as low as 0.3 tonnes (FAMA, 1968). The basic reasons for the poor performance of the small holders sector can be attributed to very poor standards of farm maintenance and manuring during both immature and mature periods reduce not only the yield per ha but also shorten the economic life span of the palms. Adoption of modern agronomic practices throw the balance of advantages strongly towards estates,

particularly large estates, for clearly the adoption of new sophisticated method is quite out of the question for small estates and small holders.

Copra Processing and Oil Extraction

The copra produced in estates is of high standard and hence obtains a premium in price. Fresh split coconuts are dried for about 60 hours continuously in kilns. The resulting copra is brittle and evenly dry with a low moisture content. There is strong demand for this copra from both local and overseas markets. However, since 1962, the volume of copra exported has declined because an increasing share of the total production is locally purchased for oil extraction.

On the other hand, in the small holder sector, copra production techniques are highly inefficient. The period and degree of drying depend on the urgency of cash; the greater the need for cash the shorter the period of drying and the higher the moisture content. Small holders, who do not own or have access to kilns, resort to sun-drying. In the kiln drying method, the period of drying ranges from a maximum of 30 hours to a minimum of 10 hours. There are wide differences in the size, structure, type and performance of kilns used. Hence, the quality of copra produced shows wide variations, depending on the method of drying used, type of kiln used, the period of drying, the intensity of heat applied applied, and care given. Generally the small holder's copra has a higher moisture content, often exceeding 15%. The result is that the quality of the oil extracted is poor with high free fatty acid content. The efficiency of drying copra has considerable influence on the efficiency of oil extraction and on the quality of the final products.

The aim of every coconut oil producer should be to recover from the copra as much oil of the highest possible quality as possible and at the lowest possible cost. But, the oil milling industry in Malaysia is beset with problems of efficiency. A very high proportion of the mills are small, old and outdated with an oil extraction rate of 50-54% only. The best mills, mainly on British owned estates, have a maximum rate of 60% (FAMA, 1968). By comparison with the west European coconut oil extracting industry, where the average recovery rate is around 65%, the performance of the Malaysian industry offers considerable scope for improvement. Copra has an oil content of 60-68% normally.

Marketing

Two main marketing systems have been developed in the disposal of coconut products, one dealing with export markets and the other to cope with domestic disposal of the produce. The salient problems in the *export trade* of coconut products are given below :

1. With an unfavourable price trend in relation to substitutable oils and fats like palm oil, palm kernel oil, soyabean oil, fish oil, tallow, etc. and faced with high production costs and declining yields, coconut holdings hardly find the price trend in copra and coconut oil favourable for carrying out improvements to their holdings. As coconut oil is a fairly close substitute for other oils and fats in some industrial uses, any undue increase in the price of coconut oil is likely to affect adversely its demand in the world market.

2. The export trade in copra and coconut oil in Malaysia has been closely tied up with the availability of low priced copra from Indonesian sources (Table 3). After 1963, when Indonesian sources were cut off, exports of coconut oil and copra slumped sharply. More important is still the fact that even if local copra production had been increased to meet the shortfall in supply, it is unlikely that the oil mills would have been able to obtain these at prices lower that those prevailing for Indonesian copra. Thus, until the full benefits of the coconut replanting and rehabilitation programme are realized, it is likely that Malaysia will have to depend on external sources for some of her copra requirements.

TABLE 3. Exports and imports of copra (in tonnes)

Year	Exports	Imports	Imports from				
			Sumatra	Singapore	Thailand	Sabah	Others
1965	16,013	1,040	5	60	321	525	138
1966	12,651	2,037	96	48	1,217	606	70
1967	2,761	3,313	1,161	238	—	1,857	57
1968	3,537	7,006	5,686	24	16	1,226	54
1969	2,473	6,473	2,279	25	16	4,139	14
1970	555	2,848	603	69	126	2,020	30
1971	134	2,456	415	6	118	1,910	7
1972	304	5,213	98	13	—	5,102	—
1973	294	2,960	287	—	—	2,673	—

Source : Oil Palm, Coconut and Tea Statistics, Department of Statistics, Malaysia, Kuala Lumpur, Various Issues.

3. The need for efficient processing plants to produce high quality copra and oil at lowest possible cost, to offset high production cost. Many of the mills have low oil recovery rates and this in turn affects price paid to producers. One of the main defects of copra produced by small holders is that it is under-dried, and this causes rapid deterioration of the produce. As there are no specified gardens to determine quality of copra purchased by oil mills, there are wide variations in prices quoted to different producers.

In the case of the *internal market* for coconuts and coconut products, the major problems are listed below :

1. Low prices received by farmers. While the marketing of estate copra is highly organized, no organized marketing system exists for small holder's copra. Most estates follow a system of auctioning their copra, under which quotations are invited from potential buyers and the highest bidder secures the copra offered for sale. This system ensures, in the absence of strong collusion, a fair price for the output of estates.

The small holders' copra is handled by a chain of intermediaries before it reaches the final consumer. The margins going to the middlemen are high if one takes into account the fact that there is only one intermediary between producer and consumer and the product requires little sophisticated handling or storage. In the case of copra, the problem is even more complicated because of the variations in quality and distance from the oil mills, number of buyers in operation and the degree of collusion among the buyers. In general, small holders are indebted to middlemen to such an extent that they are unable to command any bargaining power.

2. The availability of cheap, good quality copra from Indonesia has made coconut farmers apprehensive of future prospects in the industry. This has been particularly so with the ending of confrontation and a resumption of trade with Indonesia. Prices received by local producers for copra have always been geared to import prices of copra from Indonesia. While a source of cheap, high quality copra is essential for the survival of the coconut oil industry, it has meant increased competition for the local producers.

The main obstacle to the introduction of any market improvement proposals is that the level of income from majority of holdings even with fairly high yields cannot be regarded as adequate. This is because of the uneconomical size of holdings and high production costs. Unless the basic unit of production can be developed as a viable unit, it is unlikely that any marketing improvements will make any significant differences to the income of the farmers.

Two other factors of major importance in determining the income of the small holders are: (i) marketing practices relating to grading of copra; and (ii) indebtedness of farmers. Assessment of copra grades at the producer level is done entirely by visual judgement and feel. Copra producers have no incentive to produce better quality, well dried copra, because it weighs less and any increase in price which they might receive may not offset the reduction in weight.

The problem of credit is particularly acute in the coconut small holder sector. Farmers who are indebted generally receive lower prices than those are free from debts (FAMA, 1968). Differences of M$ 3.3-5.0/ quintal of copra or M$ 5.00-8.00/1,000 nuts exist. Indebted farmers are obliged to sell their products to their creditors, otherwise they risk their credit facilities. The ability of the farmer to choose between different outlets instead of being tied to one, and the possibility of bargaining over

the price at which his produce is sold are opportunities only made possible when the sources of credit are independent of marketing operations. It is a cardinal point that the means by which credit is rapid often determines the channels through which the farmer markets his crop.

More often than not, in most coconut growing areas, the small holder faces a monopsonistic or oligopsonistic market as the number of purchasers of coconuts or copra is limited. Such monopsony or oligopsony is reinforced when the coconuts or copra purchaser also fulfils the functions of money lending and merchandising.

Government Action

In view of the importance of coconut industry to the Malaysian economy, particularly the small holder sector, the Government has taken the following measures.

1. *Establishment of a Coconut Replanting and Rehabilitation Scheme*

This scheme was established by the Government in 1963. It aims at improving the economic position of the coconut small holders by making coconut cultivation more lucrative, and net income per unit area comparable to the other crops in the country.

A coconut holding is eligible for a replanting grant of M$ 1250.00/ha under the scheme, if less than 25 palms/ha are economic and can be retained. Any holding having more than 25 economic palms/ha is eligible for a rehabilitation grant of M$ 750.00. An economic coconut palm is one estimated to produce a minimum of 60 ripe nuts/year. In both replanting and rehabilitation, the aim is to achieve an optimum density of 135 palms/ha. The subsidy is to meet the cost of fertilizers, pesticides, and selected seedlings supplied and for work in the farm to recondition the drainage system and for the clearance of weeds and undergrowth.

Since the return from a coconut holding is lower than that from such crops as rubber or oil palm, the scheme requires intercropping to be carried out by participating farmers so that their income from coconut holdings would become comparable to those of rubber or oil palm holdings. Depending on the locality and soil suitability, crops accepted for this purpose are pineapple, banana, coffee, maize, cocoa, sweet potato, and vegetables. In this manner, not only are the coconut holdings improved but the small holders are taught to make the best use of all the available land. Thus, while waiting for the coconut palms to come into production, the cash crops will give quick returns and thereby supplement the small holders' income.

The response from the small holdings has been satisfactory but shortage of funds has acted as a limiting factor to a more rapid rehabilitation of the small holder coconut industry. Rehabilitation has so far resulted in an increase in average yield of 30-35%. During the Second Malaysia Plan (1971-75), an estimated expenditure of M$ 26.79 million was made on coconut replanting/rehabilitation. Under the Third Malaysia Plan

(1976-80) an allocation for M$ 62.30 million was made to replant/rehabilitate 40,000 ha of small holdings. Of the total, about one-fourth area has been intercropped.

2. *Establishment of a Coconut Marketing Scheme*

The scheme was implemented in May 1973. By regulating the trading activities of marketing intermediaries as well as by active participation in the coconut and copra trade and the processing of copra, the scheme seeks to secure maximum returns for the small holders. The regulatory aspect of the scheme involves the licensing of any person who purchases copra or more than 50 nuts, except for the purpose of retailing. The issue and annual renewal of the licence are subject to compliance with the terms and conditions imposed by the Authority to ensure acceptable marketing practices that would result in fair returns to the producer. The second feature of the scheme involves the direct participation of the Authority in the purchasing of coconuts and copra for the purpose of processing them into high grade copra. Three crops processing centres, one in each of the districts of Lower Perak, Sabak Bernam, and Batu Pahat became operational in 1974. By the end of 1976, a further 22 centres were set up in the principal coconut producing areas.

3. *Formation of an Asian Coconut Community*

In November 1968, an Agreement was reached between the main coconut producing countries—India, Sri Lanka, Western Samoa, Indonesia, the Philippines, Thailand, and Malaysia—to form an Asia Coconut Community to improve the production and marketing of the commodity. The aims of this community are to coordinate the activities of the coconut industries in member countries, promote the establishment of processing industries, stabilize prices, conduct market surveys, and provide training and research facilities for the improvement of the industry.

Conclusion

The various measures taken by the Government to tackle the problem of the coconut industry, particularly the small holding sector are commendable. Some of the measures like the Replanting and Rehabilitation Scheme have produced positive results in increasing yields. The intercropping programme also seems to be on the road to success. However, the Replanting and Rehabilitation Scheme seems to favour the larger acreage small holders. As the gestation or waiting period of the coconut is about four years, small holders, with smaller holdings and in the absence of other sources of income, have shown little response to the subsidy under the scheme. Our of an estimated total of 70,000-80,000 coconut small holders about 17,000 are in poverty group. It is suggested that the replanting and rehabilitation grants be given on a sliding scale—the smaller the area a small holder has, inter alia, the larger the grant be.

The establishment of Coconut Marketing Scheme is certainly a long overdue move in the right direction. As the scheme is still being implemented, it is premature to assess it. However, if well implemented, it should be able to achieve the desired objectives.

In 1974, coconut oil constituted only 5.6% of the total world's oils and fats production. The world production of copra has remained almost stagnant since 1960. Coconut oil is only one of a large number of oils and fats. As a result of technological developments, these oils and fats have become increasingly interchangeable. The degree to which oils or fats can be substituted for one another depends upon their physical characteristics, but the degree to which within these physical constraints they are substituted for one another, depends upon their economic characteristics. The most important economic factor in extending markets for coconut oil has been and will continue to be, its price in relation to other oil and fats.

In view of the rapidly increasing supplies of soyabean oil, palm oil, and other oils and fats entering the world market, increasing productivity and efficiency are both necessary and desirable for coconut oil's survival in a rapidly changing technological market. Major producers of coconut oil, either through their own national programmes or jointly through the Asian Coconut Community, should intensify their efforts towards production and market research.

The importance of research can scarcely be overestimated. Oils and fats exported from developed countries are the subject of considerable research. These appears to be compelling deed for Asian exporting countries to introduce coordinated research. Production research will result in greater efficiency and lower production costs, and market research will enhance in understanding marketing conditions and consumer requirements. Research into the development of further end uses coconut oil may be beneficial because it may shift the demand curve and increase income elasticity of demand.

Major coconut producing countries should also examine the scope for the establishment of integrated coconut complexes. In Malaysia, yearly production of nuts averaged 800 million in recent years, but almost all the nuts were converted to copra with the bulk of the nut products going to waste. The various products of commercial value which can be obtained from the whole coconuts have not been sufficiently exploited—products like desiccated coconut, coir dust, fibres, ropes brushes activated carbon, and so on, for which there are established overseas markets, can be effectively produced if there were well planned processing complexes.

Some important publications are listed under 'References'.

References

Arasu, N.T. (1972). Coconut Improvement in West Malaysia. pp. 302-308. In Wastie, R.L. and Earp, D.A. (Eds.) *Cocoa and Coconuts in Malaysia.* Incorporated Society of Planters, Kuala Lumpur.

Commonwealth Secretariat (1973). pp. 105-119. In *Vegetable Oils and Oilseeds.* London.

Federal Agricultural Marketing Authority (1968). The coconut industry in Malaysia. *Workshop Proc.* FAMA, Kuala Lumpur.

Khera, H S. (1976a). *The Oil Palm Industry of Malaysia : An Economic Study.* pp. 354 University of Malaya Press, Kuala Lumpur.

Khera, H.S. (1976b) *Oil Palm : World Demand Prospects.* In *The Economic Bulletin.* 13-19 pp. Academic Publishers Sdn. Bhd., Kuala Lumpur.

Anonymous (1971a). *Second Malaysia Plan 1971-1975.* 267. pp. Government Printers, Kuala Lumpur.

Anonymous (1971b). *Third Malaysia Plan 1976-1980.* 430. pp. Government Printers, Kuala Lumpur.

Nair, R. (1968). The coconut industry in West Malaysia. 12-43. pp. In *The Coconu Industry in West Malaysia, Workshop Proc.* FAMA, Kuala Lumpur, Malaysia.

Othman bin Mohd., Lela (1972). The coconut replanting and rehabilitation scheme in West Malaysia. In Wastie, R.L. and Earp, D.A. (Eds). *Cocoa and Coconuts in Malaysia* 444-448. pp. Incorporated Society of Planters, Kuala Lumpur.

Ramanathan, P. and Ng Boh Koh (1972). The coconut industry in Sabah. Ibid. 282-285 pp.

Research and Extension: The Keys to Coconut Development in Jamaica

D.H. ROMNEY

Directorate of Research, Coconut Industry Board, Kingston, Jamaica West Indies

Abstract

The development of the coconut industry of Jamaica over the past two decades is described to show the advantages of decentralizing the responsibility for development of a crop to a specialized agency in which research, extension work, marketing and farmer services, can be vertically integrated. Significant items of development are: (i) a market for coconuts in any quantity; (ii) a fund for hurricane insurance; (iii) testing and propagating the disease-resistant 'Malayan Dwarf' to replace the susceptible local Tall; (iv) initiation of an industry-financed replanting scheme; (v) development of rain- repellant baited rat poison; (vi) a complete her bicide research programme culminating in recommendations to farmers; (vii) identification of responses of coconuts to major fertilizer elements on main coconut soils; (viii) provenance of a disease-resistant hybrid and development of techniques to produce plants in quantity; and (ix) delivery of plants, fertilizer and herbicide to farmers.

Organization for Development

The Coconut Industry Board, established in 1945, is a statutory body with five members elected by coconut growers and four nominated by Government. The Board is responsible for and advises the Government on coconut industry. In the early days, its main functions were the orderly disposal of the coconut crop and the provision of Hurricane Insurance for coconut trees. The administrative costs of the Board and the savings made towards the hurricane fund came from a cess imposed upon copra. In 1959, it was decided to set up a research department; this decision being influenced by the benefits seen in Jamaica from crop-orientated research with sugar and banana. The financing of research and development was done by a cess on the coconut crop.

Although research on coconuts was being done by the Ministry of Agriculture even prior to setting up a separate research department in the Board, it was discontinuous. There was no long-term research. Decentralization of coconut research to the Board was welcomed both by

Government and the growers as a means of obtaining continuity, and of assuring long term finance (by charging the work to the crop). Since the Research Department is part of a grower's organization, the research is project-oriented and performed with a sense of responsibility to the growers. As the effectiveness and convenience of the arrangement rapidly became apparent, Government agreed to give the Board responsibility for plant production, advisory work, and all facets of coconut development.

Development Policy

The Board's coconut development policy is to increase the efficiency of production by means of (a) plant improvement by selection and breeding and (b) identification of improved management methods. This has been achieved by research to answer the basic questions, and extension of these answers to the farmers.

When lethal yellowing disease appeared in the main coconut belt in 1961, selection and breeding put emphasis on disease resistance, and the management methods studied became those suited to resistant cultivars. Technical and financial aid were obtained from international agencies to carry out research into the cause and possible cure of lethal yellowing since the problem was not confined to Jamaica. At that time, the identification of the cause and cure was expected to require a limited numbers of years ; also, it was important not to distract the attention of scientists carrying out continuous research (and therefore, development) on plant improvement and management. It has since transpired that the substantial amount of research findings to date on the cause of lethal yellowing has not produced a solution to the problem, and the coconut industry of Jamaica is being developed using resistant varieties.

Plant Improvement

Parallel to the longer term work being done to select or breed improved varieties, it was necessary to advise on seed and plant selection for the farmer. The plant improvement programme followed classical procedures. Local varieties were identified, characterised botanically, and tested for their agronomic performance. At the same time, information was obtained to characterise exotic material in its place of origin and to introduce and test it. Fortunately, a cultivar introduced previously, the Malayan Dwarf, was found to have resistance to lethal yellowing. The Research Department proceeded to assess this resistance quantitatively and also to assess the yield factors. The degree of inbreeding of the Malayan Dwarf was studied using a genetic marker, namely, petiole and fruit colour. By 1962, the resistance and productivity were sufficiently proven and thousands of Dwarf mothers were selected and marked as the

basis for regular seed production. From that time, even in areas not yet attacked by the lethal yellowing disease, planting of Malayan Dwarf largely superseded planting of the disease-susceptible local Jamaica Tall.

It was apparent by the early 1960's that very small yield improvement had been obtained in other countries by mass selection of mother palms of the Tall variety or even by identifying and crossing Tall prepotents. This is doubtless due to heterogeneity in the Tall and its outcrossing habit and also to the length of time required to distinguish prepotency. Hence, the work of selection and improvement of Malayan Dwarf was strengthened with a programme to make a range of F1 hybrids, with the Dwarf as one parent as source of resistance, and test them under local conditions.

In 1971, it became clear two-parent hybrid seed gardens, of which some had been established in Jamaica, were too small and inflexible for large scale seed p♀duction. Before mass controlled pollination could be introduced, research had to be carried out to produce large quantities of viable pollen. This was closely followed by research on emasculation techniques and methods of pollen application to obtain optimum seed set, and led to the establishment of routine procedures, including the use of a mobile pollen workshop.

By 1974, the cross between Malayan Dwarf and Panama Tall had shown sufficient disease resistance and productivity to be released to farmers under the name Maypan. Because of its large nut size and expected resistance to poor conditions such as seasonal moisture stress, Maypan was put to use in the establishment of coconuts on land too poor for economic production of Malayan Dwarf. Hybrid seed production increased from 47,000 in 1974, to 57,000 in the first six months of 1976. In 1974, 52 ha of selected Malayan Dwarf mothers of the yellow colour form were planted in an isolated area with the aim of producing 700,000 hybrid seeds per annum in the near future.

Longer term breeding work includes the botanical characterisation of all cultivars available for breeding, and the sibbing of those members of each cultivar which have proved their field resistance to lethal yellowing disease. Other F_1 hybrids are being made and tested. A late generation hybrid between Malayan Dwarf and Fiji Dwarf (Nui Leka) has been taken to the next generation and is being selected in the field with a view to fixing a desirable type possessing dwarfness, thick trunk, early bearing, numerous large nuts and disease resistance.

Better Plant Management

The Agronomist faced the task of improving the methods of coconut management for the task existing Tall variety, and developing modified methods for new varieties, whilst at the same time giving day-to-day advice to the farmers. With the Tall, research concentrated on the use of

fertilizer, the benefits of cultivation, i.e., tillage, methods of managing bearing coconut trees with intercrops, and control of rats. Great progress was made in the identification of nutrient deficiencies in the major coconut soils by measuring the yield responses and correlating these with foliar analyses. The competition between a pasture intercrop and Tall coconut trees was measured and methods found to obtain optimum growth of both crops. The work done on rat control was notable, the damage being measured over two years on a number of sites, several methods of control investigated, and eventually a water proof-baited poisoned block developed, which has subsequently been used regularly by farmers in coconuts throughout Jamaica and in some other territories.

The advent of new varieties—initially the Malayan Dwarf and then the Maypan F_1 hybrid—involved the Agronomist in a new range of experiments to ascertain the most desirable spacing for each variety. As the experiments progressed, it became apparent that correct spacing influenced not only yield but also weed control. Planting experiments studied size of planting hole, depth of planting, additives to the planting hole, etc., these showed that any small differences in growth immediately following planting were negligible compared to the benefits of good weep control and fertilizer given subsequently. Investigations into coconut nutrition continued with the new cultivars. Experiments on intercrops became important economically because of the farmer's need for some returns during the non-productive phse of coconut's life; in general, it was found that only intercrops which competed with the coconut for light were undesirable; there appeared to be negligible competition for nutrients or water. Pioneer work was done to screen herbicides for use in coconuts to ascertain the safety limits for both foliage uptake and root uptake by the coconut; growth and yield responses to weed control were measured, and routine herbicide recommendations developed and adopted by farmers in Jamaica and in other territories. Research on mulching, including the use of polythene, showed great responses in dry seasons, but similar responses were obtained by maintaining a weed-free circle of the same size as the mulched circle.

In the course of these experiments, some physiological characteristics of coconuts became evidents. For example, the Malayan Dwarf has the ability to commence flowering less than 24 months after planting if given suitable growing conditions. The fibrous root system of the coconut enables fertilizer to be applied to one part of the root system only. Coconuts are very sensitive to light intensity. The lengths of time lags between various treatments and responses were measured. Within reason, a coconut tree which has received poor treatment in the early years can be brought to high yield if good treatment is applied later.

Recognition of the Board's Policies

The organization of the Board and its development policies, with their basis on research, earned recognition both at home and internationally, with the result that aid for specific short-term problems was readily obtained. Notable amongst these was research into the cause and cure of lethal yellowing disease, for which aid was obtained from USAID. UNFAO, UKODM, and the University of the West Indies. Leaf spot was handled by UWI, and help was obtained from the Ministry of Agriculture over the recent mite problem. Assitance was obtained from ODM over certain aspects of pollen research, and a double-ended research project into vegetative propagation of coconut involving ODM and the Board's Research Department was continued for ten years. The recognition earned has involved the Board's scientists in consultancies to FAO, ODM, the International Board for Plant Genetic Resources, the South Pacific Commission, the Commonwealth Fund for Technical Co-operation, and the Governments of Mexico, Dominican Republic, and Venezuela.

Services

Nurseries have been expanded so that reliably disease resistant plant material is available year-round within a few kilometres of any farm, and plant production increased from 100,000 to 600,000 selected palms per annum. In 1966, the Board initiated a replanting scheme, also financed from a cess on the crop. This scheme provides selected plants and cash instalments to growers losing Tall palms to lethal yellowing disease. The rate of planting under this scheme in recent years exceeds 300,000 plants per annum.

The extension of information found by research to the coconut growers was obviously an essential step requiring the forging of a functional link between research and extension workers. The Coconut Industry Board is a vertically integrated organisation with all services under one roof, and transmission of information from researcher to advisory staff was facile.

The Board provides growers with markets, hurricane insurance and technical advice. In addition physical services are provided to the growers, including the supply of quality planting material, delivered to the farm, at any time of the year; agricultural chemicals (fertilizers, herbicides, rat poison) suitable for use in coconuts and also delivered to the farm; a free foliar analysis service; staff to demonstrate field techniques or to assist with them, e.g., liming, weed spraying, and fertilizer application.

Development

Development in the Jamaican coconut industry since 1945 can be summarized by a chronological list of the main events.

1945 Enactment of the Coconut Industry Control Law establishing the Coconut Industry Board, so setting the stage for future development.
1949 Enactment of the Coconut Insurance Law, enabling the industry to be protected from hurricane, and later, from disease.
1959 Initiation of Research Department.
1960 Testing of Malayan Dwarf begun.
1961 Herbicide research begun.
1962 Production of selected Malayan Dwarf seed commenced.
1962 Continuous research begun into the cause and cure of lethal yellowing.
1962 Research commenced into rat damage.
1962 Planned introductions of seed and pollen of exotic cultivars.
1963 First Coconut Industry Board nurseries set up and Malayan Dwarf seed gardens established.
1963 First experimental hybrids Produced for field testing.
1964 Initiation of Advisory Division.
1964 Rat blocks first produced for farmers, and made available to copra factories or delivered to the farm.
1964 Herbicide recommendations first made to farmers.
1964 Free foliar analysis service for growers begun.
1965 Collection of exotic cultivars with ODM aid.
1966 Enactment of Lethal Yellowing Insurance Regulations under which properties affected by disease can be rehabilitated.
1967 Collection of exotic cultivars with FAO aid.
1968 Delivery of fertilizers and herbicides to the farm first done.
1971 Planting of Malayan Dwarf exceeded half million per annum for the first time.
1971 First experiments on pollen collection by fluid bed dryer leading to mass controlled pollination.
1971 Mycoplasma-like bodies found associated with lethal yellowing.
1974 Maypan hybrid named and approved for release to farmers. Seed production commenced.

Author Index

Abdu, K.M. 16
Abdullah, I. 120-126
Abeyratne, D.J. 170, 173
Abeywardena, V. 98-106 98, 99, 106, 127
Abraham, A. 62, 66, 67
Abraham, V.A. 361-375, 368, 385, 386
Adair, D. 239, 240
Adriano, F.T. 320
Agate, A.D. 267
Ahmad, R. 358
Allen, C.F. 121
Alzina, F.I. 71
Ambuja, R. 268
Anandan, A.P. 136
Ananthanarayanan, K.P. 366, 367
Anthonypillai, G.M. 195, 198
Antony, J. 361-375, 362, 363, 364, 365, 385
Apavatjrut, P. 304
Arasu, N.T. 47, 121, 124
Arnaud, F. 407, 408
Asana, R.D. 22, 97, 106, 167, 295, 425
Ashby, S.F. 333
Aslam Ali, A. 279-283
Atputharajah, J.D. 169-179
Avasthi, P.N. 385
Azeemoddin, G. 274-278

Bachy, A. 406, 407
Bagchee, K. 326, 327
Bagchi, P. 222
Bakshi, B.K. 326, 327, 351
Balaga, H.Y. 66
Balakrishnamurti, T.S. 127-135, 129
Balakrishnan, M.S. 333
Balasubramaniam, K. 221-228, 222, 223, 226, 227, **293-295**
Balingasa, E.N. 71-81, 71, 82
Banerjee, S. 328
Bannerjee, S.N. 371
Barde, N.K. 107-113
Barrant, C. 304, 311
Baseden, S.S. 194
Bavappa, K.V.A. 44-55, 45, 48, 49
Beakbane, A. 443
Beakbane, B.A. 408, 416
Bear, F.E. 148
Beckman, C.H. 424
Bedford, G.O. 363
Betrabet, S.M. 263
Bey, P.M. 227
Bhaskaran, U.P. 106, 136-143
Bhat, J.V. 259-273, 261, 263, 264, **267**, 268, 269, 272
Bhat, N.T. 144, 273
Bilapete, G.G. 385, 386
Bisby, G.R. 326
Bist, J.S. 284, 287
Biswas, B.B. 66
Black, C.A. 116
Blair, B.P. 341
Blake, J. 304, 310
Boccardo, G. 410-414
Bond, R.L. 279
Bonner, J.T. 298
Bose, B. 302
Bose, J.C. 189, 192
Bradstreet, E.D. 189
Brasier, C.M. 338
Braun, E.J. 424
Breitfeld, H. 369, 371
Browning, K.C. 170
Brunin, C. 17, 157
Bulla, R.A. 407
Busck, A. 333
Butler, E.J. 9, 326, 333, 334, 343

Carlos, Juan T. Jr. 71, 185, **439, 464-476**
Carlson, C.W. 148
Carpio, C.B. 71-81, 71
Carter, W. 415
Cater, C.M. 240
Cecil, J.E. 231-244
Cecil, S.R. 117
Chandrasekar, N.R. 93-97
Channa Basavanna, G.P. 355
Chapman, G.P. 64

Chapman, H.K. 116
Charles, A.E. 44, 46
Chee, Y.F. 121
Cheesman, E.E. 121
Chen, E. 120-126, 124
Cherian, M.C. 367
Child, R. 64, 120, 141, 181, 227
Choudhury, D. 222
Clark, F.E. 116
Clausen, C.P. 368
Cochereau, P. 371
Cole, C.V. 130
Coomans, P. 152-159
Copeland, E.B. 71, 368
Cowap, J.C. 170
Crosier, W. 334, 338
Cuevas, Severino E. 464-476
Cumber, R.A. 363
Cutter, V.M. Jr. 66, 226

Dabek, A.J. 416, 443, 446
Dale, J.L. 418
Darwin, Charles 298
David, H. 385
Davis, T. Antony 5, 6, **296-299**, 296, 297, 298, 299, 310, 345
De Guzman, E.V. 66, **316-321**, 317
De Nuce De Lamothe, M. 23-29 38-43 57, 58, 59, 73, 75, 200, 407
De Silva, M.A.T. 195, 198, **210-219**, 210, 212, 222, 223
De Taffin, G. 407, 408
Dean, L.A. 130, 145
Deb, D.L. 144
Del Rosario, A.G. 66, **316-321**, 317
Dendy, D.A.V. 239, 240
Deshpande, A.D. 385, 386
Deshpande, S.V. 385, 386
Devaraju, C. 144
Dharmadhikari, P.R. 356-360
Dharmaraju, E. 367, 379
Dhawan, N.L. 47
Dinauger, R.C. 116
Dollet, Michel 406-409, 407, 408, 424
Donselman, H.M. 422-448
Du Charme, E.P. 423
Dube, J.F. 226
Dube, G.R. 66
Dutky, S.R. 368
Dutta, M. 66
Dwivedi, R. Snehi 143, 202, 220, 331
Dwyer, R.E.P. 86

Earle, E.S. 333
Eaton, P.M. 148
Eden, T. 127
Edwards, D.F. 121
Eeuwens, C.J. 304, 306, 309
Elizabeth, G. 362, 363, 364
Emilio, K.M. 160
Ensminger, L.E. 116
Esau, K. 424
Evans, D.D. 116
Evans, J.W. 371

Fawcett, W. 415, 442
Ferguson, J. 98
Fernando, H.E. 379
Fernando, M. 98
Fernandopulle, M.S.S. 477-484
Fiori, B.G. 369, 371
Fisher, J.B. 444
Foale M.A. 75
Foneska, W.T. 369
Frankel, F. 204
Fredholm, A. 333
Freeman, B. 66
Fremond, V. 200
Fremond, Y. 17, 73, 106, 119
Friederichs, K. 368
Fulford, R.M. 304
Fussel, D. 233

Gadd, C.H. 98, 333, 369
Gambrell, F.L. 369, 371
Gangi Reddy, N.C. 274-278
Gangolly, S.R. 313
Garrett, S.D. 349
Gater, B.A.R. 364
Geake, F.H. 170
George, Joseph. 284-290, 284, 285, 286, 287 288
George, M. 47
George, M.V. 161
Ghani, M.A. 358
Giannotti, Joseph. 406-409, 407, 408, 424
Goode, J.E. 99
Gopinath, P. 33, 66, 67, 86
Gopinathan Pillai, N. 401
Goswami, Ashok K. 254-257
Govinda Rao, P. 327, 347
Govindankutty, M.P. 420, 421-425
Govindu, H.C. 325-332, 386
Gower, J.C. 127
Green, A.H. 194
Grigg, J.L. 148
Grimwood, B.E. 239
Groves, M.J. 254

Grylls, N.E. 415, 416
Guinn, G. 213, 214
Gunawardene, K.J. 451
Guruprasad, B.K. 393-397
Gwin, G.H. 442-448
Gyrisco, G.G. 369, 371

Haddon, A.V. 121
Hagedorn, H.C. 204
Hagenmaier, R. 240
Hammel, H.T. 189
Handover, W.P. 66
Harder, R.J. 130
Hardward, M.E. 130
Haridasan, M. 115-119
Hariharasubramanian, V. 401
Harindranath, C.S. 107-113
Harland, S.C. 15, 17, 36, 49
Hasmer, P.H. 148
Hassen, T.M.F. 356-360
Hassid, W.Z. 222
Hassler, J.W. 279
Heinze, K.H. 416, 417
Heller, R. 306
Hemmingson, E. 189
Hendrix, J.W. 334
Henry, P. 42
Herstein, K.M. 176, 177
Hewitt, E.J. 211
Heyn, A.N.J. 261
Hibban, C.R. 418
Hicks, P.G. 338
Highkin, H.R. 204
Hoestra, H. 406, 407
Holmes, F.O. 345
Hoover, A.A. 222, 223, 226
Huger, A.M. 363
Hunt, P. 408, 413, 416, 443, 446
Hutson, J.C. 368

Indira, P. 421, 424]
Iyer, R.D. 291

Jack, H.W. 45, 66, 85
Jackson, M.L. 116, 145
Jacobs, M.B. 176, 177
Jaganathan, M. 194-202, 273, 331
Jaganathan, T. 433-438, 438
Jain, R.K. 288, 289
Jakobson, S.T. 199
Janaki Ammal, E.K. 62
Jansz, E.R. 170, 173
Jayalath, T.M.S. 222, 223, 226
Jayaratnam, T.J. 367
Jayasankar, N.P. 160-165, 167, 267, 268, **300-303**
Jayatilaka, P. 170
Jenson, B.N. 204
Jeyra, E.E. 170, 173
Joham, H.E. 213, 214
Johansen, D.A. 422
John, C.M. 344
Iohnson, D.G. 416
Johnston, J.R. 333
Jones, L.K. 338
Jones, L.P.M. 148
Joseph, J. 62, 64
Joseph, Thomas 333-340, 401, 421
Joshi, A.B. 47
Joshi, H.C. 284, 285, 286, 288, 289
Joy, P.J. 366
Justin, S. 304

Kalra, A.N. 385
Kamala Devi, C.B. 115-119, 117, 118, **144-151**, 210
Kamalakshyamma, P.G. 160-165
Kanagaratnam, P. 376-384
Kasturi Bai, K.V. 203-209
Katznelson, H. 302
Keitt, G.W. 338
Keshava Murthy, K.V. 325-332
Khera, Harcharan Singh 126 **485-494**, 486
Kim, K.S. 418
Kolandaisami, S. 433-438
Koshy, M.M. 145
Koyamum, K. 31, 45, 49, 85
Krishnaji, N. 9
Krishnamoorthi, C.S. 435, 437
Kulkarni, D.S. 97, 181-185, 295
Kumar, S.N.S. 326, 327
Kunjan, P.V. 45
Kunjan Pillai, N. 342
Kuntala, K.G. 264, 268, 269
Kupfer, E.M. 313
Kurian, Chandy 353, **361-375**, 362-370, 385, 386
Kushwah, P.L. 160
Kyron, N.C. 338

Lal, S.B. 344, 345
Lalitha Kumari, H. 328
Latta, R.K. 415
Lawrence, K.O. 386
Leach, J.R. 122
Leela, K. 136-143
Leeper, G.W. 148
Lehman, E.L. 298

Lela, O.B.M. 120
Lennarz, W.J. 227
Leonard, C.D. 215
Lepesme, P. 370
Lever, R.J.A.W. 364, 369, 370, 371
Lindsay, W.L. 213, 214, 215
Liyanage, A.W. 170
Liyanage, D.V. 15, 16, 34, 45, 46, 47, 57, 73, 76, 86
Lockhead, A.G. 301
Loganathan, P. 127-135, 129
Lorenzo, C.Z. 160
Louis, C. 408
Louis, I. Henry. 93-97, 293-295
Ludwig, W. 298

McCoy, R.E. 408, 411, 415, 416, 419 **442-448**, 443, 444, 446, 447
MacDonald, I. 98
McRae, W. 333, 338
Maharaj, S. 377
Mahmood, T. 326
Majumdar, N. 385, 386
Manahan, M. 320
Mandal, R.K. 66
Mantell, C.L. 279
Manthriratna, M.A.P.P. 22. 32, **56-61**, 126
Maramorosch, Karl. 342, 344, 408, 413, 416, **430-439**, 440
Marar, M.M. 136, 142
Marar, M.M.K. 47, 182, 194, 203, 208
Marchoux, G. 408
Mariau, D. 390 **392, 426-432**
Markose, V.T. 160
Martell, E.E. 213
Martin, A. 301
Martyn, E.B. 407
Marwitz, R. 416, 417
Mason, D.D. 130
Mathen, J. 385
Mathen K. 342-346, 365, 370, 385
Mathes, D.T. 129, 195, 198
Mathew, C. 313
Mathew, Jacob 15-22, 45, 48, 49
Mathew, P.M. 62, 66, 67
Mathews, P.T. 298
Mattil, K.F. 240
Menon, K. 366
Menon, K.P.V. 300, 313, 317, 334, 344, 362, 370, 385
Menon, R. 349
Menon, R.M. 32, 45
Merril, B.D. 71
Meunier J. 23-29
Milburn, John A. 189-193, 189, 190, 193
Miller, J.W. 442
Mohanram, H.Y. 291
Mohapatra, A.R. 144
Mondal, H. 66
Moore, D.P. 130
Mukherjee, A.K. 222
Mukherjee, S.N. 327
Mulivar, M.K. 117, 449
Mumford, D.L. 412
Munch, E. 192
Murashige, T. 306
Murthy, B.R. 13, 70
Murthy, R.S. 107-113

Nadarajan, L. 355
Nagabhushana, S.R. 107-113
Nagarkatti, S. 367
Naidu, G.V.B. 326, 327
Nair, M.R.G.K. 370, 375, 391, 438
Nair, P.N. 64
Nair, R.B. 186-188, 313-315
Nair, U.K. 344
Nambiar, C.K.B. 144-151
Nambiar, K.P.P. 45, 36, 47
Nambiar, M.C. 7, 45, 46, 47, 50, 62, 64, 66, 67, 313
Nambiar, T.V.P. 245-253
Nambudiri, A.M.D. 261, 263, 268, 269, 272
Nampoothiri, K.U.K. 16, 17, 45
Napitupulu, W.P. 233
Narasimhan, M.J. 329
Natarajan, P. 361-375
Natarajan, S. 434, 435, 436, 437
Nathanael, W.R.N. 222, 223, 227
Nelliat, E.V. 9, 89, 97, 106, 160, 295
Nethsinghe, D.A. 131, 132, 133, **195, 196**, 197
Newhauser, W. 386
Ng, S. K. 122
Niemczyk, H. D. 386
Ninan, C. A. 15, 16, **30-37**, 32, 33, 34, 44, 49, 50, 51, 54, 62, 64, **66**, 67, 86, **88**, 312, 340, 405
Ninan, Sunny. 220
Nirula, K. K. 353, 362. 366, 367, 368, 369, 385, 425, 440
Noordam, D. 403
Norin, J. P. 426-432
Norvell, W. A. 213, 214, 215
Nutman, F. J. 407

Obi Reddy, T. 274-278

Ohler, J. G. 160
Ollagnier, M. 407, 408
Olsen, R. V. 148
Olsen, S. R. 130

Padmanabhan, V. 182
Pancho, J. V. 66, 67
Pandalai, K. M. 86, 136, 142, 187, 203, 208, 313, 317, 334, 370
Pandey. P. C. 327
Pandit, S. V. 347-351
Pankajakshan, A. S. 15, 16, 32, 33, 38, 47, 67, 86
Paparao, A. 327, **347-351**, 347
Park, M. 98, 136
Parthasarathy, M. V. 189, 408, 415, 416, 424, **441**
Patel, J. S. 45, 86, 136, 141, 142
Pereira, P. A. C. R. 356-360
Personius, K. K. 386
Petch, T. 333
Pethiyagoda, U. 169-179, 180, 209, 220
Petzold, H. 416, 417
Phang, C. I. 121, 124
Pikovskaya, R. I. 301
Pillai, G. B. 361-375, 362, 363, 364, 366, 367, 368, 384, 391
Pillai, N. G. 5, 6, 117, 118, 144-151, 160-165, 187, 210
Pillai, N. Gopinathan, 342-346, 345
Pillai, R. V. 62, 64. 142, 181, 184
Plavsic-Banjac, B. 408, 413, 416, 443
Posnette, A. F. 408, 416, 443
Potti, V. P. 160-165
Potty, V. P. 300-303
Prabhu, G. N. 258, 264, 268, 269
Prasannakumari, T. O. 64
Premaratne, I. G. 170, 173
Prevot, P. 117
Price, W. C. 410, 411, 412
Puri, S. N. 385, 386

Quarmby, A. 233
Quillec, G. 426-432

Radha. K. 160-165, 161, 300, **333-340, 342-346**, 362, 399
Rafols, A. G. 66, 316-321
Rajagopal, V. 144
Rajasekharan, W, 239
Ramachander, D. 278
Ramadasan, A. 421, 424
Ramadasan, K. 120-126, 124, 126, 143, **203-209**, 220
Ramakrishnan, K. 399
Ramakrishnan, T. S. 333
Ramasami, R. 433-438
Ramayya, D. Atchyuta. 274-278
Ranaweera, D. J. W. 369
Randles, J. W. 410-414, 411, 413
Ranganathaiah, K. G. 386
Rangaswamy, G. 302, 323, 332, 340
Rao, A. N. S. 325-332
Rao, B. V. 263, 268
Rao, C. H. 181
Rao, C. V. N. 222
Rao, M. B. S. 31, 45, 49, 85
Rao, M. R. N. 126
Rao, R. N. 106
Rao, Y. R. 367
Raodeo, A. K. 385, 386
Rasa, E. A. 424
Ratnam, T. C. 45
Raveendranath, T. G. 62, 64
Ravindran,P. N. 62-70
Ray, P. K. 220
Reddy, B. R. 278
Reddy, M. A. R. 327
Remamony, K. S. 370
Renard, J. L. 426-432
Rewther, T. S. S. 300
Rillo, Erlinda P. 410-414
Rishbeth, J. 350
Roberts, D. A. 442
Roberts, F. M. 407
Rodrigo, P. A. 160
Rognon, F. 23-29, 38-43, 57, 58, 59, 75, 76
Romney, D. 442
Romney, D. H. 304, 311, **495-500**
Rosenquist, E. A. 121
Rovira, A. D. 302

Sachdev, M. S. 144
Sadanandan, A. K. 186-188
Sahasranaman, K. N. 160-165, 366
Sakai, K. I. 46, 47, 73, 76
Salgade, M. L. M. 127
Salter, P. J. 99
Samarajeewa, U. 169-179, 180
Samogyi, M. 204
Sands, W. N. 45, 66
Sankaranarayanan, M. P. 118, 229
Sannamarappa, M. 326, 327
Santhirasegaram, K. 160
Santos, G. A. 71
Santos, J. K. 62
Sarangamath, P. A. 181-185
Sarkar, A. 328
Sarkar, S. K. 62, 67
Sarma, Y. R. 340

Sasikala, M. 401-405
Sathiamma, B. 365
Satyabalan, E. 142
Satyabalan, K. 13, 15-22, 32, 33, 34, 35, 36, 45, 49, 50, 51, 54, 64, 67, 85, 86, 88, 181
Satyanarayana, B. 347-351
Scher, M. 227
Scholander, P. F. 189
Schuiling, M. 416, 443, 446
Schwabe, W. W. 304-312, 304, 312
Selvaraj, S. C. J. 364
Sentheshanumuganathan, S. 170
Seymore, C. P. 442
Shanta, P. 323 **401-405**, 401, 404, 420, 421
Shantappa, P. B. 181-185
Shantha, P. 345
Shapiro, A. H. 298
Sharma, A. K. 62, **67**
Sharples, A. 333
Shaw, E. 145
Shaw, F. J. 333, 338
Shekhar, P. S. 369, 385
Shepherd, R. 122
Sherman, C. D. 148
Shetty, G. D. 279
Shetty, K. S. 302
Shirsalkar, M. M. 284, 285, 286
Shivaprasad, C. R. 107-113
Simmonds, F. J. 371
Simmonds, H. W. 363, 364
Singh, S. 327
Sinclair, W. A. 424
Sinnathamby, S. V. 356-360
Sirsi, M. 328
Skoog, F. 306
Slater, C. H. W. 408, 416, 443
Smith, R. W. 194, 304, 311
Smith, Roger 304
Smoluchowski, M. 255
Sockalingam, T. 121
Solomon, J. J. 401-405, 405
Somogyi, M. 222
Sothary, R. D. 222
Soudant, C. 408
Soumini, C. K. 333
Southern P. J. 194
Sperber, J. I. 302
Sreenivasan, A. 239
Srihari, K. 393-397
Srinivasan, H. R. 164
Steenbjerg, F. 199
Steiner, K. G. 408
Steinhaus, E. A. 363, 365
Steward, F. C. 309
Steward, I. 215
Stockdale, F. A. 333
Suah, J. R. 415
Subramanyam, K. 347-351
Subramanyan, V. 181, 229
Sukumaran, C. K. 44-55, 45, 48, 49, 187
Sumbak, J. H. 82-84, 83
Sundararaman, S. 333, 338
Sunny, A. F. 160
Surany, P. 363, 364
Swaminathan, M. 181
Swaminathan, M. S. 3-11, 50, 62, 64, 66, 67
Swelley, C. C. 227
Symons, C. T. 170

Tammes, P. M. L. 86, 190
Tan, Koonlin 326
Tashiro, H. 369, 371
Tashiro, N. 386, 387, 389
Taxton, R. H. 301
Taylor, T. H. C. 357, 359, 370, 371
Tendolkar, G. S. 279
Teoh, K. C. 120-126
Teotia, T. P. S. 385, 386
Thakoor, N. R. 279
Thampan, P. K. 232, **453-463**
Thankamma Pillai, P. K. 62-70, 64
Thieme, J. G. 232
Thirumalachar, M. J. 329
Thomas, D. L. 415, 416, 438, 443
Thomas, K. J. 66
Thomas, K. M. 85-89, 89, 119, 151, 244, 331, 333, 340, 438
Thompson, B. E. 60
Thompson, D' Arcy 298
Thorold, C. A. 334
Timmins, W. H. 231-244 239, 240, 244
Tomlinson, P. B. 189, 422
Torres. J. P. 316
Trirmalarao, S. D. 274-278
Tsai, James H. 415-420, 416, 420
Tucker, C. M. 333
Turner, P. D. 122, 237

Upadhaya, M. D. 62

Vago, C. 408
Van den, Driessche 194, 199
Van der Schaf, P. 386, 387
Van Die, J. 190
Van Regenmortel, M. H. V. 403, **404**
Van Slobbe, W. G. 408
Vanialingam, T. 120-126, 124
Varadarajan, P, 268

Varkey, Thomas 160-165
Veeresh, G. K. 126, **385-391**, 385, 386, 390, 391
Velayutham, M. 91, **115-119**, 119, 438
Vellaichamy, K. **421-425**
Vankataraman, A. 449
Venkataraman, K. 64
Venkataraman, T. V. 363, 364
Venkatarayan, S. V. 326, 328, 329, 347
Venkatasubban, K. R. 62
Venkatesan, R. 302
Venkita Subbaiı, C. S. 364
Venugopal, K. R. **107-113**
Verghese, E. J. 181, 194
Verghese, T. 145
Vijayakumar, G. **62-70**, 64
Vijayan, K. M. 434, 435, 436, 437
Vold, R. D. 254

Wahid, P. A. 117, 118, **144-151**, 144, 210
Walksman, S. A. 302
Watanabe, F. S. 130
Weststeijn, G. 407
White, J. L. 116
White, P. R. 306
White, R. T. 368
Whitehead, R. A. 45, 46, 60, 64, 67
Wijeratne, N. C. P. 169-179
Wijesundera, S. 222, 223, 226
Wilcox, L. V. 148
Williams, L. V. 60
Wilson, K. S. 66, 226
Wolanski, B. 418
Wong, I. F. T. 121

Zelazny, B. 363
Zimmermann, M. H. 189, 190
Ziller, R. 73, 117, 200, 203
Zinter, D. 386
Zinter, M. 386
Zuniga, L. C. 316

Subject Index

Aceria (Eriophyes) *Guerreronis* 392
Actinomycete 301
Agapostemon/ Splendens 417
Allelopathy 8
Allograpta/Cubana 417
Ambakelle 56, 57
Amitosis 66
Ammalo, insulata 383, 384
Ananas (*Comosus*) 121, 466
Anatomy Cortex 422
Anatomy DNA in phloem cells 407
Andaman and Nicobar Islands 10, 313
Andhra Pradesh-India 347
Angochlora/Pura 417
Antigen 403
Antiserum 402, 403, 404
Apis/indice 57
Apis/mellifera L 417
Apium graveolens 415, 418
Arachis/hypogla 468
Area under coconut in India 455
Area under coconuts in Malaysia 486
Area under coconuts in Sri Lanka 477
Arecanut 327
Arthropod vectors 415
Aspidiotus/destructor 356-360, 370
Asymmetry, foliar 296-299
Autodiploid 50
Avena sativa L 416

Bangalore districts (Karnataka) 107
Basidiospores 327
Bedford, G.O. 363
Biochemical changes 221-220, 225
Biological control 361-372
Biological control exotic natural enemies 358
Blair, B.P. 341
Breeding behaviour 72
Breeding objectives 45
Breeding systems 45
Breeding value 16, 17
Black pod of cacao 334
Boards from coconut pith 287, 288
Botryodiplodia 9
(Brachiaria mutica) 469
Bubia (New Guinea) 83
Building meterials from retted pith 284 - 289
By-products 248, 284-289
By-products, air filters 258
By-products, coconut flower 247, 248
By-products, coconut honey 247
By-products coconut milk 63, 66, 246
By-products, coconut proteins 247, 457
Yield 248
By-products, coconut water 66, 246
By-products, cooking gas 248
By-products, desiccated coconut 478, 479
By-products, food products 457

By-products, husk particle boards 285-289
By-products, panel materials 288, 289
By products, particle boards 284-289, 285, 287
By products, rugs 258
By-products, shell carbon 248
By-products, utilization of 284-289, 455

CPCRI 8, 9, 10, 36, 64, 67, 161
Cacao cultivation effect 122
Cacao, intercropping in Malaysia 120-125
Calvin cycle pathway 4
Callistephus chinensis N 415, 418

Cameroun 406 452
(*Capsicum/annum*) 468
Car Nicobar 313
Carbohydrate change in 223
Carbohydrate contents in leaves 203, 206
Carbohydrate, fractions 208
Carbohydrate, level changes 203-209
Carbohydrate, metabolism 221
Carbohydrate seasonal changes 204
Carbons activated 279-283
Caribbean Islands—Jamaica 441, 452
Catharanthus/roseus Don 415, 416
Centrosema/pubescens 161, 469
Ceratocystis paradoxa 329
Ceylon Coconut Research Board 480
Chilocorus/nigritus L 356, 357
Chromosome Centromere 62, 63
Chromosome Satellited 62
Chilocorus politus 370
Cockchafer beetle 368-369
Coconut Cultivation Board, Sri Lanka 482
Coconut development
India 460-463
Philippines 464-473
Sri Lanka 477
Coconut Fibre Board and Development of Coconut Rehabilitation 480
Coconut in Tamil Nadu (India) 93-97
Coconut Industry Board Jamaica 495
Coconut industry, Philippines 464
Coconut Marketing Board, Sri Lanka 482
Coconut oil 247, 274-278
Coconut oil cake 457
Coconut Oil Specifications 275
Coconut oil uses 277
Coconut oil yield 248
Coconut Processing Board Sri Lanka 482
Coconut, research 3-11
in India 460-463
in Philippines 464
in Sri Lanka 477, 479
Coconut Research Board Sri Lanka 482
Coconut Research Institute Sri Lanka 56, 480
Coconut products, Consumption pattern 458
Coir fibre 184,248 259-272, 470
Coir fibre Brown fibre 258
Coir fibre Carpets 258
Coir fibre Extraction 260
Coir fibre Foot mats 258
Coir fibre Mattings 258
Coir fibre, pith 279-283
Coir fibre products 436
Coir fibre white fibre 258
Coir fibre Yarn 484
Collar girth 15, 16, 17, 18, 93, 94
Colocasia esculentum 468
Combining ability 38-43
Companion crops 466, 467
Constraints analysis 7
Constraints biophysical and technological 7
Constraints socio-economic 7
Contheyla rotunda H 369
Copra 24, 40. 456, 465, 478, 479
Copra Composition 183
Copra content 30, 47, 48,
Copra, making 470
Copra Mineral content 184
Copra Moisture content 182
Copra, prices 120
Copra, process 251
Copra, processing in Malaysia 488
Copra, production of 77
Copra, production in Malaysis 487
Copra varietal differences 181-184
Copra, weights 36, 41, 182
Copra yields 31, 32, 77, 123, 124, 153
Crop canopy 8
Cropping systems 9, 125, 466
Cropping systems in the Philippines 464
Cropping systems Intercropping with Fodder grasses 160, 161, 162
Cross fertilization 8, 45, 52, 78, 85-88
Crossing natural 67
Crossing plan 39, 40
Cryptognatha/nodiceps Mohl 370
Cultural operations in coconut gardens 93, 94
Cultural operations effect on Root Systems 293-295
Cultivars Makapuno 62
Cuscuta campestris 415, 416
Cytochemical studies 407
Cytology Coconut 62, 67
Cytology of abnormal palm 64

Darna trima 467
Dead sprouts 87
Delphacidae 431
Detection, root (wilt) disease 401-405
Development Bank of the Philippines 471
(Dicanthium aristatum) 469
Diseases Anabe roga 325-330
Diseases Betelnut plague 326
Diseases, blast 426, 429, 430
Diseases, Bronze leaf wilt 441
Diseases Bud rot 333-338, 469
Diseases, Cadang - Cadang 45, 410-414, 469
Diseases Chemotheraphy 411
Diseases Coconut decline 10
Diseases Control with antibiotics 329, 330 411
Diseases Control methods 426, 432
Diseases Coronie wilt 441
Diseases Curvularia infection 427
Diseases Diplodia infection 427
Diseases Disease index 434
Diseases lodder transmission 415
Diseases *Drechslera incurvata* 82, 83, 84
Diseases Dry bud rot 426, 427, 429, 430
Diseases Effect of mixed farming 160-165
Diseases epidemiological studies 407, 434
Diseases *Erwimia* sp 334, 336
Deseases Fomes lucidus (Leys) Fr. 326
Diseases Fungal diseases 325, 433
Diseases *Fusarium roseum* 427
Diseases *Fusarium sp.* 336, 337
Diseases *Fusarium solani* 427
Diseases *Ganoderma lucidum* 325-330, 328, 347-351, 433, 434
Diseases Ganoderma wilt disease 325-350, 347-351
Diseases general 323
Diseases Heart rot 44
Diseases Histopathology of 421-424
Diseases in India 326
Diseases in middle Ivory coast 426-432
Diseases Kaincope 407, 408
Diseases Kerala wilt etiology 439
Diseases Leaf spots 469
Disease Lethal yellowing 4, 408, 413, 439, 441, 442-448
Diseases Lethal yellowing control 442-448
Diseases Lethal yellowing in Jamaica,4,45
Diseases Mushroom disease 325, 433
Diseases Mycoplasmal etiology 408, 416
Diseases Red ring 341
Diseases *Rhizoctonia/batatícola* 427
Diseases root rot 9
Diseases Thanjavur wilt 435-437
Diseases of uncertain actiology 30, 49, 399
Diseases of seedling 17, 430, 431
Diseases Phythium splenders 427
Diseases *Polyporus* (*Fomes*) *lucidus* 326
Diseases Prophylactic treatment 442-448
Diseases *Pseudomonas* sp 334, 336
Diseases resistance 10
Diseases resistance to blast 430
Diseases Root disease 342-345
Diseases Root (Wilt) disease 4, 9, 10, 44, 45, 220, 349, 401-405, 421-424, 342-345, 350
Diseases Root (Wilt) disease terminology 342-345
Diseases Shading effect 429
Diseases *Thielaviopsis* sp. 338
Diseases Viroid etiology 410-414, 439
Diseases Wilt disease 4, 9,10, 342-345, 433-437
Diseases Yellow Disease 406-409
Diseases Yellow mottle decline 410
DLVO theory 254
Dorymyrmex pyramicus 417
Drought index 99, 100, 102
Droughtiners 98, 99, 100, 102, 103, 104, 105
Dry matter production 4, 6

Electrotyters effect 255
Emasculation 58, 59
Embryosac 64
Empryo 16
Endocarp 59
Endosperm 16, 24, 28, 38, 59, 62, 66, 221-226
Endosperm cytology 62, 64

Farming systems Coconut/cattle farming 469
Farming Coconuts with Cacao 120-125
Farming systems Inter-Cropping 8, 10
Farming systems economics of mixed farming 160-165
Farming systems Intercropping with Coffee (Coffea sp) 121-466
Farming systems Intercropping hybrid napier and coconut palm 300-302
Farming systems Intercropping in Malaysia 120-125
Fermentation analytical characteristics of controlled fermented sap 176
Fermentation controlled 172, 174, 178

Fermentation, effect of fentonite 175
Fertilization self 71, 78, 85
Fertilization cross 8
Fertilizers bicalcia phosphate 154
Fertilizers muriate of potash 94, 127, 128, 129, 130, 131, 132
Fertilizers phosphate fertilizers 302
Fertilizers potassium chloride 152, 154, 157
Fertilizers rock phosphate 127
Fertilizers saphos phosphate 128, 129, 130, 131, 132
Fertilizers sulphate of ammonia 94, 116, 127, 128, 130, 131, 132
Fertilizers superphosphate 94, 116
Fertilizers urea 152, 154
Flowering Female, 58, 137, 315
Fiji 455
Florida (USA) 415, 417, 442
Flowering 17, 77, 317
Flowering Female phase 77, 78, 79
Flowering fertilizer effect 155
Flowering floral biology 45, 316-320, 317, 319
Flowering Interspadix overlapping 45, 46
Flowering Male flowers 58, 316
Flowering Male phase 77, 78, 79
Foliar yellowing 145, 160, 150, 162, 443
Fruits Fruit set 141
Fruits of *in vitro* palms 316-320
Fruits of sterile coconut 313-315
Fruits Mesocarp 59
Fumigation 355
Fungicides 329, 348, 436, 437
Fungicides Bordeaux mixture 433

Gap analysis Management gap 7
Gap analysis Research gap 7
Gene action Epistatic 51
Gene erosion 10
Genetic potential 71-80
Genetic resources 5, 10
Genetic variability 8, 51, 71
Genetics of colour CDO WCT 52, 53
Genotypes
general 38
Genotypes high yielding coconut 115, 119
Germination 221-228, 225
Germination in CDO×WCT crosses 52, 54
Germination rate 86
Germplarm collection 452
Ghana 406
Grater blades Bycycle 236, 237, 238
Graters 231, 232, 233, 237
Grating systems 231
Grating tools 231
Green manuring
Glyricidia maculata 121
Growth early stages 15
Growth measurements 84, 216
Growth of coconut 122
Growth of inflorescence 307
Growth of leaves 209, 307
Growth of stem 307
Growth rate 15
Gulf of Guinea 406

Haploidy 64
Harvest index 4, 5, 8, 75
Harsan-district (Bangalore) 107
Heritability 46, 48
Heterozygous segregants 54
Hexaploid 66
Histopathology of roots 421-424
Holotrichia serrata 385
Honey 247, 248
Husk 258, 284-289, 360, 436
Husk residual content 270, 271
Husk retting 268, 269
Husk retting chemistry 266, 268
Husk retting microbiology 261
Husk retting process 260
Hybrids natural hybrids 30, 33,
Hybrido seed production 82
Hybridizations Natural crossings 67, 85

Idioderma/*Vireseens* (Van Duzee) Membracidal) 417
Improvemet by breeding 44-54
Improvement by selection 44-54
in vitro method of propagation 320
Inflorescences 58, 64, 77, 80, 86, 98, 304, 407, 408, 411, 416, 417
Inbreeding effect 48 62, 64, 66, 67, 77
Inbreeding by self pollination 76
Index leaf 115
India coconut development 453-463
India Coconut Diseases 326
Indonesia 455, 492
Input supply 7
Insect vectors 57
Insect pathogens 380
Insect populations 426, 431
Insect traps 377
Insecticides 377, 341
Interculture effect 93-97
Iron effect of 217
Irrigation 100, 102, 196, 198, 200, 433

Irrigation effect 93-97
Irrigation effect on root system 293-295
Irrigation effect on yield 96-102
Irrigation trial 435
Ipomea batatas 467, 468
Ivory Coast 36, 57, 58, 82 452
Manuring 152-159

Jamaica 10, 45, 415, 417
Research and Development 495-500

Kerala (India) 88, 136-143, 144-151, 160
Keravat (New Britain) 83
Karnataka (India) 107-113, 385-389
Karyomorphology 62
Karyotypes 63
Kernel 222, 231-243, 239, 246
Kernel development 141
Kernel fresh 239
Kieserite 152, 154, 157
Koch's postulates 9

Laccadive small 36
Lakshadweep 10
Lansium domesticum 467
Leaf analysis 196, 197
Leaf position 194
Leaf production 15, 16, 17, 18, 19
Leaf splitting 8
Leaves ribbing 401
Legumes 160, 161, 469
(*Leucena, latisiliqua*) 469
Leucopholis coneophora B 368-369, 347
Levuena/iridisuns B. Bak 371
Limestone 122

Macroplectra nararia 369
Macrosteles fascifrons 415, 416, 418
Magnesium deficiency 194-201 195
Magnesium manuring 157, 158
Malaysia 10, 85, 161, 451
Malaysia intercropping 120-125
coconut industry 485-493
Magnesium nutrition 194-201
Manganese effect of 217
Manganese nutrition 210-218, 215
Manitot utilissima 467
Mannan synthatase assay 223
Mannans, biosynthesis of 226
Mannan synthesis 224, 227
Mannitol 173
Manuring effect on root systems 293-295
Manuring fertilizer recommendations 128
Manuring fertilizer requirements in Sri Lanka 127-135
Manuring fertilizer trial 435
Manuring foliar absorption 220
Manuring foliar diagnosis 125, 194-201
Manuring High yielding coconut genotypes nutrition of 115-119
Manuring in Ivory Coast 152-159
Marketing in Malaysia 488
Manuring effect 430
Manuring manurial trials 435
Manuring of hybrid coconut 152-159
Manuring organic manurial trial 435
Manuring rate 154
Manuring requirements 122-152
Marketing 7
Marketing in Malaysia 492
Marketing of products 470
Maternal effects 8
Maturation 221-228, 225
Maturity of nut 141
Mechanical composition of soil Karnataka 111
Meiosis irregularities 62
Meiosis meiotic behaviour 64
Meiosis meiotic studies 64
Meteorological factors 334, 335
Microclimate 334, 335
Microflora 178, 300-302
Microffora Rhizosphere 301, 302
Microflora Root zone 300-302
Micro nutrients 307
Micronutrient deficiencies 407
Micronutrients status 144-151, 147
Middle Ivory Coast diseases of coconut 426-432
Moisture stress effect on yield 96-102, 99
Monocrop 120
Mother palm selection 46, 47
Musa/balblsiana 121, 466
Mutalion 64
Mycoplasma 406, 408, 411, 439

NPK Fertilizers application 127
NPK fertilizers effect of 117
NPK fertilizers experiments 129, 130
NPK fertilizers nutrition 116, 221, 302
Nematode infection 341
Nematode lesions 423
Nephantis/serinopa 355, 365-368, 463
Nitrogen fixing bacteria 301
Nitrogen nutrition 122, 306
Nuclear division 62
Nuclear fusion 66

Nucleic acids 410, 411
Nursery 15, 462
Nursery diseases 426-432, 428
Nursery practices in Philippines 464, 466
Nutrient content of leaves 161
Nutrition iron in coconut leaves 210
Nutrition iron nutrition 210-218
Nutrition of coconut seedlings 210-218
Nutrition mineral 152
Nutrition nutrient level 118
Nutrition nutrients in leaf 200
Nutrition of high yielding coconut genotypes 115-119
Nutrition of seedlings 21, 218
Nutrition of coconut palm 194
Nutrition phosphate 122
Nuts, barren 313-315
Nuts characters 137, 140
Nuts components analysis 23
Nuts component characters 75, 76
Nuts composition 24
Nuts fruits 24
Nuts production 23, 73, 320
Nuts varietal difference 181-184
Nuts yield 30
Nutifall immature 98

Off types natural 49
Off-type progenies 86
Oil 247, 274-278
Oil content 41, 66
Oil coconut oil 3, 458
Oil emulsion 254
Oil export from Malaysia 487
Oil extraction 240, 242, 243
Coir fibre processing 260
Oil in copra 47
Oil palm 28, 121
Oil palm kernel oil 274-278
Oil palm oil 28, 274-278, 486
Oil production 3
Oil variation in content 42
Oncometopia/nigricans 415, 416, 418
Operational research projects 7
Optimum management 6
Oryctes/rhinoceros L 362-365
Oryza sativa 302, 467, 486
Outcrossing 51
Ovule 64
Oxytetracycline use for lethal yellowing 442-448

Pachodynerus/erynnis 417
Pachytene analyses 64
Packaging materials 258
Package programme 461
Panicum maximum 469
Papua New Guinea 82-84, 455
Paradasynus rostratus 370
Parasa/lepida 370
Parasites 379
Parasitism 328
Pearl mitlet 302
Penicillin 411
Pestalotia 427
Pests control 361-372
Pests control in Sri Lanka 376-384
Pests general 352
Pests lace wing bug 370
Pests leaf-eating caterpillar 365-368
Pests leaf hoppers 416
Pests management 469
Pests Melolonthine beetles 385
Pests Red palm weevil 134, 368, 469
Pests Rhinoceros beetle 362-365, 469
Pests Root grubs 385-389
Pests Slug caterpillars 369, 469
Pests white grubs 385-389
(*Phaseolus aures*) 468
Philippines 45, 71, 160, 451
  disease unknown etiology 410, 413
  coconut research 464-473
  coconut development 464-473
Philippine Council for Agriculture and Resources Research (PCARR) 472, 473
Phloem 424
Phloem sap 418
Phloem sap exudation 190, 192
Phloem tissues 423
Photosynthesis efficiency 4
Phyllotaxy 296, 297
Physiology 167, 189, 191
Phytophthora/Palmivora 333, 334, 336 337
Plant protection 7
Planting pattern 39, 124
Plantlets 45
Ploidy 62
Polistes/fuscatus 415
Pollen 38, 40, 57, 86
Pollen fertility 63
Pollen parent effect 42
Pollen parents 57, 60
Pollination 39
Pollination 33, 49
  open 64
Pollination open-pollinated seednuts 16, 85
Pollination progency seedlings 15

Pollination technique 86
Population evaluation 26
Port Bouet (Ivory Coast) 23, 38, 57, 153
Port-harvest technology 4, 7, 10
Potassium manuring 158
Potassium nutrition 122, 157
Potato spindle tuber viroids 410
Predator distribution 360
Predators 357, 380
  breeding of 358
Prepotency Genetic value 15
Prepotent palms identifications 15-22
Production nuts 73
Production stability 4
Productivity 3, 7, 454
Progeny rows 34
Promecotheca/cocruleipennis 371
Promecotheca/cumingi 371
Propagation rapid techniques 10
Propagation vegetative 45
Proteins 240, 247
Proteins in coconut 246
Protozoa (Trypanosomatidae) 408
Pruning 122, 224
Pueraria Javanica 161, 432

Quarantine 20

RNA 410, 412, 413
RNA anomalous association 410-414
RNA pathogens 410
RNA transmission 412
RNA species 411, 412
Radioactive phosphorus 220
Radopholus/similis 421
Rainfall 137, 141, 208
Randomized block design 100, 116
Relative humidity 334
Replanting 471
Replanting programme in Philippines 464
Replanting VI Rehabilitation Scheme in Malaysia 491
Research in Jamaica 495-500
Research problems 3
Residual effects 104
Retting Bacterial flora 262, 264, 265
Retting yeast flora of 263, 264
Rhadinaphelenchus cocophilus 341
Rhizosphere 300, 302
Rhynchophorus/ferrugineus F 58, 368
Rodents control 393-397
Rodents damage 393-397
Roguing 57
Roots anatomy 421
Roots cells 62
Roots culture of 304
Roots damage 422
Roots development of 293-295
Roots infected plants 408
Root, systems development 293-295
Roots tissues 304
Rubber 121, 486

Seeding selection 35, 36
Seedling vigour 15
Seedlings hybrid 85, 88
Segregation
  in CDO 50
  in WCT 49
Segregants 48, 49
Selection of mother palms 46, 48
Selection of seed parents 33
Selfing 46
Serological test 401-405, 402
Serratia/marcescens 469
Shell carbon 248
Shell products 458
Shell 24
Seed parents selection 33
Seed programme in Papua New Guinea 82
Saccharomyces strains 170
Saccharum officinarum 468
Sap 169, 178, 404
Sap concentration 191
Sap pressure 191
Sassandra cast (Ivory Coast) 152
Schistose rocks 108
Seasonal variations 140
Seed coconuts 85-88
Seed gardens 56, 57, 58, 462, 471
Seed parents 56
Selection pressure 48
Sodium dodecyl sulphate 254-257
Soil amendment trials 436
Soil analysis 108, 115-119, 144, 153
Soil bacteria 162
Soil chemical characteristics of Karnataka soils 111
Soil colour 109
Soil insecticides 388
Soil microflora 161, 349
Soil nutrient status 118, 160
Soil structure 109
Soil texture 109
Soil types 109, 144-151, 403
Soils acidic 210
Soils alluvial 107, 121, 145-149
Soils clay alluvial 120, 403
Soils clay 128

Soils coastal sandy 145, 149
Soils, coconut garden 107-113
Soils, colluvio-alluvial 107, 113
Soils laterite 145, 149, 403
Soils lateritic gravels 128
Soils lateritic loams 128
Soils loams 128
Soils Morphological characteristics of Karnataka soil 109
Soils Bangalore district 113
Soils of Karnataka 107-103
Soils of Tumkur districts 113
Soils physico-chemical properties 146
Soils quartzites rocks 108
Soils reclaimed marshy 145-149
Soils Sandy loam 100, 145-149
Solanum melongena 468
Solar radiation 209
Solomon Islands 83
Solvol process 246-253, 251
Sorbitol 173
(Sorghum vulgare) 468
Spadix abortion 137
Spadix development 136, 142
Spadix growth analysis 141
Spadix production 137
Spangbergiella sp 415, 416, 417
Spathes 58, 77, 86, 98
Spatial isolation 57
Spikelets 58
Spiroplasma 439
Split plot design 93
Spores 424
Sporophore 327, 330
Spraying 432
Sprouts death 51
Sri Lanka 46, 56, 57, 58, 59, 96-102, 127-135, 356-360, 376-384, 455, 477-484
Stability of production 4
Stability of coconut oil in water emulsion 254-257
Stability of yield 8
Starch contents in leaves 206
Starch seasonal changes 204
Stephanitis typicus 370
Sterlity 64
Stylosanthes/gracilis 161, 469
Sugars Fructose 173
Sugars Galactose 173
Sugars Glucose 186-188
Sugars Glucose content Tall and Dwarf coconut 187
Sugars Glucose Variation 186-188
Sugars in coconut sap 170
Sugars Lactose 173
Sugars maltose 173
Sugars nucleolide effect 226
Sugars reducing determination 222
Sugars Seasonal changes 205, 207
Sugars Sucrose 173
Sugars total sugars determination 222
Sulphur nutrition 194-201
Sunshine hours 137, 308
Super palm 5, 6, 7
Surinam 441
Survey plantation in Kerala 144

Tamil Nadu (India) 93-97, 329, 433-437
Temperature 108, 137, 170, 309, 334, 355
Tefracycline 411, 442
Tetranychus tumidus 15, 416, 417, 418
Thailand 451, 455
Thanjavur district (Tamil Nadu) 433
(Thosea/sinensis) 369, 469
Tillage 466
Tissues culture 304, 305
Toddy 171, 178
Toddy Fermentation of 171, 173
Toddy, fermentation characteristics 169-179
Toddy microflora 170
Toddy natural fermentation 173, 177, 178
Toddy sweet 178
Toddy yeast types isolated 169-179
Togo 406
Trichoderma/viridae 330
Trinidad and Tobago 455
Triploid 66

USA 189
Ultrastructural studies 408

Variability genetic 8
Variability in nut production 74
Variability in populations 74
Variability for yield components 74
Variability nut component characters 76
Variance component analysis 47
Variance tests 85, 88
Variation in rainfall 138
Varietal trials 82-84
Varieties Andamans 186-188
Varieties Andamans Dwarf 183
Varieties Apriwt 64
Varieties Baga-Oshiro 72, 73
Varieties Baybay 72, 73, 80
Varieties Bilaka (Javanica) 465
Varieties CRIC 65 Typica × Pumila 482
Varieties CRIC 60 *Typica* × *Typica* 482
Varieties Chavakadu Dwarf Orange
Indian Dwarf Orange 8, 44, 46, 48, 51

Varieties Chavakadu Dwarf Green 8 also Indian Dwarf Green 63
Varieties Cameroon Red Dwarf 38, 39, pollen 40, 41
Varieties Chowghat Dwarf Green (C.D.G) 46, 63
Varieties Chowghat Dwarf Orange West Coast Tall 203, 204
Varieties Chowghat Dwarf Orange 44, 46, 48, 63 (CDO)
Segregants-50
Varieties Coconino (Nana) 465
Varieties differences in nut and copra characters 181-184
Varieties Dwarf 7, 30, 46, 58, 62, 64, 66, 71, 74, 121, 123, 124
Varieties Dwarf × Gazelle Tall 82
Varieties Dwarf × Rennel Island Hybrid 82
Varieties Dwarf × Tall Hybrids 8, 30, 31, 32, 34, 36, 64, 86, 87, 115
Varieties Dwarf × Tall Cross 85-88
Varieties Dwarf × West African Tall 82
Varieties Dwarf Green 31, 45, 48, 59, 64, 85
Varieties Dwarf Ivory Yellow 57
Varieties Dwarf Orange 31, 36, 45, 64, 85, 86
Varieties × T Hybrids Dwarf Orange 33, 36
Varieties Dwarf Pollen 58
Varieties Dwarf Progenies 56
Varieties Dwarf Populations 72, 77, 80
Varieties Dwarf pure 59
Varieties Dwarf Red 64
Varieties Dwarf seed 30, 56
Varieties Dwarf seedlings 35
Varieties Dwarf Spicata 465
Varieties Dwarf types 8
Varieties Dwarf yellow 8
Varieties East Coast Tall 94
Varieties environmental variabilities 203-209
Varieties environmental variabilities in Tall palms 203-209
Varieties Equatorial Guinea Green Dwarf × WAT 153
Varieties Gazelle Tall (GT) 83
Varieties Ghana Yellow Dwarf × West African Tall 153
Varieties Green Dwarf × WAT 430
Varieties Gangabondam 183
Varieties Green Dwarf 38
Varieties Hybrids 60, 86, 158, 159
Varieties Hybrid manuring 152-159
Varieties Hybrid napier 161, 300-302
Varieties Hybrid napier+Pueraria javanica 161
Varieties Hybrid napier+Stylosanthes gracilis 161
Varieties Hybrid, seed production, 56-60 82
Varieties Hybrid seedlings 59, 85-88
Varieties Hybrid WCT × G 204, 205
Varieties in the Philippines 465
Varieties Indian Dwarf Orange 30
Varieties Kaithathali 183
Varieties Kappadam 36, 183
Varieties Kar Kar Tall (KKT) 82, 83, 84
Varieties Kulasekharam Dwarf Green 46
Varieties Kulasekharam Dwarf Orange 8, 46
Varieties Kulasekharam Dwarf Yellow 46
Varieties Laccadive Dwarf 183
Varieties Laccadive Ordinary 46, 64, 183
Varieties Laguna 70, 72 73
Varieties Malayan Dwarfs 4, 45, 46, 82, 85, 190, 441, 496, 497
Varieties × FMS Federated Malayan States 83
Varieties Malaya Dwarf × Fiji Dwarf 497
Varieties × GT (Gazelle Tall) Malayan Dwarfs 83
Varieties Malayan Dwarf × Panama Tall 497
Varieties Malayan Dwarf (MD) × RIT 83
Varieties × ST (Solomons Tall) Malayan Dwarfs 83
Varieties WAT (West African Tall) × Malayan Dwarfs 83
Varieties Malayan Dwarf Red × Niu Leka Crosses 46
Varieties Malayan Dwarfs Yellow 59
Varieties Malayan Yellow Dwarf 152
Varieties Markham Tall (MT) 83, 84, 123, 124
Varieties Panama Tall 497
Varieties Philippines 46, 62, 183
Varieties Philippine Dwarf 67
Varities Prepotent Talls 36
Varieties Polynesia 23, 24, 25, 27, 28
Varieties Pumila 58, 59
Varieties Pumila × typica 56, 59
Varieties Red Dwarf 157
Varieties Red Dwarf × WAT 430
Varieties Rennel Island Tall (RIT) 83
Varieties S S Green 183

Varieties San Ramon 71, 72, 73
Varieties *San Ramon* × *Pumila* 482
Varieties spicata chemical composition 183
Varieties Tacunan 71, 72, 73, 80
Varieties Tagnanan 72, 73, 80
Varieties Tahiti Tall 38, 39, 41, 42
Varieties Tall 3D 8, 56, 63, 64, 70, 74, 80, 186, 316
Varieties Tall × Dwarf 8, 32, 45, 47, 138-143 138, 139
Varieties Tall × Dwarf Hybrid 5, 6, 64
Varieties Talls Variability 28
Varieties typica 58, 59, 465
Varieties West African Talls 23, 24, 25, 27, 28, 38, 39, 41, 42, 157, 392, 430
Varieties West Coast Tall 5, 15-22, 30, 31, 32, 44, 45, 47, 48, 49, 63, 64, 85, 88, 115, 136-143, 152, 183, 203-204, 402, 422
Varieties West Coast Tall × Chowghat Dwarf Orange 203, 204
Varieties West Coast Tall × Dwarf Orange/Green 8
Varieties West Coast Tall × Gangabondam 203, 204
Varieties Yellow Dwarf 38, 87, 157, 392
Varieties Yellow Dwarf × West African Tall 430, 432
Varieties Zamboanga 72, 73
Vascular Physiology 189-193
Vascular Tissues 421
Vectors 415-419
Vegetable oils 120
Vegetative propagation 45, 304-311
Veitchia palms 417
Viroids citrus exocortis 410

Water Management 7
Weed control by insects 383
Weed control in Sri Lanka 376-384
Weeds 432
Weight unhusked nuts 35
West African yellow disease 406-409
West Indies 413, 415, 442
Western Samoa 455
Wetmilling 231-243, 239

Xanthomonas sp 334, 336
Xenia 28, 36, 38-43
Xylchorus sp beetles 434
Xylem sap pressures 189, 190, 192

Yeast strains 169, 170
Yield 58, 59, 141, 162
Yield analysis 31
Yield attributes 137, 140
Yield average 5
Yield components 73, 74
Yield economic characters 77
Yield effect of climatic variations 74
Yield fertilizer effect 156
Yield improvement 30
Yield index 8
Yields in India 455
Yield 138
  in Sri Lanka 96-102
Yield of copra 44, 77
Yield of nuts 31
Yield of oil 44
Yield of Tall × Dwarf palms 136- 143
Yield seasonal influence 136-143
Yield stability 8
Yield West Coast Tall 136-143
Yields prediction 101

Zanzibar 455