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DR. K. V. AHAMED BAVAPPA
General Chairman
PLACROSYM–V

FOREWORD

This publication is the fifth volume in the PLACROSYM series of annual symposia, covering all the disciplines of plantation crops research held at Central Plantation Crops Research Institute, Kasaragod. Like the earlier four symposia, this symposium also provided a common platform to a sizeable proportion of researchers and developmental agencies in the country working on different plantation crops to present their works and share their thoughts with fellow workers. In this symposium, a total of 91 papers were presented of which 58 were oral presentations spread over 7 Technical Sessions and the remaining were poster presentations.

Eventhough plantation crops contribute significantly to the Indian economy by way foreign exchange earnings, import substitution, and generation of employment, it has to be admitted that the attention paid to research efforts in this sector, particularly in the case of smallholder plantation crops, such as coconut, arecanut, cashewnut, cacao, black pepper and cardamom, has not been adequate. The productivity of these crops and their declining trend in recent years have become matters of great concern to research workers and planners. In contrast to this, the production and productivity in tea, coffee, and rubber have shown a steady increase. All the same, the researchers in these crops used to have very little chance for interaction due to the isolated nature of the concerned institutes. PLACROSYM in this context is a laudable effort that has helped to bring together researchers, extension workers and all others connected with plantation crops industry, for consolidating and exchanging available knowledge on these challenging crops.

During this symposium, a special discussion on "Mycorrhizae" was also arranged for the benefit of the researchers in this exciting and new field. The participants had the chance to share the expert views of Dr. C. L. Powell, a leading scientist in this area of research. Besides this, there was a discussion on the prospect of establishing a National Information Centre for Plantation Crops to promote the dissemination of research results among the fellow scientists all over the world for mutual benefit. A book exhibition was also organized at the symposium venue.

Although the participation in the Symposium was satisfactory, there has been a general feeling that ample scope existed for improving the quality of papers and standard of presentation. With a view to encouraging high quality research and attracting presentation of high standard research papers, the PLACROSYM Standing Committee and the ISPC Executive Committee have decided to institute awards for the best paper presented in future Placrosyms as also for the best article appearing in the Journal of Plantation Crops. We are happy that the C. S. Venkata Ram Memorial Trust has come forward to institute two awards, one each for this purpose. It is hoped that these incentives will help to improve the standards of research contributions in future Placrosyms.

K. V. AHAMED BAVAPPA,
General Chairman (Placrosym-V) and
Director, Central Plantation Crops
Research Institute, Kasaragod-670 124.

Kasaragod
26 Nov. 1984

ACKNOWLEDGEMENT

In the successful conduct of the Fifth Annual Symposium on Plantation Crops (PLACROSYM-V 1982) at the Central Plantation Crops Research Institute, Kasaragod, several organizations and individuals have made valuable contributions. Grateful acknowledgement is made of the active support received from the Indian Council of Agricultural Research, New Delhi, the Sustaining Members, and several other firms listed in Appendix I, and above all the large number of delegates who presented papers and actively participated in the discussions, thus making PLACROSYM-V a worthwhile effort.

Although Dr. O.P. Gautam, Director-General, ICAR could not attend, PLACROSYM-V greatly benefitted by the active participation of Dr. M. V. Rao, Deputy Director-General, ICAR, who delivered the Inaugural Address, and stayed on throughout the deliberations. The efficient conduct of the Sessions by the various Chairmen, and recording of proceedings by the Rapporteurs is gratefully acknowledged. The painstaking efforts of the Conveners and Members of the Local Organizing Committee (Appendix II) has greatly contributed to the success of the Symposium.

The editorial help and advice received from Drs. P. Rethinam, C. C. Biddappa, A. Ramadasan, Rohini Iyer, O. P. Joshi, and E. V. V. Bhaskara Rao, and Messrs Jacob Mathew, M. V. George, Jacob Annamalai, P. Gopalasundaram, Yateendra Joshi and S. Shivashankar are gratefully acknowledged.

Finally, appreciation is recorded for the active co-operation of M/s Sharada Press, Mangalore, in bringing out these proceedings in a befitting manner.

EDITORS

INAUGURAL ADDRESS

DR. M. V. RAO
Deputy Director–General, Indian Council of Agricultural Research,
New Delhi.

Distinguished colleagues on the dais, Ladies and Gentlemen,

I feel greatly honoured to be here today and I am grateful to the organizers for having given me this opportunity to participate in the deliberations of the Fifth Annual Symposium on Plantation Crops, and also to interact with the scientists working on various aspects of these crops. Those who conceived the idea of holding periodical symposia on plantation crops deserve congratulations since it has helped to get the numerous scientists working on these crops on a common platform for discussion and review of their research results. It is indeed very sad that the moving spirit behind these symposia, Dr. C. S. Venkata Ram, former Director of UPASI Tea Research Institute, is no more with us. We pray to Almighty for the peace of the departed Soul.

The plantation crops in this country occupy around 2 per cent of the total cultivated area, but earn a foreign exchange of about Rs. 8900 million rupees annually which amounts to about three-fourths of the export earnings of all our agricultural commodities. Besides their importance in our national economy, this group of crops have many features in common.

A perusal of our achievements in increasing the production and productivity of the plantation crops shows that whereas substantial increase in production has been achieved in crops like rubber, tea and coffee, in the remaining plantation crops, production has almost stagnated. Even in the case of the three crops mentioned above, the increase has been due to better cultural, manurial and plant protection methods. The contribution of improved varieties in increasing the production of plantation crops has been limited, mainly because of the narrow genetic base available in these crops at present. Hence our immediate task should be to diversify and widen the genetic base and have more varieties to cover large areas. If we look at rice, varieties like 'Jaya', 'Padma', or 'IR-26' occupy millions of hectares, and one feels that we are sitting at the tip of a volcano, since, any time a large-scale epidemic might occur when such a variety can succumb to a new virulent race of pathogen. In wheat, for example, out of 22.5 million ha, 8 million ha is occupied by a single variety 'Sonalika' right from Pakistan to Bangladesh. In plantation crops also, we have examples of rubber and coffee, where whole plantations have been wiped out by disease epidemics. In coffee, it is said that nearly two-thirds of world's collections have originated from a single tree, and so is the case with rubber. Restricted flow of genetic materials due to fear of introducing new pests or diseases, particularly of unknown etiology has been the major factor for this. In coconut, the narrow genetic base available in the country has received the attention of the ICAR and, to ameliorate the situation an expedition sponsored by FAO/IBPGR was sent in 1981 to the Pacific Ocean Countries in Polynesia and Melanesia. Another expedition would be undertaken to Indian Ocean region, and these efforts are expected to enlarge the genetic diversity in coconut, considerably. The seedlings of these newly acquired germplasm accessions have been raised in the Andamans where a World Coconut Germplasm Centre has been started.

There is also an urgent need to collect and catalogue indigenous coconut germplasm, right from Goa to Cape Comorin, and the Eastern regions of Manipur and Mizoram, as also the Andaman, Nicobar, and Lakshadweep group of Islands.

It is for the younger generation to organize more expeditions to collect the naturally occurring variability, not only in the above mentioned areas but also in the indigenous biosphere reserves such as Silent Valley forests, in all our commercial crops, including black pepper. At the same time, systematic hybridization efforts should be made to recombine the useful characters in the existing collections. In black pepper for example, screening for *Phytophthora* reaction has revealed that while the disease incidence is about 45 per cent in some genotypes, it is about 95 per cent in Panniyur-I. Perhaps if we make crosses between genotypes showing low incidence, we might get transgressive segregation, or recombinants which are likely to be more resistant than either parents. Such heterosis could be elegantly exploited in these crops and fixed through vegetative propagation. Similarly, in cardamom the breeders at Appangala Centre of CPCRI have induced mutants exhibiting resistance to 'katte' virus and this also offers tremendous scope for exploitation through vegetative propagation.

An assessment of the recent developments in Tissue Culture shows that India has lagged behind other countries, owing to limitations of staff and infrastructural facilities. There is tremendous scope for exploitation of tissue culture technique in propagation of crops like sugarcane, rubber, coconut, cashew, black pepper, cardamom and other plantation crops, ornamentals, medicinal plants, and so on. Realizing the importance of this field, the Scientific Advisory Committee to the Union Cabinet has identified Tissue Culture as a priority area. The ICAR is also seized of the problem and proposes to convene a National Seminar at CPCRI, Kasaragod in March, 1983, to bring together all the experts from CSIR and ICAR Laboratories, Universities and private sector, and identify priority areas and crops for intensifying our efforts to give a new thrust to this exciting field full of potential.

Another aspect to which I would like to draw your attention is the research effort required for breaking the yield barrier. For most of the plantation crops we do not have precise data on indices like photosynthetic efficiency, total dry matter production and method of partitioning the total dry matter produced (harvest index). In coconut, methods have recently been developed for estimating leaf area and drymatter production as well as the harvest index. Attempts have been made in the past for calculating the yield potential and existing gaps, though in a purely tentative and somewhat speculative manner, in the case of coconut, rubber, cashew and pepper. The ratio of $\frac{\text{record yield}}{\text{average yield}}$ worked out based on the available data in coconut $\left(\frac{5.6}{0.6}\right)$, rubber $\left(\frac{10{,}000}{500}\right)$, cashew $\left(\frac{125}{5}\right)$, and pepper $\left(\frac{11.3}{0.25}\right)$ are 9.3, 20, 25 and 45.2 respectively. These figures show the tremendous untapped potential in the available cultivars/varieties in plantation crops which could be harnessed to take these crops to much higher levels of productivity. One of the constraints in achieving higher production levels in most of these crops has been our inability to meet the ever-increasing demand for elite planting materials to raise new plantations. Though commercial methods of propagation are available, I feel that there is a need for resorting to non-conventional methods of propagation such as meristem and tissue culture for increasing the pace of progress in this area to catalyse their production and productivity.

With regard to root (wilt), a serious disease of coconut with which the farmer has been co-existing for the last 100 years, apart from suggesting prophylactic measures to contain the disease and prevent its further spread, we are now also definite about the pathogen involved. We have to emphasize the management aspects.

The entire field of physiology of growth regulation is now assuming greater importance, and in palms, in addition to morphological characters, the physiological parameters should also be considered for assessing and predicting the performance of adult palms. Preliminary data on some parameters such as chlorophyll content, nitrate reductase activity and NAR, are available for predicting adult palm potential based on seedling scores for these characters.

Several commercial formulations such as Mixtallol, are reported to have given 40-50 per cent increase in yield in vegetable crops. Similar information on plantation crops is lacking.

With regard to Economics, Marketing and Extension, the point of concern is that the farmer is not getting the right price for his produce. The case of apples is quite relevant, where the farmers of Kashmir, Himachal Pradesh and Uttar Pradesh get only Rs. 0.50 per kg. whereas in Delhi markets we pay Rs. 5/- or more. Hence, we need to evolve a system of price protection.

While reviewing the work on spices, we find that in crops like vanilla and allspice not much has been done, and so is the case with other minor spices. Cess Fund Schemes of ICAR can be thought of if these are not included in the regular Plan budget. Similarly, there are a number of under-utilized plants such as Guayule rubber for which there seems to be good scope in Haryana. As regards oil palm, it remains a big question still, whether India should go in for this. Malaysia has an ideal rainfall distribution for oil palm, unlike Kerala which has 3-4 months of drought. Moreover, it would be disastrous to destroy the forests in Andamans for planting oil palm. India with its vast potential in traditional oilseeds, including coconut, need not go in for oil palm, at the cost of destroying our valuable forest wealth.

I have briefly presented before you some of my thoughts on the problems requiring your attention in the hope of stimulating further thinking and discussion during this Symposium.

I have great pleasure in inaugurating this Fifth Annual Symposium on Plantation Crops, and I wish your deliberations all success.

KEYNOTE ADDRESS

PLANTATION CROPS REASEARCH-PRESENT AND FUTURE

DR. K. V. AHAMED BAVAPPA
General Chairman PLACROSYM V, and Director CPCRI Kasaragod

Placrosym Delegates, Ladies and Gentlemen,

Plantation Crops are cultivated over an area of 2.97 million ha in the country. In most of the countries where plantation crops are cultivated, the percentage of small holdings ranges from 54.6 per cent in the Near-east to 71.1 per cent in the Far-east. The average holding size in these countries is in the range of 0.7 ha in the Far east and 2.7 ha in Latin America. In India, a good proportion of holdings in the plantation crops sector are marginal to small in size. (Table 1). Homesteads which constitute a sizeable

Table 1, Distribution of holdings by size*

Crop	Holding size (ha)	No. of holdings	Percentage
Tea	<5	11,292	86.1
	5-50	608	4.6
	>50	1,217	9.3
Coffee	<2	32,653	73.6
	2-4	5,646	12.7
	>4	6,080	13.7
Rubber	<2	1,10,340	85.95
	2-4	11,210	8.73
	>4	6,868	5.32
Coconut**	<1	—	89.9
	1-2	—	7.9
	>2	—	2.2

*Bavappa (1976)
**Kerala State

proportion of such holdings have already been mix-planted indiscriminately with various tree species. Such unscientific planting has resulted in overcrowded stands in millions of homesteads all over the tropical countries. The mid-country of Sri Lanka where diverse species are planted in such gardens, are rightly called "Forest Gardens". In these gardens, the production levels and net return are poor (Mc Connel and Dharmapala, 1973) due to mutual competition and wrong choice of species. In the prevailing context of changing social outlook and land policy, these home gardens have a totally different role in the farming systems of these countries. Many of the families have no other land to farm or other sources of income to support them. In addition, the new 'home-farmsteads' (small farms where the farmer has also his house in the farm as distinct from farmsteads) which are being established under different settlement programmes in limited areas of land per holding will invariably have to support a few heads of animals and poultry thus forming a micro plant-animal-human ecosytem. In most cases, the only source of income of the farmer will have to come from these small holdings.

In India, while the production and productivity of crops such as tea, coffee and rubber grown on an estate scale has shown considerable increase during the last two decades, production and productivity of other plantation crops like coconut, cashew, cacao, cardamom and pepper have remained static or even shown a downward trend during the same period. To check this trend of low production as well as for increasing the productivity of the small and marginal holdings and making them viable units of production, there is an urgent need to evolve production technologies suited to such situations.

Concepts in maximising production

The concepts of production could primarily be based on energy on one side and income on the other. Since conversion of energy into biomass is the primary function in any production activity, a critical analysis of this area is worthwhile. This will mean that the production components such as land, air space, inputs and time dimension will all have to be considered together. It is also necessary that in the place of one crop per unit area and time, more crops are planned to be raised either in sequence or together. Therefore, it is essential that a clear understanding of the optimum exploitation levels of the above basic components by a crop community alone will enable maximisation of production through this pathway. Biomass in terms of the present context of the small farmer should be capable of providing food, fuel, fodder and timber in additon to being income generating.

Compared to annuals, perennial plantation crops offer better scope for maximising production per unit area. These crops if chosen on the basis of canopy and root architecture and space appropriately, can make better use of the soil both in the horizontal and vertical planes, and air space to greater heights, intercepting solar energy at different strata of the crop canopies, and producing much higher quantities of biomass as well as higher income.

High density multispecies systems with plantation crops

Attempts to raise high density multispecies cropping systems for high biomass production and high income generation have been found to be promising in Sri Lanka. One such system suitable for lower elevations with 13 crop species was laid out with large canopy crops such as jack, breadfruit, avocado, mango, coconut, nutmeg and clove planted 12.2m apart. The crops with medium canopy viz. papaya, arecanut, lime, banana, pepper and coffee (*robusta*) were planted at a spacing of 2.44×2.44m in between the large canopied crops. San Ramon coffee plants having small canopy were planted at 1.22×1.22m spacing, the total population of plants planted being 3606/ha. Among these crops, while jack, breadfruit, avocado, mango and papaw are mostly for home needs, coconut, lime and banana will meet both cash and food needs of the farmer. Similar high density cropping models are also available for higher elevations with coffee, pepper, coconut and other crops. Models for homesteads with crops having different root and canopy architecture and ability to stand varying moisture conditions have also been developed (Bavappa and Jacob, 1982).

Economic analysis

Economic evaluation of the results obtained in Sri Lanka and India has revealed that the return from plantation crop mixes are many times more than the returns from the sole crop. In Sri

Lanka the net return per hectare of tea mix-cropped with clove is Rs. 57,464 as against Rs. 5,900 from the sole crop of tea, Rs. 46,500 in the high density multispecies cropping, and Rs. 17,493 in coconut and cacao as against Rs. 5049 from coconut alone. In India, while the monocrop of coconut gives Rs. 5625 net return, mixed cropped areas of coconut and cacao give Rs. 17,610 per ha. The economic advantages are thus apparent.

New research areas

Research efforts are required for understanding the root and canopy architecture of different crop species, PAR profile of the system, and energy input and output. Studies on the canopy of different species should include inter-plant competition among component crops keeping time dimension as an important factor. The component crops will have to be screened for their sensitiveness to low PAR availability and also amenability to canopy management through pruning. Studies on energy input should aim at understanding the needs of cultural energy such as tillage, fertilizers, irrigation and plant protection of the entire system. While there are strong indications that considerable saving is possible in the input of energy in a high density crop community, this has to be quantified. Indeed the prospects for adoption of some of the practices like zero tillage in these systems is very bright.

A critical assessment of the self-generated energy of the system and the accompanying favourable soil and climatic changes require continued monitoring. A simple system like coconut and cacao had prompted the growth of free nitrogen fixers, phosphate solubilizers and growth promoting fungi (Nair and Rao, 1977). There are also indications that mixed cropping favours mycorrhizae which can suppress plant pathogens, thereby reducing the energy requirement for plant protection. The energy output from the system can also be enhanced by extra system exploitation. Studies have shown that by-products of cacao can be used for biogas generation, and also arecanut husk and sheath for growing mushroom. After degradation, these could be used as cattle feed and manure. A critical economic evaluation of the inputs and outputs extending over decades is also essential. A highly multi-disciplinary approach is, therefore, necessary in this vital area of plantation crop production.

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Rapporteurs	:	**Shri C Kailasam**
		Shri V Govindarajulu

QUALITY OF CARDAMOM ARRIVING AT SOME IMPORTANT AUCTION CENTRES IN KERALA

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Indian Cardamom Research Institute, Myladumpara, Idukki 685 533. Kerala

ABSTRACT

A survey was conducted in three important auction centres of Idukki District during 1978–79, to assess the quality of cardamom with regard to litre weight, size of the capsule, maturity and thrips attack. Size, maturity, and thrips attack influenced the litre weight. Multiple regression equation was worked out correlating litre weight with other quality determining factors. Effective control of thrips and sufficient care in harvesting will greatly help in improving the quality of saleable cardamom.

INTRODUCTION

For quality assessment of cardamom, the Government of India has prescribed specific standards under the Agricultural Produce (Grading and Marketing) Act of 1937 known as Agmark Grades. Detailed specifications were prescribed based on the physical characters such as colour, size, density, moisture content, and physical deformity. Size, colour and density depend on harvesting and curing. The present study was taken up to evaluate the quality of cardamom produced in different areas of Idukki District, Kerala which is the largest cardamom tract of India.

MATERIALS AND METHODS

Cardamom, *Elettaria cardamomum* L. (Maton), samples were collected from the lots brought to auction centres at Vandanmettu, Parathodu and Santhanpara in Idukki District by planters from neighbouring areas during 1978–79 season. The litre weight and number of capsules per litre were determined. The capsule size was assessed by sieving through sieves of 7, 6, 5 and 4 mm diameter, and by weighing the fraction retained by each sieve. These fractions were further examined to find out the percentage of thrips-affected capsules and immature ones.

RESULTS AND DISCUSSION

Litre weight was positively correlated with percentage of 7 mm capsules and negatively correlated with percentage of thrips-affected capsules, percentage of immature capsules and number of capsules (Table 1). The correlation coefficient between litre weight and percentage of immature 7 mm capsules was found to be 0.678 and that between litre weight and thrips-affected 7 mm capsules was −0.396, both being statistically significant.

The multiple regression equation correlating litre weight and other component characters was worked out as:

$$Y = 589.09 - 0.0394X_1 - 0.4840X_2 - 0.3560X_3 - 1.1656X_4$$

where:

Y = Litre weight
X_1 = Number of capsules
X_2 = % 7 mm capsules
X_3 = % thrips-affected capsules
X_4 = % immature capsules

The standard errors for coefficients and the levels of significance are given in Table 2. The coefficient of determination (R^2) of the function was found to be 69.3 per cent. Therefore, about 69.3 per cent of the total variability in litre weight could be explained from a quantitative assessment of the various characters studied.

Table 1. Correlation matrix of litre weight and its component characters

	X_1	X_2	X_3	X_4	X_5
X_1	1.00				
X_2	0.743**	1.00			
X_3	0.678**	0.877**	1.00		
X_4	0.396**	0.352**	0.404**	1.00	
X_5	0.773**	0.715**	0.740**	0.308*	1.00

(** p=0.01) (* p=0.05)

X_1 = Litre weight
X_2 = No. of capsules in one litre
X_3 = % 0.7 mm capsules
X_4 = % thrips affected capsules
X_5 = % immature capsules

Table 2. Regression coefficients, their standard errors, and 't' values for the component characters, for assessing the litre weight of cardamom

Character	Regression Coefficient (bi)	S. E. (bi)	't' value
No. of capsules	–0.0394	0.00104	37.8810**
% of 7 mm capsules	–0.4840	1.06480	0.4545 NS
% of thrips affected capsules	–0.3560	0.27909	1.2755 NS
% of immature capsules	–1.1659	0.41766	2.7907**

** Significant at 1% level of probability

NS–Not significant

Table 3 Influence of immature and thrips-affected capsules on litre wt., no. of capsules, and % 7 mm capsules

% immature/ thrips–affected capsules	Litre wt. (gm.)	No. of capsu-les in one litre	% 7 mm capsules (w/w)	Litre wt. (gm.)	No. of capsu-les in one litre	% 7 mm capsules (w/w)
0–10	451.85	2335	81.60	417.50	2760	70.67
10–20	432.53	2560	69.67	408.20	2832	63.77
20–30	410.07	2756	70.14	395.66	2942	59.40
30–40	394.15	2986	66.90	395.50	3150	61.33
40–50	381.98	2945	55.25	—	—	57.00
More than 50	347.48	3703	33.80	372.77	3172	46.25

The maximum litre weight recorded in the samples was 476.4 gm, which contained 4.0 per cent immature capsules and 83 per cent capsules above 7 mm size. The minimum litre weight recorded was 241.3 gm and all the capsules were immature and there was only 1 per cent of the capsules above 7 mm size. The maximum amount of immature capsules permitted in AGEB grade (by Agmark), which is considered to be the best quality of Indian cardamom is 2 per cent and the size of the capsules should be 7 mm or above. The litre weight was found to vary from 451.85 to 347.48 gm and the percentage of immature capsules increased from 10 to more than 50 (Table 3).

The average recovery of cured cardamom from green cardamom is only 18-19 per cent, and the same is 25-26 per cent in well managed plantations. Based on this it has been concluded that on account of improper harvesting alone the possibility of crop loss is as much as 28 per cent of the total production (Krishna, 1979). By improving the harvest technology to reduce the percentage of immature capsules, recovery on curing would go up by 28 per cent.

There was decrease in litre weight from 417.5 gm to 372.77 gm and in the percentage of 7 mm capsules from 70.67 to 46.25, as the percentage of thrips-affected capsules varied from 10 to 50 or above (Table 3). The results of the study indicate that there is ample scope for improving the quality as well as quantity of the cardamom that is produced in the cardamom tract of Idukki, by adopting efficient plant protection measures and improvements in harvesting.

ACKNOWLEDGEMENT

The authors are thankful to Sri P. V. Prabhakaran, Associate Professor, Kerala Agricultural University, Vellanikkara for statistical analysis of data, and Sri K. V. George, Director, Cardamom Board, Cochin for the facilities and encouragement.

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DISCUSSION

N. MURALEEDHARAN (UPASI): Could you determine the exact period during which maximum percentage of thrips–infested capsules were present?

C. R. SIVADASAN: No. The lots analysed were brought by the planters to the auction centres, and they were not reporting the actual period of harvest.

TURMERIC SITUATION IN INDIA WITH SPECIAL REFERENCE TO WORLD TRADE*

PRAFULLA K. DAS

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ABSTRACT

The production and export of turmeric in India has been fluctuating widely during the last two decades. The compound growth rate of production and productivity in Bihar, Karnataka and Meghalaya was more than 5 per cent per annum during the 70's. This calls for organized efforts for turmeric development in these states. The compound growth rates of the quantity exported, export earnings and unit values per annum in respect of Indian turmeric during 1970s were estimated at 4.7 per cent, 20.3 per cent and 14.8 per cent respectively. Among the top importers of turmeric, Iran and USA each imported from India about 87 per cent of their total imports during the last decade. Our main competitors in the field of turmeric export are Bangladesh, China, Taiwan, Pakistan, Jamaica, Peru and Haiti. The outlook for this crop however, seems to be very bright.

INTRODUCTION

Turmeric of commerce is the cured and dried rhizome or underground stem of a perennial herb, *Curcuma domestica* Val. (syn. *Curcuma longa* L.). For commercial exploitation, it is grown as an annual, in parts of tropics. It is one of the most important spices used extensively by all classes of people in India. Besides, it is one of the most ancient and traditional items of export for this country. The demand for turmeric mainly arises from its use for culinary purposes. Important among the producers of this condiment are, India, Bangladesh, Pakistan, Sri Lanka, Burma, China, Taiwan, Indonesia, Jamaica, Haiti and Peru. Like Indians, other people in Asia are heavy consumers of turmeric and some of the Asian producers are even net importers of this produce. However, the available statistics both on production and trade of turmeric in respect of several countries in the world are far from adequate.

*CPCRI contribution No. 226.

Any attempt to analyse the world situation in turmeric, therefore, makes the task of a researcher somewhat difficult. The scope of this paper is limited to the analysis of turmeric situation in India with special reference to world trade.

Materials and Methods

The area, production and yield figures used for the present analysis are the estimates of the Directorate of Economics and Statistics, Ministry of Agriculture, Govt. of India. The data on India's exports, export earnings and unit values are the estimates made by the Directorate General of Commercial Intelligence and Statistics, Govt. of India. The source of import data in respect of the leading importing countries is the International Trade Centre, UNCTAD/GATT. The wholesale price data are the compiled figures of the Directorate of Cocoa, Arecanut and Spices Development, Govt. of India.

Results and Discussion

Production and supply trends

India is by far the largest producer of turmeric in the world, but the production of this crop has been highly unstable. In 1950-51 India produced 152,000 tonnes of turmeric from an area of 56,000 ha. The average productivity for that year works out to 2764 kg/ha and this is the record average productivity for turmeric in the country so far. The area and production of turmeric during 1960–61 were of the order of 39,000 ha and 105,000 tonnes, respectively. The corresponding figures for 1970–71 were, 81,000 ha and 151,000 tonnes, and for 1980–81 were 99,000 ha. and 210,000 tonnes. The crop statistics reveal that between 1960–61 and 1980–81 the area and production of turmeric went up by 151 per cent and 100 per cent respectively, while its productivity came down by 20 per cent. The year 1979-80 was the peak year for Indian turmeric both in respect of area (105,000 ha) and production (235,000 tonnes), but not in productivity.

The index numbers of area, production and yield of turmeric with the base at 1960–61 reveal that the supplies of Indian turmeric were highly uncertain over these years because of severe fluctuations in area as well as productivity of this crop. The compound growth rates of area, production and yield of turmeric in India per annum for the period 1970–71 to 1979–80 were estimated at 1.82 per cent 1.33 per cent and (–) 0.48 per cent, respectively.

The main turmeric growing areas in India are distributed in the States of Andhra Pradesh, Orissa, Tamil Nadu, Maharashtra, Assam, Bihar, and Kerala. During the 1970s, Andhra Pradesh alone constituted on an average 26 per cent of the total turmeric area and 36.4 per cent of the total production in India and continued to maintain its position as the largest termeric producing State. While area-wise Orissa, Tamil Nadu, and Maharashtra constituted 20.8 per cent, 12.8 per cent and 12.2 per cent production-wise their shares were 9.4 per cent, 24.2 per cent and 9.1 per cent respectively at the all-India level. The average productivity per hectare was highest in Tamil Nadu (3602 kg), followed by Karnataka (2725 kg.) and Andhra Pradesh (2666 kg). The productivity for Orissa and Assam was around one-fourth and one-sixth of that in Tamil Nadu (Table 1).

Table 1. Spatial distribution of average area production, and yield of turmeric in different States during 1970–71 to 1979–80

State	Area %	Production %	Yield (Kg/ha)
Andhra Pradesh	26.0	36.4	2666
Assam	7.5	2.3	595
Bihar	7.7	6.1	1500
Karnataka	1.8	2.5	2725
Kerala	4.8	2.6	1040
Maharashtra	12.2	9.1	1410
Meghalaya	1.8	0.8	824
Orissa	20.8	9.4	857
Tamil Nadu	12.8	24.2	3602
Others	4.6	6.6	2683
All India	100.0	100.0	1902

The following inferences can be drawn from the estimated compound growth rates of area, production and productivity of turmeric for different States during 1970–71 to 1979–80.

(*i*) In respect of area, only four out of nine turmeric growing States had positive growth, Orissa (7.41 %) having the highest growth followed by Assam (6.40 %) and Karnataka (2.87 %).

(*ii*) As regards production, barring Kerala and Maharashtra, all other seven States had positive growth, Bihar (15.08 %) having the highest growth followed by Karnataka (9.41 %) and Assam (6.58 %).

(*iii*) So far as yield is concerned, five states had positive growth, Bihar (16.28 %) having the highest growth followed by Karnataka (6.60 %) and Meghalaya (6.18 %).

For the country as a whole, the annual growth rate in production is as small as 1.33 per cent (Table 2).

Table 2. Estimated compound growth rates (per annum) of area, production and yield of turmeric for different States during 1970–71 to 1979–80

State	Compound growth rates (%)		
	Area	Production	Yield
Andhra Pradesh	(+) 0.37	(+) 0.01	(−) 0.36
Assam	(+) 6.40	(+) 6.58	(+) 0.17
Bihar	(−) 1.04	(+) 15.08	(+) 16.28
Karnataka	(+) 2.87	(+) 9.41	(+) 6.60
Kerala	(−) 3.08	(−) 5.05	(−) 2.03
Maharashtra	(−) 0.77	(−) 3.69	(+) 4.50
Meghalaya	(−) 0.70	(+) 5.43	(+) 6.18
Orissa	(+) 7.41	(+) 0.46	(−) 6.53
Tamil Nadu	(−) 0.003	(+) 0.03	(−) 0.006
All India	(+) 1.82	(+) 1.33	(−) 0.48

While it is absolutely necessary to attain a much higher growth rate in production, it may not be possible to achieve this goal through area expansion beyond a certain point. Under this situation, a negative growth rate in productivity is a matter of great concern. The other serious matter in the case of supply of turmeric in India is its violent fluctuations from year to year. Moreover, the requirement of very high seed rate (10 to 20 % of the yield) for raising the crop reduces the marketable surplus potential of this commodity.

Utilisation and Demand

In India, turmeric is widely used as an important condiment. It is usually used in the form of ground spice and is blended into curry powder. It is also used as a dyestuff in the textile industry.

To a small extent, turmeric is utilised for medicinal purposes as it has antiseptic and deworming properties. It is extensively used as an indigenous cosmetic item. Apart from these uses, turmeric is considered as an auspicious commodity by Indians, particularly the Hindus who need it in their rituals and social customs (Anonymous, 1965). In view of the above, the bulk of India's turmeric production is consumed locally.

Depending upon the agro-climatic conditions in which the crop is raised and the harvest and post-harvest technology that are applied, the commodity prepared for the market in different regions is found to develop some kind of regional characteristics. Among the commercial varieties, Alleppey turmeric, Rajpuri turmeric, Madras fingers, Guntur turmeric, and Cuddapah turmeric, are important in Indian markets (Menon, 1975).

The volume of utilisation of any commodity at a given time could be considered as the apparent demand for the commodity for that period. As such, the average internal demand for turmeric in India for the period 1975–76 to 1979–80 came to 137,000 tonnes/annum. In other words, nearly 91 per cent of India's turmeric production in the late 70s was consumed and utilized locally.

Export situation

India, the largest exporter of turmeric in the world, exported around nine per cent of the country's production during the last five years of the 70s. India has been an exporter of turmeric for the past several decades. The volume of exports varied from 2.2 to 8.1 per cent of the total production during the 1960s, to 5.6 to 10.7 per cent during the 1970s. Like the production of turmeric, its exports from India was highly fluctuating over the years. In the year 1960–61, the quantity of turmeric exported from India was of the order of 1210 tonnes valued at Rs. 2.6 million. During 1980–81, the volume of exports was found to be 11,900 tonnes valued at Rs. 63.1 million. The highest volume of exports as well as the export values for turmeric recorded during 1979–80 was 21.510 tonnes valued at Rs. 162.4 million. However, the record unit value realization was Rs. 10,730/tonne, during 1978–79.

The index numbers in respect of the volume of exports, export earnings and unit values of turmeric suggest that the trends of the export sector were of the increasing order. The compound growth rates of the quantity exported, export values and realized unit values in respect of Indian turmeric for the period 1970–71 to 1979–80, were estimated at 4.7 per cent, 20.3 per cent and 14.8 per cent, respectively. The export earnings from this commodity constituted only 6 to 12 per cent of the total earnings from spices in India.

This spice is exported to as many as 64 countries. An analysis of the zone-wise exports of turmeric from India reveals that during the 1970s, around half of the exports was to the Middle East alone. East Asia, America and the Western Europe accounted for 15.84, 13.87, and 10.82 per cent respectively of the total exports during the same period. Although the volume of Indian exports increased significantly during 1970–71 to 1979–80 over that of 1960–61 to 1969–70 irrespective of the zones, the maximum change was noticed in the case of the Middle East (245%), followed by Eastern Europe (225%) (Table 3).

Table 3. Zone-wise exports of turmeric from India during 1960–61 to 1979–80

Zone	Average for 1960–61 to 1969–70 (period 1)	Average for 1970–71 to 1979–80 (period 2)	Change between periods 1 & 2
	Tonnes	Tonnes	%
1) Eastern Europe	10.75	35.06	(+) 226.14
3) UK & Other European countries	672.73	1310.91	(+) 94.86
3) Middle East	1795.58	6204.05	(+) 245.51
4) East Asia	1660.15	1910.47	(+) 15.08
5) Africa	684.53	778.45	(+) 13.72
6) Australia & Oceania	118.38	151.21	(+) 27.73
7) America	1106.09	1672.05	(+) 51.17
Total	6048.21	12062.20	—

Presently, the main importing countries in the world for turmeric are, Iran, the USA, Japan and the UK. During the 1970s, the average annual imports for Iran and the USA were of the order of 3843 tonnes each. It was 2128 tonnes for Japan and 1545 tonnes for the UK. India's share in the total imports of Iran and the USA came to 61.54 per cent in each case, for Japan 38.62 per cent, and for the UK 52.94 per cent, for the period under reference. Though the volumes of imports of other importing countries such as Sri Lanka, Iraq and Saudi Arabia are relatively small (250 to 600 tonnes), they were found to lift nearly 87 to 90 per cent of their total imports from India. Curiously Sri Lanka, one of the major importers of turmeric during the 1960s, could achieve near self-sufficiency in turmeric inthe next decade (Table 4).

Table 4. Import of turmeric into major markets and India's share (In tonnes/annum)

Country	Average of 1960–69		Average of 1970–79	
	Total Import	India's share % of total	Total import	India's share % of total
F.R.G.	NA	..	408[a]	35.05[a]
Iran	2226	44.56	3843	61.54
Iraq	278	81.65	325	87.08
Japan	1391	50.00	2128	38.62
Morocco	553	86.62	NA	NA
Netherlands	NA		239[a]	53.14[a]
Saudi Arabia	NA		596[b]	87.08[b]
Sri Lanka	1157	79.43	253	88.93
U.K.	NA		1545[c]	52.94[c]
U.S.A.	1347	44.56	3843	61.54

[a]figures relate to Av. of 1972–78
[b]figures relate to Av. of 1971–76
[c]figures relate to Av. of 1973–78

The total world exports of turmeric were estimated at 24,000 tonnes for 1976. According to the available figures for 1976, India's export in the context of the world exports was of the order of 83 per cent. The exports from the other exporting countries such as Pakistan (7.5 %), China (3.3 %), Taiwan (3.1 %), Burma (1.5 %), Haiti, Peru and Jamaica (combined 1.3 %) were relatively small as compared to India (Table 5). While the main importing countries for Indian turmeric weie the USA, Iran, and the UK, the major importer foi Pakistan turmeric was Muscat, and for Taiwan turmeric, Japan.

No reliable information about the current situation of international trade in turmeric is available at the moment. However, most of the Arab nations notably Iraq, Libya and Morocco are

Table 5. World export of turmeric by the major producing countries and their share in total export at different points of time (In tonnes)

Country	1957	1961	1965	1971	1976
Burma	NA	56 (1.1)	257 (1.9)	250 (1.3)	350 (1.5)
China	NA	NA	112 (0.8)	400 (2.1)	800 (3.3)
India	11078 (96.4)	3460 (68.8)	10403 (77.9)	16500 (84.6)	20000 (83.3)
Jamaica	NA	141 (2.8)	117 (0.9)	NA	NA
Pakistan	NA	677 (13.6)	1698 (12.7)	1500 (7.7)	1800 (7.5)
Taiwan	336 (2.9)	604 (12.1)	688 (5.1)	700 (3.5)	750 (3.1)
Others (Haiti, Peru etc.)	81 (0.7)	91 (1.8)	96 (0.7)	150 (0.8)	300 (1.3)
Total	11495 (100.0)	5029 (100.0)	13371 (100.0)	19500 (100.0)	24000 (100.0)

(Figures in parentheses show the percentage of the total)
NA=Not Available

now importing substantial quantities of turmeric. A high proportion of Bangladesh's exports are shipped to Muscat and Oman. Bangladesh has gained equal importance with India as an exporter to Iran. China has also become a supplier of this spice to Iran. A significant part of USA's turmeric imports are now met from Jamaica, Haiti, Peru and Taiwan, although India continues to be the major source of this produce. International trade in ground turmeric is very small. The demand for ground turmeric mainly comes from certain African countries, notably Zambia. The volume of imports for the importing countries are seen to fluctuate widely as in the case of the volumes of exports, due to obvious reasons. Although turmeric is grown mainly in the Asian sub-continent, all the producers in this region are heavy consumers of their own produce, and some like Sri Lanka are even net importers (Purseglove *et. al.*, 1981). In Indonesia, for example, it is known that turmeric is cultivated extensively, but none of the major importing countries lists Indonesia as a source of turmeric and, therefore, it must be supposed that the entire produce is consumed locally (Manning, 1969).

The main types recognized in international trade are, the 'Madras' and 'Alleppey' turmerics, and 'West Indian or 'Haiti' turmeric. 'Alleppey' turmeric is distinguished from others by its deep yellow or orange colour. This property is the characteristic expression of high curcumin content in the variety. Madras turmeric possesses mustard yellow or bright yellow colour as well as a delicate aroma. 'Haiti' turmeric is regarded as of a lower quality and value in comparison with the Madras and Alleppey types due to its dull yellowish brown appearance (Manning, 1969).

In the USA and Western Europe, a substantial demand for turmeric comes from the pickle manufacturing units. However, a striking difference in the consumer's tastes and preference for texture and colour in pickle could be observed between the USA and Western Europe. On account of this difference, 'Alleppey' turmeric fetches a premium price in the USA, while 'Madras finger' gets a higher value in the UK and other Western European countries (Purseglove *et al.*, 1981).

Price trends

There has been an overall rising trend in the unit value realization from turmeric, eventhough the year-to-year variation is found to be very wide. Taking 1960–61 unit value as the base, the unit value realised from turmeric exports showed a rise upto 1963–64 then declined for two years, again moved upwards until it reached 458.3 points in 1969-70. Thereafter, the unit values fluctuated widely and touched 952.9 points in 1978–79. It then fell to 670 points in 1979–80 and further declined to 470.9 in 1980–81. During the period 1976–77 to 1980–81, the unit value averaged at Rs. 7005/tonne.

A comparison between the turmeric prices at one of the Indian markets namely, Erode market and the London international market shows that, the London market prices were 23 to 147 per cent higher than that in Erode during the 1970s. In six out of the ten year period, the difference was less than 50 per cent (Table 6). With the unprecedented rise in the internal transport, handling as well as shipping costs in recent years, the price difference is bound to widen. The correlation coefficient (r) for the prices of Erode and London markets between 1970–71 and 1979–80 was 0.91, suggesting that the trend of turmeric prices in international market is moving closely with the trend in the Indian markets.

Table 6. Turmeric (Erode Finger) prices at Erode and London markets for the period 1970–71 to 1979–80 (Rs./Qtl.)

Year	Prices at		% Increase in price at London over the price at Erode
	Erode	London	
1970–71	265	337	27.17
1971–72	141	250	77.30
1972–73	235	289	22.98
1973–74	392	564	43.88
1974–75	327	513	56.88
1975–76	293	408	39.25
1976–77	389	534	37.28
1977–78	720	998	38.61
1978–79	694	1318	89.91
1979–80	329	812	146.81

Outlook

With the food and drug regulations becoming increasingly stringent day by day, the demand for quality turmeric and its products is bound to exhibit a rising trend. Turmeric oil has a wide acceptance in confectionery and aerated water units in the western countries. Similarly, turmeric oleoresin has a good demand from the pickle manufacturers of USA. India being one of the leading manufacturers of turmeric oil and oleoresins, the prospect for the expansion of turmeric trade at the international level is very bright.

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DISCUSSION

P. S. SREENIVASAN(KAU, Vellanikkara): Is there a general downward trend in yield of turmeric?

P. K. DAS: Yes, The cultivation has been extended to marginal lands in most of the turmeric growing states; hence this outcome.

P. S. S.: A.P. has a high yield of turmeric while the adjacent State of Orissa has the lowest yield. Comment.

P. K. D.: The genetic potential of Orissa turmeric cultivars is very low as compared to Andhra cultivar. Also, the cultural practices followed in Orissa are much inferior to that of A.P.

P. S. S.: What are the reasons for the violent fluctuation in prices?

P. K. D.: Price trend in turmeric indicates that the fluctuation follows a cob-web model i.e. in one year the price is high and the following year it is low. This is because of the fact that high price incentive motivates the farmer to extend the area under the crop, which results in increased production and consequent glut in the market leading to a decline in price.

P. S. S.: Export in 1979–80 is nearly double that of 1980–81. Are there any reasons to explain the above?

P. K. D.: The variations in export figures are due to the supply situation of the competing countries in any particular year. If the crop is poor in the other producing countries, India gets a fairly large business in the international market and vice-versa. Hence such fluctuations are not unusual.

UNIFORMITY TRIALS: OPTIMUM SIZE AND SHAPE OF PLOTS AND BLOCKS IN EXPERIMENT WITH GINGER*

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ABSTRACT

Fairfield Smith's equation with standard notations $Y = ax^{-g}$ and its generalisation in the form $Y = ac^{-g_1} r^{-g_2}$ were fitted to the uniformity trial data on ginger conducted at Hirehalli during 1976–77 and 1977–78 where Y is the CV for the plot size x with r rows and c columns, taking the ultimate unit as (i) one row of 5 plants and (ii) number of plants in 1m × 1m bed. Row-wise heterogeneity was higher than column-wise heterogenity showing thereby that formation of plots with more rows will give more homogeneous blocks for experiments. The cost of experimentation per treatment to estimate the means at 5 per cent CV was worked out under different price situations. Plot size consisting of 3-4 rows of one column in the case of ultimate unit of plants in 1m × 1m bed, and plot size of 6 rows of one column in the case of ultimate unit of one row of 5 plants each, were found to be optimum.

INTRODUCTION

In agricultural experiments, the researcher is generally faced with the problem of adopting the suitable size and shape of the plot so as to obtain maximum information from his experimental material. The size and shape of plots depends on the inherent variability present in the crop and the environment in which it is grown. Our problem is to find out the suitable size and shape of the plot and block for which the plot to plot variation is minimum. Fairfield Smith (1938) worked out an empirical relationship between plot size and the CV for yield. Several earlier attempts have been made to determine the optimum size and shape of plots and blocks for various crops (Abraham *et al.*, 1969; Agarwal *et al.*, 1968;

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George *et al.*, 1979; and Shrikhande, 1958) but so far no such attempt has been made with regard to ginger plot size. In this paper, an attempt has been made to evaluate the optimum size and shape of plots in blocks, under different price situations.

MATERIALS AND METHODS

Uniformity trials on ginger were laid out at CPCRI Research Centre, Hirehalli for 1976–77 and 1977–78 with 24 beds of size 1m×24m. During 1976–77, there were 4 rows of 120 plants each and during 1977–78, 5 rows of 120 plants each. Ultimate unit was taken as a row of 5 plants (this is considered as Case-1) and total weight of the produce was considered as the yield of the ultimate unit. This resulted in 96 rows of 24 units during 1976–77 and 120 rows of 24 units during 1977–78. Plots of varying sizes and shapes were formed combining adjacent units column-wise and row-wise, and the corresponding *CV* was worked out for both the years.

Later, the ultimate unit was altered to 1m×1m plot (this is considered as case-2) for both the years, so as to suit the normal practice of raising the crops in beds of 1m breadth by adding 4 rows of 5 plants each for the year 1976–77, and 5 rows of 5 plants each (5 units row-wise) for 1977–78. This resulted in 24 rows of 24 columns each for both the years which were again subjected to analysis.

Fairfield Smith's law $Y = ax^{-g}$ was fitted to find the relationship between plot size (x) and $CV(y)$, where g is the heterogeneity coefficient. Generalization of this law in the form $Y = ac^{-g_1} r^{-g_2}$ was also tried to compare the heterogeneity of rows and columns, where g's denote the corresponding heterogeneity coefficients.

The plot size and shape giving the required information at a minimum cost was taken as the optimum. The cost of experimentation per treatment to estimate the means at 5 per cent *CV* was worked out for four different price situations K_1, K_2, K_3 and K_4 using the relationship:

$$CK_i = C_1 r + C_2 E$$

where CK_i is the cost for the i-th price situation.

C_1 is the cost of maintaining experimental plot,

C_2 is the cost of maintaining experimental plants,

r is the number of replications and

E is the number of experimental plants.

The arbitrary cost ratios $C_1 : C_2$ for price situations K_1, K_2, K_3 and K_4 are 1 : 1, 2 : 1, 1 : 2 and 1 : 4, respectively.

Results and Discussion

In both the years and for both the cases under study, the *CV* decreased with an increase in plot size in both the directions. Decrease was more rapid in row-wise direction. The *CV* values determined for various size and shape of plots followed closely the relation $Y=ax^{-g}$. The equations along with its R^2 values for both the cases and for both the years are presented in Table 1. In both the years, no appreciable reduction of per unit decrease in *CV* was noticed, when the plot size exceeded 4 in case–2, and 6 in case–1. Hence, plot sizes of 4 and 6 were taken as optimum, for case 2 and case 1, respectively.

Table 1. Fairfield Smith's law $Y=ax^{-g}$

Year	Case	
	1	2
1976–77	$Y=56.48x^{-0.30}$ ($R^2=0.98$)	$Y=33.75x^{-0.22}$ ($R^2=0.97$)
1977–78	$Y=73.19x^{-0.17}$ ($R^2=0.96$)	$Y=57.37x^{-0.19}$ ($R^2=0.96$)

Table 2. Fairfield Smith's Generalized relationship $Y=ac^{g1}r^{g2}$

Year	Case	
	1	2
1976–77	$46.54c^{-0.21}r^{-0.24}$ ($R^2=0.92$)	$31.32c^{-0.18}r^{-0.19}$ ($R^2=0.88$)
1977–78	$78.23c^{-0.17}r^{-0.23}$ ($R^2=0.89$)	$63.66c^{-0.14}r^{-0.32}$ ($R^2=0.92$)

Case 1. One row of 5 plants
Case 2. Plants in 1m×1m bed
Y is the *CV* for the plot size *x* with *r* rows and *c* columns.

The generalized Fairfield Smith's Law represented in the form: $Y=ac^{-g_1} r^{-g_2}$ was a satisfactory fit for both the years and both the cases under study. The equation along with its R^2 values are given in Table 2. The row-wise heterogeneity was significantly higher than column-wise heterogeneity, thereby suggesting that formation of plots with more number of rows will give more homogeneous blocks for experiments.

The relative cost of experimentation per treatment under 4 different price situations when the plots are arranged in blocks of 4, 6, 8 and 12 for different sizes and shapes of plots based on the observed CV, was worked out for 1976–77 and 1977–78 and for

Table 3. Cost of experimentation per treatment for different price situations in 4-and 12-plot blocks. Case-1: Ultimate unit 1 row of 5 plants (1976–77)

Shape of Plot	Size of Plot	4 plot						12 Plot					
		C.V.	r	K_1	K_2	K_3	K_4	C.V.	r	K_1	K_2	K_3	K_4
1:1	1×1	56.60	123	256	384	384	640	57.51	132	264	396	396	660
	2×2	57.81	134	670	804	1206	2278	31.76	40	200	240	360	680
1:2	1×2	42.90	74	222	296	370	666	43.65	76	228	304	380	684
	2×4	23.65	22	198	220	374	726	24.42	24	216	240	408	792
1:3	1×3	36.27	53	212	265	371	689	36.96	55	220	275	385	715
	2×6	20.96	18	234	252	450	882	21.55	19	247	266	475	931
1:4	1×4	31.83	41	205	246	369	697	33.26	44	220	264	396	748
1:6	1×6	28.61	33	231	264	429	825	28.37	32	224	256	416	800
1:8	1×8	24.56	24	216	240	408	792	25.77	27	243	270	459	891
1:12	1×12	23.66	22	286	308	550	1078	22.38	20	260	280	500	980
2:1	2×1	89.21	61	183	244	305	549	40.25	65	195	260	325	585
	4×2	23.56	22	198	220	374	726	23.54	22	198	220	374	726
3:1	3×1	34.20	47	188	235	329	611	35.01	49	196	245	343	637
	6×2	20.39	17	221	238	425	833	20.91	17	221	238	425	833
4:1	4×1	25.39	26	182	208	338	650	26.00	27	189	216	351	675
6:1	6×1	29.30	34	170	204	306	578	29.71	35	175	210	315	595
8:1	8×1	23.38	22	198	220	374	726	22.44	20	180	200	340	660
12:1	12×1	20.20	16	208	224	400	784	20.40	17	221	238	425	833
2:3	2×3	25.69	26	182	208	338	650	26.97	29	203	232	377	725
3:2	3×2	26.92	29	203	232	377	725	27.39	30	210	240	390	750
3:4	3×4	20.52	17	221	238	425	833	21.92	19	247	266	475	931
4:3	4×3	18.93	14	182	196	350	686	20.00	16	208	224	400	784

Table 4. Cost of experimentation per treatment for different price situations in 4-and 12 plot blocks Case-2: Ultimate unit 1m×1m plot (1976–77)

Shape of Plot	Size of Plot	4 Plot						12 Plot					
		C.V.	*r*	K_1	K_2	K_3	K_4	C.V.	*r*	K_1	K_2	K_3	K_4
1:1	1×1	31.73	40	80	120	120	200	33.29	44	88	132	132	220
	2×2	32.45	42	210	252	378	714	21.94	19	95	114	171	323
1:2	1×2	25.58	26	78	104	130	234	27.26	30	90	120	150	270
	2×4	25.25	26	234	260	442	858	18.24	13	117	130	221	429
1:3	1×3	21.80	19	76	95	133	247	21.95	18	72	90	126	234
	2×6	14.74	9	117	126	225	441	15.77	10	130	140	250	490
1:4	1×4	17.58	12	60	72	108	204	20.26	16	80	96	144	272
1:6	1×6	15.77	10	70	80	130	250	17.55	12	84	96	156	300
1:8	1×8	11.94	6	54	60	102	198	15.63	10	90	100	170	330
1:12	1×12	12.39	6	78	84	150	294	12.16	6	78	84	150	294
2:1	2×1	23.69	22	66	88	110	198	25.39	26	78	104	130	234
	4×2	14.75	9	81	90	153	297	17.49	12	108	120	204	396
3:1	3×1	10.38	4	36	40	68	132	12.77	7	63	70	119	231
4:1	4×1	16.13	10	50	60	90	170	18.30	13	65	78	117	221
6:1	6×1	14.90	9	63	72	117	225	16.95	11	77	88	148	275
8:1	8×1	20.26	16	64	80	112	208	21.76	19	76	95	133	247
12:1	12×1	10.91	5	65	70	125	245	12.79	7	91	98	175	343
2:3	2×3	18.14	13	91	104	169	325	17.66	12	84	96	156	300
3:2	3×2	17.27	12	84	96	156	300	19.38	15	105	120	195	375
3:4	3×4	11.60	5	65	70	125	245	14.62	9	117	126	225	441
4:3	4×3	14.00	8	104	112	200	392	13.91	8	104	112	200	392

both the cases. Tables 3 and 4 give the relative cost of experimentation for blocks of sizes 4 and 12 for 1976–77 foı case-1 and case-2, respectively. The number of replications decreased rapidly as the plot size increased. A close study of the analysis reveals (Table 3) that plots of 6 rows of one column each gave the minimum cost for 1976-77 for case-1. The subsequent year's data undoubtedly confirmed this result. The plot size obtained by the graphical method also confirmed this result. In case-2 where the ultimate unit is 1m×1m, 3 rows of one column each were found to be optimum for block sizes 4, 6 and 8 plots and 4 rows of one column each for 12-plot block (Table 4). Hence, plot size of 6 rows of one column in the case of ultimate unit of one row of 5 plants each, and 3-4 rows of one column, in the case of ultimate unit of plants in 1m×1m bed, were found to be optimum.

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DISCUSSION

V. S. SHARMA (UPASI, Cinchona): Do you think it is necessary to study the interaction between the cultivar used and the plot size because tillering and the number of fingers may interact with the spacing and plot size?

BHAGAVAN: Yes, it will be a really interesting study to know the interaction between cultivars and the plot size. If interaction is found to exist, one may have to go in for different plot sizes for different groups of cultivars.

SEASONAL FLUCTUATIONS IN THE PRICES OF COCONUT, COPRA AND COCONUT OIL IN KERALA*

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ABSTRACT

Long term movements in the prices of coconut products are explained to a large extent by the trends in the imports of copra and coconut oil. An attempt has been made here to study the seasonal fluctuations in the prices of coconut, copra and coconut oil. Seasonal indices for coconut oil prices were found to be influenced by the availability of oil inthe market, and those for coconut by the demand from copra makers which in turn depended on the pattern of rainfall. The influence of supply factors on the price of coconut was negligible. With increase in prices a shift in the pattern of variation was noticed in the case of coconut. The amplitude of the fluctuations had increased in all cases. Its adverse effect on the small cultivator has been discussed.

INTRODUCTION

With 6.7 lakh hectares under coconut, Kerala accounts for nearly two-thirds of the area under the crop in the country. The estimated number of coconut holdings in the state is more than 30 lakhs and 90 per cent of these holdings is one ha or less in size. According to a survey conducted during 1959–66, the cultivating households were selling 78 per cent of their produce in the form of raw nut itself, after retaining about 18 per cent for home consumption (Anon., 1963, 1966 and 1967) Similarly, coconut and coconut oil are used in almost every household in the state for culinary and toiletry purposes. Therefore, the prices received by the cultivators as well as those paid by the consumers are of utmost importance. The long-term movements in the prices of coconut products are explained to a large extent by the trends in the imports of these products (Mathew, 1978). Seasonal variations in the prices of coconut, copra and coconut oil are presented in this paper.

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*CPCRI contribution No. 243.

MATERIALS AND METHODS

Month-wise data available from the Directorate of Economics and Statistics, Trivandrum on the farm price and wholesale price of coconut, copra and coconut oil was made use of for this study. The price data of copra was available from 1961 only. In the other cases, data from 1958 onwards was made use of. The wholesale prices of coconut and copra were collected from Alleppey market, and those for coconut oil from Cochin. The results of this study will apply to the other markets also, since the markets for coconut and coconut products are well integrated. In the case of farm, prices, published data were available on district basis only, and hence the mean for the state as a whole was used for this study. For the estimation of seasonal indices, a multiplicative model ($O=T\times S\times C\times I$, where O represents the original data, T the trend, S the seasonal variation, C the cyclical variation, and I the irregular component) was assumed.

RESULTS AND DISCUSSION

Seasonal indices calculated for the farm price of coconut and wholesale prices of coconut, copra and coconut oil, are presented in Table 1. Farm price of coconut was very high during November to February and low during June to September. The prices were

Table 1. Seasonal Indices for the prices of coconuts, copra and coconut oil

Month	Farm price of coconuts in Kerala	Wholesale price of coconuts at Alleppey	Wholesale price of Copra at Alleppey	Wholesale price of coconut oil at Cochin
January	105.0(5.2)	103.2(4.4)	104.1(7.3)	103.1(7.0)
February	103.9(3.7)	101.8(5.5)	98.9(4.9)	98.8(5.2)
March	101.0(2.7)	98.4(4.5)	92.8(2.7)	93.0(3.2)
April	101.3(4.4)	100.5(4.8)	93.5(3.8)	94.4(4.1)
May	99.4(4.1)	94.9(4.5)	94.0(5.1)	93.8(5.4)
June	95.9(4.8)	98.1(4.3)	94.7(4.8)	95.3(5.1)
July	94.5(5.6)	96.0(7.6)	98.1(5.6)	99.5(5.5)
August	94.5(5.0)	95.0(5.1)	99.0(5.9)	100.7(4.9)
September	96.9(4.7)	98.2(6.9)	102.6(4.4)	104.9(5.3)
October	99.8(5.1)	102.4(7.1)	105.5(5.2)	108.7(6.5)
November	103.6(6.7)	105.8(6.2)	110.0(6.3)	109.7(9.9)
December	104.2(5.9)	105.7(6.9)	106.8(6.7)	98.1(9.5)

Note: Figures in parentheses denote the coefficient of variation (%)

showing a decreasing trend from January onwards, which continued upto July, and thereafter it was steadily increasing. In the case of wholesale price of coconut, the amplitude of the fluctuations was slightly higher compared to the farm prices, the highest price being received in November-December. Though the prices started decreasing from January onwards, the seasonal indices were slightly higher in April and June, compared to that in previous months. An upward trend in the prices was noticed from August onwards. The pattern of variation as well as the amplitude of the fluctuations were very similar in the case of wholesale prices of copra and coconut oil. The lowest prices were registered in March and the highest in November. However, the sudden fall in the prices of coconut oil in December was conspicuous (Fig. 1.).

SEASONAL VARIATION IN THE PRICES OF COCONUT, COPRA AND COCONUT OIL

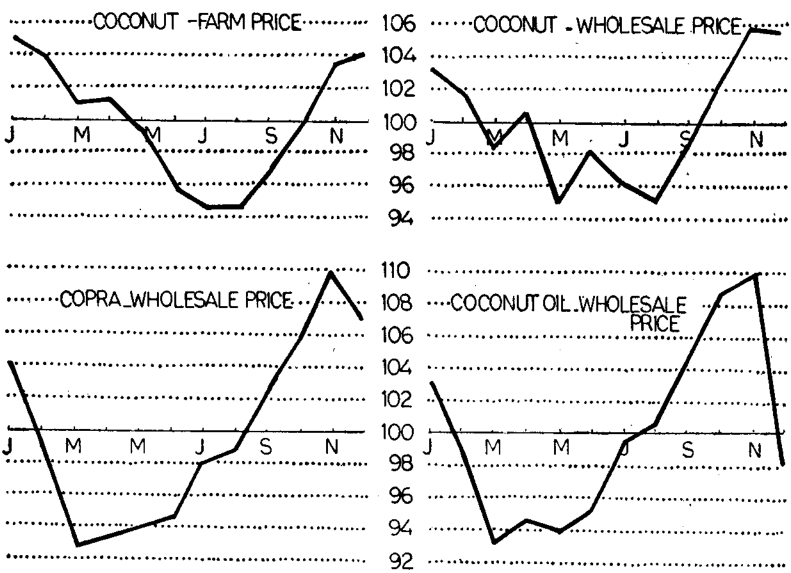

Fig. 1.

Coconuts, though harvested in almost every month, show seasonality in production with about 62 per cent of the nuts harvested during the first six months (January to June) of the year (Table 2).

Table 2. Percentage of nuts harvested and the distribution of rainfall during the different months of the year

Month	% of nuts harvested (1959–66)	Distribution of rainfall (mm) (1958–78)	Month	% of nuts harvested	Distribution of of rainfall (mm)
January	9.2	10	July	4.8	727
February	10.3	16	August	6.3	419
March	12.2	37	September	6.2	267
April	11.4	121	October	6.3	275
May	9.9	282	November	6.6	171
June	9.0	566	December	7.8	45

Source of basic data: Directorate of Economics and Statistics, Trivandrum

Eventhough the data in this paper concerns only the period 1959–66, it is presumed that a similar trend can be assumed during any given period. In the case of availability of copra as well as the producion of oil, similar trends were observed. The oil mills generally have brisk business during the summer months as they start getting the copra by October-November. Though the arrival of copra stops by May-June, with the onset of monsoon, their stocks run the mills for few more months. Because of the seasonal supply factor, the prices of coconut oil are generally low during the summer months and the early periods of monsoon. During the latter half of the year, the production of coconut and availability of copra are low as reflected in the rise of market price of coconut oil. In the case of copra, though the demand from the oil mills is high during the summer months, the prices remain low due to the greater supply of the commodity. Copra prices show a declining trend from November, with the arrival of copra in the market after the monsoon. Thus, it can be seen that the seasonal variations in the prices of copra and coconut oil are more due to supply factors than due to demand factors.

Kerala receives about 1700 mm rain during the period from June to August (SW monsoon) and another 700 mm during September to November (NE monsoon). The period from May to October accounts for nearly 96 percent of the total annual rainfall. During this period, the seasonal indices for the farm price of coconut is below normal. This is due to the lack of facilities for conversion of nuts to copra during the monsoon months. From October onwards the wholesale prices of coconut are above normal because of the favourable weather factors, consequent upon heavy demand from copra makers and the low supply position. This rise in price has been reflected in the farm prices from November onwards. Though there is abundant supply of nuts during the first half of the year, the prices have not fallen below normal because of the heavy demand from the copra makers and oil mills. Therefore, it is clear that the seasonality in the prices of coconut is more due to demand factors which in turn depend on the pattern of rainfall. The influence of supply factors on the price of coconut is limited.

The relationship between the production cycle of coconut and pattern of rainfall with seasonal variation in prices can be seen from Table 3. Multiple regression analysis showed that 79 per cent of the variations in the farm price of coconut, 86 per cent and 74 per eent of the variations in the wholesale prices of copra and coconut oil, respectively, are explained by these two variables alone.

Table 3. Seasonal variations in prices in relation to the production cycle of coconuts and pattern of rainfall

	Coefficient of Correlation with	
	Production cycle of coconuts (x_1)	Distribution of rainfall (x_2)
Farm price of coconuts (y_1)	0.4503	–0.8866
Wholesale price of coconuts (y_2)	0.0221	–0.6216
Wholesale price of copra (y_3)	–0.6005	–0.2270
Wholesale price of coconut oil (y_4)	–0.6945	–0.0091
$y_1 = 105.09 + \underset{(0.3031)}{0.1518x_1} - \underset{(0.0031)}{0.0157x_2}$	($R^2 = 0.7919$)	
$y_2 = 110.64 - \underset{(0.4439)}{0.8270x_1} - \underset{(0.0045)}{0.0_153x_2}$	($R^2 = 0.5571$)	
$y_3 = 127.174 - \underset{(0.3800)}{2.6896x_1} - \underset{(0.0039)}{0.0216x_2}$	($R^2 = 0.8557$)	
$y_4 = 124.76 - \underset{(0.5043)}{2.5222x_1} - \underset{(0.0052)}{0.0151x_2}$	($R^2 = 0.7355$)	

Though the average annual wholesale prices of coconut and coconut oil were showing a rising trend from the mid-50s four different phases are clearly discernible. The period from 1958–63 (Phase-I) is marked by slow increase in prices. It is followed by a period 1964–70 (Phase-2) of slightly higher rate of increase. Phase-3 (1970–75) is conspieuous for the sudden increase in prices, accompanied by wide fluctuations from year to year, whereas during the period following this (1976–81; Phase-4) the prices were increasing at a very fast rate. Seasonal indices computed for these commodities separately for the different periods (Table-4) showed that with increase in prices, the amplitude of the fluctuations has also increased. This was more pronounced in the case of wholesale prices of all the three commodities. The range of values for the wholesale prices of coconut was only 7.8 points during Phase-1 and it steadily increased to 17.6 in Phase-4. During the first phase, the farm price of coconut was maximum during February, whereas in the subsequent phases the maximum was in January or earlier. During the earlier phases, though the decline in prices generally started during January-February only, in Phase-4 it was from as early as November Similarly, the prices were generally below normal during June to October, compared to the low prices from March onwards in Phase-4. This shifting trend in the indices as well as the increase in the fluctuations are against the interest of the cultivators, majority of whom are small farmers who resort to distress sales. The average seasonal index for the farm price as well as the wholesale price of coconut during the peak period of production (January to June) accounting for nearly two-thirds of the annual production) were 102.3 and 100.5 respectively during Phase-1 and it steadily declined to 98.9 and 95.7 in Phase-4. It is true that the price index has shown an increase during the lean periods of production, but only the big farmers who can store the nuts from the first half of the year can reap benefits from this kind of price structure.

In the case of copra and coconut oil also, the amplitude of the fluctuations was found to increase with increase in prices. The range of variation was around 23 points in Phase-4, compared to about 14 points two decades ago. With the increase in prices, a further depression was noticed during March-May, when there was abundant supply of oil and a further upward rise in prices during October-November when fresh stock of oil just started arriving. Such a situation only favours the traders with sound financial backing.

Table 4. Seasonal indices for the prices of coconuts, copra and coconut oil in the different phases

Period	January	February	March	April	May	June	July	August	September	October	November	December
a) Farm price of coconuts in Kerala												
1958–63	104.4	105.4	102.8	102.7	100.9	97.7	95.1	93.9	95.6	99.1	101.1	101.3
1964–69	105.2	103.8	101.8	103.1	99.9	94.3	93.3	94.1	96.5	98.7	104.1	105.2
1970–75	106.1	104.1	100.7	102.1	101.0	96.9	94.3	94.4	95.1	98.7	102.3	104.3
1976–81	104.5	102.3	98.7	97.2	95.8	94.6	95.3	95.7	100.5	102.8	107.0	105.6
b) Wholesale price of coconuts at Alleppey												
1958–63	101.2	102.1	100.6	99.8	100.3	98.8	95.4	95.4	97.3	102.1	103.8	103.2
1964–69	101.4	102.9	101.6	104.7	100.9	98.1	92.5	94.5	97.2	98.6	103.2	104.4
1970–75	107.9	105.8	97.0	99.9	98.8	98.0	96.6	91.6	93.3	100.7	104.6	105.8
1976–81	100.3	94.9	93.3	95.7	94.2	96.0	98.5	97.3	104.1	107.1	110.9	107.7
c) Wholesale price of copra at Alleppey												
1961–63	103.7	101.2	94.3	93.5	96.6	96.3	97.3	99.7	103.3	104.7	107.2	102.1
1964–69	103.9	98.4	93.2	94.5	93.6	94.1	97.7	99.9	102.5	105.8	109.1	107.3
1970–75	105.5	98.6	93.2	94.1	95.6	95.6	98.7	99.4	99.9	103.3	109.2	106.9
1976–81	102.9	98.6	91.2	91.8	91.8	93.5	97.9	97.1	105.4	107.9	113.4	108.5
d) Wholesale price of coconut oil at Cochin												
1958–63	101.1	100.7	96.2	95.1	96.5	97.4	99.2	101.9	101.9	104.8	109.4	97.9
1964–69	103.2	98.8	93.4	95.2	92.9	94.1	100.7	102.0	105.5	110.2	109.4	94.6
1970–75	105.0	97.6	92.2	94.0	94.9	95.8	99.3	99.9	104.7	110.1	107.0	99.5
1976–81	102.4	98.1	90.5	93.2	90.8	93.9	98.4	101.2	107.5	109.5	113.9	100.6

It is reasonable to assume that the fluctuations observed in the case of these commodities could be the direct effects of the inflation which has been observed during this period. To amplify further, the price trend and the wholesale price indices have been on the increase from the early '60s, but as in the case of other commodities, in coconut also, the increased inflation rate has affected the purchasing power of the consumer and not the selling power of the producer, which is apparent from the near stable/marginal differences in farm prices. From the above analysis it follows that the full benefits of the rise in prices have not reached the ordinary coconut cultivators.

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SOME CONSIDERATIONS IN ANALYSING THE YIELD DATA OF COCONUT*

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ABSTRACT

Examination of yield data of coconut for individual years revealed that the distribution is always positively skewed and leptokurtic. Pooling the data for consecutive years as well as consideration of palms in groups did not improve the distribution. Among the different transformations tried, $\sqrt{x \times 10}$ transformation was found to bring the data to a near normal distribution in most cases. Another difficulty experienced while analysing the yield data of coconut experiments is the large error variance. With pooling of data for consecutive years. variance was found to get reduced. Covariance analysis was found to result in increased efficiency.

INTRODUCTION

Though the statistical techniques followed in experimentation with annual crops and perennial crops are essentially the same, one specific difficulty experienced while analysing the yield data of coconut experiments is the large error variance. This is mainly due to the heterogeneous nature of the experimental material, differential response of individual plants to the varying weather conditions over the years, and soil fertility differences arising out of the vast area required for laying out any meaningful experiments. Because of the large error variance, real treatment differences are often masked and go undetected. Reduction in residual variation is generally achieved through methods of calibration and covariance analysis. Shrikhande (1957) and Abeywardena (1970) have illustrated the use of pre-experimental yield data while designing new experiments with coconuts. Govinda Iyer (1957) has observed that the pre-experimental data for three years as the concommittant variate will help in detecting treatment differences most efficiently. According

*CPCRI Contribution No. 257.

ing to Abraham and Kulkarni (1963), data collected about two years immediately prior to the experimental period was sufficient for covariance analysis. In the light of the above, the variability in the yield of coconuts in the different years, its distribution, relationship between yields obtained in different years, and ways to reduce the experimental error, have been studied and results are presented.

Materials and Methods

Individual tree yield data available for the period 1961–80 from two plots at Central Plantation Crops Research Institute, Kasaragod, was made use of for this study. The palms in Plot 1 (RS 28 Central Block, n = 155 palms) were 35-40 years old at the beginning of this period, and those in Plot-2 (RS 29 North Block, n = 354 palms) were aged 45-50 years. The palms were growing under rainfed conditions and receiving the recommended dose of fertilizers. Normality of distribution of yield data was tested by working out the coefficients for skewness (b_1) and kurtosis (b_2). The variances for individual years and for cumulative yields for five years, and the reduction in variance due to covariance analysis using one to five years' pre-experimental yield data, were also worked out.

Results and Discussion

The valid application of tests of significance in analysis of variance requires that experimental errors should be independently and normally distributed with a common variance (Eisenhart, 1947). This, in other words means that in an experiment-free material, the distribution of the original data should be normal. Tests for normality revealed that in general, the distribution of annual yield of coconut is always positively skewed and leptokurtic, generally following a Pearson Type IV distribution (Table 1). This is due to the presence of proportionally higher percentage of palms giving below average yield. In the years of low production skewness was found to be more. Among the two plots considered, coefficient of skewness was comparatively less in Plot 2, where the yield was higher. Similarly, distribution was found to be leptokurtic in the years where yield was generally lower. Studies conducted in other perennial crops like cocoa, coffee and oil palm (Butters, 1964; Chapas, 1961; Cunningham and Burridge, 1957; Lotode and Muller,

1974) have also shown that the distribution of their yield data is far from normal.

Table 1. Measures of central tendency (mean), skewness (b_1) and kurtosis (b_2,) for the yield data of coconut at Kasaragod

Plot 1 RS 28 Central Block (n=155)				Plot 2 RS 29 North Block (n=354)			
Year	Mean	b_1	b_2	Year	Mean	b_1	b_2
1967	48.8	0.98**	4.41*	1961	56.2	0.19	2.93
1968	44.2	0.83**	3.61	1962	54.5	1.51**	9.92**
1969	40.2	0.88**	3.92*	1963	47.2	0.63**	4.19**
1970	53.6	0.78**	3.26	1964	66.6	1.00**	5.85**
1971	47.6	1.41**	7.43**	1965	44.5	0.56**	3.82**
1972	58.2	0.73**	3.64*	1966	68.6	0.96**	5.00**
1973	50.1	0.95**	4.35**	1967	58.3	0.40**	3.99**
1974	41.4	0.97**	4.09*	1968	53.8	0.74**	4.07**
1975	55.0	0.52**	3.26	1969	59.1	1.99**	17.68**
1976	43.4	0.81**	4.05*	1970	69.0	0.53**	4.33**

*Significant at 5% level, **Significant at 1% level

Among the different transformations tried, square root transformation of the form $\sqrt{x+10}$ was found to be the best. This was effective in reducing the magnitude of skewness and kurtosis in

Table 2. Effect of square-root transformations on the normality of distribution of yield data of coconut

Plot 1:RS 28 Central Block (n=155)					Plot 2:RS 29 North Block (n=354)				
	$\sqrt{x+3/8}$ transformation		$\sqrt{x+10}$ transformation			$\sqrt{x+3/8}$ transformation		$\sqrt{x+10}$ transformation	
Year	b_1	b_2	b_1	b_2	Year	b_1	b_2	b_1	b_2
1967	–0.03	2.93	0.22	2.88	1961	–0.67**	3.58*	–0.44**	3.09
1968	–0.16	2.61	0.05	2.54	1962	–0.02	4.62**	–0.29*	4.67**
1969	–0.18	2.98	0.16	2.79	1963	–0.31**	3.30	–0.08	3.09
1970	–0.06	2.78	0.16	2.55	1964	–0.13	4.23**	–0.09	3.96**
1971	–0.09	4.29**	0.33*	4.07*	1965	–0.43**	3.15*	–0.14	2.85
1972	–0.47**	3.73*	–0.06	3.06	1966	–0.06	3.62*	–0.18	3.59
1973	–0.12	3.21	0.18	3.01	1967	–0.41**	3.33	–0.26*	3.21
1974	–0.17	2.97	0.20	2.84	1968	–0.15	3.14	–0.05	2.96
1975	–0.09	2.70	–0.01	2.51	1969	–0.13	5.47**	–0.20	5.61**
1976	–0.12	3.04	0.13	2.88	1970	–0.48**	4.11**	–0.28*	3.75**

*Significant at 5% level **Significant at 1% level.

all the years. In some cases, a shift to negative skewness was also noticed. The conventional types of square root transformations like $\sqrt{x}$, $\sqrt{x+3/8}$, and $\sqrt{x} + \sqrt{x+1}$ were found to be of limited use only, in the case of coconut (Table 2).

The effect of pooling data for consecutive years on the distribution was further examined. Since bienniality has been shown to be a significant feature in coconut also (Abeywardena, 1962, and Jacob Mathew, unpublished), the effect of extreme values obtained in alternate years gets evened out when the data for adjoining years are pooled. The coefficients of skewness and kurtosis were found to get reduced when data for two to five years were pooled. With transformation, skewness was found to decrease, accompanied by a shift from positive to negative skewness (Table 3).

Table 3. Effect of pooling data for consecutive years on the normality of distribution of yield of coconut (Plot 2:RS 29, n=252)

Period	Original data		$\sqrt{x+3/8}$ transformation		$\sqrt{x+10}$ transformation	
	b_1	b_2	b_1	b_2	b_1	b_2
1961–62	0.39**	3.65*	–0.34*	3.68*	–0.21	3.53*
1962–63	0.57**	4.17**	–0.25	3.89**	–0.09	3.73*
1961–63	0.34*	3.58*	–0.37**	3.63*	–0.24	3.47
1962–64	0.59**	4.03**	–0.15	3.74*	–0.02	3.61*
1961–64	0.41**	3.62*	–0.27*	3.60*	–0.15	3.46
1962–65	0.39**	3.58*	–0.31*	3.70*	–0.17	3.48
1961–65	0.30*	3.47	–0.38**	3.64*	–0.25	3.45
1962–66	0.52**	3.76*	–0.16	3.71*	–0.04	3.54*

Cunningham and Burridge (1959) in cocoa, and Chapas (1961) in oil palm could get normal distribution of yield data by grouping of trees. In coconut also, grouping of data for trees was found to reduce the skewness (Table 4). In the different years for which this was attempted, a gradual reduction in skewness was noticed with increase in plot size, and with square root transformation of the form $\sqrt{x+10}$, the distribution of yield was found to become normal. However, in years where the distribution of original data itself was highly skewed, not much improvement could be noticed with grouping of trees, even with square-root transformation (Table 4).

Table 4. Effect of multi-tree plots on the normality of distribution of yield of coconut (Plot 2:RS 29, n=354)

Year	Plot size (No. of trees)	Original data		$\sqrt{x+10}$ transformation	
		b_1	b_2	b_1	b_2
1967	1	0.41**	4.04**	–0.26*	3.21
	2	0.40*	3.97*	–0.08	3.60
	3	0.45*	3.03	0.16	2.79
	4	0.56*	3.12	0.34	2.82
	5	0.64*	3.07	0.46	2.83
	6	0.45	2.85	0.27	2.69
1968	1	0.74**	4.07**	0.05	2.97
	2	0.63**	2.54	0.21	2.95
	3	0.30	2.67	0.01	2.43
	4	0.43	2.70	0.19	2.65
	5	0.32	2.62	0.13	2.52
	6	0.70*	3.76	0.41	3.24
1969	1	1.99**	17.68**	0.20	5.61**
	2	1.60**	9.81**	0.73**	5.66**
	3	1.46**	7.24**	0.91**	4.95**
	4	1.19**	5.91**	0.70**	4.71**
	5	1.26**	5.28**	0.93**	4.34**
	6	1.17**	4.84	0.87**	4.25*
1970	1	0.53**	4.33**	–0.28*	3.75**
	2	0.73**	4.42	0.20	4.01*
	3	0.42	2.73	0.21	2.56
	4	0.50*	3.29	0.24	3.01
	5	0.40	3.54	0.14	3.33
	6	0.27	2.39	0.13	2.36

*Significant at 5% level **Significant at 1% level.

It follows from the above analysis that square-root transformation of the form $\sqrt{x+10}$ is necessary while analysing the yield data of coconut, for normalising the distribution. Even when multi-tree plots are used, the above transformation is suggested before the yield data is subjected to tests of significance, using analysis of variance technique.

The inter-relationship between the yields obtained in the different years was also examined. Coefficients of correlation, r_{piq}, were calculated for the mean yields of single trees between an earlier period of p (=0, 1, 2, 3, 4 and 5) years and a later period of q (=1, 2, 3, 4, and 5) years separated by an interval of i (=0, 1, 2, 3, 4 and 5) years. The yield data for 1961–80, for a group of 252 palms (RS-29, North Block), was used for this study. It was seen that, though the yields obtained in the different years are highly correlated, the relationship is comparatively weak when the annual data for immediately preceding and succeeding years are considered. This is due to the alternate bearing tendency shown by some of the palms. Compared to this, the correlation was much higher when there was a gap of one year, between the two years under consideration. When the data for groups of years were considered, the coefficients of correlation were found to go upto 0.9. However, marginal decreases in values were noticed when the gap separating the earlier and later periods was increasing.

The use of ancillary variables in the analysis of covariance for reduction of experimental errors is a widely accepted practice. The variation in perennial plants is mainly due to environmental variation and also inherent genetic variability. Covariance analysis is intended to even out the genetic variation, which is generally of greater magnitude. Shrikhande (*loc. cit*). has found that genetic and environmental components are in the ratio of 2:1 or 3:2, though Pankajakshan (1960) later showed that environmental component is more important when data are considered in blocks of four years or more. In view of the close relationship observed between the yields obtained in the different years, covariance analysis was attempted using different combinations of earlier and later periods. Relative efficiency of this type of analysis, as measured by the ratio of inverses of error variances, was calculated in all these cases (Table 5). Pooling the data for consecutive years was found to increase the efficiency by about 50 to 60 per cent. However, when pre-experimental data were used in covariance analysis, substantial reduction in variance and consequent improvement in efficiency was noticed. Use of two years pre-treatment data was found to almost double the efficiency, compared to what was obtained with single year's data. Relative efficiency was seven times higher with the use of two years pre-treatment data and nine

Table 5. Efficiency of pooling data for post-treatment period with and without covariance analysis (n=252, period: 1961–80)

Gap(i)	Earlier period(p)	Later period (q) 1	2	3	4	5
—	0	100	148	155	160	163
0	1	121	262	280	314	333
	2	176	482	538	657	720
	3	179	513	606	718	789
	4	192	569	697	824	903
	5	200	574	714	827	946
1	1	202	331	367	382	389
	2	219	531	631	718	738
	3	224	575	705	790	820
	4	227	604	741	844	913
	5	229	605	746	884	917
2	1	143	273	306	327	346
	2	187	436	555	607	656
	3	197	488	597	646	729
	4	209	527	652	740	796
	5	203	524	669	724	814
3	1	147	266	295	308	321
	2	179	436	490	537	585
	3	184	449	515	594	605
	4	169	455	550	600	644
	5	164	468	548	615	696
4	1	157	285	318	340	368
	2	200	439	516	582	598
	3	197	455	559	590	642
	4	202	500	597	657	703
	5	211	507	615	649	715
5	1	160	287	324	359	364
	2	183	414	496	530	573
	3	183	455	525	568	615
	4	201	477	575	623	669
	5	209	491	567	620	659

times higher with five years' pre-treatment data, when data for five years in the post-treatment period was considered. From the above analysis, it may be concluded that, as and when the experiment progresses, it is desirable to use the progressive average yields for analysis, instead of analysing the annual yield data every year. That is to say, in the first year of the experiment, the first year's data can be analysed, while in the second year, the average yield for the first two years, and in the third year, the average yield for the first three years and so on, may be considered for analysis. Except in places where past yield records are regularly maintained, it is enough to consider only two years' data immediately prior to the commencement of the experiment, for covariance analysis. Present data did not support Govinda Iyer's (1957) suggestion of using three years' pre-experimental data for covariance analysis. Sen and Biswas (1966) have shown in tea, that adjustment of yield due to co-variance analysis generally ceased to be efficient after the first five years' experimentation in manurial trials. In the case of coconut, no such trend was noticed, though marginal decline in efficiency was visible, as the gap between pre-and post-experimental periods was increasing.

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DISCUSSION

A. I. JOSE: Did you try the transformation $\sqrt{x+1}$? Can the $\sqrt{x+10}$ transformation be applicable to all types of experiments in coconut?

JACOB MATHEW: Yes, we tried $\sqrt{x+1}$ transformation along with transformations like $\sqrt{x+2/3}$, $\sqrt{x+20}$, $\sqrt{x+30}$, $\sqrt{x+40}$, $\sqrt{x+50}$, $\text{Log}_e(X+10)$, etc. $\sqrt{x+10}$ is expected to be applicable for all types of experiments irrespective of the type of treatment.

A. I. J.: What should be the minimum period for taking cumulative yield? Is it not dependent on the type of treatment?

J. M.: This aspect was not studied.

N. R. SHANTHAMALLAIAH. Can we take five years average yield data of coconut and subject it to analysis after $\sqrt{x+10}$ transformation? This I want to know because coconut needs 3½ years from flower primordium to harvest of ripened nuts.

J. M. Our suggestion is to use the progressive averages for analysis. As and when the experiment progresses, we can go on adding the data. If you expect delay in getting response to treatments, we can leave a gap of one or two years, immediately after the commencement of the experiment.

PRE-HARVEST FORECASTING OF CASHEW YIELD BASED ON BIOMETRICAL CHARACTERS

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ABSTRACT

A study conducted for three years during 1978–81 to standardize a technique for forecasting cashew yield based on seven biometrical characters recorded at weekly intervals, revealed that yield can be forecast with reasonable precision (R^2=0.64) by a single spot observation made during the peak flowering period (February-March). The number of variables could be brought down to three viz. the number of nuts on the tree, condition of flowering (graded 0 to 5), and canopy area, without substantially affecting the accuracy of the estimate (R^2=0.61).

INTRODUCTION

Pre-harvest forecasting of agricultural crops is essential in research and development programmes. In annual crops like paddy, wheat, cotton, jowar, and jute, methods have be.n dev.loped for pre-harvested forecasting. Singh, Jha and Aneja (1979) have discussed various forecas ing methodologies and reviewed the various forecasting systems in relation to annuals, but there is very little work on perennial crops. Vernon (1971) estimated the annual yield of cocoa from sample picks. Arul Raj, Narasimhayya, Haveri and Rajasulochana (1979) estimated coconut yield based on snap observations. George and Vijaya Kumar (1979) developed a forecasting method for cashew based on sample observations taken on different occasions during the flowering period.

The harvest of cashew extends to about 4 months and it is rather difficult to collect the yield data from individual trees. The present study was conducted to identify suitable biometrical characters, to find out the optimum period of sampling and to standardize a technique of forecasting cashew yield based on, if possible, a single observation.

CPCRI contribution No. 245.

Materials and Methods

Forty cashew trees in the 15-20 years age group were selected at random each year, for three years beginning from 1979, from the cashew plantation of Plantation Corporation of Kerala at Muliyar. Observations were recorded on the number of shoots (x_1), number of panicles (x_2) and number of nuts at all stages of maturity (x_3) counted from $\frac{1}{2}$m × $\frac{1}{2}$m dimension on the canopy of the tree taken from four directions, north, east, south and west. The total number of nuts in the tree (x_4) was counted and the condition of flowering (x_5) recorded at weekly intervals. The first round of observations for the initial year was recorded during the last week of February (when about 50% of the trees had nuts in the peanut stage) and for the next year (1980) during the middle of February. During the last year (1981) the first round of observations were recorded during the last week of January in order to study the early stages of flowering also. The observations were continued for 14 weeks during the first year, 12 weeks in second year, and 8 weeks in the third year. The canopy area (x_7) was worked out. The total yield of nuts (Y) in the daily harvest and average weight per nut (x_6) was determined. Multiple regression equation of the form $Y = b_o + \Sigma b_i x_i$ using the above observations were worked out for each week to forecast the final yield (Y). The regression equations were tested for homogeneity, and combined estimates were arrived at for each year. The regressions were further pooled over the years after eliminating the year effect to get a forecasting equation for any year.

Results and Discussion

Table 1 gives the coefficients of determination for the multiple regression equations based on the 7 biometrical characters. During 1979, first round of observations gave the maximum coefficient of determination, while in the second year, the 3rd, 4th and 5th rounds gave very high R^2 (0.92 to 0.94), and during 1982, higher R^2 values were obtained for 6th, 7th and 8th rounds (0.84 to 0.89). When tested for homogeneity of regressions over the rounds, 1st, 2nd and 3rd for 1979, 3rd, 4th and 5th rounds during 1980 and 5th, 6th, 7th during 1981, were found to be homogeneous. It was seen that these rounds in each year corresponded to the peak flowering phase with large number of nuts in the peanut stage, thereby showing that

Table 1. R^2 values for the regression equation to predict total yield using seven biometrical characters

Rounds/Weeks	1979	1980	1981
1	0.55**	0.82**	0.65**
2	0.42**	0.91**	0.60**
3	0.44**	0.92**	0.77**
4	0.47**	0.94**	0.65**
5	0.38*	0.94**	0.75**
6	0.46**	0.81**	0.84**
7	0.38**	0.87**	0.89**
8	0.39*	0.68**	0.89**
9	0.40*	0.59**	
10	0.41*	0.62**	
11	0.45**	0.38*	
12	0.39*	0.49**	

*Significant at 5% level; **significant at 1% level.

this is the correct stage for recording observations to predict the yield.

Table 2 gives the coefficients of determination obtained by combining 3 rounds of observations within each year and pooled estimate over the years eliminating year effect for all the 7 characters together, as well as the three important characters namely, number of nuts (x_4), condition of flowering (x_5), and canopy area (x_7), and then taking number of nuts (x_4), and canopy area (x_7) only.

Table 2. R^2 values for regression equation to predict the total yield by combining rounds and years.

Years	With all the 7 characters	With 3 characters x_4, x_5 and x_7	With 2 characters x_4 and x_7
1979 (1, 2 and 3)	0.43	0.36	0.20
1980 (3, 4 and 5)	0.88**	0.84**	0.84**
1981 (5, 6 and 7)	0.81**	0.80**	0.79**
Pooled for 3 years	0.64**	0.61**	0.59**

**Significant at 1% level.

The contribution from characters other than x_4, x_5 and x_7 were found to be negligible as was evident on comparing the respective R^2 values. The trend was same in all the years. The R^2 values were low in 1979 and high in 1980 and 1981. The year 1979 was a lean year for production because of severe tea-mosquito attack which may be the possible reason for low R^2 for that year. The regression equation obtained for forecasting the total yield (in kg) of cashew obtained by pooling the combined regressions for the three years, eliminating the year effects was as follows:

$$\begin{aligned} Y = -2.401 - &\underset{(0.0045)}{0.002x_1} + \underset{(0.0071)}{0.013x_2} + \underset{(0.0111)}{0.015x_3} + \underset{(0.0008)}{0.010x_4} \\ &+ \underset{(0.0728)}{0.228x_5} + \underset{(0.0485)}{0.204x_6} + \underset{(0.0020)}{0.007x_7} \qquad (R^2 = 0.64) \end{aligned}$$

It is seen that the coefficients for the characters, number of shoots (x_1), number of panicles (x_2), and number of nuts (x_3) per unit area were not significant. Average number of nuts can be obtained only after harvesting at least a few nuts from the trees and as such this character cannot be observed in the pre-harvest stage. It is seen from Table 2 that the contribution of these four characters is not substantial (R^2 is reduced from 0.64 to 0.61). Hence, the prediction equation is reduced to:

$$Y = 1.459 + \underset{(0.0005)}{0.0094x_4} + \underset{(0.0058)}{0.3314x_5} + \underset{(0\ 0019)}{0.0082x_7} \quad (R^2 = 0.61),$$

where x_4 is the number of nuts on the tree, x_5 is the condition of flowering graded from 0 to 5 depending upon the flowering at any time during the peak flowering period of about a month, x_7 the canopy area (in m^2), and Y is the estimated yield in kg. It shows that by taking a single spot observation on these three characters at anytime during the peak flowering period, the yield can be forecast with reasonably good precision ($R^2 = 0.61$). In cases where high personal bias is suspected in recording the condition of flowering (x_5) the same can be deleted, and the prediction equation reduced to: $Y = -0.43 + \underset{(0.0005)}{0.01x_4} + \underset{(0.002)}{0.0075x_7}$, without much loss of precision

(R^2=0.59). Considering the cumbersome nature of the procedure for finding out the yield per tree based on daily harvest of nuts for a period of 3-4 months, the above result based on a single spot-observation is very much relevant. By this method, the estimate of the final yield can be made 4-5 months before the completion of harvest. This study also specifies the period of recording observations for forecasting cashew yield as the peak flowering phase, and only one round of observations is needed for the purpose. Thus, this is an improvement over our previous study (George and Vijaya Kumar, 1979).

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DISCUSSION

R. C. MANDAL: Branching habit of cashew is extremely variable. Hence the prediction may not hold good.

M. V. GEORGE: As the canopy area is directly correlated with branching habit, the prediction will hold good.

C. RAMACHANDRAN: Can we use this formula for forecasting future yield from a tree?

M. V. GEORGE: No. This technique is applicable only for the current season.

IMPACT OF EXTENSION SERVICE ON SMALL TEA GARDENS IN THE NILGIRIS

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ABSTRACT

The results of a survey conducted to study the impact of 3 UPASI—Tea Board's small tea growers development schemes, namely training, supply of clonal plants, and demonstration plots, on the yield of small tea gardens in the Nilgiris, are reported in the paper. The training imparted by the centre has enlightened over thousands of small farmers who have formed nuclei for further diffusion of scientific methods of tea cultivation. Demonstration plots serve not only to remove mental inhibitions of small farmers which prevent them from adopting new innovations as something beyond their capabilities and resources, but also as pre-extension research centres for identifying the technical, economical and social constraints in adopting them and the modifications required to make them acceptable. These attempts resulted in many unemployed graduates accepting commercial v.p. nurseries as one of the economically viable self-employment avenues.

INTRODUCTION

In the Nilgiris, tea is a major crop of economic importance grown in about 24,738 ha. The main departure from the rest of the tea growing areas in the State is the existence of a large number of small tea gardens, 6344 holdings of 1.1 ha average size occupying 29.2 per cent of the total tea acreage of this district(Table 1). The small

Table 1. Small Tea Growers in South India

District	Number	Area (ha)
Nilgiris	6344	7210
Kottayam	3684	1799
Other Districts—Kerala	205	328
Other Districts—Tamil Nadu	2	6

Source: Tea Statistics (1980–81), Tea Board, Calcutta.

tea growers practice traditional or subsistence culture; their average yield is about 800 kg/ha compared to more than 2000 kg/ha made tea in the corporate sector. If average yield of the small tea gardens is increased to the level of the corporate sector, this alone will add Rs. 12 crores/annum to the revenue of the district. This paper deals with the UPASI-Tea Board Schemes to educate the small tea growers on scientific cultivation practices, and their impact on yield as well as on the awareness of small growers to utilize the institutional supports available to them for their uplift.

MATERIALS AND METHODS

The UPASI-Tea Board schemes essentially envisage, (*i*) training (*ii*) demonstration, and (*iii*) supply of high yielding clones at subsidized cost. In the training programme, the effective transfer of technology appropriate to the specific conditions and resources of the small growers is planned and executed. Taking into account the rural socio-economic background of the small growers, the curriculum includes, besides tea crop husbandry practices, (*i*) general horticulture, (*ii*) soil conservation, (*iii*) animal husbandry, and (*iv*) environmental hygiene and family welfare. They are educated about the development schemes operating in the area and also about the institutional supports available for resources and finance in particular, and for techological advice. The trainees are given a stipend of Rs. 100 besides the actual travelling expenses for attending classes, and free stationery materials. The trainees include local teachers owning tea gardens, small tea growers, and also the womenfolk who are actually engaged in field work. About 2500 persons have been trained so far, in 80 batches, since the inception of the scheme in 1979.

Demonstration plots are maintained in nine centres, Bangalmattam, Mulliyur, Kattabettu, Selas, Mahalinga, Kil-Kotagiri, Manjoor, Yedakadu, and Glysdale, where all the operations are carried out in presence of small tea growers of the area. The main objective is to break the mental barriers of the small tea growers who think that the new innovations are beyond their capabilities and resources, and also to have free discussions with them to identify any technical, social or economic constraints in adopting the operations, and the modifications required to make them acceptable.

The pamphlets providing necessary technical information of the operations carried out each time, are also distributed to those present. As the high cost inputs should virtually come from outside the traditional system, the supply of improved clonal plants at subsidized cost is also made to those trained for consolidation of their area by infilling, and also for new planting and replanting.

The contact with the trainees is kept alive through a follow-up involving, (*i*) advisory visits, (*ii*) refresher courses for reorienting the trained grower, (*iii*) mass contact programmes, regionwise, and (*iv*) field days.

All these schemes were started in 1979. To study the impact of the schemes, a random sample of 10 per cent of the small growers who were trained in 1979, were selected and the data collected using a structured interview schedule (Lingan, 1981; Chandrasekaran, 1981) in three parts: (*i*) basic information like area under tea, crop harvested during the last 5 or 6 years (*ii*) adoption level of various recommended practices and the problems faced if any by them, and (*iii*) the knowledge level of the respondents with regard to scientific cultivation practices and their awareness and utilization of institutional supports.

Results and Discussion

1. Adoption of scientific/improved practices

The extent of adoption of improved practices in various areas of tea cultivation is given in Table 2.

It is gratifying to note that the small tea growers have started adopting the new recommendations even in areas involving high cost inputs such as manuring, and also those with a gestation period for pay off such as consolidation by infilling and extension planting. This is partly due to the healthy competition among the institutions, the cooperative factories and private bought leaf factories, for absorbing the green leaf produced by the small tea garden which helped to maintain the bargaining power of the small gorwers at reasonably good level.

However, there are certain relatively high pay off low input areas such as plant protection, correction of zinc deficiency and

Table 2. Extent of adoption of recommended practices (per cent)

Area	Member estates*	Small growers	Specific aspects of improvement
Manuring	90	47 (30)	Nutrient ratios and split applications
Plant protection	97	38 (20)	Correct dosages, timing and spraying techniques
Cultural	90	56 (25)	Pruning, tipping and plucking practices
Weed control	75	12 (5)	Use of herbicides for weed control
Zinc deficiency	90	67 (15)	Correct dosage and timing
Consolidation efforts	80	65 (10)	Use of v.p. plants
Horizontal expansion	**	75 (30)	Contour double hedge planting and use of suitable clones.
Soil conservation	80	60 (50)	Contour stone walls, drains and staggered trenches

*Evaluation of tea culture, development and prospects in South India—a survey and presentation by UPASI 1977.

**Limited by land registration laws.

Figures in brackets denote the extent of adoption in early seventies..unpublished survey report of the Advisory Officer, Nilgiris.

liming, where the level of adoption is lower than normally expected. This is because of the difficulties in procuring them in small quantities required by small tea growers.

The overall extent of adoption of recommended practices in small tea gardens as compared to member estates is given in Table 3.

Table 3. Overall extent of adoption of recommended practices

Extent of adoption	% Distribution Member estates*	% Distribution Small tea growers
Low upto 35%	5	26
Medium 35-70%	15	53
High Above 70%	80	21

*Evaluation of tea culture, development and prospects in South India—a survey and presentation by UPASI, 1977.

The small tea growers who were once predominantly low adopters are now mainly medium adopters, and this change especially during the period of tea crisis is quite commendable. With the improvement and stabilization of tea prices, the rate of adoption in intensity and extent is certainly bound to increase.

2. Knowledge Level of Trained Growers

The knowledge level of the trained growers interviewed after 2 to 3 years of the training is given in Table 4. There was considerable improvement in knowledge level of the small tea growers, showing 58% increase in persons having medium level, and 5% in persons having high level of knowledge. The subjectwise knowledge level of the trained growers is given in Table 5.

Table 4. Overall knowledge level of trained growers

Level	% Distribution	
	Before*	After
Low	78	15
Medium	15	73
High	7	12

*Judged at the time of admission of growers to training.

Table 5. Knowledge level of trained growers—subjectwise

Subject/area	Knowledge level (%)
Planting, training of young tea	60
Pruning and plucking	45
Manuring, liming and correction of zinc deficiency	52
Plant protection	42
Soil conservation	60
V.p. nursery	84
Credit sources and institutional support	80

Source: Chandrasekaran (1981).

The knowledge level on various aspects of crop husbandry practices was quite good even after 2-3 years of the training. Where finance is concerned, such as credit sources, and where the commercial exploitation is possible, such as in v.p. nursery, the knowledge level is very high indicating the eagerness of the small tea growers to enhance their socio-economic status by utilizing the institutional supports available to them. The knowledge level on soil conservation is always of high degree in the Nilgiris because of the awareness created by the good work done by the Central Soil Conservation Research and Training Centre at Ootacamund, and also the generous subsidy offered by the various Government agencies, like the Hill Area Development Project and Kundah River Valley Project.

3. Impact of the Schemes

The positive influence of the UPASI-Tea Board schemes on the knowledge level of growers and the extent of adoption of improved practices is seen by the increase in, (*i*) yield (*ii*) consolidation efforts (*iii*) new replantings (*iv*) utilization of institutional supports and, (*v*) commercial exploitation of v.p. nurseries by educated unemployed. The impact on yield is shown in Table 6. The impact on yield is more strongly felt in an area in the vicinity of Demonstration plot as shown in Table 7.

There was a considerable increase in awareness and utilization of institutional supports (Table 8). The farmers have utilized institutional supports for the purposes for which they are sought and they have used them to appreciate their assets by longterm planning, such as consolidation of areas by rejuvenation pruning and infilling, new replantings, and commercial exploitation of v.p. nurseries (Table 9). The number of v.p. nurseries managed by educated

Table 6. Impact on yield (surveyed gardens)

Yield level	1976–78 (kg/ha)	1979–80 (kg/ha)	Increase %
Maximum	1847	2839	53.7
Average	1065	1314	32.8
District average	1874	1994	6.4

Table 7. Impact of Demonstration plot on yield
(Member gardens of bought leaf factory in the vicinity of the Demonstration plot)

Item	Increase (%)
Area in ha	13.4
Yield in kg/ha	22.8
Total green leaf supplied	39.3
Demonstration plot yield kg/ha	86.4

Table 8. Awareness and utilization of institutional support

Institution	Increase/annum No.	Per cent
Tea Board	242	36.5
NABARD	58	94.1
HADP	953	88.6
Total	1253	70.3

NABARD: National Bank for Agriculture and Rural Development.
HADP: Hill Area Development Project.

Table 9. Impact of schemes—Long-term planning

Item	1979–81	1976–78
Rejuvenation ha/yr	628	396
Replanting ha/yr	27	14
V.P. nurseries	18	6
Plants raised lakhs/yr	13.0	6.7
*Plants purchased (HADP) lakhs/yr	5.9	5.5
**Plants purchased (NABARD) lakhs/yr	9.0	4.5

Source: *Executive Engineer, HADP, Ootacamund, Nilgiris.
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unemployed and small tea growers increased from 6 to 18 after the training. The total number of plants raised and purchased by the small farmers from various agencies also showed a high rate of growth consistent with their consolidation and planting programmes.

The rate of adoption of a new practice by a traditional farmer, even if they are provided with the means to buy the necessary inputs, depends on profitability with due allowance for risk and uncertainty (Arnon, 1978). The increase in rate of adoption of new improved practices during 1979–81 in spite of tea crisis, speaks of the psychological change on the mental attitudes of small tea growers in Nilgiris who look forward to a better standard of living and socio-economic status. The change is expressed and measured as a desire for adoption of better cultivation methods with long-term interest such as, consolidation efforts (rejuvenation pruning and infilling), and horizontal development (new and replantings). There is a general improvement in the knowledge level of trained small growers and the retentivity of imparted knowledge is also good.

While discussing the changing soil quality concepts in agricultural systems, Warkentin and Fletcher (1977) reported that the future constraint in crop productivity efforts will be institutional/organizational for effective technological transfer (knowledge use) and also for resource distribution. Creating awareness about the institutional supports available for resources, and finance in particular, and for technological advice, and teaching the small growers how to utilize them, have given expected rewards, increase in utilization of institutional supports and also making them recognize the importance of long-term interests.

Carrying out the operations in presence of small tea growers in demonstration plots with free discussions, have helped them understand the basic principles involved in the improved practices and also these plots have served as pre-extension research centres for identifying the technical, economical and social constraints in adopting the recommendations and modifications required to make them acceptable. Low degree of adoption of plant protection, correction of zinc deficiency, liming, and also manuring to some extent, is due to difficulties in getting these agro-chemicals in small packings and also due to lack of retail outlet in the interior areas. The impact of the above schemes is quite impressive, and by extending the institutional support in intensity and extensity, it is possible to completely break the mental inhibitions of traditional growers and make them accept new innovations, which have proved useful in the adjacent gardens of the corporate sector, as something within their capability and resources.

As the small tea growers started recognizing the importance of long-term planning, the demand for v.p. plants has grown out of proportion within a short peiiod. Many educated unemployed have taken up commercial v.p. nursery as a self-employment avenue, and their success is mainly due to timely institutional support for resources and technological advice. The Nilgiri farmers have also accepted tea as a diversification crop in steep potato areas, and already 40 acres of tea have been planted as demonstration units in the last two years under the UPASI-Tea Board scheme for diversification of crops in Nilgiris.

To sum up, UPASI-Tea Board have produced tremendous influence in breaking the mental inhibitions of small tea growers, prevented them from adopting new innovations, and some of the areas where breakthrough is pronounced and strongly felt are: (*i*) v.p. nursery as a commercially exploitable avenue, (*ii*) tea as a diversification crop in the non-traditional areas, (*iii*) confidence in scientific practices, (*iv*) confidence in their capabilities, and (*v*) exploitation of institutional support for resources and finance in particular, and for technological advice.

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TRENDS IN COCONUT AREA AND PRODUCTION IN INDIA

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ABSTRACT

Between 1950–51 and 1980–81 though the area planted under coconut has been quite noticeable, the production growth rate has always lagged behind the planting rate, suggesting that productivity is declining. During the 1970s, the compound growth rate of coconut yield for Kerala was (–) 2.0 per cent/annum, while the corresponding rates for the other major producing states, namely Tamil Nadu and Karnataka were 1.0 per cent and 0.17 per cent respectively. Largely influenced by Kerala, the trend in all-India productivity for the period under reference was (–) 0.9 per cent/annum. We should plan for a growth rate of 7.0 per cent to bridge the supply gap.

INTRODUCTION

In India, Coconut is mainly grown in homestead gardens as a small holder's crop. Its cultivation is largely localized in the west coast region and to a small extent in the east coast. The crop is grown under a very wide range of soil conditions from littoral sand to clayey soils, strongly acidic peaty to alkaline calcareous soils, and ill-drained, low-lying marshes to well-drained hill slopes. The cultivation of coconut and related activities offer employment to about 10 million people in India. In the last two decades coconut situation in the country is far from satisfactory mainly because of socio-economic constraints. This paper aims to study the trends in coconut area, production and yield in the country in general and major coconut growing states in particular, during the sixties and seventies. The data on the area, production and yield used in this paper are the estimates of the Directorate of Economics and Statistics, Ministry of Agriculture, Government of India.

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Trend in Coconut Area

As regards India, the area under coconut has been increasing during last three decades, from 622,000 ha in 1950–51 to 717,000 ha in 1960–61, 1046,000 ha in 1970–71 and 1082,000 ha in 1980–81. In other words, the coconut area expansion was at the rate of 1.15 per cent per annum during the fifties, 1.46 per cent during the sixties and 1.03 per cent during the seventies. The coefficient of variation (CV) in coconut area in India between 1960–61 and 1979–80 comes to 13.78 per cent and for the major coconut growing states notably Kerala, Karnataka and Tamil Nadu the same was 12.72 per cent, 17.32 per cent and 19.91 per cent respectively. At present, Kerala alone accounts for two-thirds of the total area under the crop. Karnataka and Tamil Nadu are other major states, the former accounting for nearly one-seventh and the latter around one-tenth of the country's coconut area (Table 1).

Table 1. State-wise distribution of Area and Production of Coconut during the Sixties and Seventies (per cent of India)

State	1960–61 to 1969–70		1970–71 to 1979–80	
	Area	Production	Area	Production
Andhra Pradesh	3.98	4.56	3.66	2.86
Assam	0.39	0.22	0.42	0.33
Karnataka	12.37	8.45	13.65	12.88
Kerala	68.30	67.64	65.54	60.72
Maharashtra	0.99	0.67	0.84	0.85
Orissa	0.92	0.75	1.20	0.88
Tamil Nadu	9.00	14.66	10.01	17.86
West Bengal	0.79	0.43	0.62	0.38
Andaman & Nicobar Islands	0.95	0.71	0.170	1.03
Lakshadweep	0.30	0.35	0.26	0.36
Other States	2.01	1.56	2.10	1.87

All-India Index Numbers of coconut area with triennium ending 1959–60 touched 157 points in 1980–81. The maximum expansion was noticed in the case of Assam (675 points), followed by Orissa (500 points), Andaman and Nicobar Islands (345 points), Tamil Nadu (219 points) and Karnataka (184 points). In the case of Kerala however, the Index Number rose to 157 points in the year 1974–75, then declined to 138 points in 1978–79 and further moved to 140 points in 1980–81.

District-wise estimated compound growth rates in area reveal that in the case of Kerala, barring Kozhikode district, in all other districts the growth was negative leading to (–) 1.33 per cent growth rate per annum for the state during 1970–71 to 1979–80. In the case of Tamil Nadu, four out of twelve major coconut growing districts, namely Thanjavoor, Tiruchirapalli, Ramanathapuram and Coimbatore, showed negative growth, while the remaining districts recorded positive growth in area. The growth rate for the state as a whole was 0.86 per cent per annum. Similarly, Karnataka registered a growth rate of 2.84 per cent with all the nine coconut growing districts having positive growth rates. The compound growth rate for India as a whole is found to be (–) 0.14 per cent per annum for the period under reference (Table 2).

Table 2. Estimated Compound Growth Rates of Area, Production and Yield of Coconut in different Districts of Coconut-growing States during 1970–71 to 1979–80 (% per annum)

	Area	Production	Yield		Area	Production	Yield
KERALA:	–1.3	– 3.4	– 2.0	Mandya	3.2	0.7	– 1.9
Trivandrum	–0.4	– 3.7	– 3.4	Mysore	4.7	–5.7	–10.0
Quilon	–2.4	– 6.9	– 4.6	Tumkur	2.4	12.8	10.1
Alleppey	–3.9	– 6.8	– 3.0	North Kanara	0.6	–3.0	– 3.6
Kottayam	–4.5	– 8.1	– 3.7	South Kanara	2.9	3.0	0.1
Idukki	–6.8	–17.2	–11.1	TAMIL NADU	1.0	2.5	1.4
Ernakulam	–0.7	– 2.3	– 1.5	Chengalpet	4.1	29.3	24.1
Trichur	–1.1	– 0.8	0.17	South Arcot	2.2	13.7	1.13
Palghat	–2.3	– 3.6	– 1.2	North Arcot	0.3	3.6	3.2
Malappuram	–1.0	– 1.1	– 0.03	Salem	4.7	8.2	3.3
Kozhikode	1.1	– 1.0	– 2.2	Dharmapuri	6.7	12.6	5.4
Cannanore	–1.0	– 0.2	0.7	Coimbatore	–0.1	–4.8	– 4.6
				Tiruchirapalli	–2.2	0.5	2.8
KARNATAKA	2.8	3.2	0.1	Thanjavoor	–5.1	0.07	5.5
Bangalore	4.8	2.2	– 2.4	Madurai	1.6	–2.4	– 4.0
Chickmagalur	1.9	–11.9	11.0	Ramanathapuram	–0.5	–0.2	– 6.2
Chitradurga	3.2	4.6	1.3	Tirunelveli	1.3	7.3	6.0
Hassan	2.1	2.2	0.09	Kanyakumari	2.7	6.2	3.4
				INDIA	–0.1	– 1.0	– 0.9

Trend in Coconut Production

The production of coconut in India increased from 3582 million nuts in 1950–51 to 4639 million nuts in 1960–61, and to 6075 million nuts in 1970–71. The record harvest of 6124 million nuts was observed in the year 1971–72; thereafter it declined to 5851 million nuts in 1973–74, and in the following year it increased to 6030 million nuts, but again continuously declined and reached the level of 5413 million nuts in 1977–78. The production picked up modestly to 5471 million nuts in 1978–79 and 5830 million nuts in 1979–80, and fell to 5677 million nuts in 1980–81. The coefficient of variation in coconut production in India between 1960–61 and 1979-80 comes to 9.42 per cent.

The average production of nuts in India for the fifties, sixties and seventies were of the order of 4157 million nuts, 5087 million nuts and 5840 million nuts, respectively. In other words, coconut production in the sixties was 22.4 per cent higher than that of the fifties and in the seventies, it was 14.8 per cent higher than that of the sixties. This shows that the production is increasing at decreasing rate eventhough the trend is not very stable.

All-India Index Numbers of coconut production with triennium ending 1959–60 rose to 133 points in 1971–72 and then moved downwards to 118 points in 1977–78, again increased to 127 points in1979–80 but slided down to 124 points in the following year. While the index numbers in respect of Kerala and Andhra Pradesh were reduced to 93 and 55 points, respectively in 1980–81, the same were raised to significant levels in Karnataka (189), Tamil Nadu (265), Orissa (274), Assam (279), and Maharashtra (181).

The compound growth rates of coconut production during 1970–71 to 1979–80 were found to be negative in all the districts of Kerala leading to (–) 3.41 per cent growth per annum for the state as a whole. In the case of Tamil Nadu, only in three districts namely, Coimbatore, Madurai and Ramanathapuram, the growth rates were found to be negative and in the remaining districts these were positive resulting in a growth rate of 1.83 per cent per annum for the State. Similarly, in Karnataka in three out of nine coconut growing districts, namely Chikmagalur, Mysore and North Kanara the production growth rates were negative, while the state's growth rate was 3.24 per cent per annum. The compound growth rate for coconut production in India for the period 1970–71 to 1979–80 comes to (–) 1.06 per cent per annum (Table 2).

Kerala accounts for nearly 53.3 per cent of the total production of coconut in the country, while Tamil Nadu and Karnataka account for nearly 20 per cent and 15.5 per cent respectively. These three southern States together constitute 89 per cent of total coconut production while accounting for the same 89 per cent of total coconut area in India.

Trend in Productivity

The average yield of nuts per ha in India was 5779 in 1950–51. The productivity averaged to 6366 nuts for the fifties, 5911 nuts for the sixties and 5411 nuts for the seventies. It reveals that the yield of coconut in India per unit area is of the decreasing order over these years and the decline comes to 7.1 per cent between fifties and sixties and 8.5 per cent between sixties and seventies. Between 1950–61 and 1980–81, the maximum yield of 7012 nuts/ha was observed in the year 1953–54, and the minimum yield of 5121 nuts/ha in the year 1977–78. So far as the majoı coconut producing states are concerned, the per hectare productivity for the 50s, 60s and 70s in the case of Kerala averaged to 6462, 5854, and 5013 nuts, respectively, whereas in the case of Karnataka it was 4410, 4039, and 5106 nuts, and for Tamil Nadu it was 7832, 9635, and 9657 nuts. Taking into consideration the 1980–81 figures, the average yields of Kerala and Karnataka are 13 per cent and 1.3 per cent lower, and of Tamil Nadu 86 per cent higher than the all-India average of 5246 nuts/ha.

The estimated compound growth rates for different districts in Kerala suggest that in all the districts excepting Cannanore and Trichur, the growth was negative and the State's growth rate duıing 1970-71 to 1979-80 was found to be (–)2.11 per cent per annum. In the case of Karnataka, in four districts namely, Mysore, Bangalore, North Kanara and Mandya the growth was negative and in the remaining districts under review it was positive, the State's growth being 0.17 per cent per annum. Similarly, in the case of Tamil Nadu, the productivity was found to be negative only in respect of Ramanathapuram, Coimbatore and Madurai districts and the State's growth rate was 1.40 per cent per annum during the 70s. However, the compound growth rate in coconut productivity for the country as a whole was (–) 0.92 per cent per annum during the period under reference (Table 2).

Index Numbers for coconut productivity in India with base at triennium ending 1959–60 slided downwards and touched below 80 points during 1977–78 and 1978–79, and rose marginally to 84 points in 1979–80 but again fell to 81 points in 1980–81. In the case of Kerala it has come down to 66 points while Karnataka and Tamil Nadu recorded 103 points and 121 points in 1980–81.

The coefficient of variation in the productivity of coconut between 1960–61 and 1979–80 was 9.96 per cent for Kerala, 15.08 per cent for Karnataka and 11.17 per cent for Tamil Nadu, while the same was 5.98 per cent for India as a whole.

Summing Up

The demand for coconut in India has been estimated for 2000 A.D. by the National Commission on Agriculture as 13,585 million nuts. In order to achieve self-sufficiency in coconut, the country's production has to be raised by nearly 140 per cent from its present level within a period of twenty years. This suggests that India should plan for a growth rate of 7.0 per cent per annum to bridge the supply gap. Considering the technological potential available within the country, India can achieve the target by removing the socio-economic constraints and institutional bottlenecks.

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PERFORMANCE OF COCONUT CULTIVAR 'BENAULIM' IN GOA—A CASE STUDY

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ABSTRACT

'Benaulim', a local tall coconut cultivar of Goa is potentially a high yielder, but the productivity of coconut in Goa, in general, is low, because of lack of irrigation, non-application of fertilizers and very close spacing. In a well-managed farmer's field, the variability in yield of individual palms was recorded, based on the previous thirteen years' production performance. The response to fertilizers and beneficial use of irrigation for increasing yield has been observed, and the economics of coconut cultivation worked out.

INTRODUCTION

Coconut palm shows wide variability in yield depending upon its genetic make up, agro-ecological situations under which it is cultivated, and the management practices adopted. Under improved management practices, the genetic potential of palms becomes fully manifest, compared to the palms of the same variety under neglected conditions.

In Goa, the coconut palms do not receive adequate fertilization, and hardly 5 per cent of the growers adopt balanced manuring. The general practice among growers is to apply a limited quantity of organic manure and common salt every year before the onset of south-west monsoon. Of late, some farmers are using limited quantity of mixed fertilizers. It is found that the continuous cultivation of coconut for a long period without application of fertilizers and adopting suitable agronomic practices, has caused the exhaustion of soil, resulting in low productivity. Adoption of better management practices including optimal fertilizer use, timely irrigation and other cultural practices like weed control, and interculture would

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improve nut production. A case-study illustrating the above, is presented on the performance of the indigenous tall coconut cultivar 'Benaulim' of Goa.

Materials and Methods

The material of 'Benaulim' cultivar was planted in 1951 at 'Vancor' farm Sanguem, 25 km from the Goa coast, situated close to the perennial 'Kushavati' river. The soil of the farm is of two different types, namely, clay-loam in upper plots and sandy-loam in the lower areas, with a pH of about 5.5. The palms planted at a spacing of 7m × 7m have been receiving uniform cultural and manurial practices and were under regular irrigation during December to May. The irrigation was started from 1971 onwards. Prophylactic measures were taken from time to time to control rhinoceros beetle, by filling the leaf axils with a mixture of 5% BHC dust and sand in equal proportions.

Results and Discussion

Distribution of palms in yield groups

Considerable variation in yield among the palms has been observed in the plantation. The distribution of palms in 'Vancor' farm among various yield groups is presented in Table 1.

Table 1. Distribution of palms in different yield groups

Yield group (nuts/palm/yr)	No. of palms	Percentage
35– 50	46	8.8
51– 70	84	16.0
71– 90	138	26.3
91–110	98	18.7
111–130	57	11.0
131–150	57	11.0
151–170	29	5.5
>170	14	2.7

The Table reveals that in this well-managed plantation, the high and medium yielding groups (51-130 nuts) together constitute more than two-thirds of the total population.

Influence of agro-climatic factors on nut yield:

In Goa, the annual rainfall ranges between 3000 to 4000 mm and the dry period extends to over 4 to 5 months in a year (Table-2). Both the heavy downpour during the short rainy season (June to mid-Sept.) and the long dry spell (Nov. to May) might be causing the fluctuations in nut yield.

Table 2. Rainfall distribution pattern at the farm (Av. of 9 years: 1973–81)

	May	June	July	Aug.	Sept.	Oct.	Nov.	Total
Rainfall (mm)	58	1030	1080	688	292	116	45	3309
No. of rainy days	4	22	30	29	17	9	5	116

Lack of irrigation during the long dry spell from Nov. to May is a major factor limiting the productivity of coconut palms in Goa. The varying number of nuts harvested at different periods of the year are clearly indicative of the seasonal variability due to rainfall pattern (Table 3).

Table 3. Average No. of nuts harvested at different periods of the year (mean yield/palm over 5 years)

Harvest group	I Jan. Feb.	II March	III Apr.-May	IV June	V Aug-Sept.	VI Oct.-	VII Nov.-Dec.	Total	Mean
35–50	6.8	10.8	8.4	5.4	4.4	5.6	1.2	46.8	6.7
51–70	12.1	12.0	12.6	6.8	6.8	5.6	7.2	62.1	8.9
71–90	12.8	14.8	18.0	11.1	10.2	6.8	4.4	78.2	11.2
91–100	18.0	25.5	26.0	14.1	7.9	3.9	5.3	100.7	14.4
111–130	22.8	26.4	27.3	19.8	12.9	8.2	6.4	123.8	17.7
131–150	22.6	30.0	33.7	23.1	20.1	9.7	5.5	145.7	20.8
>150	34.5	54.4	46.5	21.0	15.4	10.5	7.9	190.2	27.2
Total	126.6	173.9	172.5	101.3	77.8	50.3	37.9	747.5	
Mean	18.5	24.8	24.7	14.5	11.1	7.2	5.4	106.8	

During the last 10 years, high yields have been observed from January to May harvests, and low yields during September to December. Hence in dry months, frequent irrigation and improved soil moisture conservation practices, would immensely help in maintaining stability of production.

Effect of manuring and irrigation on coconut yield

The yield data recorded upto 1971 on a rainfed crop, and thereafter on an irrigated crop, has shown significant differences in growth and yield. Further, the effect of irrigation has become more pronounced at this farm in combination with balanced fertilization (Table 4).

Table 4. Yield trends during pre-and post-irrigation periods (planted 1951)

Pre-irrigation		Post-irrigation		Irrigation & Fertilizer appln.	
Year	Nuts/ha	Year	Nuts/ha	Year	Nuts/ha
1969	5683	1972	11,009	1977	17,308
1970	5013	1973	12,943	1978	16,667
1971	5867	1974	10,076	1979	20,987
		1975	13,000	1980	22,003
		1976	14,950	1981	16,333
Mean	5408		12,396		18,666

Elite palms

At this farm, the average yield of palms was 18,666 nuts/ha during the last 5 years; hence this could be considered as a high yielding plantation. Amongst the population, 27 palms yielded 155 to 200 nuts per palm per year for 5 consequetive years (1977 to 1981). Six other palms which recorded 200 to 300 nuts consistently, may be considered as elite palms.

Production Economics:

Attempts have also been made to work out the production economics based on total nut production, sale proceeds realized, and the expenditure incurred during the last 13 years. The nuts after harvest were sorted into two marketable grades, and disposed off at the wholesale rate. The item-wise expenditure incurred during the last 5 years indicated that about 23.4 per cent was spent for supervision, 31.2 per cent for labour including plucking and dehusking; 31.3 per cent for fertilization; 7.0 per cent for irrigation; 5.3 per cent for transportation, and 1.8 per cent for pesticide application. Since the cost of irrigation is relatively small compared to the realized benefits, the farmers should be educated to irrigate their coconut plantations wherever irrigation sources exist.

The net income per ha during pre-irrigation period of 3 years, post-irrigation period for 5 years, and integrated use of manuring, irrigation and other cultural care for 5 years, is estimated at Rs. 774, Rs. 5800, and Rs. 14,120 respectively (Table 5).

Table 5. Production economics/ha/year

	Pre-irrigation (av. of 3 yrs)	Post-irrigation (av. of 5 yrs)	Irrig.+manuring (av. of 5 yrs)
Nuts produced/ha	5,408	12.396	18,666
Rate of nuts/1000 (Rs)	617	782	1,110
Gross income/ha (Rs)	3,361	9,693	20,719
Expenditure incurred/ha (Rs)	2,587	3,793	6,598
Net income/ha (Rs)	774	5,800	14,120
%increase in net income			
over pre-irrig. period	—	688	1,724
over post-irrig. period	—	—	143

CONCLUSIONS

The study reveals that irrigation alone increases the yield/ha by 6988 nuts (129%), and irrigation-cum-manuring by 13,258 nuts (24.5%) over no manuring and no irrigation. Further, irrigation-cum-manuring could increase the yield/ha by 6270 nuts (50.5%) over irrigation alone. It may thus be concluded that coconut cultivation adopting proper management practices would be a very profitable proposition in Goa region, using the local cultivar 'Benaulim'.

SOME METHODOLOGICAL PROBLEMS IN ESTIMATING COST OF PRODUCTION OF PLANTATION CROPS

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ABSTRACT

Scientific study on cost of production of plantation crops is of interest to a very wide range of users of cost data and assumes particular importance in planning agricultural strategies. The methodological problems of estimating the cost of production of plantation crops are discussed in this paper.

INTRODUCTION

While agriculture is the chief national resource for almost all the developing countries, plantation crops such as tea, coffee, rubber, oil palm, coconut, cashewnut, cardamom, black pepper and tree spices assume great importance in many of these countries including India, because of their economic potential through export promotion and/or import substitution. Accordingly, considerable attention of several Governments of the Third World is drawn towards the plantation crops sector. To meet this need, the planners and policy makers look for realistic economic analyses of developmental programmes and projects with rational use of scarce resources. Plantation crops are basically perennials where there is a flow of income and expenditure over a long period. These crops usually have a long time-lag between initial investment and first pay-off, and they need replanting only at relatively long intervals. Since plantation crops are different from seasonal and annual crops in respect of investment and returns, the economic as well as financial analyses of plantation crops deserve different treatments due to obvious reasons. This paper discusses some of the issues relating to cost analysis in plantation crops.

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Materials and Methods

Garg and Yadav (1965) worked out the cost of cultivation of mango for five periods, namely, (*i*) establishment stage (1st to 6th year), (*ii*) growth stage I (7th to 10th year), (*iii*) growth stage II (11th to 20th year) and (*iv*) declining stage (21st year and above). Heady (1968) suggested that the costs of the present can be put on a basis for comparison with returns of the future by causing the current costs to grow with time, or returns in the future can be shrunk with time by reducing them to a basis comparable to costs of the present. It is possible to bind the future with the present in the first case through the process known as 'compounding' and in the second case through the process known as 'discounting'. Venkateswarlu and Suryanarayana (1971) divided the cost of cultivation of grapes under two main heads, namely (*i*) pre-bearing stage and (*i*) bearing stage. While the first head was further divided into three sub-heads such as (*a*) fixed assets, (*b*) working assets and (*c*) operating assets; the second head was divided into two sub-heads namely, (*a*) pre-harvest charges, and (*b*) post-harvest charges. Baumol (1973) observed that it is the characteristic of capital that during establishment and maintenance, call for expenditure at different dates, its yields are obtained at still other points of time. The interest rate concept should be broadened to cover all costs which accrue automatically with the passage of time. The discount rate or the opportunity cost concept is tied to the market rate of interest, only if the capital market is approximately perfect.

Results and Discussion

Though the importance of economic analysis of plantation crops is well recognised, so far, a foolproof and simple methodology for undertaking such studies is not available to researchers. The methodology that is now widely used all over the world comprise project appraisal tools. It is extremely difficult to incorporate objectives of different nature and varying intensity into a yardstick with which to evaluate the plantation crops.

In the case of small–holder plantations of coconut, arecanut, pepper and cashewnut, the plants are scattered in nature, usually grown in house compounds alongwith several garden–land crops. In such situations, it is not easy to apportion various cost items for individual species. Things become more difficult in presence of unorganized intercropping, mixed cropping and mixed farming systems in plantations.

Again unlike annual crops, in small-holder plantations, plantings are carried out at different stages, depending upon several factors. In any given area, one can find trees of different age groups as a result of gap filling, underplanting, replanting and/or new planting. The input requirements and the output vary according to age of these plantations. Similarly, there is a tendency among the farmers to plant several types of cultivars in their plantations at different times as well as at the same time. Therefore, in a coconut garden, there can be a mixture of local talls, dwarfs, T×D or D×T hybrids. Though these cultivars represent a single crop, from the point of view of the economic analysis they should be considered as different crops because of their genetic diversity.

Further, it is not always easy to estimate the productivity of a plantation per unit area, on account of wide variations in the volume of end products. For example, in coconut we notice significant differences in the volume of copra per nut between cultivars. At the same time, the copra content in the nuts of a particular palm shows variation from season to season as well as from one nutrient level to another.

Apart from these, considerable difference exists in the labour wage structure for various farm operations in plantations. The climbers, for example, charge different rates from that of other categories of labourers who are engaged for manuring, irrigation, and other operations and again the same climbers charge different wage rates for different operations such as harvesting of nuts, cleaning of crown and spraying pesticides., These charges also vary depending upon some arbitrary norms and not on per tree or palm basis.

Assessing the investment in plantations appears to be more difficult than determining the maintenance costs. In plantations, land shaping is one of the most important operations from the investment point of view, but the nature and extent of land shaping and levelling necessarily differs according to topography and slope of the land and soil types, Contour bunding, bench terracing and stone terracing, require investments of various sizes that significantly influence the overhead cost.

Another major area of investment in certain plantations is the irrigation structure and the water management systems, such as sprinkler, perfo-spray, drip or underground irrigation. Cost-wise, one can find a lot of difference between concrete/cement/asbestos pipes, plastic pipes and steel pipes. In such situations, it is not sound to follow a standardized cost for different plantations.

On the returns side, one may face equally difficult situations as in the case of investment. The yields of plantation crops fluctuate more widely than that of seasonal or annual crops. It is true that both climatic, disease and pest problems affect all the crops whether annual or perennial, but in the case of perennials, there are physiological constraints such as alternate or irregular bearing habit, seasonal yield pattern and senility which do not occur in crops of non-perennial nature.

These are some of the issues which need careful consideration while computing the costs and returns and making economic analysis on plantation crops.

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SESSION II

Genetics, Plant Breeding and Horticulture

Chairman	:	Dr NM Nayar
Rapporteurs	:	Dr VS Sharma
		Dr EVVB Rao

VEGETATIVE PROPAGATION IN TEA—A REVIEW

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ABSTRACT

Research on vegetative propagation of tea in S. India over the past 32 years is reviewed. Investigations on the treatment of mother bush, source of cuttings, use of polythene cloche in the nursery, pretreatment of rooting medium for the amendment of pH, control of root-knot eelworm, and nutrition in the nursery, have yielded positive recommendations on raising vegetatively propagated tea nurseries. Development of a rooting hormonal formulation specific to tea cuttings, grafting of fresh clonal cuttings in the nursery, and basal wounding of cuttings to promote better rooting, are highlighted.

The need for basic studies on the anatomy of internode, and physiology of mother leaf, for a better appreciation and possible refinement of nursery techniques is stressed.

INTRODUCTION

The knowledge that tea plant lends itself favourably to vegetative propagation is, perhaps, as old as the discovery of wild tea by Bruce, in Assam. Watt (1907) has mentioned that Bruce, in the 1820's, had cut off branches of tea and buried them one or two inches below the soil to find, in due course, numerous shoots sprouting all along the length of the branches. Much later, it was demonstrated in Indonesia, that tea could be multiplied by budding or grafting on root-stocks, which found application chiefly in raising seed gardens comprising selected bushes (Maas, 1921; Keuchenius, 1923; Hoedt and Keuchenius, 1931). Grafting, as well as layering was found to be of no practical value in raising commercial tea gardens (Visser, 1969).

Propagation of tea by cuttings was investigated subsequently, by several scientists in different tea growing regions (Tunstall, 1932; Tubbs, 1932, 1939; Wellensiek, 1933), though its practical application was then not known. However, the advent of blister blight leaf disease of tea in epidemic proportions during the 1940s, focused attention on the utility of multiplying the resistant bushes in a population, by cuttings (Emden, 1950). In the following decades wide interest was generated in this technique of propagation and extensive research done in all the important tea growing areas. Consequently, the use of single-node cuttings was recommended, because of the greater ease in propagating them making more efficient use of the limited material available than multiple-node cuttings (Emden, 1950; Kehl, 1961, 1963; Portsmouth, 1952, 1953; Venkataramani, 1963b, 1970; Visser, 1959b, 1961, 1969; Visser and Kehl, 1958; Wight, 1960); this has now become the most successful method of vegetative propagation in tea.

In South India, as in other tea growing areas, some planting companies examined the technique of multiplication of tea by cuttings during the late 1940s. Studies on this important subject were initiated by the UPASI Scientific Department in the year 1950 (Rau, 1951), and the same intensified in the mid-fifties. The purpose of this review is to summarize the advances and contributions made, and focus attention on the promising areas for future research.

It is important to situate a tea nursery in a site with proper drainage, but nearer a perennial water source; it should also be naturally protected from wind (Sharma, 1976b). The periods of April-May and September-October were found to be ideal to strike cuttings, though they may be put out any time of the year (Venkataramani, 1957b).

Source Of Propagation Material

In tea, as in other perennial crops, rooting of cuttings is influenced by the source and age of the parent plant. A juvenile source gave a higher percentage of rooting in cuttings (Emden, 1950; Venkataramani, 1960a, 1961a, 1963a, 1966b). In 14-16 weeks, cent per cent rooting was obtained in cuttings harvested from 2-year old clonal plants, but only 28-59 per cent rooting at the end of 16 weeks in the cuttings taken from 30-year old mother bush; however, rooting of cuttings from old bushes could be enhanced to the level of those from younger plants by harvesting shoots arising from mother bush after appropriate pruning (Venkataramani, 1961a, 1963b), and inducing juvenility in the old bushes.

Green, semi-hardwood cuttings from the third to eighth nodes of primary shoots, root with equal ease provided the leaf is mature (Venkataramani, 1960a, 1963b.). Generally, the cuttings taken from the centre of the bush rooted faster and better than those taken from peripheral shoots; but, at the end of 16 weeks the percentage of rooting was same in the cuttings obtained from both positions (Venkataramani, 1963a, b). There was no difference in rooting performance between the cuttings obtained from orthotropic and plagiotropic shoots, though the axillary shoots in the former were more vigorous than those in the latter which grew at an angle to the main axis (Venkataramani, 1963a, b).

Good rooting could be achieved in cuttings obtained from a healthy mother bush supplied with balanced nutrients; foliar application of one per cent urea, 1-2 weeks before harvesting cuttings, led to quicker rooting and better sprouting of the axillary bud (Venkataramani, 1958b, 1963b). However, a firm recommendation on manuring of mother bush was made much later (Ranganathan, 1973, 1976, 1979; Sharma, 1976b). Zinc application to the mother bush, irrespective of deficiency symptoms, in the form of 2 per cent zinc sulphate, 2-3 weeks prior to harvesting cuttings, was found to increase the rate and volume of rooting significantly, (Sharma, 1974, 1976b; Ranganathan, 1979, 1981). Addition of manganese and boron to zinc sulphate spray at 500 and 1000 ppm respectively, was reported to increase the efficiency of zinc utilization, (Ranganathan, 1981). Foliar application of sulphates of aluminium and magnesium, 1-2 weeks before harvesting cuttings, was found to improve growth of the latter, after rooting (Ranganathan, 1981).

Pretreatment Of Cuttings

Growth substances: The use of hormones and hormone-like substances to promote rooting in clonal tea cuttings began very early (Venkataramani, 1957b, 1958b). Pretreatment of cuttings with IBA and succinamic acid induced an early and heavy root system, and the former in combination with NAA exhibited a synergistic effect (Venkataramani, 1959, 1961a, 1961c; Haridas, 1975). The roots produced by treatment with IAA, IBA and NAA and their combinations were long, heavy and fibrous. IPA, 2, 4-D and 2, 4, 5-T failed to induce good rooting; IAA and 2,4-D suppressed the growth of the axillary bud, while no such ill-effect was noticed with IBA and NAA. Gibberellic acid helped in breaking dormancy of the axillary bud, but not in rooting (Venkataramani, 1961b). These investigations proved that IBA and NAA, alone or in combination, and succinamic acid, are beneficial in promoting early and profuse rooting, without altering the ultimate percentage of rooting after a prolonged period in nursery beds (Venkataramani, 1960a, 1961a, 1961c, 1965). Venkataramani (1961c) observed variation in clonal response to various hormonal treatments. In subsequent studies (Sharma *et al.*, 1981, 1982 the effect of hormones on rooting percentage was found to decrease after 16 weeks, and thereafter, it was the same both in treated and untreated cuttings; however, the dry weight of roots in treated cuttings continued to be significantly superior even upto the end of 24 weeks. It is thus evident that pretreatment of cuttings with hormones, aids in producing a larger number of rooted cuttings with heavier roots in a shorter duration.

Of the various trade hormonal formulations studied, Seradix B_1, Seradix B_2, Alar-85 and Rootone were found to give significant improvement in rooting performance (Venkataramani, 1962a, 1963a, 1963b; Haridas, 1975; Sharma *et al.*, 1981). Seradix B_2 was noticed to promote excessive callus formation and consequent delays in rooting; its pH was around 6.2. To develop a rooting hormonal formulation specific to tea cuttings, several formulations based on IBA, using various cheap native dusts at varying levels of pH as carriers, were developed and tested (Sharma, 1974, 1975, 1976c). These studies revealed that the pH of the formulation in the range of 4.2 to 4.8 is ideal, and strong acidic pH of the carrier enhanced the stimulatory effect of hormones, whereas mildly acidic or near-neutral pH affected the rooting adversely (Sharma, 1974, 1975). The rooting hormonal formulation developed by the UPASI Scientific Department proved to be significantly superior to the available trade formulations (Sharma *et al.*, 1981). The effect of this formulation on rooting of cuttings was found to be independent of the texture and pH of rooting medium, thus permitting certain amount of flexibility in the choice of medium with varying levels of pH and texture (Sharma, 1978, 1979; Sharma *et al.*, 1981, 1982).

Nutrients: Several experiments were carried out to identify suitable nutrient-pretreatment of cuttings (Venkataramani, 1961a). While spraying mother leaf with 1 and 2 per cent aqueous solutions of urea and sucrose respectively, expedited rooting, treatment of cuttings with Mn, Zn, B, and Fe failed to improve rooting (Venkataramani, 1961 a, b). Pretreatment of the basal cut end with boron was not beneficial; in fact, concentrations above 10 ppm suppressed root growth, even in combination with IBA (Venkataramani, 1962 a, b). A mixture of zinc and IBA, at 5000 ppm each, proved to be superior to either of them used independently (Sharma, 1974).

Mechanical: Cincturing (ring barking at the base of a shoot, above an axillary bud) three weeks prior to harvest of cuttings was reported to induce early and heavy rooting, particularly in shy rooting clones (Venkataramani, 1963a, 1964). Dormant axillary buds were stimulated to sprout by cincturing.

Wounding the basal end of the cutting by a single vertical split of about 1 cm length, and two such splits at right angles to each other, expedited rooting in slow rooting clones, and increased the dry matter content of roots in all the clones (Satyanarayana, 1981; Sharma *et al.*, 1981). Pericycle in poor rooting clones is usually multilayered and sclerenchymatous, with only a few patches of thin walled cells (Sharma, 1976a); basal splitting in such clones, perhaps facilitates the emergence of more root primordia through the ruptured pericycle along the length of the split, while at the same time increasing the surface area of rooting.

Rooting ability of a cultivar is genetically controlled and can be stimulated without altering the ultimate percentage of rooting; however, dry matter accumulation in roots can be enhanced by pretreatment of cuttings with different techniques.

Rooting Medium

Sandy loam soils with good drainage but with certain amount of water-retaining capacity are ideal for rooting of tea cuttings; organic matter content in the rooting medium is of no significance as far as rooting is concerned (Venkataramani, 1956, 1957b, 1963a, b; 1967). Too much of either sand or clay content and both high and low air/moisture ratio in the medium promotes excess of callus formation (Venkataramani, 1963a, b). A good rooting medium could be obtained by mixing jungle soil or sub-soil with river-sand in appropriate proportions to contain over 60 per cent of sand (Venkataramani, 1956). Texture and pH being the same, lateritic sub-soil was found to be superior to jungle top soil for inclusion in the medium (Sharma, 1976c).

An ideal pH of the medium for good rooting ranges from 4.5 to 4.8 (Sharma, 1976b, c; Sharma *et al.*, 1981); pH over 5.5 often induced over-callusing and consequent delay in rooting or shedding of mother leaf without callus formation (Venkataramani, 1958b; Sharma, 1976b). At higher pH levels, roots of young nursery plants die due to "bitten-off" disease (Sharma, 1976b); too low a pH depresses rooting (Sharma, 1976c). Tea cuttings tolerate higher than optimal pH levels in open soils, such as sand-soil mixture, better than in a medium with a lower sand content (Venkataramani, 1960a; 1963b). Venkataramani (1961a; 1961d) opined that rooting of tea cuttings is influenced more by texture than by pH of the medium, but, in the same medium rooting is better at a lower pH. However, subsequent studies showed that pH, rather than the texture, of rooting medium exerts more influence on rooting performance (Sharma, 1976c); pH being the same, sandy soils are better suited for rooting of cuttings. Sandy loams should be preferred in commercial nurseries for reasons of proper drainage and moisture retention. As mentioned earlier, the problem of indifferent texture and pH of the rooting medium could be surmounted to a certain extent, by pretreating the cuttings with hormonal formulations (Sharma *et al.*, 1981, 1982).

Pretreatment of nursery soils with 1 or 2 percent aqueous solution of aluminium sulphate was suggested to reduce the pH to desired levels while preparing the rooting medium (Sharma, 1976b). Additionally, application of aluminium sulphate to the medium was reported to improve the growth of root and shoot, and enhance dry matter accumulation in the former (Venkataramani, 1961e). Addition of phosphatic fertilizers to the medium did not help rooting; on the contrary, it increased the pH and depressed rooting (Venkataramani, 1965).

Vermiculite, which is known to retain moisture, was found to increase the pH when mixed with the nursery soil and led to excess callus formation (Venkataramani, 1963a). Well composted paddy husk and tea waste were found to be good substitutes for sand to reduce costs on collection and transport of the latter (Sharma, 1973; 1976c).

Use of 30-45 cm long, 10 cm lay-flat polythene sleeves, was suggested in the place of bamboo baskets as containers in the nursery (Venkataramani, 1960b; Sharma, 1976b); length of the sleeve and nursery life of a plant could be increased proportionate to the duration of drought in a given area, subject to a maximum of 45 cm, to promote a deep root system so as to withstand the drought better. The lower three-fourths of the sleeve is filled with jungle soil-sand mixture and the top one-fourth forming the rooting medium, with subsoil-sand mixture, to economize on costs (Sharma, 1976b).

SHADE AND IRRIGATION

Light intensity and moisture regime are to be regulated in order to keep the soil and ambient atmosphere in the nursery reasonably cool and moist, and to prevent wilting and sun scorch (Visser, 1959a). Too dense a shade coupled with heavy watering will lead to rotting of cuttings, besides hampering photosynthesis. While it is known that tea cuttings root well in light intensities ranging from 200 to 500 foot candles, the ambient temperatures should be taken into consideration for providing shade, since the two factors interact with each other (Venkataramani, 1963b).

Experiments with several types of shade like, (1) bracken fern stuck in nursery beds, (2) low "pandal" of ferns, (3) frames of bamboo laths, and (4) closely woven coir-mat supported on a wooden frame either 60 cm (low "pandal") or 2 m (overhead "pandal") above the ground, were carried out to determine the appropriate shade that permits optimum light intensity on to the nursery beds (Rau, 1951; Venkataramani, 1963b). Shading with coir-mat of 3.5 mm^2 mesh at mid-elevations and 6.5 mm^2 mesh at high elevations was found to be superior to other types of shade; coir-mats of these specifications, spread 60 cm above the nursery beds, permitted light intensities of approximately 15 and 20 per cent respectively of the outside day light (Venkataramani, 1963b). With the advent of polythene cloche over nursery beds, overhead "pandal" with a coir mat of 6 mm^2 mesh is found to be more convenient for routine operations and supervision in large nurseries; this allows about 33 per cent of the outside sunlight on to the beds (Sharma, 1976b). Raised overhead shade becomes imperative if cuttings are struck under polythene cloche; a low "pandal" over polythene cloche is likely to increase the temperature within and lead to wilting of cuttings.

Moisture regime, both in rooting medium and the atmosphere around rooting beds, is critical for the success of a nursery. Too much or too little moisture in the rooting medium promotes excess callusing and consequent delay in rooting (Venkataramani, 1961a). The moisture level in the medium should be maintained at 50 per cent of its water-holding capacity and the relative humidity at about 90 per cent (Venkataramani, 1963b). A polythene cloche over the nursery beds reduces transpiration from the young shoots of cuttings, conserves moisture both in rooting medium and in the air surrounding the cuttings, protects the cuttings from wind damage and regulates temperature within to some extent, all of which contribute to a greater success in rooting of cuttings and economy in watering (Venkataramani, 1956; 1957a, b; 1958a, b; 1959; 1960b; 1961a; 1963b).

Yellow transparent polythene cloche was reported to increase shoot growth, without affecting the rooting performance of cuttings (Venkataramani, 1962c). Subsequent investigations, however, demonstrated not only an increase in dry matter accumulation in roots and shoots, but also advanced rooting in a higher number of cuttings (Sharma *et al.*, 1981). This discrepancy may be due to the variable response of the clones used for the experiments. Yellow screens filter off violet-blue from the spectrum of incident light (Nakayama, 1980), which should explain the vigorous growth of cuttings.

NURSERY GRAFTING

The technique of grafting fresh, single node and callused tea cuttings in the nursery, was first developed in the UPASI Scientific Department in 1972, and the composite plants thus raised were transplanted in the field, the following year (Sharma, 1972; 1973). Survival in the field through successive droughts, and biomass production was found to be higher in the grafted composite plants than in the standards (Satyanarayana, 1980; Sharma, 1975, 1979; Sharma and Satyanarayana, 1982; Sharma *et al.*, 1981). Teas manufactured from composite plants and standards were reported to be similar by professional tasters (Sharma, 1978). Thus, it is evident that while the stock exerts influence on the vigour of scion, it has no effect on quality. Investigations on techniques of grafting in the nursery, pretreatment of graft partners (Haridas, 1979; Sharma, 1979; Sharma and Satyanarayana, 1982; Sharma *et al.*, 1981), and compatibility between different tea clones (Sharma, 1977, 1978, 1979; Sharma and Satyanarayana, 1982; Sharma *et al.*, 1981), unfolded new vistas with immense potential to raise commercial populations of composite plants developed in the nursery. This technique has the tremendous advantage of raising a composite plant with high yield and quality of one clone and drought–tolerance of another, combined by grafting at fresh cutting stage in the nursery itself. Additionally, the plants raised thus, were found to be more vigorous than those of either of the partners raised on their own root, and were ready for transplanting earlier (Satyanarayana, 1980; Sharma *et al.*, 1981).

MANURING

Sterilized animal meal, applied to the soil, seems to be the only manure used in vegetative propagation during the early years. Venkataramani (1963a) did not find any difference between plants manured with sterilized animal meal, and soluble nursery fertilizer mixture (NPK 1:1:1); however, he noted the advantage of avoiding soil stirring and also, the reduction in labour use, since the application of soluble nursery fertilizer mixture could be combined with watering. He also demonstrated that soil application is superior to foliar application and that addition of potash to ammophos induced vigorous growth in nursery plants (Venkataramani, 1964). These studies were followed by a firm recommendation on the use of soluble nursery fertilizer mixture containing NPK and Mg at the ratio of 1:1:1:1, to be applied through a watering can (Venkataramani, 1966a). Addition of zinc sulphate to nursery fertilizer mixture was reported to assist in better root development and dry matter accumulation in cuttings (Ranganathan, 1979, 1980).

Nursery Problems

Besides rats and caterpillar pests, there are certain problems that crop up in vegetatively propagated tea nurseries, more important of which are reviewed here.

(1) **Excess callusing**: Usually, pH levels above 5 and sub-or, supra-optimal moisture status in the rooting medium promote excess callus formation and "club-footing"; hence, it is imperative to adjust them appropriately.

(2) **"Bitten-off" disease of roots**: Mildly acidic and near-neutral pH levels of the rooting medium lead to die-back of roots (Venkataramani, 1962a; Sharma, 1976b). As the initial symptoms appear, 0.5 per cent aqueous solutions of aluminium sulphate may be applied to drench the medium; this will help alter the pH favourably and prevent further die back of roots (Venkataramani, 1962a) However, the best remedy is to prevent such a situation from arising, by using a rooting medium with a pH below 5.

(3) **Flowering in cuttings**: Cuttings taken from mature bushes which were under plucking, often tend to flower in the nursery. Also, "china" type of cultivars and their hybrids have a genetic proneness to flower; removal of flower buds by hand and application of 0.5 per cent aqueous solution of urea will prevent flowering (Venkataramani, 1961a). Cuttings should be manured after root formation, to encourage vegetative growth.

(4) **Root-knot eelworm**: *Meloidogyne incognita* (Kofoid & White) Chitwood, is ubiquitous in the jungle soils of South India and if the nursery soils are not pretreated with appropriate chemicals,

it will lead to nodular development on roots, stunting and defoliation of young plants (Venkataramani, 1962a; Sharma, 1976b).

(5) **Zinc deficiency**: Zinc deficiency in tea was first noticed in vegetatively propagated nursery in the year 1962; it was then demonstrated that it could be rectified by foliar application of zinc sulphate at 1 per cent, two or three times at fortnightly intervals (Venkataramani, 1962a).

(6) **Manganese toxicity**: Heat treating the nursery soils against root-knot eelworm has been a practice for a long time. However, if the soils are heated to over 80°C, manganese is released in available form, causing speckled chlorosis and defoliation in young plants (Sharma, 1976b).

(7) **Stalk-rot**: Occasionally, stalk-rot of cuttings before rooting caused by *Pestalotia theae* Sawada, *Colletotrichum camelliae* Massee, and root-rot caused by species of *Pythium* Pring. *Cylindrocladium* Morg., and *Fusarium* Link ex Fr. were recorded in tea nurseries; use of appropriate soil acting fungicides were suggested as remedial measures (Venkata Ram, 1960).

Future Scope Of Research

Work done so far, on vegetative propagation in tea by single-node cuttings has been a tremendous success, but basic knowledge on the development of adventitious roots in tea cuttings, nutrition and physiology of mother bush and mother leaf, and certain important biochemical aspects, is woefully scarce. Studies along the lines suggested hereunder, should assist in generating valuable information for a better understanding of rooting in tea cuttings.

(1) **Anatomical studies**: Studies on origin, development and emergence of adventitious roots and the histological barriers that make a cultivar easy or difficult to root will be of immense help. Collateral studies to determine the effect of different pre-treatments on the histology and root formation, if any, will have direct utility.

(2) Mother bush: It is known that the general health and nutrient status of mother bush play important role in rooting of cuttings harvested from it. However, it is not known as to which of the nutrients are crucial for rooting and what role they play in rooting. Studies on this aspect are likely to give information that may be of direct application.

(3) Starch reserves and rooting: Preliminary studies have amply indicated that good rooting clones are richer in starch, reserves than shy rooting ones (Venkataramani, 1961a). Determination of carbohydrate levels in mother leaf in relation to rooting and the effect of various treatments of mother bush on the carbohydrate content in mother leaf of various clones will be of practical value.

(4) Role of aluminium in rooting: Aluminium is suspected to play a critical role in rooting of tea cuttings, though its exact nature is not known (Ranganathan, 1981; Sharma, 1976a; Venkataramani, 1961c). Investigations to determine the role of aluminium, manganese, zinc and certain sequestrene compounds in rooting of tea cuttings will be useful.

(5) Biochemical investigations: Screening the clones for chemical factors and their levels responsible for easy rooting or otherwise, will assist in understanding the physiology of adventitious root development in tea. These studies may also throw light on compatibility between clones for grafting purposes.

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ADVANCES IN TEA BREEDING IN NORTH-EAST INDIA

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ABSTRACT

Studies were conducted during 1970–81 to determine the extent of variability in flushing behaviour of tea genotypes. Over 20 clones and seed stocks representing China. Assam, Cambod & hybrid forms which are commercially grown by the tea industry of North-East India, were studied in a Randomized Block Design. The yields of made tea in the first round of plucking and by the end of June were used as criteria for classifying genotypes. The planting materials differed significantly in their flushing behaviour. Out of 20 genotypes studied, 7 were classed as early, 4 mid, and 4 late flushers. Remaining are being studied further. The high early crop was not found to be always correlated with early flushing, which is governed by many other factors also. The possibilities of using flushing behaviour of genotypes in breeding new planting materials of tea are discussed.

INTRODUCTION

The breeding of tea (*Camellia sinensis* (L) O. Kuntze) in India dates back to the introduction of tea seeds and plants from China in the beginning of 19th century when tea gardens were started in Assam, the Himalayas and the Nilgiris. The commercial potential of tea was realized only after the discovery of Assam type (*Camellia assamica* (Masters) Wight) by Robert Bruce in 1823. It took another decade for this indigenous type to be accepted by the tea growers of N.E. India.

Although there are a number of papers on the programmes and achievements of tea improvement work at Tocklai (Wight, 1948, 1956, 1958a, 1961a,b; P. K. Barua, 1963; Barua, 1963b, Bezbaruah, 1967a, b; 1968, 1969, 1974, and 1982), a comprehensive review is lacking. The present review is an attempt to bridge this gap.

I. Early endeavours on tea improvement

Seeds were the only source of propagating tea during the early years of tea cultivation and for more than a century afterwards. The need for better planting materials of tea, and competition among seed growers numbering over 100 in N.E. India, prompted the early growers to start unplanned tea breeding by way of collecting superior types of Assam tea from the wild tea patches in the hills of Assam, Nagaland, Manipur and Burma. The seed gardens were established using these collections (Wight, 1961a). The first such attempt to improve tea in N.E. India was made by two German brothers Amos and Julia Stiefalhagen in 1860 by establishing standard sources of tea seeds. Mass selection, mainly on the basis of some morphological characters like leaf shape, size, texture, growth habit and flushing behaviour, were carried out on nursery seedlings and the selected seedlings, were planted out for establishing 'seed-baries'. This approach in tea breeding resulted in the development of several improved populations (seed varieties) with higher yield, better quality and morphological uniformity. Such seed varieties having distinct characteristics, were popularly known as 'jats' like Betjan, Dhonjan, Rajghur and Tingamira, after the location of a particular seed-bari. This may be considered as the first step towards improvement of tea in N.E. India. These 'jats' remained the primary source of planting materials for over a century for establishing tea estates not only in N.E. India but all over the world. Today, over 60 per cent of the World tea acreage has received its planting materials primarily from the old tea jats of N.E. India (Singh, 1979).

The successive mass selections in the same populations did not bring much improvement, possibly due to lack of adequate genetic variability. Towards the end of 19th century between 1880 and 1900, Sir George Watt assisted the tea planters of N.E India in classifying tea varieties and hybridizing them to produce superior types of "seedjats". His hybridization efforts led to the development of "Rajghur" jat in which the high leaf quality of a light-leaf Assam jat, and the vigour and hardiness of a dark-leaved Manipuri jat were combined (Wight, 1962).

The scientific approach to tea cultivation started only after the inception of the Tocklai Experimental Station of the Indian

Tea Association, at the beginning of this century. The collection of genetic variability was intensified by the early workers (Table 1). Collections were made from cultivated, wild or semi-wild sources of tea populations growing in various parts of Assam, North-Eastern Frontier Agency, Nagaland, Manipur, Burma, Ceylon, Japan, and Indo-China (presently Laos, Cambodia and Vietnams). Of the early collectors, Mrs. Tunstall had made a significant contribution to the collection of tea germplasm, from which several clones of TV series have been developed.

II. Scientific Approach to Tea Breeding in North-East India

Even after the establishment of the Scientific Department of the Indian Tea Association and its experimental station at Tocklai in 1900, the tea breeding activities were limited only to the collection of germplasm (Table 1). Tea breeding became an organized scientific endeavour of the Tocklai Experimental Station only after the inception of the Botany Department in 1930, and planned breeding started only in 1936, after the recommendation of an Enquiry Commission in 1935. However, the actual work could not be started till 1946, primarily due to the intervening war years.

The following objectives were laid out in order to evolve superior planting materials:

(*i*) Selection of promising bushes for the production of improved seed varieties and experimental strains;

(*ii*) Selection of outstanding bushes possessing high rooting ability, yield and quality for vegetative propagation.

Over the years, the methods of introduction, selection, hybridization, polyploidy and mutation breeding were employed to achieve the above objectives.

1. Germplasm Collection:

Efforts were made from the very beginning of organized tea research at Tocklai to collect the diverse germplasm from indigenous and exotic sources and several introductions were made during 1931 to 1982 (Table 1). Out of a total of 778 collections now maintained at Tocklai, Dr. Wight had collected a total of 482, and Capt. Kingdon Ward 83; of these, 88 were of wild and

Table 1. Collections of tea genetic resources in North-East India

Period	Notable Collectors	No. of collections Wild	Cultivated	Remarks
Early endeavours				
1903–1910	C. M. Hutchinson	5	0	Popular N. E. Indian seed varieties.
1910–1920	Mrs. A. C. Tunstall	59	1	Local and exotic seed varieties of N.E. India, Burma & Indo-China.
1917	L. O. Wilson	4	1	Wild & cultivated teas of upper Burma from the valley of Irrawady river.
Planned tea breeding				
1931–1962	W. Wight	450	32	Local and exotic tea varieties, wild and related *Camellia* spp. from N. E. India, Burma, Sri Lanka, U.S.A. & Japan.
1946–1956	Kingdon-Ward	31	51	Plant explorations in, N. E. India and interior Burma. Collections helped in establishing origin of tea.
1962–1980	D. N. Barua H. P. Bezbaruah	43	—	Clonal selections in the tea estates of N. E. India and tea breeding plots of Tocklai.
1978–1982	I. D. Singh	66	—	Clonal selections from T.Es. of West Bengal
1900–1980	Others	30	5	Popular varieties of N.E. India and Burma
Total		688 +	90 =	778

related *Camellia* species. These collections were used extensively in the development of clonal and seed varieties of tea (Bezbaruah, 1974; Bezbaruah and Dutta, 1977; Bezbaruah and Singh, 1978; Singh, 1979, 1980a, b).

The importance of preserving tea germplasm has been highlighted by Tocklai on many occasions, primarily due to massive uprooting of seed-grown sections of tea, the seed sources of which no longer exist, and clearing of busti and jungles for extension of agricultural activities. The situation is further made alarming, as such areas are being replanted although at a slow rate, with few popular vegetative clones developed in recent times, thereby narrowing the genetic base of Indian tea populations. Once the old seed-grown sections and wild patches of a tea garden which are gold mines for tea genes, are uprooted, they will be lost for ever (Bezbaruah, 1967a, 1968, 1969, 1971a, 1974; Singh and Bezbaruah, 1978; Singh, 1980a).

Wight (1958a) pointed out that one out of every 40,000 bushes from the old seed-grown populations may be selected as a golden bush. Besides collection of diploid tea and its wild and weedy relatives, several polyploid genetic stocks, numbering over 116, have also been developed and maintained at Tocklai.

2. Selection

The improvement of tea in North-East India has been based primarily on mass selection, line breeding and clonal selections. Mass selection method advocated by Wight (1956) for the improvement of tea, failed to produce desired results. Hence, this method was replaced later on by line breeding (Wight, 1961a; P.K. Barua, 1963) where each selection was maintained separately to establish a new seed-bari from which further selections were made. The concept was further extended to produce biclonal seed varieties.

(i) Advent of vegetative propagation: About a hundred years from the date of introduction of tea in India, the method of vegetative propagation from single leaf cuttings was reported by Tunstall (1931) from Tocklai. This encouraged tea breeders to develop clonal varieties like in many fruit crops. However, it took another 20 years to standardize the technique of vegetative propagation and develop selection procedures for clones. This has been a major breakthrough responsible for the development of clonal varieties in N. E. India. Tocklai has so far released 24 clones of TV series to the N.E. Indian tea industry (Bezbaruah, 1970; Bezbaruah and Singh, 1980).

Besides the Tocklai clones, over 100 clones have also been selected by the tea estates which are in the list of planting materials approved by the Tea Board.

(ii) **Approaches to tea improvement**: Due to the wide genetic variability in tea populations of N.E. India created by the indiscriminate early introductions and free hybridization among them, clonal selection to exploit natural variability for the improvement of tea has been advocated (Wight, 1956; Barua, 1963a; Bezbaruah, 1968, 1969). The bush population even in a single small field of tea shows great variation in growth, branching habit, size, shape, texture and pose of the leaf, as well as in the inherent quality and yield of the bushes. Wight (1939) reported that about 10 per cent of the tea bushes in a commercial field in N. E. India produced only 2 per cent of the total crop, and about 0.5 per cent bushes produced as much as or more than 300 per cent of the yield of an average bush possibly due to their inherent superiority in yield. In a recent study made at Tocklai it was observed that yield of individual bushes in a field may vary upto 500 per cent between the lowest and the highest yielders and that approximately 67 per cent of these variations may be due to environment and remaining 33 per cent due to genetic differences (unpublished report, Statistics Department, Tocklai Experimental Station).

Besides developing of clonal varieties, Tocklai has also developed five biclonal and one polyclonal seed varieties using the technique of line breeding (P.K. Barua, 1963), and hybridization. Thus, the experience of developing clonal and seed varieties of tea for over 50 years at Tocklai has led to the formulation of a long-term approach for the improvement of tea in N.E. India which is commonly referred to as the "Clone-seed cycle" (Fig. 1).

(iii) **Development of clonal Varieties**: The development of superior clones with high yield and better quality has been one of the major achievements of the Tocklai breeding programme whereby natural as well as recombinant genetic variability has been fixed.

The selection of clones is a laborious process and usually takes 7-10 years before a clone could be released for commercial planting (Barua, 1963a; Bezbaruah, 1968, 1974). The initial selections are done mainly by eye estimation of the bush size, frame, and plucking point density, and subsequent selection is based on rooting response, yield and quality (Barua, 1965). Following

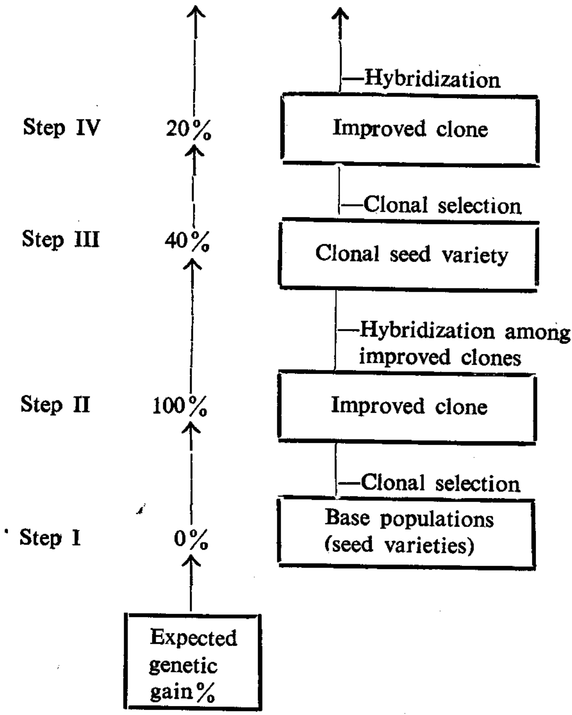

Fig. 1. A schematic diagram of the clone-seed cycle

the above technique of clonal selection, a total of 34 clones have been released to the N.E. Indian tea industry (Tables 2 and 3), of which 14 are for Darjeeling (Barua, 1963a; Bezbaruah, 1970; Sarkar *et al.*, 1975; Bezbaruah and Singh, 1980).

It is evident from Table-2 that, out of 24 clones, 19 have been developed purely through clonal selections and 5 after certain degree of hybridization among selected clones. Furthermore, during early days of systematic tea breeding (1949-1959) when considerable natural variability was available, clonal selection could bring about considerable improvement. However, during the last two decades, hybridization has played a considerable role in the improvement of tea.

Clones released for Darjeeling are listed in Table-3. It was only after the establishment of the Clonal Proving Station (CPS) at Ging Tea Estate, Darjeeling in 1967, that local adaptability of new planting materials could be tested before their release (Sarkar *et al.*, 1975).

Out of 49 clones planted in 1967-71 at CPS, Ging, 14 were certified. The Tocklai Experimental Station withdrew 7 TV clones (TV-2, 3, 4, 5, 6, 7 and 8) in 1980 (Bezbaruah and Singh, 1980), after reviewing their long-term performance in commercial plantings, in order to safeguard the long-term interests of the N.E. Indian tea industry. These clones were found to be inferior to others in yield, quality and drought resistance.

Table 2. Development and release of Tocklai vegetative (TV) clones in N.E. India

Period & Breeding method used	Category of the clone			Total	Remarks
	Standard	Yield	Quality		
1949–1959					
Selection	TV-1, TV-2, TV-3, TV-4, TV-5, TV-6, TV-7.	TV-8, TV-9	—	9	TV-1 DR
Hybridization	—	—	—	—	—
1960–1970					
Selection	TV-10, TV-11, TV-12, TV-13,	TV-15, TV-18	—	6	TV-18 DR
Hydridization	TV-14, TV-16, TV-17	—	—	3	All DR
1971-1981					
Selection	—	TV-19, TV-22, TV-23	TV-21	4	TV-19 DR
Hybridization	TV-20, TV-24	—	—	2	TV-20 DR
Total:					
Selection	11	7	1	19	24
Hybridization	5	—	—	5	

DR=Drought resistant

Average yield=1600 kg/ha of made tea at maturity in Jorhat area

Average quality=Quality of a popular light leaf Assam Jat of tea in Jorhat area

Standard=Clone with above average (>20%) yield and quality

Yield =Clone with very high (>50%) yield but average cup quality

Quality =Clone with very high cup quality but average yield.

Table 3. Development and release of clonal varieties for Darjeeling tea industry (1970–80)

Method of breeding	Category of clone				Remarks
	Standard	Yield	Quality	Total	
Selection	P-312, B-157, AV-2, T-246, T-372, T-383	T-253 R/R 4/5 T-78 T-135	T-145 B-777 B-688	13	DR-P 312, B-157, T-145, AV-2, T-253, R/R 4/5, B-668, TV-14, T-87, T-383
Hybridization	TV-14	—	—	1	
Total	7	4	3	14	

DR=Drought resistant

Average yield=Yield of TS-378 (Nanda Devi) at Ging T.E. Yields of 20% and 50% more than average are classed as above average and high respectively.

Average quality =Quality and flavour of both TS-378 and Ging flavoury jat at Ging T.E. Darjeeling.

(iv) Clones in the pipeline: Achievements of clonal selection work during the last 12 years are summarized in Table 4. Part of these results have been reported by Bezbaruah (1982). A total of 68 promising clones in 26 long term trials (LTT) are in the pipeline in different regions of N.E. India. The yield of selected clones in LTT was 166 per cent higher than control.

Table 4. Summary of clonal selection programme in N.E. India (1970–1982)

Region/Period		No. of clones		No. of promising clones	% increase in yield over control
		Selected	Under LTT		
Assam	1970–75	183	119 (9)	31	0.4– 33.0
	1976–82	113	16 (3)	2	18.1– 32.4
Dooars	1973–82	—	98 (7)	20	0.5–100.0
Darjeeling					
	1973–78	—	45 (5)	11	0.0–166.0
	1979–82	—	20 (2)	4	Yield not yet recorded
Total:		296	337 (26)	68	

Figures in parentheses indicate number of long-term trials

(v) Selection of clones in the tea estates: The old tea plantations of N.E. India which were raised from seed are highly heterogeneous. Such populations are likely to be a good source for the selection of elite clones. The seed sources from which these plantations were raised, are also no longer existing. Moreover, such old plantations (50 years or more) are due for uprooting (Bezbaruah 1971a; Singh and Bezbaruah, 1978; Singh, 1980b).

Under the District Selection Scheme introduced in 1971-72, interesting sections of tea estates having wide genetic variability, were surveyed to select locally adapted elite clones and valuable germplasm, following the procedure described by Barua (1965).

So far, from about 6000 ha of tea in 138 estates of N.E India surveyed, more than 5300 elite mother bushes have been selected. After initial field selections based on eye estimation and rooting trials, 761 bushes have been put under long term trials, and another 97 promising elite bushes are in the pipeline. Already, 4 clones have been given certificates of approval by TRA. Another 10-12 clones are expected to get the certificate this year once the trials are reviewed.

3. Hybridization

The hybrid seeds of tea were initially produced in two stages. Firstly, a large number of selected clones (150) were crossed by hand-pollination. The seeds thus produced were grown in the nursery and observations recorded on some desirable economic characters like growth habit, vigour, uniformity of leaf shape, shoot size, yield and quality. The F_1 stocks producing highly heterogeneous and less vigorous progenies were rejected. The selected F_1 stocks were planted in the long term trials with popular commericial varieties as controls, and continued for 8 to 10 years (Wight, 1948, 1956; P.K. Barua, 1963).

Since the production of seed by hand-pollination is very expensive and may not compare with seed produced under natural conditions, the method was slightly modified in its second stage. The parental pairs of the promising stocks, selected on the basis of initial trials, were propagated vegetatively, and grown in isolated seed-baries to produce seeds under natural conditions. Seeds from these experimental baries were then tried in different agro-climatic regions of N. E. India. Only the successful stocks (TS-378, TS-397, TS-449 and TS-450) from these trials were ultimately released to the industry. Thus, it took 23 to 27 years to develop the improved clonal seed varieties.

The initial procedure of line breeding to develop clonal seed varieties as outlined above, has been modified in order to reduce the time-lag (Bezbaruah, 1982). In the modified method, the initial stage has been eliminated (Table-5), and the selected parental pairs grown in isolated micro seed-baries to produce hybrid seeds under natural conditions. Such seeds are then tried directly in different agroclimatic regions from which the successful stocks are released after 6-7 years of trial.

Table 5. Approximate time required for the development of clonal seed varieties following hybridization

Particulars	Earlier method	Modified method
Present selection Hand pollination Seed Nursery	2 years	
Long-term trial	8-10 yrs.	
Interim stock selection	—	Parent selection on morphology
Micro seed-bari	5 yrs	5 yrs
Long term trial of naturally pollinated seed	8-10 yrs	7 yrs
Pruning cycle	2	2
Release	23–27 yrs	12 yrs

The modified method has been possible only due to a large number of hand-pollination studies carried out in the past at Tocklai (Bezbaruah and Saikia, 1977). These results have clearly indicated that: (i) crossing between morphologically divergent parents generally results in heterosis (hybrid vigour) for yield, and, (ii) the hybrids from such crosses generally show a quality which is average of the parents without any dominance or interaction. The period of breeding seed varieties after adopting the modified method has been reduced to almost half that of the earlier procedure (Table-5).

(i) **Clonal seed varieties**: Following the earlier method of line breeding, 150 selected clones were crossed manually in biclonal combinations to produce F_1 hybrids. Out of about 400 combinations tried during 1946-1962, only about 45 per cent crosses produced sufficient seed for planting long-term field trials. Based on their initial evaluation in the nursery, only six pairs of clonal combinations could be selected for establishing micro seed-baries in isolation (Table-6). Finally, four stocks could be released after the completion of long-term field trials. All the released stocks had higher yield (20-25 per cent) and better quality than controls.

After 1968, all the micro-seed-baries have been planted according to the modified method of producing clonal seed varieties. Out of a total of 64 micro-seed-baries established during 1949-82, 54 have been planted after 1968 (Table-7). For the first time, 26 micro-seed-baries have been planted in Darjeeling at various elevations (1000-4000 ft. above m.s.l.).

Table 6. Development and release of early biclonal seed stocks in N.E. India

Biclonal stock	Pedigree	Year of			Remarks
		Establishing micro seed-bari	Starting LTT	Release	
TS 206	19/29/13× 19/29/1	1957	1962	NR	
TS 378	14/5/35× 14/6/28	1958	1962	1968	Recommended for Darjeeling
TS 384	24/6×24/7	1958	1962	NR	
TS 397	19/29/13× 19/35/2	1959	1964	1976	
TS 449	19/31/14× 19/29/13	1962	1967	1970	
TS 450	270/2/13× 20/23/1	1959	1964	1970	

Table 7. Three decades of breeding clonal seed varieties in N. E. India

Period/Location	No. of seed-baries estd.	No of stocks in LTT	No. of stocks to be evaluated	Remarks
1949–1967				
Assam	10	7	3	5 released including one polyclonal
1968–1982				
Assam	28	11	17	One released in 1980
Darjeeling	26	—	26	Planted in 1982
Total:	64	18	46	

The yield of recently released TS-462 was found to be 14 to 31 per cent higher than the control stock TS-449 over the years in different agroclimatic regions (Bezbaruah, 1982). Even its overall quality was found to be better than the control (TS-449). Once the remaining trials are completed, another 2-3 good biclonal seed varieties would be released to the industry.

(ii) Development of synthetic seed varieties: The early breeding efforts at Tocklai were aimed at producing synthetic seed varieties to replace the popular seed jats of tea in N. E. India. A group of selected clones were planted in isolated seed orchards to produce the seed under natural conditions. Such seed orchards were commonly known as 'polyclonal seed-baries' and the stock as 'polyclonal seed stock'. Out of four polyclonal seed baries consisting of nine clones each planted in 1946 (Barua, 1963a), only three could be evaluated in L.T.T. as one was destroyed during the Second World War. After extensive testing, stock-203 was released to the industry as "Gaurishaknar" in 1954. However, the polyclonal stocks were found to be of unpredictable performance, and more unstable than biclonal seed stocks.

(iii) Basic hybridization studies:

(a) Combiner clone: The concept of 'combiner clone' was advocated by Wight (1961a) in the breeding of biclonal and polyclonal seed varieties of tea in order to increase the efficiency of selecting clones. However, this concept could not be pursued further in tea due to its long reproductive cycle.

(b) Inbreeding: Attempts were made at Tocklai as early as 1946 to produce homozygous pure lines of tea through inbreeding. The programme of inbreeding continued for over 20 years. Thousands of controlled pollinations were done. However, the programme suffered a great set-back due to extremely low percentage of success in seed-set under selfing. Besides this, a large number of segregates resulting from selfed populations further complicated the situation, which led to the discontinuance of this line of approach in tea breeding. The scheme could progress only upto the second generation. Presently, efforts are being made to produce homozygous diploid lines through anther culture. (Raina and Iyer, 1974; 1983).

(c) Inheritance studies: Wight (1958b) reported quantitative inheritance of the calcium oxalate crystal frequency (phloem index) of the leaf petiole. Bezbaruah (1971b) observed partial dominance of the small-leaved China variety over the broad-leaved Assam varieties. Besides leaf, many other characters are polygenic and inherited quantitatively. The quality of made tea of F_1 hybrids generally approached the mid-parent values and there was no dominance or interaction (Bezbaruah, 1971a). He also reported absence of any significant difference in yield and quality of reciprocal hybrids from crosses between morphologically different varieties. Positive correlations were observed between the mean yields of parents and progenies in crosses involving widely different clones, but there was no correlation when morphologically similar clones were used (Rept. Tocklai Expt. Stn. 1966). Heterotic response for yield, ranging from 21 to 85 per cent over the mid-parental value, was observed (Bezbaruah, 1971a), which indicated the possibility of increasing yield of tea by exploiting hybrid vigour.

(d) Interspecific hybridization: Wight and Barua (1957) attempted interspecific hybridization in tea with Wilson's *Camellia, C. irrawadiensis*. The F_1 hybrids resembled tea in their morphological characters but were inferior in quality. The extreme vigour observed in the hybrids indicated the possibility of their utilization in further breeding (Bezbaruah, 1971b). In crosses between *C. sinensis* L. and *C. japonica* L., regular meiosis and high fertility was observed (Bezbaruah and Gogoi, 1972). Morphological similarity of these hybrids indicated the possibility of existence of species hybrids in cultivated tea.

4. Polyploidy Breeding

Most of the cultivated teas of the world are diploid (2n=30) and highly hetrerogeneous as a result of free natural hybridization between geographical races during the long history of their cultivation. The development of polyploid vaiieties of tea have been advocated possibly due to the winter hardiness and increased vigour especially of triploids and tetraploids over diploids.

Wight (1962) identified a vigorous stock 28/2 out of an introduction made from Indo-China in 1917. The stock was subsequently identified as a triploid by Bezbaruah (1971b). The open-pollinated progenies of St. 28/2 produced natural diploids, triploids, tetraploids and aneuploids (Ann. Rept. Tocklai Expt. Stn. 1969-70, p.40; 1976-77, p.32; 1978-79, p.45; Bezbaruah, 1968, 1971c; Singh, 1980a; Singh *et al.*, 1982). Natural triploids and tetraploids exhibited poor quality in their preliminary evaluations. Therefore, controlled hybridization was attempted between natural tetraploids and high quality diploids during 1972-75, for the production of high quality triploids (Ann. Rept. Tocklai Expt. Stn. 1973-74, p. 42 and 1974-75, p. 31). So far, a total of 116 polyploid stocks have been produced (Table-8) representing 103 euploids and 113 aneuploids.

Table 8. Tea polyploids bred at Tocklai

Polyploids	Chromosome No. (2n=30)	No. of	
		Genetic stocks	Living plants
I. Euploids		103	284
Triploid	45	96	277
Tetraploid	60	5	5
Pentaploid	75	2	2
II. Aneuploids	2n±1 to 29	13	20
Total:		116	304

The preliminary results indicated the superiority of triploids and tetraploids over diploids in their rooting ability, leaf size and leaf dry weight (Singh, 1980b; Singh *et al.*, 1982). Generally, pentaploids and most of the aneuploids were poor rooters and produced smaller leaves of lighter weights than diploids, triploids and tetraploids. Presently, 56 selected polyploids have been planted in long-term trial for evaluation of their field performance and cup quality.

5. Mutation Breeding

Tocklai initiated mutation breeding in tea during 1967-68 to induce desirable mutants. The treatment of the seeds, cuttings and pollen grains with physical (X-rays and gamma rays) and chemical (ethyl methane sulphonate) mutagens, met with little success (Ann. Rept. Tocklai Expt. Station, 1968-69; 1969-70; 1974-75). LD_{50} for fast exposure was found to be about 3 Krad both under dry and wet conditions, whereas the LD_{50} for slow exposures was 6 Krad and 10 Krad under dry and wet conditions respectively.

Efforts were further continued to induce desirable mutations for superior cup quality and resistance to diseases, pests and drought, besides standardizing the technique of mutation breeding in tea (Ann. Rep. Tocklai Expt. Stn. 1979-80, p. 50-51; Singh, 1980b; Singh and Sharma, 1982). An exposure level of 2 Krad appeared to be the upper limit for the survival as well as induction of mutations in stem cuttings. Clones differed significantly in their response to doses of gamma radiation. TV-1 and TV-18 exhibited the maximum, and TV-23 the least tolerance, to gamma irradiation beyond 2 Kr.

III. Summary and Conclusions

The major objective of tea breeding in N.E.India as laid out in the beginning of the programme in 1936, was to evolve improved seed and clonal varieties. During the last 40-44 years of tea improvement, the above objectives have been achieved to a considerable extent. So far, 6 clonal seed varieties and 38 clonal varieties have been developed which are being cultivated commercially in N.E. Indian estates. The different varieties have been developed to suit the requirements of the various agroclimatic regions. It has been established that the improvement of tea could be brought about by following a 'clone-seed cycle' approach where improved clonal and seed varieties would be complementing each other.

The methods of introduction, selection, hybridization, polyploidy and mutation have been used to improve tea in N. E. India.

However, only introduction, selection and hybridization have been used with success. The other two methods of breeding, namely polyploidy and mutation, have been used only to the extent of generating some basic knowledge about their possible use for tea improvement. They hold great promise for the future improvement of tea in N.E. India.

Tocklai maintains perhaps the largest collection of tea germplasm in the world comprising 778 entries. However, the heterogeneous genetic make up of the major tea acreage, the fast uprooting of such sections followed by their replacement with few genetically improved clones and seed varieties, and loss of wild tea patches, a valuable source of tea germplasm, warrants an immediate action to save the valuable tea genetic resources before they are lost for ever.

The current programmes of clonal selection and biclonal stock breeding in N.E. India are expected to pay rich dividends to the industry. There are over 165 promising clones, and 3-4 promising biclonal seed stocks, in the pipe-line. With the adoption of modified method of line breeding, the efficiency of developing clonal seed varieties has been increased.

Triploids and tetraploids are expected to be the future planting materials of tea as they have exhibited superiority over diploids. Polyploidy breeding, therefore, needs to be strengthened.

Genetics of tea is poorly understood. Proper selection criteria have not yet been established. The prediction of the performance of mature tea based on their evaluation in the early years, has not yet been perfected. Field plot techniques to handle breeding populations of tea are poorly understood. It would, therefore, be worthwhile to take up studies on basic genetics, selection index, early generation testing, and field plot techniques in tea.

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SELF-INCOMPATIBILITY IN *EXCELSA* COFFEE: THE GENETIC SYSTEM AND NUMBER OF ALLELES

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Abstract

Self-incompatibility in *Coffee excelsa* Chev. was studied by stylar squash method and the genetic system and number of self-incompatibility alleles determined by deductive genetic reasoning. The genetic system of compatibility is under gametophytic control with multiple oppositional factors. The individual genotypes of the plants and the total number of S-alleles were enlisted.

Introduction

Coffea excelsa Chev. is a gigantic tree species with fruit characters very similar to *arabica* coffee and produces coffee of agreeable liquoring quality (Cheney, 1925). *Excelsa* is the only coffee adapted to the arid and semi-arid land stretches in Central and Western Africa (Haarer, 1962). Improvement of liquoring qualities through selection and hybridization was suggested (Haarer, 1962) in view of the adaptibility of the species and the relative ease of cultivation. *Coffea excelsa* ($2n=2x=22$) falls in the diploid species constellation of the genus *Coffea* and is highly self-incompatible. Present study describes the genetic system and allelic relationships controlling the reproductive biology of the species.

Materials and Methods

Selected plants of *C. excelsa* in the germplasm collection at the Central Coffee Research Institute were irrigated for induction of blossom. Crosses were performed according to a minimum-cross design (Table 1) for studying the compatibility reaction patterns. Styles were harvested 24 hours after pollination and fixed in lactic-ethanol (1:3). A stylar squash method (D'Souza,

1972) was combined with deductive genetic reasoning for rapid determination of the compatibility reactions and the number of self-incompatibility alleles involved in each cross. The data are presented in Tables 2 and 3.

Results And Discussion

In the genus *Coffea*, swelling, branching and other deformities of the pollen tube tip in the stylar tissues was known to reflect the incompatibility (Sybenga, 1960; Mendes, 1961; Ram *et al.*, 1982). During the present investigation a microscopic study of pollinated styles led to the identification of three types of compatibility reactions: (*i*) all pollen tubes in the style are normal (*ii*) approximately 50 per cent of pollen tubes in the style are deformed, and (*iii*) all pollen tubes in the style are abnormal (self-pollination).

In the plant kingdom, the control of pollination and fertilization to promote out-breeding is accomplished by a variety of means and genic self-incompatibility is one of them (Nettancourt, 1977). Genic self-incompatibility is broadly divided into two categories: the gametophytic incompatibility wherein the genic factor carried by the pollen grain (♂ gamete) plays a determining role in the accomplishment of fertilization, and the sporophytic incompatibility in which the diploid constitution of the plant producing the spores plays the crucial role. Besides genic self-incompatibility, morphological systems like heterostyly, dichogamy, protogyny, and protandry also promote out-breeding.

Table 1. The minimum-cross selector

♀ \ ♂	ex–1	ex–2
ex–2	+	
ex–3	+	+

Minimum-cross formula for larger populations

$$x = \frac{n\ (n-1)}{2}$$

Where x=The number of crosses required
n=The number of individuals in the population

Table 2. Compatibility responses of cross partners of *C. excelsa*

Crosses/selfs	No. of pollen grains on stigma	Germination %	No. of normal pollen tubes	No. of abnormal pollen tubes	Incompatible pollen tubes %	Compatibility class	Expected ratio	$P(X^2)$
ex-2 × ex-1	270	73.70	100	99	49.75	PC	1 :1	0.90–0.80
ex-3 × ex-1	149	70.47	93	12	11.43	C	1 : 0	0.30–0.20
ex-3 × ex-2	287	77.70	105	118	52.91	PC	1 : 1	0.70–0.50
ex-1	234	34.62	14	67	92.56	IC	0 : 1	0.20-0.10
ex-2	164	50.61	4	79	95.40	IC	0 : 1	0.70–0.50

C=Compatible, IC=Incompatible, PC=Partially Compatible

Table 3. Genetic analysis of results

Cross/Self	Compatibility classes: Compatible	Partially Compatible	Incompatible	Inferences: Number of alleles	Nature of alleles
ex-2×ex-1**	—	+	—	2+1	$S_{1/2}.x(_{1\cdot 2})$ *
ex-3×ex-1	+	—	—	2+2	$S_{3\cdot 4}$ $(_{1\cdot 2})$
ex-3×ex-2	—	+	—	2+2	$S_{3\cdot 4}$ $(_{1/2}.x)$
ex-1	—	—	+	2+0	$S_{1\cdot 2}$ ....
ex-2	—	—	+	2+0	$S_{1/2}.x$ ..

*Figures in parentheses represent the genotype of male parent

**Plant ex-1 is given the arbitrary genotype $S_{1\cdot 2}$

In the genus *Coffea*, self-incompatibility was demonstrated in *C. canephora* (De Vreaux *et al.*, 1959) and a gametophytic self-incompatibility system of oppositional factors recorded in *C. congensis* (Mendes, 1961). Further, it is known that in plants with gametophytic self-incompatibility, total compatibility is possible only when the incompatibility alleles carried by the partners are different namely, $S_{1\cdot 2}$, $S_{3\cdot 4}$ and so on, but partial compatibility can be observed in crosses like $S_{2\cdot 3} \times S_{3\cdot 4}$ and such others. Here, obviously the only functional pollen grains are those carrying the factor S_4. Total incompatibility results when crosses are made between $S_{1\cdot 2} \times S_{1\cdot 2}$ (*see* Muntzing, 1961; Arasu, 1968).

The data from Tables 1 and 2 then analysed in the light of the information presented above leads to the following conclusions:

The genetic system: The genetic system controlling compatibility in *C. excelsa* appears to be gametophytic in the light of the total incompatibility on self-pollination and partial compatibility (both normal and abnormal pollen tubes in the same style) in certain of the crosses.

Number of self-incompatibility alleles: Deductive genetic reasoning applied to the data in Tables 1 and 2 led to the identification of the individual S-allele genotypes of the three plants studied, and the presence of 4 S-alleles, S_1, S_2, S_3 and S_4, in these plants.

An arbitrary genotype $S_{1.2}$ was assigned to the plant ex-1. Other genotypes were stipulated according to the compatibility reactions. Thus, the plant ex-2 was partially compatible with ex-1 and was assumed to be carrying S_1 or S_2 and another allele Sx; while ex-3 was totally compatible and was assigned the genotype $S_{3.4}$. The plants ex-3 and ex-2 were also partially compatible; but since ex-3 was $S_{2.2}$, and ex-2 was $S_{1/2}$.x, it is obvious that x should be S_3 or S_4 and the functional pollen here was carrying S_1 or S_2. It is hence concluded that, there are 4 S-alleles distributed in the three plants as follows: ex-1 = $S_{1.2}$, ex-2 = S(1/2).(3/4), and ex-3 = $S_{3.4}$.

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CHARACTERIZATION OF COCONUT GERMPLASM BASED ON FRUIT COMPONENT ANALYSIS

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ABSTRACT

The coconut germplasm collection at the Central Plantation Crops Research Institute consists of 62 exotic and 32 indigenous accessions. It is by far the largest collection available anywhere in the world, comprising representative samples from geographically divergent populations. The germplasm collection is divided into four major geographical sets based on the location of collection, namely, accessions from countries in South-East Asia, Pacific Islands, North-Central and South-American, and African region. Data on yield and nut characters in 40 accessions are presented in this paper. The annual out-turn of copra ranged from 7 to 30 kg/palm/year in Tall cultivars while in the Dwarfs it was less than 10 kg/palm/year. The classification system based on fruit component analysis, and the time taken for germination, has been adopted to identify the degree of introgression in different accessions. Priority areas for future collections are also discussed.

INTRODUCTION

Cocos nucifera L. is a monotypic species of pantropical distribution between 20°N-20°S latitudes. India with 1.1 milion hectares under this crop, with an annual production of 5837 million nuts, ranks third in the world in area and production. At the Central Plantation Crops Research Institute, Kasaragod, the coconut germplasm collection consists of 62 exotic and 32 indigenous accessions. It is probably the largest collection in terms of number of accessions available anywhere in the world. The exotic collection consists of accessions from 22 countries, being mostly the open-pollinated progenies of either primary or secondary introductions, obtained on exchange basis. Recently, 24 more accessions were collected from South–Pacific Islands. The identity of each individual introduction is maintained and considered as a separate accession due to the lack of reliable classification criteria through which the duplicates can be identified. Basically, there are only two distinct varieties in coconut, the Tall and the Dwaıf. While the Tall is extensively grown commercially, the Dwarf, till recently, had only ornamental importance. With the standardization of commercial production of Dwarf x Tall hybrids, the dwarfs have also attained commercial importance. The Talls in general, are cross-pollinated and exhibit a wide range of variability for height of the palm, shape of crown, colour, shape and size of nuts, yield, and annual out-turn of copra. This could possibly be one of the reasons for identifying coconut varieties, especially the talls, by the location of the collection/cultivation. In addition, some of the cultivars are also known by the special features they possess, such as Laccadive Micro (a small-fruited variant of Lakshadweep Tall), Niu Bulundrau (producing 100 coconuts per bunch, from Fiji), and Kappadam (from Kerala having large quantity of nut water). The dwarfs, on the other hand, are distinguished by the colour of the nut, and the location of their general occurrence (e.g. Chowghat Dwarf Orange, Malayan Dwarf Yellow/Orange/Green, and Cameroon Red Dwarf).

The first systematic classification of coconut varieties and forms was attempted by Narayana and John (1949). Subsequently, Gangolly, Satyabalan and Pandalai (1957) reviewed the literature on coconut varieties. Liyanage (1958) classified the Ceylon coconut varieties. The criteria employed for all these classifications were, the plant habit, juvenile period and geographical source. The third classification was proposed by Fremond, Ziller and Lamothe (1966) on the basis of floral biology. One of the criteria common to all the systems is the importance given to the weight of meat and weight of copra. Harries (1978) while reviewing the evolution, dissemination and classification of coconut has proposed the use of fruit component analysis data as a rational approach to the classification of coconut varieties. In the present paper, an attempt has been made to test this classification system on 40 accessions, which are in stabilized bearing age, and assess the degree of introgression in them.

Materials and Methods

Twelve-month-old nuts collected during summer months for analysis, were stored for one month till the husk dried completely.

Four nuts were sampled from each palm as this sample size was found to give reasonably accurate characterization of fruit components under Kasaragod conditions (Jacob Mathew, Bhaskara Rao and Satyabalan, 1978). Out of the pooled sample, 10 nuts were selected per accession randomly, and considered for analysis in the present study. An average of four consequetive annual yields was taken as the yield of the palm/year. Number of days taken for germination was recorded in the nursery starting from the date of sowing.

RESULTS AND DISCUSSION

The fruit component analysis data, along with yield and number of days taken for germination, in 40 accessions from different countries, was grouped into four major geographic groups, namely, South-East Asian, Pacific Ocean, North-Central and South American, and African accessions. For convenience in presentation, the data from 25 accessions belonging to six countries from South-East Asian region are presented in Table-1 and the rest in Table-2. The percentage of husk which has been considered as the chief distinguishing character by Harries (1978), was plotted against the weight of whole fruit (Text Figs. 1 and 2). The argument for considering this particular character to distinguish the introgressed forms from the naturally evolved types is based on the importance of proportion of husk in the natural dissemination of the crop. In addition, the data on fruit components are available from almost all the coconut growing countries, whereas the specific palm characters are not readily available. One more point in favour of using the relationship between the components rather than absolute values is that it eliminates the differences due to management or growing conditions to which the palm is exposed. In addition, the measurements in terms of absolute values of palm height, leaf length and bunch production, depend more on the age of the palm and need repeated recording, whereas the fruit components are more or less stable throughout the stabilized yield period.

Another point to be considered is that the varieties evolved through human selection are distinctly different from those evolved naturally. The kernel was given higher commercial importance,

Table 1. Fruit and yield characteristics in coconut accessions from South–East Asian countries

Country/ Cultivar (g) 1	Wt. of whole fruit (g) 2	Wt. of husked nut (g) 3	% of husk of whole fruit 4	Wt. of kernel (g) 5	Wt. of copra (g) 6	Yield of nuts/palm/ year 7	Out-turn of copra (kg) 8	No. of days for germination 9
INDIA								
Andaman Ordinary	823	511	39	287	169	127	21.5	103
	(19.9)*	(25.6)	(9.6)	(16.8)	(13.3)	(40–202)**		
Andaman Giant	1094	672	39	325	181	110	19.9	64
	(15.4)	(19.6)	(14.4)	(15.9)	(21.0)	(69–149)		
Kappadam	1806	112	38	541	299	90	36.9	72
	(8.9)	(5.9)	(12.3)	(6.9)	(8.9)	(37–156)		
Laccadive Ordinary	787	497	37	262	169	127	21.5	86
	(23.1)	(22.7)	(9.0)	(19.9)	(19.8)	(64–166)		
Calangute	708	485	31	239	127	58	7.4	97
	(23.0)	(20.0)	(11.4)	(15.5)	(7.4)	(27–112)		
Laccadive Micro	503	305	39	109	85.8	119	9.9	110
	(17.0)	(15.9)	(7.8)	(12.6)	(11.5)	(19–523)		
Nadora	888	606	32	306	163	46	7.5	96
	(9.1)	(8.3)	(8.4)	(22.9)	(16.0)	(9–107)		
Benaulim	884	482	45	240	140	73	10.2	95
	(11.6)	(11.5)	(6.7)	(18.3)	(17.3)	(14–144)		
W.C.T.	922	446	52	252	150	70	10.5	109
	(5.6)	(9.3)	(10.8)	(11.7)	(5.0)	(12–124)		

Table 1 (*Contd.*)

1	2	3	4	5	6	7	8	9
SRI LANKA								
King Coconut	448 (12.4)	304 (16.6)	32 (11.1)	204 (11.1)	125 (13.9)	52 (27–72)	6.5	101
Gonthembili	847 (5.5)	497 (8.3)	41 (5.5)	260 (23.9)	180 (13.1)	49 (39–56)	8.8	90
Ceylon Tall	1013 (23.5)	601 (22.5)	41 (10.3)	374 (26.5)	213 (21.1)	39 (16–48)	8.3	99
VIETNAM								
Cochin China	957 (7.8)	638 (11.5)	33 (8.9)	334 (9.6)	198 (10.6)	88 (17–190)	17.4	30
INDONESIA								
Std. Kudat	820 (10.6)	455 (12.5)	44 (7.3)	215 (28.3)	46 (18.1)	46 (16–69)	6.7	102
Kong Thien Yong	906 (26.9)	591 (40.4)	37 (23.2)	325 (35.0)	151 (24.1)	32 (15–59)	6.3	59
Java	1261 (5.7)	896 (8.6)	29 (10.0)	493 (7.3)	298 (5.9)	101 (61–189)	30.1	70
Borneo	1288 (23.2)	860 (23.0)	33 (20.6)	412 (20.6)	215 (17.6)	74 (31–132)	15.9	57

Table 1 (*Contd.*)

1	2	3	4	5	6	7	8	9
MALAYSIA								
SS Green	909 (6.5)	603 (7.1)	34 (4.5)	336 (5.8)	189 (8.4)	97 (74–137)	18.3	84
FMS	1241 (13.8)	816 (22.0)	35 (20.8)	442 (25.1)	240 (21.4)	82 (29–209)	19.7	81
Klapawangi	894 (12.2)	597 (10.6)	33 (8.9)	319 (6.5)	182 (6.3)	71 (35–91)	12.9	82
PHILIPPINES								
San Ramon	1753 (20.8)	1251 (19.2)	28 (25.5)	648 (12.0)	346 (12.4)	64 (58–68)	22.1	45
Phil. Ordinary	938 (14.7)	599 (8.5)	35 (16.8)	341 (10.8)	198 (9.2)	110 (70-209)	21.8	83
Phil. Lono	(1000 (12.1)	719 (13.3)	28 (11.7)	198 (14.2)	148 (8.8)	56 (36–80)	8.3	60
Phil. Laguna	(1624 (11.30)	1074 (19.7)	35 (20.7)	282 (15.6)	209 (11.8)	91 (58–97)	19.1	90
Phil. Dalig	836 (13.7)	484 (19.3)	42 (10.7)	173 (24.7)	126 (10.8)	72 (46–95)	9.1	89

*CV **range

Table 2. Fruit characteristics and yield of coconut accessions from Pacific, N.C. and S. America, and Africa

Country/Cultivar	Wt. of whole fruit	Wt. of husked nut	% of husk of whole fruit	Wt. of kernel	Wt. of copra	Yield of nuts/palm/	Outturn of copra	No. of days for germination
1	2	3	4	5	6	7	8	9
PACIFIC								
B.S.I.	685 (21.7)?	460 (21.2)	31 (43.1)	321 (25.2)	161 (21.2)	106 (62–133)**	17.1	70
Guam I	1133 (14.3)	682 (16.1)	40 (4.0)	395 (13.6)	224 (18.1)	101 (32–171)	22.6	90
Guam II	908 (13.6)	601 (11.9)	33 (12.4)	331 (11.5)	194 (14.2)	93 (46–121)	18.0	85
Guam III	1017 (20.6)	594 (21.8)	42 (7.8)	365 (24.8)	214 (23.4)	120 (21–295)	25.7	110
Fiji Tall	964 (5.2)	577 (7.1)	40 (3.9)	327 (6.1)	179 (10.7)	104 (50–163)	18.6	101
Fiji Rotuma	1448 (8.6)	1014 (12.0)	30 (20.3)	292 (15.7)	179 (4.1)	40 (16–68)	7.2	90
N.C. AMERICA								
Jamaica	1551 (9.1)	957 (14.0)	39 (9.2)	459 (21.4)	277 (13.7)	61 (29–233)	16.9	56
Panama	1609 (16.3)	912 (7.3)	42 (16.1)	340 (30.7)	248 (14.4)	74 (26–144)	18.4	109
St. Vincent	1356 (20.8)	769 (18.2)	43 (7.0)	223 (10.7)	186 (13.6)	38 (16–62)	7.1	110

Table 2 (*Contd.*)

1	2	3	4	5	6	7	8	9
Blanchissues	831 (12.5)	590 (13.5)	29 (6.2)	196 (12.6)	148 (9.7)	83 (17–158)	11.5	97
AFRICA								
Nigerian Dwarf	771 (1.3)	518 (2.5)	33 (3.1)	361 (9.1)	169 (2.5)	28 (8–60)	4.7	96
Nigerian Tall	1668 (18.9)	998 (10.6)	39 (20.3)	481 (9.0)	290 (6.3)	76 (25–104)	22.0	104
Zanzibar	826 (18.2)	566 (20.9)	32 (8.5)	343 (12.7)	215 (10.3)	101 (34–281)	21.7	84
Kenya	979 (16.1)	650 (12.7)	33 (20.2)	341 (14.3)	193 (12.6)	84 (34–155)	16.2	82
Seychelles	908 (15.4)	374 (30.1)	59 (12.6)	245 (34.1)	151 (27.9)	73 (37–125)	11.0	[illegible]

*C.V. **range.

whereby the selection pressure was always in the direction of bigger nuts (to realize higher kernel/copra) with lesser husk. Harries (1978) classified them as 'Niu Vai', and the naturally evolved ones as 'Niu Kafa' types.

Among the 25 accessions from South-East Asian countries studied, Kappadam from India, San Ramon and Philippines Laguna from the Philippines, Borneo and Java from Indonesia, and F.M.S. from Malaysia, exhibited low proportion of husk with high values for whole fruit weight (Text Fig. 1). The high values for the total out-turn of copra (Kappadam-26.9 kg/palm/year; San Ramon-22.1 kg; Philippines Laguna-19.1 kg; Borneo-15.9 kg; Java-30 kg and FMS-19.7kg), confirm the contention that these are evolved as a result of selection pressure operating towards

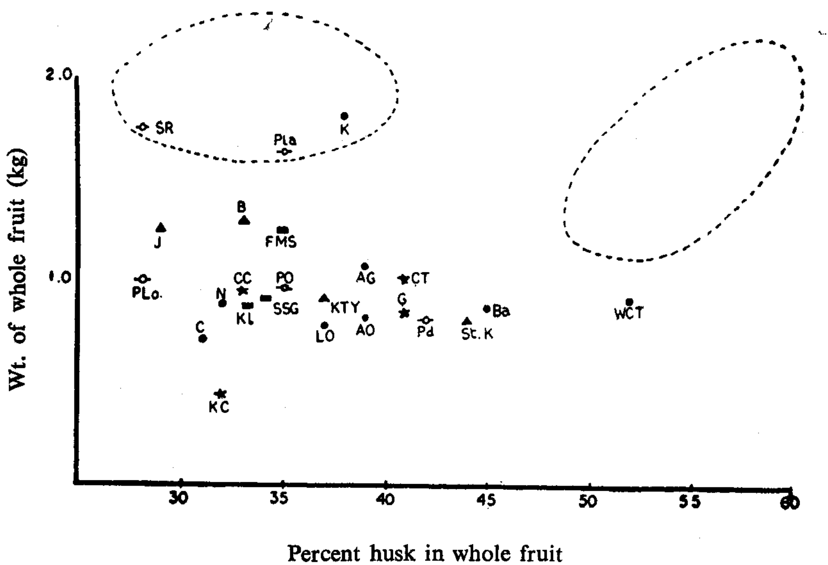

Fig. 1. Coconut germplasm accessions from South-East Asian countries

SR—San Ramon; PLa—Philippines Laguna; K—Kappadam; J—Java; B—Borneo; FMS—Federated Malay States; PLo—Philippines Lono; N—Nadora; CC—Cochin China; SSG—Strait Settlements Green; K1—Klapawangi; PO–Philippines Ordinary; KC—King Coconut; KTY—Kong Thien Yong; LO—Laccadive Ordinary; AG—Andaman Giant; AO—Andaman Ordinary; CT—Ceylon Tall; G—Gonthembili; PD–Philippines Dalig; St. K.—Standard Kudat; Ba—Benaulim; WCT—West Coast Tall; C—Calangute.

higher copra. The West Coast Tall which is the most commonly grown tall variety in the West Coast of India, showed higher husk proportion, and is very near to the values of 'Niu Kafa', the putative parental type described by Harries (1978). Similarly, Benaulim from Goa coast, Standard Kudat from Malaysia, Ceylon Tall and Gonthembili from Sri Lanka, and Philippines Dalig from Philippines, are also nearer to the 'Niu-Kafa' type. The annual out-turn of copra ranging between 6.7 kg/palm/year to 10.5 kg/palm/year, also shows the relatively less selection pressure evidenced in these accessions. The island populations from India such as Andaman Ordinary, Andaman Giant and Laccadive Ordinary with intermediate husk values and higher out-turn of copra represent introgressed forms. In general, the 'Niu Vai' showed lesser number of days for sprouting than the 'Niu Kafa' types.

The accessions from Pacific, North-Central America and Africa are plotted in Fig. 2. The interesting data recorded in the

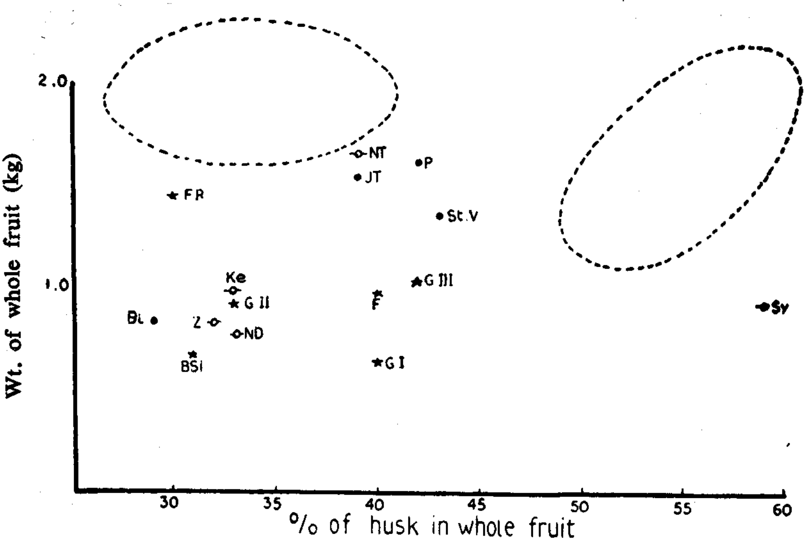

Fig. 2. Coconut germplasm accessions from Pacific, N.C. America and Africa

Fig. 2. FR—Fiji Rotuma; NT—Nigerian Tall; JT—Jamaica Tall; P—Panama Tall; St. V.—St. Vincent; Ke—Kenya Tall; B1—Blanchissues; Z—Zanzibar Tall; BSI—British Solomon Islands Tall; ND—Nigerian Dwarf; G I–III—Guam Tall I; Guam Tall II; Guam Tall III; F—Fiji Tall; Sy—Seychelles Tall.

two collections from Fiji, is that the Fiji Tall showed intermediate values in respect of husk percentage and Fiji Rotuma from the Rotuma island showed lesser proportion of husk but significantly lower out-turn of copra. However, the lesser number of days taken for germination and higher whole fruit weight values, indicate that Fiji Rotuma could be a 'Niu Vai' type and the Fiji Tall could have arisen by introgression. The Seychelles Tall from the African coastal island showing the highest value for percentage of husk (59 per cent) must have originated from the 'Niu Kafa' putative parent. The Blanchissues from West Indies, Zanzibar Tall from Zanzibar, B. S. I. from Solomon Islands, and Kenya Tall from Kenya, represent the introgressed forms derived from the 'Niu Vai' type.

The collections from Jamaica, namely the Jamaica Tall and Panama do not conform to the description of Whitehead (1966). The data showed that Panama tall with lesser husk proportion belonged to 'Niu Vai' group occurring on the Pacific Coast of America, whereas Jamaica Tall with higher proportion of husk and lesser fruit number, belonged to the 'Niu Kafa' group found on the Atlantic coast of Africa. However, in the present study, both these groups, showing intermediate husk proportion and more or less similar yield pattern for copra, can be classified as introgressed forms with greater affinity towards 'Niu Vai' group.

The classification as detailed above indicates the possible locations where the naturally evolved coconuts are still present. For genetic conservation of variability, this information would be of immense use. The areas presently known to have the 'Niu Kafa' types or the introgressed forms from 'Niu Kafa' putative parent, have hence to be extensively surveyed on priority basis. There is a greater possibility for the immediate replacement of these types due to their uneconomical characters such as higher husk and lesser out-turn of copra. The classification system itself has an added advantage in that it is simple enough to use in the field to determine the type that is generally present in any given area. This will enable the collection teams to decide whether to make a coarse-grid sampling or a fine–grid sampling.

ACKNOWLEDGEMENT

We are extremely thankful to our Statistician Shri Jacob Mathew, for the help rendered in the analysis of data. We are also thankful to the Director and the Head of the Division of Genetics, CPCRI Kasaragod, for the facilities and help rendered to us.

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DISCUSSION

M. V. RAO (ICAR, New Delhi): The data shows that there is a great deal of variability for copra yield/palm/year in the tall cultivars as compared to that obtained in the D×T and Malayan Dwarf Green. If the Talls are capable of giving high yields why should we go in for D×T or other dwarfs? Why not we exploit the high yielding tall types themselves?

R. V. PILLAI: The yield of copra in a few Tall cultivars is high and even on par with D×T. The reason for going in for D×T is that this hybrid has shown some degree of tolerance to root (wilt) disease whereas none of the cultivars has so far shown any tolerance. Moreover, the availability of the material of these high yielding Talls is also very limited.

K.U.K. NAMPOOTHIRI (CPCRI, Palode): Comment—It is found that Malayan Dwarf Green is not as homogeneous as the other Dwarfs. It will be wise to compare the experience of scientists on this variety outside the country.

K. KANNAN (R.A.R.S., Pilicode): The nut size, copra content and other fruit components are highly variable under different climatic and cultural conditions. Even in the same variety, individual tree variations are noticed. So how can we take the fruit component as a basis for classification?

R. V. PILLAI: The nut characters are definitely influenced by environment. Only the absolute values may vary, but not the ratios of the components. Hence this can be used for the classification of cultivars.

R. GOPIMONY (KAU): Will the ratio be the same for percentage of husk also?

R. V. PILLAI: The ratio will not change for the husk and copra. Only the absolute values will vary.

HIGH YIELDING VHC-1 COCONUT HYBRID

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Abstract

A study of the performance of certain intervarietal hybrids in coconut has shown that East Coast Tall × Dwarf Green is most promising in yield of nuts, copra and oil content. The importance of choice of parental trees in both Tall and Dwarf varieties was evident from the expression of heterosis in a few parental tree combinations. With a view to exploiting heterosis to step up coconut production, hybridization was repeated in such of those parental tree combinations which exhibited superior performance. As a result VHC-1 (Veppankulam Hybrid Coconut-1) was released during 1982 for commercial cultivation.

Introduction

Evolution of superior and high yielding coconut strains has been receiving attention only recently. The importance of utilising the prococious bearing character of Dwarfs in breeding was first realized by Patel (1937) who observed maximum hybrid vigour when the Tall variety was used as female parent with Dwarf as the male.

Four sets of hybrids were studied at the Regional Coconut Research Station, Veppankulam, Tamil Nadu, of which East Coast Tall × Dwarf Green was found to be the most promising and was released as VHC-1 (Veppankulam Hybrid Coconut-1) during 1982. Details of its performance are presented in this paper.

Materials And Methods

Cross pollination was effected in 1968 between East Coast Tall (ECT) as female parent, and Ayiramkachi (AY), Dwarf Green (DG), and Semi–Tall Yellow (STY), as male parents, and also a reciprocal cross involving STY as female and ECT as male parents.

Hybrid seedlings developed from these crosses were planted in 1972 along with ECT parent, which served as control.

ECT×DG hybrid is compared in this paper with another hybrid ECT×STY (a hybrid previously distributed for cultivation) as well as ECT-I of the same age group as hybrids, and ECT-II, the palms of which are 12 years older than the hybrids. Ten palms out of 60 in ECT×DG, and ten palms out of 48 in ECT×STY which showed heterosis for yield, were compared with equal numbers of palms in ECT. Yield data obtained for six years, from 1976, the year of commencement of bearing, till 1981, were used for comparison. Nut characters were studied and oil content estimated by Soxhlet method.

Results And Discussion

There was no appreciable difference in the number of spikelets per spadix when ECT×DG was compared with ECT×STY, and with ECT-I and II. ECT×DG hybrid was found to be superior to ECT×STY, ECT-I and ECT-II with regard to number of spikelets bearing female flowers, number of spikelets with more than one female flowei, and total number of female flowers per spadix.

The yield data are presented in Table-1. With a mean yield of 115 nuts/palm/year and 21,648 nuts/ha, ECT×GD hybrid was found to be significantly superior to ECT-I palms of the same age group, and ECT-II palms with stabilized high yield which

Table 1. Performance of VHC-1, ECT×STY Hybrids and Parents

Hybrid/Parent	No. of nuts/ plam/year	Copra/nut (g)	% Oil
VHC-1 (ECT×DG)	115.1	163	66
ECT×STY	110.0	131	57
ECT-I	47.7	108	57
ECT-II	87.8	128	59
DG	32.0	62	57
STY	67.9	70	52
C.D. at 5%	23.1	—	—

are 12 years older than the hybrids. Despite its numerical superiority, ECT×DG was on par with ECT×STY in number of nuts/palm, and yield of nuts/ha. However, with a mean yield of 3537 kg/ha copra and 2211 kg/ha oil, ECT×DG hybrid was found to be significantly superior to ECT-I, ECT-II and also ECT×STY hybrid. The fact that the yield of this hybrid over last six years has not fluctuated significantly adds merit to its other positive aspects. There was no buckling of bunches, a phenomenon commonly associated with other hybrids in which Dwarf parent is involved. Under good crop management there was no premature shedding of buttons in this hybrid (Fig. 1).

ECT×DG hybrid gave the highest weight of dehusked nut, copra and oil content per nut. Thus, heterosis for several economic characters, exceeding the values of both the parents is established in this hybrid, and this is found to be superior to the ruling hybrid and ECT palms of not only the same age but also that of stabilized high yielding palms. Of the sixty hybrid palms involving eleven parent tree combinations studied in ECT×DG, the expression of heterosis was of a high order in ten palms involving seven parent tree combinations. These combinations were taken into consideration while repeating the crosses for the purpose of releasing seedlings of VHC-1 hybrid.

It is worthwhile, in this context, to recall the importance of selection of both Tall and Dwarf palms with a view to obtaining optimal hybrid vigour as reported in a study of West Coast Tall× Dwarf Green coconut hybrids (Bavappa *et al.*, 1973).

Exploitation of heterosis for commercial cultivation of coconut is a relatively recent technology. Fremond and de Nuce de Lamothe (1971) have reported that MAWA hybrid PB-121 (Malayan Yellow Dwarf ×West African Tall) gave higher nut and copra yield than 'West African Tall'. 'Maypan' a hybrid developed between Malayan Dwarf×Panama Tall was reported to be resistant to lethal yellowing disease, and hence recommended for commercial cultivation in Jamaica (Harries and Romney, 1974). In Sri Lanka, superiority was observed for copra and oil content in 'typica'×'nana' hybrids where three colour forms of variety 'nana', namely, 'pumila', 'eburnea' and 'regia' were used as male parents (Manthriratne, 1973).

Fig. 1 VHC–1 Coconut Hybrid

The identification of superior hybrids in the present combination of ECT × DG, which excel not only the ECT variety of the same age group, but also the high yielding ECT palms which show stabilized performance, and also the ruling hybrid ECT × STY which was popularized recently, is likely to go a long way in coconut improvement. This is particularly so, because of the unique breeding problems presented by this crop and the tardy progress made in coconut breeding work in India (Ninan and Pandalai, 1962).

ACKNOWLEDGEMENT

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DISCUSSION

R. D. IYER (CPCRI Kasaragod): Please clarify whether the yield data presented pertain to rainfed or irrigated conditions?

T. RAMANATHAN: The yield data relate to irrigated condition.

A.O.N. PANIKKAR (RRII, Kottayam): Do the data relate to a single trial (in one location), or are they pooled from multilocational trials?

T. RAMANATHAN: The data relate to a single location trial conducted at Coconut Research Station, Veppankulam.

P. RETHINAM (CPCRI, Kasaragod): 1. What is the justification for releasing this variety as State variety?

2. What are the nut, copra and oil yields in ECT×DG and ECT×Ayiramkachi?

3. What is the dwarf green used?

T. RAMANATHAN: 1. The yields (nuts, copra and oil) in ECT×DG were superior to those in other hybrids and ECT parent; and hence released as VHC-1 hybrid.

2. Cross

Cross	Yield (kg/ha) Copra	Oil
ECT×DG (VHC-1)	3537	2211
ECT×AY	1932	1194

3. Malaysian Dwarf Green was used as male parent.

ASSESSMENT OF SPECIFIC AND GENERAL COMBINING ABILITIES OF NINE COCONUT CULTIVARS

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ABSTRACT

A diallel programme with 36 crosses and nine parents was undertaken to analyse the general and specific combining abilities (*gca* and *sca*) of nine coconut cultivars of diverse origin, and their hybrids, for five important characters. Results of diallel analysis showed that girth, height, total leaf production and leaf production during the year, were significant among the characters studied. The cross combinations, Laccadive Ordinary × Jamaica, and Fiji × Jamaica exhibited high *sca* effects for total leaf production and leaf production during the year. Laccadive, Jamaica, Java, Fiji and San Ramon cultivars proved useful as parents among the Tall cultivars. The D × T and T × D crosses involving Gangabondam as the dwarf parent flowered early. The total leaf production was also high in these crosses. In T × T crosses, Java × SS Green, Laccadive Ordinary × Jamaica, and Fiji × Jamaica flowered early.

INTRODUCTION

Coconut occupies a unique position among the commercial crops of India. The need for developing early flowering, high yielding hybrids suitable for different areas, and less susceptible to pests and diseases, has been keenly felt. To achieve this objective a diallel programme involving 36 crosses among nine parents, was undertaken for the first time. Nine different coconut cultivars of diverse origin were selected to study their general and specific combining abilities, in order to understand not only the genetic make-up of diverse parental materials, but also to provide useful information on breeding potential of selected genotypes. By introducing new, exotic varieties, the variability can be increased in existing coconut populations. The number of nuts of Tall palms required to produce 1 ton of copra is said to be 4500 in Philippines, 4,800 in Ceylon, and 6,000 to 8,000 in South India and Pacific Islands. Similar variations exist within countries. In San Ramon variety of Phillippines, and certain Tall forms in other parts of the world the out-turn index is 2,800 to 3,300, and in the dwarf palms and few other Tall forms with very small nuts, it varies from 8,400 to 10,000.

Based on fruit analysis of important commercial varieties of coconut in Fiji, Satyabalan (1972) showed that the same variety grown in different islands showed great variation for different characters studied. Kannan and Nambiar (1974) using Gangabondam as male parent in crosses with six Tall types, found that Laccadive Ordinary × Gangabondam combination was superior to all others in respect of leaf production, fruit-set, nut yield and copra out-turn. Satyabalan *et al.* (1964) observed that the West Coast Tall × Gangabondam hybrid was significantly better than Tall × Tall hybrid with respect to number of days taken for germination, girth at collar and total number of leaves, and better than other Tall × Dwarf hybrids, in days taken for germination. WCT × G also had greater collar girth than the WCT × CDO hybrids and produced almost as many leaves. Narasimhayya and Sukumaran (1978) worked out heritability values as above 50 per cent, for plant height, total leaf production and time taken for flowering, observed at different stages of growth in West Coast Tall cultivar. Lamothe *et. al.* (1980) mentioned that the coconut breeding method chosen by IRHO is based on estimation of combining abilities between individuals or origins and phenotypical choices for heritable characters.

MATERIALS AND METHODS

Nine cultivars, West Coast Tall, Laccadive Ordinary, San Ramon, Fiji, Jamaica, Java, Gangabondam, S.S.Green, and New Guinea, selected for this diallel mating system were planted during the years 1972 and 1973. They were crossed in all possible combinations (excluding reciprocals). A cultivar was taken as a unit, and mixed pollen of each was used separately for pollination. Thus, 360 seedlings belonging to 36 crosses and nine parents were planted at CPCRI Kasaragod in two replications of RBD with four seedlings in each plot, at a spacing of 7.5 × 7.5m^2 Observations on five important growth characters: (1) girth, (2) height, (3) total leaf production, (4) leaf production during the year, and (5) number of functional leaves on the crown, were recorded during 1981-82. The method of diallel analysis used here is based on that of Griffing (1956), applicable generally to diallel crosses n (n-1)/2, where n is the number of varieties to be tested namely, 9(9-1)/2 =36.

Results And Discussion

Table-1 gives a list of good general and specific combiners with regard to various characters under study. Diallel analysis shows that the treatment and general combining ability differences are found to be significant for girth, height, total leaf production, and leaf production during the year, whereas the specific combining abilities are found to be significant only with regard to total leaf production. A perusal of Table 2 indicates very high σ_e^2 (environ-

Table 1. Good general and specific combiners for different characters

Character	Good general combiners	Good specific combiners
Height	Java (+)* Gangabondam (–)*	West Coast Tall×Laccadive (–) Laccadive×Fiji (+) Laccadive×Jamaica (+) Laccadive×Java (–) Laccadive×SS Green (+) Jamaica×Gangabondam (–) Java×Gangabondam (–)
Girth	Gangabondam (–)* San Ramon (+)* Jamaica (+)	Laccadive×Gangabondam (+) Gangabondam×New Guinea (–)
Total leaf production	Gangabondam (+)* West Coast Tall (–)*	*Laccadive×Jamaica (+) *Fiji×Jamaica (+) *Java×Gangabondam (–) Java×SS Green (+)
Leaf production during the year	San Ramon (+) Gangabondam (+) New Guinea (–)	Laccadive×Jamaica (+) Fiji×Jamaica (+) Java×SS Green (+)
Number of functioning leaves	West Coast Tall (–)	Laccadive×Jamaica (+) Fiji×Jamaica (+)

*Significant at 5% level
+ indicates positive value for combining ability
– indicates negative value for combining ability

Table 2. Table showing estimates of components of variance

Character	σ^2_{GCA}	σ^2_{SCA}	σ^2_{e}	σ^2_{a}	σ^2_{d}
Height	589.00*	721.00	1160.00	1177.00	720.84
Girth	29.72*	0.00	38.06	59.44	0.00
Total leaf production	2.89*	13.09*	18.83	5.78	13.09
Leaf production during the year	0.1132*	0.1664	0.5583	0.2264	0.1664
No. of functional leaves	0.00	0.7241	4.5884	0.00	0.7241

*Significant at 5% level
Zeros indicate negative values of the variance estimates.

mental variance) which may be the main cause for not detecting the significance of the specific combining ability differences with regard to the remaining characters also. Table-2 also indicates the larger additive genetic variances with regard to height, leaf production during the year, and girth, compared to dominance variances, whereas with regard to total leaf production, dominance variance is larger compared to additive genetic variance. The estimates of general combining ability and the additive genetic variances for number of functional leaves, and specific combining ability for girth are found to be negative. Since variances cannot take negative values, zero values are shown against them.

Java is found to increase plant height and Gangabondam decreases height in their hybrid combinations with the cultivars selected in the trial. Laccadive Ordinary induces greater height in F_1 when crossed with Jamaica and Fiji, whereas it decreased the height when crossed with Java and SS Green. Jamaica also increased height and Java decreased it in the F_1 hybrids with Gangabondam.

San Ramon and Gangabondam increased leaf production during the year whereas New Guinea decreased the same. The crosses of Laccadive Ordinary and Fiji with Jamaica, and Java × SS Green, also increased the leaf production during the year.

When Tall cultivars are crossed with Gangabondam the pre-flowering leaf production increased in their T×D hybrids. In crosses of Laccadive and Fuji with Jamaica, and in Java×SS Green also, the total leaf production increased.

San Ramon, Jamaica, Java and West Coast Tall are good general combiners for girth. In West Coast Tall, the girth of seedlings showed a high correlation with yield. Gangabondam decreased the girth, whereas San Ramon and Jamaica induced larger girth in their F_1 hybrids. Gangabondam when used as male parent in crosses with Laccadive Ordinary, increased girth, but as a female parent in crosses with New Guinea, it decreased the girth.

Thus, the choice of parents should be based not only on their combining ability for one main component, but also on their merit in cross combinations with other major components.

The results presented in Table-3 also show that both D×T and T×D crosses involving Gangabondam as the Dwarf parent flowered early. The total leaf production is also high in these crosses. The results indicate that the Dwarf parent induces early flowering. The data also shows that the T×T crosses namely, Java×SS Green, Laccadive×Jamaica, Fiji×Jamaica, and Fiji×SS Green also flowered early. Lamothe *et al.* (1980) showed that the T×T hybrids are as precocious and productive as D×T. West African Tall×Rennel Tall crosses had produced 14.3 tons of copra/ha by the end of 9th year which is the same as that of MAWA hybrid PB-121, and 2.27 times more than that of the West African Tall control. These results justify the undertaking of studies on individual combining abilities of Rennel and West African Talls. Diallel cross analysis also shows that Laccadive× Jamaica, and Fiji×Jamaica are also good combiners for total leaf production and leaf production during the year.

Conclusions

A study of the effects of general and specific combining abilities would indicate better combinations involving one or both parents of high *gca* effects, for exploitation in breeding programmes. Laccadive Ordinary, Jamaica, Java, Fiji and San Ramon

Table 3. Mean values of morphological characters and flowering in diallel cross progenies

Cross	Total Plants	No. of seedlings flowered	Time taken for flowering (months)	Flowering leaf axil No.	Total leaf production	Total height (cm)
Gangabondam as a male parent in T×D crosses						
Laccadive×G	8	7	64.3	48.3	88.5	555.8
Fiji×G		6	67.3	54.4	85.1	695.3
Java×G		5	72.7	50.7	73.7	549.4
West Coast Tall×G		6	74.7	51.9	80.8	606.7
San Ramon×G		8	75.8	61.3	90.8	515.3
Gangabondam as a female parent in D×T crosses						
G×S. S. Green	8	8	53.0	44.3	91.9	545.0
G×New Guinea	8	7	42.7	40.0	93.7	524.7
Tall×Tall crosses						
Laccadive×Jamaica	8	7	69.7	60.1	94.4	722.8
Fiji×Jamaica		6	69.8	52.7	86.4	628.7
Java×S.S. Green		6	69.3	52.2	92.5	681.7
Fiji×S.S. Green		8	70.8	55.8	89.5	675.6
Laccadive×Fiji		6	71.9	55.9	83.9	655.8
West Coast Tall×Java		6	78.8	55.4	78.4	704.3
W.C. Tall×Laccadive		8	80.8	53.5	77.8	527.9
S.S. Green×New Guinea		5	80.7	57.4	82.0	658.8
Jamaica×S.S. Green		6	87.9	50.1	83.1	642.3
Laccadive×San Ramon		7	87.8	68.6	85.5	636.1

are found to be useful parents among the Tall varieties, and Gangabondam Dwarf parent induces early flowering in both D×T and T×D cross-combinations.

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I wish to thank Dr. K. V. Ahamed Bavappa, Director, Central Plantation Crops Research Institute, for providing facilities; Dr. R. D. Iyer, Head, Division of Genetics, for guidance, scrutiny of the manuscript and valuable suggestions; Sri M. V. George and Sri G. Narasimhayya Biometricians, for help in statistical analysis and interpretation of the data. Thanks are also due to Drs. M. C. Nambiar and K.U.K. Nampoothiri who were associated with this work during the initial stages.

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Discussion

C. S. SRINIVASAN (Coffee Res. Sub-Station, Chethalli):

1. Which is more important in coconut breeding, G.C.A. or S.C.A.?
2. Whether homozygosity of the parents was assured before taking up diallel crossing, as it is a prerequisite?

C. K. SUKUMARAN: (1) SCA is more important; (2) Homozygosity has not been assessed but material was drawn from a relatively homogeneous population.

K.U.K. NAMPOOTHIRI (CPCRI, Palode): The author recommends production of T×T crosses in view of the earliness of some combinations. This interesting observation needs thorough deliberation before publication.

C. K. SUKUMARAN: This point can be fruitfully deliberated when the yield of these palms also become available.

PERFORMANCE OF LAYERS, GRAFTS AND SEEDLINGS OF CASHEW

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ABSTRACT

The performance of cashew seedlings, grafts and layers studied at Cashew Research Station, Ullal, indicated that the layers yield twice that of seedlings. Even twenty-five year old clonal progenies were significantly superior in yield to seedling progenies. The coefficient of variation of layers and grafts are 45.4% and 56.9% respectively as compared to 99.7% of seedling progenies indicating a higher heterogeneity in seedling than in clonal populations.

INTRODUCTION

The cashewnut (*Anacardium occidentale* L.) being a cross pollinated crop, a high degree of heterogeneity exists in the population. Therefore, vegetative propagation is an important tool in cashew breeding work, to evolve high yielding clones.

Ohler (1979) states that air-layering is the most successful method in India. Madhava Rao (1957), and Gowda *et al.*, (1976), opined that air-layers of cashew yield better and earlier. The precocity of the inarches and air-layers has been two or more years compared to seedlings (Gowda *et al.*, 1976).

MATERIALS AND METHODS

With a view to comparing the performance of seedlings, layers and grafts derived from a single parent tree, an experiment was laid out in 1957 at Cashew Research Station, Ullal, Karnataka. A randomized block design was used with six replications, each treatment consisting of six plants. The plants were spaced at 6m × 6m. A fertilizer dose of 128g N, 160g of P_2O_5, and 120g K_2O per tree was applied. Plant protection measures were undertaken to control cashew pests.

The observation on yield per tree was recorded. The yield data of the earlier period (1960-1974), and of the later period (1975-1982) of the trial were subjected to statistical scrutiny and compared with the earlier results.

RESULTS AND DISCUSSION

The average yield per tree per year of treatments, namely seedlings, grafts and layers are presented in Table-1. The yield data is grouped into two categories, namely, yields during early period of growth (1960-1974) and yields of aged plants (1975-1982). It is evident from the Table that during the first 15 years of production the clonal progenies, namely grafts and layers have given significantly superior yield than the seedling progenies. However, there is no significant difference in yield between grafts and layers during the earlier period (1960-1974), eventhough the layers have yielded better than grafts, but there is significant difference between grafts and layers during later period (1975-82), when the layers have yielded twice that of seedlings.

Table 1. Comparative yields of seedlings, grafts and layers

Treatments	Average number of nuts/tree/year	
	1960–1974	1975–1982
Seedlings	40	225
Grafts	95	328
Airlayers	106	436
C.D. at 5%	23	91
C.D. at 1%	33	130

Table 2. Extent of heterogeneity in average yield (no. of nuts) of cashew seedlings, grafts and layers (1975–1982)

Treatment	Mean	Range	Coefficient of variation %
Seedlings	225	20–800 (780)	99.7
Grafts	328	32–746 (714)	56.9
Layers	436	59–620 (561)	45.3

Several workers have expressed doubt regarding the better performance of the layers during the later part of their growth, as they did not possess the tap-root system. It can be seen from the table that even the 18 to 25 years old clonally propagated plants (1975 to 1982) have yielded significantly more than seedlings. Here agin, the layers have yielded twice that of seedlings.

The poor performance of seedling progenies may be attributed to the heterogeneity of the population as cashew is a cross pollinated crop. The mean, range and coefficient of variation in average yield of seedlings, grafts and layers is given in Table-2. The range and the coefficient of variation of layers is less(45.4 per cent) compared to that of seedling progenies (99.7 per cent). This clearly indicates that, heterogeneity in seedling progenies is more than that of clonal progenies. The grafts exhibit more heterogeneity than layers. This may be due to the effect of stock on scion, as the grafts possess the root system of seedlings. The variation among layers, may be due to environmental factors like soil, insect damage, and weather conditions.

The superior yield of the clonal progenies may be due to the better genetic make up of the plants as they perpetuate true to type. The spreading and profusely branching habit of the clonal progenies resulted in more efficinet interception of solar energy by the well spread-out canopy. Thus, better accumulation of photosynthates and greater spread of roots in grafts and layers (Rai and Vidyachandra, 1981) would be the likely source of extra energy for better flowering and production of the vegetatively propagated cashew plants. The vegetative frame-work of the plants of clonal progenies is better than that in the seedling progenies. Therefore, the yield performance is also better contrary to the assumption that the yield of layers will be reduced as the age advances. Eighteen to twenty five year old layers also give significantly higher yields. Absence of a tap-root system has not affected the yield. The layers could perform better with their better genetic make up and vegetative frame work.

Rai and Vidyachandra (1981) explained that in case of 3–year–old layers, the lateral roots grow sufficiently deep into the soil (6–15ft.), and the spread of the root is 10–27ft. The total number of roots including small tertiary roots, are definitely more in layers than in seedlings. Therefore, the root system of layers is better than that in seedlings, resulting in higher yields.

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Discussions

S. NAGABHUSHANAM (CPCRI Shantigodu): Why not take weight of nuts into consideration while computing the yield, instead of number of nuts? What is the survival percentage of grafts/airlayers/seedlings after 25 years in the experiment?

S. I. HANAMASHETTI: 1. Earlier workers had recorded only the no. of nuts/tree and hence the same observation was continued. The suggestion to record weight of nuts would be given due consideration in future.

2. Only two or three trees died during the past 25 years due to stem borer attack.

G. SREEKANDAN NAIR (KAU Vellayani): 1. What is the average yield of cashew in Karnataka?

2. If it is two kg, then your experimental materials are below average; what is the explanation for the above?

3. Have you studied sex ratio, setting percent, shelling per cent, etc. in the various materials.

S. I. HANMASHETTI: 1. The average yield per tree in Karnataka is 2.0 kg of raw nuts.

2. The CRS, established in the year 1953, is one of the pioneer Res. Stations in India. At that time, based on certain criteria, mother trees were selected. During that period there was not much progress in respect of selection and breeding work in cashew. However, even if we take the high yielding varieties, I am sure the same trend is going to continue, namely layers would perform better than seedlings.

3. There was not much variation in sex ratio. We have not recorded shelling per cent. Due to better growth and branching habit, and better root system, the yield obtained by layers is more.

R. C. MANDAL (CPCRI, Kasaragod). Yield of plants raised through seedlings is comparatively lower than layers or grafts. It is to be considered whether emphasis is to be given for layers or grafts, considering the need for quick vegetative propagation of this crop.

S. I. HANMASHETTI: Emphasis is to be given for air-layering in case of cashew, as it is a quick and easy method of propagation, as observed in CRS Ullal.

M. K. NAIR (CPCRI, Calicut): 1. Please clarify whether the seedling and clonal progenies were used from the same mother tree?

2. What is the stability of the layers with respect to the rooting system, since layers lack a tap root?

S. I. HANMASHETTI: 1. The seedlings, and clonal material used were from the same mother tree.

2. There was no problem about establishment, as round about S. Kanara 91% establishment was there, and root system was better. One has to choose the suitable method of vegetative progagation appropriate to different regions of the country. In Vengurla (Maharashtra), they say grafts are better. So it varies from region to region.

ISOLATION OF HIGH CURCUMIN VARIANTS OF TURMERIC FROM TISSUE CULTURES

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ABSTRACT

Variants with a high curcumin content were isolated from callus cultures of *Curcuma domestica* Val. (syn. *longa* L.) cv. Tekurpeta after treatment with mutagenic agents and colchicine. Of several plants regenerated from these cultures two were selected which contained 7 and 8% curcumin respectively. Field performance of these plants to determine the stability of the curcumin character for three successive generations, was also studied.

INTRODUCTION

Turmeric is a valuable spice obtained from the rhizomes of *Curcuma domestica Val.*; (Zingiberaceae). Turmeric powder contains 3.5 per cent of an aromatic essential oil and 2.5–6 per cent of a bright yellow pigment, curcumin.

Oleoresin obtained by solvent extraction of the ground spice consists of the total extractives of turmeric and is used where the colour and flavour of turmeric are important. It is a dark, brownish-red, highly viscous liquid. The oleoresin is used as a colouring agent in the food, and the pickle industry, and in products such as processed cheese and mustard paste (Krishnamurthy *et al.*, 1976).

Curcumin, the principal coloring matter, forms about one-third of the standard oleoresin. The oleoresin is priced according to its curcumin content. Curcumin in a pure state is a crystalline powder having a melting point of 180-182°C.

Curcumin is used in the dye industry and in cosmetic preparations such as facial creams, shampoos, lotions, and sprays.

The average percentage of curcumin in most of the cultivars varies from 2 to 5 per cent. However, varieties having a higher curcumin content have also been isolated.

A recent application of tissue culture is in the isolation of different types of mutants (Nabors *et al.*, 1975). This application has been mainly due to two reasons:

1. Callus cultures often show wide spontaneous variability in chromosome number which is also observed in plants regenerated from such cells.

2. Mutations can be induced in callus or suspension cultures efficiently by treatment with mutagenic agents at the cellular level.

In the present paper, the tissue culture method for isolation of mutants containing high curcumin, and the stabilization of their character by successive field trials, will be discussed.

Materials and Methods

We have earlier described the tissue culture methods for the rapid multiplication of two varieties of *Curcuma domestica* Val. (syn. *C. longa* L.), Tekurpeta and Duggirala (Nadgauda *et al.*, 1978). On repeated subculture of shoots, a swelling was observed at the base of the leaves. These swellings when carefully removed and cultured on an agar medium (M) containing Murashige and Skoog's (1962) salts supplemented with 0.1 mg/l Kinetin, 0.2 mg/l BAP, and 10 per cent coconut water, formed a callus under dark incubation. This callus readily differentiated into shoots when incubated in light and could be maintained indefinitely by monthly subculture. These cultures could be broken down to a fine cell suspension comprising small clumps of 5-50 cells when transferred to liquid agitated medium M. Cell suspension cultures of var. Tekurpeta were used for these studies.

Mutagenic treatment was given by growth of the cell suspensions in the presence of chemical mutagenic agents, EMS and ethydium bromide, which were filter-sterilized and added to the medium at concentrations and time intervals ranging from 0.1 to

1 per cent for 24-72h respectively. γ-ray treatment was given by subjecting the cells in a petri dish to doses of 1, 2, 3, & 4 KR from a cobalt^{60} source. A filter-sterilized colchicine solution was also added aseptically to the liquid medium (M) in Erlenmeyer flasks. Cells were grown in the presence of different concentrations of colchicine ranging from 0.01 to 0.1 per cent for different time intervals ranging from 8-48h.

After the desired treatment, the cells were washed 3 times with sterile liquid medium by alternate decantation and removal of supernatant, and later inoculated to agar medium (M). Plantlets were regenerated by the two stage method reported earlier (Nadgauda *et al.*, 1978). Cytological studies were also carried out in the control and high curcumin plants, using the HCl-giemsa method of Joshi and Ranjekar (1980).

Results and Discussion

Treatment with mutagenic agents resulted in a marked inhibition of the differentiation capacity of the callus. A few plants which developed after mutagen treatment of cell suspensions, did not survive when grown in the field. However, about 500 plants obtained from γ-ray, and 0.01 per cent and 0.05 per cent colchicine-treated cultures, were successfully planted in the field. At the end of the growth period (1979) the curcumin content was analysed in the dried rhizome powder by the standard method described in American Spice Trade Association (ASTA) analytical method No. 18. An average of 5 readings was taken to determine the curcumin percentage. The plants numbered 221 and 222 were found to contain 7 and 8 per cent curcumin respectively as against 4 to 5 per cent in control Tekurpeta.

In the next growing season (1979-80), the finger rhizomes of these plants were grown in pots in order to multiply the seed material for conducting further field trials.

In the following year (1980-81), fifty rhizomes of identical weight each of Nos. 221 & 222, and control Tekurpeta were planted. After harvest, the curcumin content of the rhizomes was determined; 20 plants of 221 and 27 plants of 222 contained 7.5 to 8 per cent curcumin. The average initial and final rhizome weights of 221, 222 and control were, 8 g at planting and 350 g, 392 g and 251g respectively, at harvest.

Rhizomes having a high curcumin percentage were separated and replanted together with controls in a 400m^2 area in 1981-82. The curcumin content of the rhizomes of all plants was determined. At this stage, the high curcumin character (7.5—8 per cent) was detected in over 8 per cent plants, indicating a gradual selection for this character.

Further trials are now in progress in a 700m^2 area. Analysis of the curcumin content of the rhizomes at harvest in this experiment will confirm whether this character has stabilized.

Cytological studies were also carried out in plants 221, and 222 and control Tekurpeta using root tips. These studies revealed that the chromosome numbers in 221, 222 and the controls range within the limits of 56-63, indicating the absence of obvious polyploid series. Aneuploids, however, could not be confirmed because of the high number and small size of the chromosomes.

Ross (1965) has made a series of observations regarding the mutational effects of colchicine in *Sorghum* species. He observed somatic reduction of chromososmes from tetraploid to diploid or from diploid to haploid followed by gene mutation, which further undergoes diploidization. A similar phenomenon could have occurred with the turmeric plants obtained by treatment with colchicine in the presnt studies.

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DISCUSSIONS

M. V. RAO (ICAR, New Delhi): You now have 2-3 years of yield data on the new high curcumin content varieties/mutants. Some of them are quite promising. From here where do you go?

R. S. NADGAUDA: Actually we have conducted large-scale field trails at NCL. This year (1982–83) we have planted about 600 m^2 area; but still there are some limitations, So we feel that if any agricultural institution will take up these rhizomes and multiply, it would be better.

M. C. NAMBIAR (CPCRI Kasaragod): We have the collection of *C. longa* selections with curcumin content varying from 5 to 14.5%. The material could be made available for your studies, if you so desire.

R. S. NADGAUDA: Yes, if we get the rhizomes we can multiply it by tissue culture.

M. K. NAIR (CPCRI, Calicut): 1. The material you have used is obviously *C. longa* with $2n=63$, and the range of chromosome numbers reported may be due to lack of clarity.

2. We have selections at CPCRI with curcumin content upto 14 per cent. The selections are Sl. No. 20, and 21 of 'Muvattupuzha'. It would have been better to utilize these materials for your study. If required, the mate rials could be made available.

NADGAUDA: Your materials with high curcumin will be most welcome for tissue culture multiplication.

PERFORMANCE OF RRII 300 SERIES CLONES IN THE SMALL SCALE TRIAL

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ABSTRACT

The Rubber Research Institute of India has been trying to evolve planting materials of *Hevea brasiliensis* through breeding and selection from 1954 onwards. During the first phase, emphasis was given to evolve planting materials of high production potential. This paper summarizes the performance of progenies of the 1958 hand-pollination programme in the small scale trials. An evaluation of the performance has resulted in eleven primary selections from this series. Selections RRII 300 and RRII 308 showed very promising production potential with an average yield of 97.5 and 71.5g per tree per tap of dry rubber respectively during the first eleven years of tapping.

INTRODUCTION

Crop improvement by breeding and selection was started by the Rubber Research Institute of India in 1954 (Nair & Jacob, 1968; Nair & George, 1968) and certain clones developed by the Institute have gained wide popularity among planters (Nair *et al.*, 1975; George & Panikkar, 1980). In this paper, the 1958 hand-pollination programmes, establishment of the small scale trials, selection of RRII-300 series clones and their performance, are discussed.

MATERIALS AND METHODS

In 1958, 22 cross combinations incorporating 15 clones had been attempted, from which 480 seedlings were obtained. These seedlings were raised in the nursery at the RRII and were subsequently transplanted to the main field in 1960. The trees were opened in 1966 and S/2 d/3 system was followed for the tapping.

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The seedlings were cloned simultaneously and a small-scale trial of these clones started in the same year. The number of trees of the different clones varied depending upon the budding success. Tapping was commenced in this trial in 1969, and S/2 d/2 system of tapping was followed.

Regular yield recordings were done in the fields by cup coagulation method. Girth at 125cm height was recorded from the fifth year after planting for the clones.

On the basis of the mean annual yield for the first three years and the vigour at opening, a preliminary selection was made from among the clones, and the topmost 11 clones were selected for further trials. The 11 selections are listed as RRII - 300 series clones and numbered from RRII-300 to RRII-310. Recording of yield and vigour were continued and secondary characters were also observed. Drought tolerance was assessed on the basis of the percentage drop in summer yield from the mean annual yield. An yield drop of 25 per cent or below in the summer is considered as high tolerance and a drop above 50 per cent is described as high susceptibility.

Results and Discussion

All the 22 crosses made as per 1958 hand–pollination programme and their family-wise mean annual yield per tree per tap are given in Table-1. Out of the 11 clones selected from among the buddings nine clones come under the families which have above average yield.

Table-2 shows the percentage and the mean yield per tree per tap of RRII-300 series clones, and the control in the virgin bark and the renewed bark. The selections gave higher yields than the control Tjir-1. From the virgin bark, highest yield was obtained for RRII 302 followed by RRII-300, RRII-310 and RRII-308, the yields being 79g, 73g, 71g, and 70g, dry rubber per tree per tap respectively, when the control clone gave only 41g.

Yield of the selectionss on the renewed bark did not follow the same pattern. RRII-300 was the highest yielder on the renewed

Table 1. *Family-wise yield of the seedlings (5 years' average)*

Parentage	Yield/tree/tap (gm)
Tjir 1×Lun N	23.51
PB 86×GL 1	24.76
GL 1×PB 6/50 (1)	25.28
Tjir×Mundakayam	26.18
PB 86×Tjir 1	26.53
GL 1×Tjir 1	26.91
PB 86×Lun N	28.00
PB 86×Pil B84	28.66
PB 86×PR 107	29.45
Mil 3/2×PB 5/139	30.63
PB 86×CHM 3 (1)	31.43
LCB 1320×GL 1 (1)	34.48
Tjir 1×PB 6/50	35.32
Tjir 1×Wagga 6278	35.84
Tjir 1×Mil 3/2 (1)	36.15
Tjir 1×PR 107 (1)	37.09
PB 86×LCB 1320	37.11
LCB 1320×PB 86 (1)	38.04
RsY 23×Tjir 1	40.03
LCB 1320×PB 6/50	41.17
Tjir 1×PB 6/9 (5)	42.70
Mil 3/2×PB 6/9	57.90
Overall Average	33.33

Table 2. *Parentage and yield performance of the selections*

Clone	Parentage	*Yield/tree/tap in gm* Virgin Bark (6 yrs. average)	Renewed Bark (5 yrs. average)
RRII 300	Tjir 1×PR 107	72.49	127.52
RRII 301	Tjir 1×Mil 3/2	50.27	34.39
RRII 302	Tjir 1×PB 6/9	79.25	56.57
RRII 303	Tjir 1×PB 6/9	56.05	41.12
RRII 304	Tjir 1×PB 6/9	52.73	67.04
RRII 305	Tjir 1×PB 6/9	57.26	51.39
RRII 306	Tjir 1×PB 6/9	65.06	86.31
RRII 307	PB 86×CHM 3	53.86	49.75
RRII 308	GL 1×PB 6/50	69.72	67.46
RRII 309	LCB 1320×PB 86	54.73	66.84
RRII 310	LCB 1320×GL 1	71.40	49.37
Tjir 1	Control Parent	41.40	34.97

Table 3. Per tree per tap yield of the selections for 11 years (in gm) and the mean

RRII Clone No.	70–71	71–72	72–73	73–74	74–75	75–76	76–77	77–78	78–79	79–80	80–81	Average
300	44.55	70.00	54.31	93.38	100.80	71.81	104.19	111.75	154.73	136.44	130.50	97.50
301	33.28	48.28	66.42	61.00	58.54	34.07	35.51	26.25	36.67	38.33	35.14	43.05
302	50.70	114.09	57.93	109.89	91.42	51.43	48.82	30.30	47.08	56.64	50.02	68.95
303	45.68	57.98	63.39	74.18	47.96	47.12	45.95	42.67	39.55	43.72	33.71	49.26
304	22.74	61.29	72.58	66.99	53.19	39.57	61.59	78.53	57.29	69.87	67.93	59.22
305	23.08	70.29	59.68	73.50	71.91	45.10	30.87	94.90	38.94	44.59	47.67	54.59
306	27.58	61.78	74.53	86.54	68.58	71.32	71.80	84.60	93.94	75.75	105.44	74.71
307	16.82	101.89	58.71	60.26	37.46	48.02	49.13	75.85	41.67	39.90	42.19	51.88
308	37.22	66.72	68.19	97.65	82.25	96.25	85.50	70.15	69.59	57.05	55.03	71.47
309	41.40	63.01	78.22	48.27	37.86	59.57	79.92	43.13	87.90	63.25	60.00	60.23
310	46.12	74.75	114.24	85.82	71.79	35.65	92.43	33.75	57.05	34.71	28.92	61.38
Tjir 1	38.06	42.96	36.56	60.30	41.76	28.73	40.71	39.19	28.98	28.06	42.91	38.47

bark, the mean yield being 128g per tree tap. This was followed by RRII-306, RRII-308, and RRII-304 yielding 86g, 68g, and 67g respectively. The control yielded only 35g.

The year-wise yield of the selections for the first 11 years and the mean over 11 years are furnished in Table-3. The mean yield of RRII-300 is 98g per tree per tap which is estimated as 3627kg per hectare per year. RRII-306 and RRII-308 gave 75g and 72g respectively.

The vigour at opening and rate of girth increment are summarized in Table-4. RRII-310 had 87 cm girth at the time of opening. This was followed by RRII-308 and RRII-300 having 85cm and 81cm girth. The rate of girth increment on tapping was highest for RRII-300, which was followed by RRII-302 and RRII-308

Table 4. Girth data of RRII 300 series selections

Clones	Vigour at opening (cm.)	Rate of girth increment on tapping (10 years' average
RRII 300	81.00	5.87
RRII 301	70.33	4.12
RRII 302	74.42	4.98
RRII 303	75.20	3.82
RRII 304	76.87	4.03
RRII 305	77.75	3.01
RRII 306	78.50	2.92
RRII 307	67.50	3.19
RRII 308	85.20	4.81
RRII 309	80.25	3.99
RRII 310	86.62	3.83
Tjir 1	64.50	2.75

The bark anatomical characters and certain secondary characters are detailed in Tables 5 and 6 respectively. Above average thickness of the virgin bark was observed for RRII-308, RRII-306 RRII-305 and RRII-300, though the number of latex vessel rows was not the highest for RRII-300 and RRII-308. The rate of girth increment on tapping was highest for RRII-300 with the largest number of latex vessel rows in the renewed bark. The girth increment rate and bark renewal of RRII-308 were also good.

Table 5. Bark anatomical characters

Clones	Virgin Bark (14 years after planting)		Renewed Bark (After 5 years renewal)	
	Bark thickness (mm)	No. of latex vessel rows	Bark thickness (mm)	No. of latex vessel rows
RRII 300	12.00	24.70	6.75	28.00
,, 301	8.17	27.00	4.83	17.00
,, 302	10.50	27.30	4.50	12.00
,, 303	11.32	36.00	5.50	26.00
,, 304	10.11	20.20	5.50	15.00
,, 305	12.00	31.60	6.25	13.00
,, 306	12.00	32.80	6.00	23.00
,, 307	10.15	32.90	5.17	24.00
,, 308	12.85	28.10	6.67	16.00
,, 309	10.36	26.50	6.00	16.00
,, 310	10.75	28.50	5.50	19.00
Tjir 1	9.90	16.30	5.00	15.00
Mean	10.84	27.66	5.64	18.67

RRII-300 has a straight and cylindrical stem with open and distributed canopy. This clone is characterized by low branching with strong and spathulate branch union. Leaf fall due to *Phytophthora* disease was comparatively less. The trees also did not show incidence of brown bast or wind damage. It has only average tolerance to drought. RRII-302 was affected by wind. Incidence of brown bast and leaf fall disease were also comparatively more. RRII-306 was less affected by drought, and leaf fall due to *Phytophthora* was negligible, but the incidence of wind damage was high. In the case of RRII-308, there was no incidence of wind damage or brown bast, and leaf fall due to *Phytophthora* was also negligible. RRII-310 also showed fair tolerance to drought, brown bast and wind damage.

Table 6. Secondary characters of (RRII 300 series) clones: Field observations

Clone	Stem	Branching	Canopy	Diseases	Brown bast	Wind damage	Drought tolerance
300	Straight cylindrical Terrate	No leader. Branching low. Few branches arising from the same level. Branch union spathulate and strong. Scar prominent	Open, distributed and medium	*Oidium* average. Leaf fall below average	No incidence	No incidence	Average
301	Straight cylindrical Terrate	Leader prominent. Branches few and slender, union strong	Narrow and sparse, restricted to the top	*Oidium* average. Leaf fall average	No incidence	No incidence	Below average
302	Straight	No leader. Branches arising almost at the same height	Distributed and medium	*Oidium* average. Leaf fall above average	Above average	Above average	Average
303	Straight fluted	No leader. Branches few	Distributed and medium crown obovate	*Oidium* average	No incidence	Below average	Above average
304	Straight cylindrical and terrate	No leader. Branch union strong	Medium	*Oidium* above average	No incidence	No incidence	Below average
305	Straight and cylindrical	Branches few and medium type. Branch scar bumping and prominent. Union not very strong	Medium	*Oidium* average leaf fall below average	Above average	Above average	Below average

Table 6. (contd.)

Clone	Stem	Branching	Canopy	Disease	Brown bast	Wind damage	Drought tolerance
306	Slightly fluted and cylindrical	Leader prominent, branches few	Medium and closed	*Oidium* average; leaf fall below average	No incidence	Above average	Above average
307	Straight and cylindrical	Leader prominent. Branches few and branch union strong. Branch scar prominent	Medium open and globular; leaf scar prominent	*Oidium* below average	No incidence	Average	Below average
308	Trunk slightly fluted	No leader. Several medium to heavy branches	Heavy, distributed and broom shaped	*Oidium* average; leaf fall below average	No incidence	No incidence	Average
309	Trunk straight and slightly fluted	No leader. Low branches arising at the same level. Union not strong	Crown confined to the top. Canopy broom shaped	*Oidium* below average Leaf fall average	No incidence	No incidence	Average
310	Straight cylindrical and terrate	No leader. Low branching. Branch union strong	Sparse and light	*Oidium* average. Leaf fall average	No incidence	No incidence	Above average

The yield potential of RRII-302 on the virgin bark was very promising. Owing to the tendency of falling yield trend in the renewed bark along with high incidence of *Phytophthora* leaf fall, brown bast and wind damage, this clone is not preferred to the other selections at this stage. RRII-310 was a vigorous clone with desirable secondary characters but the yield on renewed bark was not promising. RRII-306, a high yielder with rising yield trend, was found to be highly susceptible to wind damage. RRII-300 is an outstanding clone for its high yield and desirable secondary characters. The rising yield trend is also a specific character of this clone having moderately high yield in the virgin bark and a very high yield in the renewed bark, and the mean yield over 11 years for this clone was the highest among the selections. RRII-308 was a high yielder in the virgin bark and also in the renewed bark. It showed fairly good tolerance to leaf fall disease. wind damage, brown bast and drought.

ACKNOWLEDGEMENT

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DISCUSSIONS

V. S. SHARMA (UPASI, Cinchona): Are these replicated trials in which yields and the vigour of the selections were recorded?

PREMKUMARI: This is not a replicated tiral. In the small scale trial we will plant all the available clones resulting from the concerned year's hand-polinations with the available number of plants. In the next stage of testing, well laid out trials are taken up.

V. S. GOVINDARAJAN (Coffee Board, Kalpetta): 1. Is wind damage a serious problem in rubber? Is it not more correlated to slope aspect of the field, and the wind proneness of the locality? It is understood only 5 trees were taken for observation out of which 3 showed wind range. Does the wind damage the entire tree or only branches?

PREMKUMARI: 1. Wind damage is a serious problem in rubber, only in wind affected areas.

2. Only 5 trees were taken for observation out of which 3 trees were affected causing total damage to two trees and branch snap for one tree.

COMPARATIVE PERFORMANCE OF POLYBAGGED RUBBER PLANTS AND BROWN BUDDED STUMPS

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ABSTRACT

An observation trial of one block each of polybagged plants with 2-3 whorls of leaves and brown budded stumps of clone PR-107, was conducted to compare their growth, vigour, and other characters. Bagged plants exhibited more vigour than budded stumps and came to tapping one year earlier than the latter. Casualty was comparatively low among the bagged plants. There was no appreciable difference among the two treatments regarding other secondary characteristics like incidence of wind damage and diseases.

INTRODUCTION

The long immaturity period required by *Hevea* is one of the most serious handicaps faced by the Rubber Plantation Industry. Various planting techniques have been tried to reduce this long unproductive period (Anon. 1973; Edgar; 1958; Mainstone, 1962; Sergeant, 1967; Strivens, 1962). Raising plants in polythene bags in nursery during the initial stages of their growth and subsequent transplanting in the field at the appropriate stage, popularly known as polybag planting, is an important technique in this context (Anon. 1966; 1973; Mathew, 1976; Mainstone, 1962; Tinley, 1962). It has been reported that by adopting this technique, immaturity period of *Hevea* could be reduced by 24 months compared with the seed at stake technique (Mathew, 1976; Mainstone, 1962; Shepherd, 1976). An observation has been carried out to ascertain the suitability of this technique to our country, and its advantages in reducing the prebearing period.

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Materials and Methods

Germinated Tjir-1 monoclonal seeds were raised in: (1) black polythene bags of lay flat size 60×30 cm. and 300 gauge, and (2) in seedling nursery simultaneously. The seedlings were nursed properly by manuring, watering, mulching and shading. After five months of growth, the polybag plants were grafted with green buds of clone PR-107. They were cut back after three weeks and the scion allowed to grow. The seedlings raised in the nursery were grafted with brown buds of PR-107, nine months after planting. The polybag plants and the budded stumps were transplanted in the field during the subsequent planting season. At this stage, the polybag plants had a scion growth of approximately 64cm height with 2 to 3 whorls of leaves.

The planting was done on contours at a spacing of 670×340 cm (22×11ft) with 220 plants per treatment. Usual cultural operations were carried out for both the treatments in the field. However, vacancies were not supplied. Observations were noted on casualties, growth vigour, and susceptibility to wind damage and diseases.

Results And Discussion

Thirteen months after planting, the green-budded bagged plants had an average scion height of 218.5 cm, whereas the scion of the brown-budded plants had attained only 111.6 cm height. The mean girth of the trees recorded from the second year onwards, at a height of 125cm above the bud union, also revealed the comparatively better growth of the green-budded bagged plants as may be seen from Table-1. This trend was observed right from the second year upto the 9th year.

Table 1. Mean girth (cm) of the trees at 125 cm height

	Year after planting							
	II	III	IV	V	VI	VII	VIII	IX
Bagged plants	10.03	16.77	27.19	37.70	42.58	49.32	54.93	59.95
Budded Stumps	8.26	14.09	23.35	32.00	36.75	44.33	50.47	55.18

While the difference in girth between the two materials was only 1.77 cm during the second year after planting, it was more pronounced during the subsequent years, and at nine years after planting in the field, the average girth of the trees raised from bagged plants was 4.77 cm more than that of the budded stumps.

The total casualty due to natural causes was very high among the budded stumps. Only 6 per cent of the bagged plants were lost due to natural calamities from the time of planting in the field upto opening, whereas the corresponding figure for budded stumps was more than 28 per cent. In this connection, it is worthwhile to remember that the bagged plant has a well-developed scion and root system, which remained undisturbed at the time of planting. This has facilitated easy establishment of the plants and their continued growth. In the case of budded stumps, the root system had to be established afresh and the high percentage of casualties, especially during the initial years, is likely to have arisen due to difficulties in early establishment and in overcoming adverse weather conditions.

The data on the percentage of trees which attained tapable girth are summarized in Table-2. The bagged plants attained commercial tapability eight years after planting, whereas the budded stumps took one more year. While 84.7 per cent of the former were tapable after eight years, in the case of the latter, only 83.5 per cent were ready for opening even after nine years in spite of the fact that the stand was less by 28 per cent on account of the vacancies which provided better conditions for their growth.

Table 2. Percentage tapability of bagged plants and budded stumps

	Years after planting			
	VI	VII	VIII	IX
Bagged plants	2.1	48.6	84.7	92.8
Budded stumps	0.6	14.6	56.3	83.5

In general, the immaturity period is on the higher side and has been due to the poor soil conditions of the trial area which affected the growth and development of both the bagged plants and budded stumps. What is salient therefore, is that, under comparable conditions, the green-budded bagged plants attained tapability a year ahead of conventional budded stumps. Regarding the incidence of wind damage and diseases, not much difference was noticed between the two treatments.

On the basis of the studies conducted by him, Mathew (1976) has stated that by adopting polybag planting technique, immaturity period of rubber trees could be reduced by 12-18 months compared to seed at stake planting. Mainstone (1962) also has concluded that by raising budded stumps in polythene bags and planting later, the immaturity period could be reduced by 24 months compared to planting at stake. In a trial conducted by Shepherd (1967) for comparing different planting techniques, bagged plants recorded a girth of 7.62 cm more than that of brown-budded stumps, 33 months after planting.

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DISCUSSION

EAPEN GEORGE (A. V. Thomas & Co., Cochin): Is the extra cost of polybag planting justified by the one year's early tapping facility? Please incorporate this study in your programme. If you plan for cost studies, look into: 1. Cost of bag; 2. Labour cost for filling the bag; 3. Transporting cost while planting; 4. Extra labour involved in transport and planting.

J. G. M.: We have already started experiments incorporating these aspects.

JOHN M. JOHN (Cardamom Board, Cochin): Are there any special advantages for black polythene bags over transparent ones?

J. G. M.: Root development and the growth of seedlings is reported to be better in black polybags.

SEASONAL VARIATIONS IN ROOTING OF COFFEE CUTTINGS

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ABSTRACT

Seasonal variations in rooting of *Coffee arabica* L. cuttings, were studied, using invigorated and matured suckers of the cultivar S-795. Plants were invigorated by beheading at 45 cm height from ground level. Suckers raised from these stumps were collected and planted four months after beheading. IBA (500 ppm) and IBA + NAA (250 ppm each) were given as pre-planting treatments. Significant difference was noticed between periods of planting, both for root and shoot characters of cuttings. Percentage of rooting (66.75) and number of primary roots (2.95) were highest in August planted cuttings, while the number of sprouts (0.78) and their length (2.25 cm) were better in April cuttings. Sucker cuttings from onn-beheaded (matured) plants were planted in alternative months, with IBA 5000 ppm and IBA + NAA 2500 ppm each as pre-planting treatments. Highest percentage of rooting (100) and member of primary roots (10.51) were recorded in cuttings planted during June, followed by October planted ones (78.10 per cent and 3.26 primary roots). Number and length of sprouts (0.86 and 10.38) cm in June cuttings were significantly higher than in those planted in other periods.

INTRODUCTION

Rooting in stem cuttings varies with the season of planting and this has been reported in many of the horticultural crops. The loss in rooting ability of stem cuttings, as the plant becomes older, and changes from juvenility to matured stage, was reported in different crops by earlier investigators (Gardner, 1929; Cheesman and Spencer, 1936). Singh (1954) opined that the new shoots induced in old mango trees by beheading, when planted as cuttings did not indicate any relationship with age of the plant with respect to their rooting. This method of inducing vigour in the plants for taking cuttings was later used by many workers to improve rooting in different fruit and plantation crops (Venkataramani, 1963; Bhandary and Mukerjee, 1969). Later, it was found that season of beheading and collection of the material for planting also had significant influence on rooting. Present studies were conducted to ascertain the seasonal variations in rooting of invigorated and matured sucker cuttings of coffee.

MATERIALS AND METHODS

To study the invigoration effect on rooting of cuttings, about twenty plants of S. 795 (second generation of S. 288 × Kents *arabica*) were beheaded during the months of January, April, and August, 1980. For this purpose, 10-year old plants were selected and beheading was done at 0-45cm from ground level. Invigorated suckers were collected four months after beheading. Cuttings were planted in polythene bags with IBA 500 ppm and IBA+NAA 250 ppm each as pre-planting treatments, following the quick dip method. These bags with the cuttings planted in soil mixture were arranged in trenches as per the procedure given by Purushotham and Vishveshwara (1980). Similiarly, cuttings from matured (non-beheaded) plants were also planted but with pre-planting treatments of IBA 5000 ppm and IBA+NAA 2,500 ppm. These concentrations were found to be ideal for matured cuttings of coffee (Purushotham and Vishveshwara, 1982). Experiments were laid out separately with different materials., and the results analysed adopting split plot design. Growth regulator treatments of cuttings formed the main treatments, and periods of planting, the sub-treatments, replicated three times. Observations regarding percentage of rooting, number and length of primary roots, number of sprouts and their lengths were recorded, three months after planting.

RESULTS AND DISCUSSION

There was significant difference among the periods of planting in rooting percentage of cuttings. Matured cuttings rooted cent per cent when they were planted during June, followed by October planting (78.10 per cent). December-planted cuttings recorded the least rooting (18.43 per cent; Table 1). Among the pre-treatments, IBA could enhance rooting percentage. Cuttings planted during dry periods of the year did not respond to growth regulator treatments. However, interaction between periods of planting and hormonal treatments was significant (Table 1).

Table 1. Rooting in S 795 sucker cuttings planted during different periods of the year (Transformed values)

	PERIODS OF PLANTING						
Main treatments	Feb.	Apr.	June	Aug.	Oct.	Dec.	Mean
IBA 5000 ppm	52.78 (63.40)	52.78 (63.40)	90.00 (100.00)	61.22 (76.80)	63.44 (80.00)	18.44 (10.00)	56.44 (65.60)
IBA + NAA 2500 ppm each	43.08 (46.60)	45.00 (50.00)	90.00 (100.00)	54.78 (66.70)	61.71 (77.50)	21.15 (13.00)	52.62 (58.97)
Control	26.07 (19.30)	23.85 (16.30)	90.00 (100.00)	46.92 (53.30)	61.22 (76.80)	34.62 (32.30)	47.11 (49.67)
Mean	40.64 (43.10)	40.54 (43.23)	90.00 (100.00)	54.30 (65.60)	62.12 (78.10)	24.73 (18.43)	

To compare the difference of means

1. Between main treatments CD=NS
2. Between periods of planting CD=4.83
3. Between two periods with or without chemical treatments CD=8.39
4. Between main treatments in a particular period CD=8.34

(Figures in patentheses indicate actual percentage of rooting)

Development of primary roots on sucker cuttings was influenced by the period of planting, June planting recording the highest number (10.51), and December the least. June planted cuttings had longest roots and varied significantly with those of other seasons. Pre-treatment with IBA+NAA at 2500 ppm could increase the length of primaries (79.99 cm) over control (Table 2). Changes in root measurements according to season and growth regulator treatment were observed in many horticultural crops (Hartman and Loreti, 1965; Vietez and Pena, 1968; Smith and Wareing, 1972). Evans (1958) working with *Coffea arabica*, reported that cuttings planted in rainy season rooted easily. Later, in India, the same conclusion was drawn in an experiment with *arabica* cuttings of different seasons planted under solar propagators (Anonymous, 1960).

Table 2. Total length of primary roots in S. 795 sucker cuttings planted in different periods of the year

Main treatments	PERIODS OF PLANTING Feb.	April	June	Aug.	Oct.	Dec.	Mean
IBA 5000 ppm	12.21	12.14	75.47	30.16	30.17	0.55	26.78
IBA+NAA 2500 ppm each	4.09	12.69	79.99	21.67	31.79	0.68	25.15
Control	1.99	3.87	42.43	12.15	14.49	0.67	12.60
Mean	6.09	9.56	65.96	21.32	25.48	0.63	

To compare the difference of means

1. Between main treatments CD = 6.66
2. Between periods CD = 10.46
3. Between two periods with or without chemical treatments
4. Between main treatments in a particular period CD = NS

Significant differences were observed in sprout development on cuttings planted in different seasons. June-planted mature cuttings had 0.86 sprouts, followed by February cuttings (0.84). Longer sprouts of 10.38 cm were observed in June planted cuttings, and these were significantly higher than those of other seasonal plantings (Table 3). Sprout production varied significantly in different seasons. Considering both root and shoot characters, it can be concluded that sucker cuttings varied with different seasons. However, it is clear from these results that rooting of sucker cuttings coincided with the growth phase of *arabica*. Stem cuttings collected during the growth period of plant, rooted very easily as reported by many investigators (Adarsha Bala *et al.*, 1969; Nanda & Kumar, 1969). This was thought to be due to high meristematic activity due to high production of auxins (Nanda, 1970; Nanda and Anand, 1970).

In another experiment, plants were beheaded to invigorate them, the suckers grown on these stumps were collected and planted after pre-treatment with IBA 500 ppm/IBA+NAA 250 ppm. Results indicated that there was significant increase in rooting

Table 3. Length of sprout in S 795 sucker cuttings planted in different periods of the year

Main treatments	PERIODS OF PLANTING Feb.	April	June	Aug.	Oct.	Dec.	Mean
IBA 5000 ppm	7.97	3.27	10.99	0.73	1.07	0.30	4.05
IBA+NAA 2500 ppm each	3.13	4.29	12.07	0.61	0.78	0.47	3.55
Control	1.20	1.11	8.08	1.97	0.63	0.73	2.28
Mean	4.10	2.89	10.38	1.10	0.82	0.50	

To compare the difference of means

1. Between main treatments CD=NS
2. Between periods CD=0.97
3. Between two periods with or without chemical treatments CD=1.68
4. Between main treatments in a particular period CD=1.60

Table 4. Rooting in invigorated S.795 sucker cuttings planted in different periods of the year (transformed values)

Main Treatments	PERIODS OF PLANTING April	August	December	Mean
IBA 500 ppm	59.01 (73.50)	59.01 (73.50)	18.44 (10.00)	45.48 (52.33)
IBA+NAA 250 ppm each	48.85 (56.70)	50.77 (60.00)	18.44 (10.00)	39.35 (42.23)
Control	33.21 (30.00)	54.78 (66.70)	21.15 (13.00)	36.38 (36.57)
Mean	47.02 (53.40)	54.85 (66.73)	19.34 (11.00)	

To compare the difference of means

1. Between main treatments CD=5.32
2. Between periods of planting CD=2.46
3. Between two periods of planting with or without chemical treatments CD=4.27
4. Between main treatments in a particular period CD=5.88

(Figures in parentheses indicate actual percentage of rooting) percentage (66.73) when cuttings were collected and planted during August (Table 4). These suckers were collected from April-stumped trees. Beheading the plants in August and planting the suckers in December resulted in lesser success (11.00 per cent). Further, treatment of cuttings with growth regulators did not improve rooting as observed in mature cuttings (Table 4). Interactions also varied significantly. Number of primary roots developed were significantly higher in August (2.95) and April (2.32) collected cuttings. Length of these roots was also highest in these cuttings (16.86 cm and 14.77cm respectively). Significantly shorter roots were observed in December cuttings (0.7 cm). Invigorated cuttings of many perennial crops rooted better than matured (non-beheaded) plant cuttings. Length and number of roots were also higher in invigorated ones (Bhandary and Mukherjee, 1969; In the present study also, it was noticed that invigorated cuttings rooted better, and significant differences existed between the periods of planting of these cuttings. Similar observations were made by Porlingis and Therios (1976) in olive cuttings. Later, Michael and Hwei-jen Chiu (1980) reported that pecan invigorated cuttings rooted easily when they were collected during February, June and August. With regard to the sprouts, highest was in April cuttings (0.78) followed by August. Significant difference was noticed only among the periods of collections. Growth regulator treatments had almost no effect on sprout induction in invigorated cuttings. Further, when the length of sprouts was considered, longer ones were recorded in control cuttings (Table-5). However, there was significant difference among the periods of planting on the growth of sprouts. In general, planting of cuttings from non-beheaded plants in June and invigorated plants in August were found to be suitable for better rooting.

Considering both matured and invigorated cuttings planted in different periods of the year, it can be concluded that season is one of the most important factors to be considered for increase in rooting of cuttings. It is interesting to note that the impact of season on rooting and shooting in both the types of wood was similar. Seasonal variations in rooting might be due to morpho-physiological changes in plant body. Hence, further studies are being conducted to find out the physiological constituents of the plant and their relation to rooting of coffee sucker cuttings.

Table 5. Length of sprout in invigorated S.795 sucker cuttings planted in different periods of the year

Main treatments	PERIODS OF PLANTING April	August	December	Mean
IBA 500 ppm	3.12	1.30	0.19	1.53
IBA + NAA 250 ppm each	2.52	0.89	0.20	1.20
Control	1.12	2.46	0.38	1.32
Mean	2.25	1.55	0.25	

To compare the differences of means

1. Between main treatments CD = NS
2. Between periods of planting CD = 0.72
3. Between two periods of planting with or without chemical treatments CD = 1.24
4. Between main treatments in a particular period CD = 1.36

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Discussion

H. V. PATTANSHETTI (Regional Res. Station, Mudigere): Since *Coffea arabica* is self-pollinated, are there any advantages in vegetative propagation? What is the coefficient of variability in the yield of seedling population of *arabica* coffee?

K. PURUSHOTHAM: Though *Coffea arabica* is self-pollinated, the material S.795 is a second generation hybrid of S 288 Kents *arabica*. To obtain true to type plants of this hybrid, vegetative propagation was tried in this experiment.

N. SATYANARAYANA (UPASI, Cinchona): What are the reasons for seasonal variation in the response of cuttings to IBA?

K. PURUSHOTHAM: As the physiological status of the plant varies with the season, response of cuttings to IBA also differs.

RAO RAMA RAO (Cashew Res. Station, Bapatla): Clarification is sought whether, (*a*) 2500 and 5000 ppm were used by quick-dip method; (*b*) 250-500 ppm were used by soak method. The literature on PGR usage is very clear about this.

K. PURUSHOTHAM: Quick-dip method was adopted for pre-planting treatment of cuttings, with growth regulators in both the experiments.

Md. ABDUL KHADER (TNAU, Coimbatore): Why was the concentration of growth regulators in the two expts. varied? (In the first set it was 250 ppm, in the second it was 2500 ppm).

K. PURUSHOTHAM: The former belonged to invigorated batch and hence they are supposed to contain native hormones in greater quantity.

G. SREEKANDAN NAIR (KAU, Vellayani): 1. Is cutting used as a commercial method of propagation in coffee?

2. Have you tested the success under field condition?

K. PURUSHOTHAM: 1. Vegetative propagation of coffee by cottage is only being standardized.

2. Establishment of rooted cuttings is not a problem in coffee. About 95% of rooted cuttings have established under field condition.

K. RAMAN (UPASI): Did you try NAA alone? Did you compare the various concentrations of PGR?

K. PURUSHOTHAM: NAA was tried at different concentrations (from 1,000 to 10,000 ppm) and it was found that cuttings treated with NAA 5000 ppm recorded good percentage of rooting but root system was not well developed as found in other cuttings.

G. P. SHETTY (Multiplex, Bangalore): Whether cuttings at different months were subjected to chemical analysis for different nutrient levels?

K. PURUSHOTHAM: Yes. This information will be published separately.

POSTER PRESENTATIONS

YIELD AND NUT CHARACTERISTICS OF OPEN—POLLINATED PROGENY OF WEST COAST TALL AND ITS HYBRIDS WITH CHOWGHAT DWARF ORANGE AND GANGABONDAM

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ABSTRACT

A comparative study was made of the performance of open-pollinated progency of West Coast Tall (WCT), and its hybrids with Chowghat Dwarf Orange (CDO) and Gangabondam (GB) planted in laterite soil and maintained under rainfed conditions with the usual recommended dose of fertilizers. The superiority of the hybrids over WCT, and among the hybrids, the superiority of CDO×WCT over the reciprocal hybrids WCT×CDO and WCT×GB in yield of nuts, copra and oil out-turn was observed. The study has also shown that CDO×WCT hybrids will be more suitable and will have to be preferred to the other two hybrids and the local WCT to increase coconut production under the laterite soil conditions in the country.

INTRODUCTION

In coconut, Tall×Dwarf and Dwarf×Tall hybrids are reported to be promising in the countries where coconut breeding has been undertaken for increasing coconut production. In India, besides Chowghat Dwarf, Gangabondam, another dwarf type from Andhra Pradesh, has also been used as pollen parent for T×D hybrid production. Earlier studies have shown that among the three Dwarf types namely, Chowghat Dwarf Orange (CDO), Chowghat Dwarf Green (CDG), and Gangabondam (GB), CDO and GB are preferable as male parents for the production of economic hybrids with West Coast Tall (Satyabalan *et al.*, 1968, 1970). In this paper we report the results of a comparative study made on the performance of WCT×CDO, CDO×WCT, and WCT×GB hybrids, and open-pollinated progenies of selected WCT the local cultivar, planted in laterite soil. As the dwarfs are not economic types, and hence not recommended for large-scale planting, the hybrids are compared with WCT, the local Tall cultivar.

* Deceased 17-7-1982

MATERIALS AND METHODS

Open-pollinated seedlings of high yielding WCT plams and hybrid seedlings of WCT×CDO, CDO×WCT and WCT×GB were planted in 1966 in a block of laterite soil. The number of seedlings in the different groups varied from 10 in CDO×WCT to 19 in WCT. They were maintained under rainfed conditions with normal dosage of fertilizers (0.5 kg N+0.32 kg P+1.2 kg K). Observations were recorded on yield of nuts, yield attributes and nut and copra characters of these four groups of seedlings, from the time of their initial bearing.

RESULTS AND DISCUSSION

The yield attributes like the number of inflorescences produced, the number of female flowers, setting percentage and yield of nuts of the four groups of seedlings during the year 1976–79 are presented in Table 1. The mean cumulative yield from the time of initial flowering upto 1979 is also given in the Table. The data indicate that there is not much difference in the mean number of inflorescences produced, but the hybrids have produced significantly more number of female flowers than the open-pollinated progenies of WCT.

Since the hybrids came into bearing and attained stabilized yields earlier than WCT, the cumulative yield from the time of initial flowering upto 1979 was more in the hybrids than in WCT. John and Venkatanarayana (1943) had reported manifestation of hybrid vigour for early flowering in Tall×Dwarf hybrids, larger number of female flowers and higher number of nuts, besides other vegetative growth characters. In the present study, hybrid vigour was observed for early flowering, larger number of female flowers and higher yield of nuts when compared to WCT. Data presented in Table-2 indicate a decrease in the weight of fruit (unhusked nut), but the weight of husked nut has increased, indicating a reduction in the husk content of the fruit, and an increase in the size of the husked nut in all the hybrids. The husk content in the fruit of WCT is 47 per cent of the weight of fruit, whereas it is 38 per cent in CDO×WCT, 40 per cent in WCT×CDO, and 42 per cent in WCT×G. Satyabalan *et al.* (1970) have reported that the decrease in weight of fruit was due to a decrease in husk content, and the increase

Table 1. Yield and yield attributes of of West Coast Tall and the hybrids (planted in 1966)

Material	No. of inflorescences	No. of female flowers (mean of 1976–79)	No. of nuts	Setting percentage	Mean cumulative yield from the time of flowering up to 1979	No. of palms
WCT	9.8 (6.8 to 12.3)	193.5 (103.8 to 269.8)	57.0 (33.0 to 92.3)	29.4	330.0 (158 to 586)	19
WCT×CDO	9.2 (7.3 to 12.3)	228.8 (103.8 to 344.5)	61.4 (33.5 to 105.0)	26.6	421.5 (177 to 734)	12
WCT×GB	9.8 (7.5 to 12.3)	228.3 (157.5 to 522.8)	62.3 (32.5 to 88.0)	27.2	370.8 (145 to 685)	11
CDO×WCT	9.3 (5.8 to 12.0)	232.7 (168.8 to 276.8)	90 (65.0 to 107.5)	38.7	552.5 (399 to 762)	10

Figures in parentheses indicate the range

Table 2. Nut and copra characters of West Coast Tall and the hybrids

Material	Fruit weight	Husked nut (g) weight	% husked nut in fruit	Kernel weight (g)	% Kernel in husked nut	Shell weight (g)	% shell in husked nut	Weight of water (g)	% nut water in husked nut	Copra (g)	% copra in husked nut	Oil content (%)
WCT	1062.7	561.1	52.7	305.7	54.5	147.3	26.2	108.1	19.2	160.6	28.7	69.3
WCT×CDO	940.9	568.6	60.4	320.2	56.2	149.6	26.3	98.8	17.4	186.5	32.9	68.8
WCT×GB	1021.3	589.8	57.7	314.7	53.4	145.6	24.7	129.5	22.0	181.3	30.7	68.7
CDO×WCT	959.4	596.9	62.2	312.8	52.4	153.4	25.6	130.7	21.9	186.3	31.2	68.5

in the weight of husked nut was the result of an increase in the size of husked nut in WCT×CDO and WCT×GB hybrids.

The weight of husked nut is the total of the weights of the kernel, shell and nut water. In kernel weight, a positive increase over the value of WCT has been recorded in all the three hybrids. In shell weight, CDO×WCT and WCT×CDO have recorded positive increase over that of WCT, whereas in WCT×GB there was a decrease in shell weight. In nut water weight, an increase was observed in CDO×WCT and WCT×GB hybrids only, whereas in WCT×CDO there was a decrease over the value of WCT. In weight of copra per nut, an increase was observed in all the hybrids, the increase being 20.7 g, 25.7 g and 25.9 g in WCT×GB, CDO×WCT and WCT×CDO respectively over that of WCT. Thus, there was a significant increase in the weight of husked nut, kernel weight and copra weight in the nuts of all the three hybrids, when compared to those of WCT. In oil content, there was not much difference among the hybrids and between the hybrids and WCT.

Data on mean annual yield of nuts per palm, average annual copra and oil out-turn are presented in Table 3. In mean yield of nuts, all the three hybrids were superior to WCT and among the hybrids CDO×WCT was superior to the other two hybrids, In copra and oil out-turn also, the hybrids were superior to WCT and among the hybrids, CDO×WCT is superior to the other two hybrids.

Table 3. Mean annual yield of nuts, copra, and oil out-turn

Material	Mean annual yield of nuts (1976–79)	Average annual copra out-turn (kg)	Average oil out-turn (kg)
WCT	57.0	9.2	5.7
WCT×CDO	61.4	11.4	7.9
WCT×GB	62.3	11.2	7.7
CDO×WCT	90.0	16.8	11.4

As all the seedlings are planted in laterite soil, and maintained under rainfed conditions with the usual recommended dose of fertilizers, the superior performance of CDO × WCT hybrids indicates that they can perform better under such conditions than the other two hybrids and WCT. Hence, for increasing coconut production under laterite soil conditions, CDO × WCT hybrids will be more suitable than the other two hybrids and the local WCT.

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PRELIMINARY OBSERVATIONS ON A LOCAL COCONUT TYPE 'KOMADAN'

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ABSTRACT

'Komadan' a local coconut off-type, popular in the Central Travancore area of Kerala, is compared with the West Coast Tall (WCT) cultivar with regard to population structure, morphological characters, and seedling progeny analysis. The population structure of the two types based on average nut yield per tree per year was found to be basically different. While 99 per cent of the 'Komadan' population was giving more than 80 nuts per tree per year, only 15 per cent gave that yield in WCT.

The mean values of morphological characters also showed the superiority of 'Komadan' for all the nine quantitative characters studied. The 'Komadan' type further exhibited superior seedling vigour, in terms of germination per cent, height, collar girth, mean number of total leaves and mean number of split leaves.

INTRODUCTION

'Komadan' is the name given to a local coconut off-type, popular in the Central Travancore area of Kerala. It has an obscure origin associated with the family history of an old 'Tharavadu' called 'Komattil' in Aranmula Village of Tiruvalla Taluk. In the present study, the performance of this type is compared with that of the WCT cultivar.

MATERIALS AND METHODS

The materials selected for the study consisted of 50 'Komadan' trees growing in the Instructional Farm of the College of Agriculture, Vellayani. These trees were grown from seedlings originally brought from Tiruvalla and planted during the year 1958. The average annual yields per tree of these palms were compared with that of 100 WCT palms of the same age, selected randomly from the qulk population growing in the nearby coconut block of the same farm. Detailed morphological observations were taken on a random sample of ten palms each from the above two groups and compared. Further comparison between these two types of palms was based on observations taken on 2500 seedling progenies raised from selected mother palms of each of the two types.

Results and Discussion

The population structure based on the total nut yield per tree per year of the WCT and 'Komadan' types is presented in Table 1. It can be seen from the results that the population of different yield groups in the two coconut types differed widely. When 60 per cent of the WCT palms gave less than 60 nuts per tree per year only 0.5 per cent of such trees occurred in the 'Komadan' type. Moreover, even the mean yield of 'Komadan' was higher than that of the highest yielder among WCT palms. These observations clearly show the superiority of 'Komadan' over WCT in total nut yield.

Table 1. Population structure of Komadan and WCT

Yield groups (nuts/tree/yr)	Per cent of trees in sample population	
	Komadan (Sample size-50)	WCT (Sample size-100)
20 and below	Nil	2
21-40	Nil	24
41-60	0.50	34
61-80	0.50	25
81 and above	99.0	15
Mean	126.97 nuts/tree/year	62.91 nuts/tree/year
Range	55-229	20-120 ,,
CV	31.95 per cent	27.21 per cent

The mean data on morphological characters of the trees including nut and copra characters are given in Table 2. The results indicate that for all the nine quantitative characters studied on the yielding trees of the two types, 'Komadan' proved superior to WCT. This superiority was most pronounced in number of leaves per palm and number of nuts per bunch. The number of nuts per bunch of 'Komadan' was almost double that of WCT. In mean nut weight and copra content also 'Komadan' showed significant superiority over WCT.

Table 2. Morphological characters of Komadan and WCT (Mean of 10 palms each)

Characters	Komadan	WCT
Colour of petiole	Bronze	Green to Bronze
Colour of nuts	Bronze	Green to Bronze
Anthesis	Male and female phases overlap	Clear interval between male and female phases
Number of leaves/palm	38.5	24.2
Number of bunches/palm	10.4	9.3
Number of inflorescences/palm	7.8	7.6
Number of nuts/bunch	15.3	7.8
Length of nuts (cm)	25.2	24.2
Girth of nut (cm)	49.3	45.9
Mean nut weight (g)	542.5	508.0
Mean copra content/nut (g)	189.0	165.0
Copra out-turn (per cent over meat)	46.4	43.3

Even though no attempt has been made in this study to ascertain the genetic make-up of the 'Komadan' type, the finding that there is a clear overlapping of the male and female phases during antheis, as seen in the dwarf palms, indicate its self-pollinated nature, and consequently, the relative genetic purity of this type compared to WCT. Hence, it is assumed that the prepotency carried by 'Komadan' type will perhaps be transmitted to its progenies without much dilution. In conclusion, the results presented here indicate that 'Komadan' is a superior coconut off-type deserving further research attention.

Discussion

R. V. PILLAI (CPCRI, Kasaragod). Comment: 'Komadan' is the name given by a particular family of Aranmula in Tiruvalla taluk, for the seedlings of F_2 progenies of naturally occurring hybrids (D×T). The trees of the 'Komadan' were studied in depth at CPCRI from its original home and it was found to be the natural hybrid of Chowghat Dwarf Orange×WC Tall. The seedlings sold by the family from that area are F_2 and even F_3 generations of the so-called NCD (Natural Cross Dwarf) or D×T hybrid. Earlier this hybrid was also known as NCD, which arise as off-types in open-pollinated progeny of CDO. Although these seedlings are superior to those of WCT, this is by no means an indication of prepotency which should imply a high rate of transmission of parental traits to the progeny. Hence 'Komadan' as referred to in the paper cannot be taken as a separate prepotent cultiyar.

FRUIT COMPONENT ANALYSIS IN LAKSHADWEEP COCONUTS

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ABSTRACT

The Niu kafa-Niu vai Introgression (NKNVI) method was used for the comparison of the different types of coconut found in Lakshadweep Islands. The highest proportion of husk in the fruit and a high proportion of endosperm in the nut are characteristic of the *Niu Kafa* class, while, a low proportion of husk and high proportion of water in the nut are characteristic of the *Niu vai* class. Fruit component analysis indicated that the different types of Lakshadweep coconuts belong typically to the "*Niu kafa*" class and the Laccadive Small is of intermediate nature, and arose perhaps due to introgressive hybridization between the Laccadive Micro and the Laccadive Ordinary types.

INTRODUCTION

Fruit component analysis is the best method of comparing and contrasting different varieties, because it involves that part of the palm, which will be most uniform for a particular variety, in spite of the different growing conditions to which that variety may be subjected. Further, the effects of large or small fruit size or number are diminished by a consideration of the relationship between the components rather than the absolute values. In general, coconuts belong to two contrasting ancestral types, the 'Niu kafa' which disseminated naturally by floating in sea and the 'Niu vai' which was selected for nut water. The high proportion of husk in the fruit and a low proportion of endosperm in the nut are characteristic of the 'Niu Kafa' type, while a low proportion of husk and high proportion of water in the nut are characteristic of the 'Niu vai' type (Harries, 1981). The Lakshadweep coconuts are considered to be belonging to the 'Niu kafa' type (Harries, 1978). The present study was conducted to confirm this contention and also to compare the

Table 1. Observations on fruit characters in different types of

Fruit Number	Laccadive Micro					
	F.W.	%H/F	%W/N	%S/N	%M/N	F.W.
1.	470.0	61.7	16.1	27.2	56.7	904.0
2.	356.5	66.3	11.7	32.5	55.8	804.0
3.	317.5	62.2	4.2	38.6	64.2	1049.0
4.	325.5	68.7	7.9	28.4	63.7	1085.0
5.	1141.0	72.3	19.9	30.1	50.0	1116.0
6.	622.0	63.6	11.7	33.1	55.2	1240.0
7.	482.5	80.3	2.6	30.5	66.9	668.0
8.	399.0	70.4	9.8	32.2	67.0	1072.0
9.	704.0	64.1	10.0	32.2	57.8	1553.0
10.	306.5	50.2	6.2	25.3	68.5	1387.0
MEAN	512.5	66.0	9.1	30.3	60.6	1087.8
S.D.	244.8	7.5	5.7	2.5	5.9	249.4
C.V. (%)	47.8	11.4	62.7	8.1	9.8	22.9

F.W.—Fruit weight (g) %H/F=Percentage of husk per fruit %W/N=Perce kshadweep coconuts

/F	Laccadive Small %W/N	%S/N	%M/N	Laccadive Ordinary F.W.	%H/F	%W/N	[illegible]	%M/N	Laccadive Dwarf F.W.	%H/F	%W/N	%S/N	%M/N
.2	12.2	35.7	52.2	1176.0	53.7	23.5	[illegible]	36.6	1500.0	50.0	26.7	25.3	48.0
.2	15.0	27.8	57.2	1094.0	58.7	15.5	[illegible]	50.4	830.0	66.0	13.0	41.0	46.0
6	12.6	33.7	53.7	1144.0	41.4	23.9	[illegible]	51.3	475.0	32.0	18.8	28.9	52.3
3	14.8	27.9	57.2	2363.0	55.6	37.0	[illegible]	43.2	530.0	39.6	18.8	29.7	51.6
0	14.2	29.8	56.1	1206.0	46.7	27.5	[illegible]	46.2	500.0	48.4	15.9	18.2	65.9
6	15.6	29.2	55.2	1576.0	59.5	25.9	[illegible]	52.7	1005.0	51.9	31.1	20.7	48.2
5	12.1	33.9	54.0	1078.0	58.4	16.7	[illegible]	52.7	500.0	30.0	3.7	26.9	69.4
6	16.9	31.9	51.2	2045.0	61.9	32.4	[illegible]	47.6	705.0	28.0	21.8	39.6	38.6
1	20.7	33.0	46.3	1340.0	51.9	25.8	[illegible]	48.6	460.0	19.0	0.8	28.3	70.9
0	17.4	26.5	56.1	1440.0	57.9	27.6	[illegible]	46.0	554.0	35.0	20.6	21.7	57.7
0	15.2	30.9	53.9	1446.2	54.6	23.6	[illegible]	47.5	705.9	40.0	17.1	28.0	54.9
5	2.5	3.0	3.2	413.4	6.0	6.1	[illegible]	4.7	314.3	13.3	8.9	7.1	10.3
7	16.7	9.6	5.9	28.5	11.1	23.8	[illegible]	9.9	44.5	33.2	52.1	25.4	18.7

ge of water per nut %S/N=Percentage of shell per nut %M/N=Percentage of meat per nut different types of Lakshadweep coconuts namely, Laccadive Micro (LM), Laccadive Small (LS), Laccadive Ordinary (LO) and Laccadive Dwarf (LD).

MATERIALS AND METHODS

Whitehead (1966, 1968) standardized a simple procedure for fruit component analysis in field. It was slightly modified by Harries (1978). The present study was made, following that proforma. Ten fruits of each type of Lakshadweep coconuts were taken at random from Minicoy island. Each set of ten fruits was taken from ten individual palms, one fruit per palm, for each type. The fruits were taken at their proper stage of maturity, when fruit colour was changing from fresh to dry, calyx had fresh colour and the water inside splashed when fruit was shaken. The palms sampled at random were healthy specimens of that particular type. They had at least one fruit per bunch at the right stage of maturity. The entire bunch was harvested and one fruit chosen. Each fruit was weighed. The husk was removed and discarded. The nut weight was recorded. Then the nut was cut, equatorially, water drained away, and the two half-cups of shell and meat together were weighed. The meat was carefully removed with a hand knife without losing any small bit and weighed.

The mean standard deviation and coefficient of variability for fruit weight, and for husk, water, shell and meat percentages, were determined for each set of samples.

RESULTS AND DISCUSSION

With the exception of Laccadive Dwarf, the rest showed a higher proportion of husk in the fruit and a high proportion of endosperm in the nut (Table 1). Laccadive Dwarf showed a higher proportion of meat than LO and LS and lowest proportion of husk. Therefore, all the four forms of Lakshadweep coconut are typically 'Niu kafa' type.

(*a*) **Fruit weight**: Laccadive Ordinary had the highest mean fruit weight (1446.2 g), and Laccadive Micro the lowest (512.5 g). A high coefficient of variability (47.8 %) is found for this trait in the case of the Micro.

(*b*) **Percentage of husk per fruit**: Laccadive Micro showed the highest mean percentage of husk per fruit (66%), and the Dwarf the lowest (40%). The maximum variability (33.2%) for this character was seen in the Dwarf type.

(*c*) **Percentage of water per nut**: Laccadive Ordinary had the maximum mean percentage of water per nut (23.6%) and the Micro the lowest (9.1%). The variability was the maximum (62.7%) for this character in the Micro type.

(*d*) **Percentage of shell per nut**: Laccadive Small showed the highest mean percentage of shell per nut (30.9%), followed closely by the Micro (30.3%), whereas Laccadive Ordinary had the lowest (26.9%). The variability for this trait was the maximum (25.4%) in the Dwarf type.

(*e*) **Percentage of meat per nut**: Laccadive Micro had the mean percentage of meat per nut (60.6%), while the Laccadive Ordinary showed the lowest (47.5%). The variability was the maximum (18.7%) for this character, in the Dwarf type.

(*f*) **Shape of the fruit**: The fruit shape in all the types excepting the Micro, was almost similar and can be described as oblong (longer than broad). In the Micro, the shape varied from near spherical to oblong. All the types showed three prominent carpellary ridges along the length of the fruit, giving an angular appearance. The egg-shaped nut of the *Niu kafa* type and thickness of the husk are quite apparent in the cross section and quite distinct from the nut and thin husk of the *Niu vai* type.

Laccadive small occupied an intermediate position for all the measurable characters studied between the Micro and the Ordinary except for shell percentage per nut which was a little more in L. Ordinary than in the Micro. Whereas the fruit weight and water percentage per nut were found to be the maximum in Laccadive Ordinary, husk percentage per fruit and meat percentage per nut were maximum in the Micro. The coefficient of variability is the highest for fruit weight and water percentage per nut in the case of the Micro, and for husk, shell and meat percentages per nut, in the case of the Dwarf (Table 1).

CONCLUSION

From fruit component analysis, it has been established that the Lakshadweep coconuts distinctly belong to the '*Niu kafa*' type. Comparison of the four types of Lakshadweep coconuts, revealed the intermediate nature of Laccadive Small, which probably arose by introgresssive hybridization between Micro and the Ordinary types.

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CRITERIA FOR SELECTION OF SCION MATERIAL FOR PROPAGATION OF CASHEW BY EPICOTYL GRAFTING

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ABSTRACT

Selection of mature scion wood with 'pointed' apical dormant buds contributed towards high success in epicotyl grafting in cashew during monsoon. Pre-curing of scion wood helps in quick growth of the scion after grafting, although it is not quite essential. It is worthwhile trying application of morphactins to minimize erratic development of apical buds by correcting hormonal imbalances.

INTRODUCTION

Trials have been carried out to standardize techniques for propagating cashew by asexual means with varying degrees of success. The varietal success achieved with any given technique has been due mostly to the different agroclimatic situations prevalent in the east and west coast regions of the country. Besides the climatic and soil conditions, the other factors which determine the success of vegetative propagation are chiefly, the stock-scion compatibility, selection of suitable scion material, the skill of the operator, and effective management. The cumulative effect of the above factors under a given set of conditions would give the desired results.

In propagating cashew, especially by grafting, selection of scion wood is very important to realize a high percentage of success. A study made on the criteria for selection of scion material and the results obtained at CPCRI Cashew Seed Farm, Shantigodu are presented in this paper.

MATERIALS AND METHODS

Tender cashew root-stocks, 30-35 days old, raised in polythene containers (25 cm × 15 cm), were utilized for epicotyl grafting during June, July and August, 1981.

Mature shoots of previous season's growth were tagged to select scion shoots with dormant apical buds. The scion sticks were classified into three categories based on the disposition of apical buds, namely, 'pointed', 'oblique', and 'flat'. The apical buds enclosed in leafy scales project out like a needle from the central portion very conspicuously. Hence, such buds are termed as 'pointed'. The buds which show distortion and point sidewards not so conspicuously, are classified as 'oblique', and those which look oblate without any projection are termed as 'flat'.

One half of the shoots selected for grafting in each category were pre-cured while the remaining half was left uncured to assess the effect of precuring on the scion growth.

A randomized and replicated design with three major treatments (categories of scion shoots) and two sub-treatments (pre-cured and uncured), replicated five times, was laid out. At the rate of ten grafts per treatment, three hundred grafts were made during June, July and August, and the percentage success worked out (Table 1).

Table 1. Percentage success obtained with scions of 'Pointed', 'Oblique', and 'Flat' apical dormant buds under pre-cured conditions in epicotyl grafts of cashew. Fifty grafts were made in each category (1981).

Category of scion	% success in the month of June	July	August
A. Pre-cured			
(*i*) Pointed	60.0	65.0	60.0
(*ii*) Oblique	36.0	38.0	40.0
(*iii*) Flat	8.0	10.0	8.0
B. Uncured			
(*i*) Pointed	62.0	64.0	60.0
(*ii*) Oblique	40.0	40.0	38.0
(*iii*) Flat	10.0	8.0	60.0

Results and Discussion

The studies revealed that the scion shoots with 'pointed' apical dormant buds, when precured one week before severence from the mother tree, had given the maximum success of 60, 65, and 60 per cent in all the three consecutive months respectively. Not much difference was observed between the cured and uncured scions so far as the final success was concerned., but the precured scion shoots emerged out within 25 days on an average after grafting, as against the uncured ones which took 46 days on an average.

The percentage success with the scion shoots having 'flat' apical buds had varied from 6-10 per cent while those with 'oblique' apical buds recorded 20-40 per cent success, showing no significant difference between the precured and uncured scion wood under different treatments.

The results gave clear indication with regard to choice of scion shoots with'pointed' apical dormant buds to secure a high percentage of success with epicotyl grafting in cashew, during monsoon under the conditions prevailing in the west coast region. Precuring of scions was found to be desirable to secure quick growth of the scion after grafting although it was not quite essential.

The erratic development of apical dormant terminal buds in cashew might be due to hormonal imbalances, and to overcome such situations, it is worthwhile trying applications of morphactins which are known to cause deformation in plants and also affect the endogenous levels of growth substances as reported by Chadha *et al.* (1979) in their studies on mango.

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EVALUATION OF CASHEW SELECTIONS FOR 'UPGHAT' AREAS

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ABSTRACT

Based on cumulative yields of large number of indigenous collections from various parts of the country, 13 selections made provisionally at the Cashew Research Station, Ullal were vegetatively multiplied, and the clones subjected to trials in high rainfall, high altitude areas at the Regional Research Station, Mudigere. The average number of nuts per year was highest in 5/61 Alangudi-Madras (317.07 per tree), followed by 4/61 Alangudi-Madras (262.04) and 4/62 Alangudi-Madras (252.85). With respect to weight of nuts, 4/63 Chromepet-Madras recorded the highest average yield (1.198 kg/tree), followed by 5/61 Alangudi-Madras (1.108). From the point of view of distribution of yield in the harvesting season, earliness of the crop is considered as an important selection criterion in the upghat section where the delayed crop is generally damaged by premonsoon showers.

INTRODUCTION

Though the cashew plant was primarily introduced into India by the Portuguese nearly 500 years ago for checking soil erosion, it is now mainly grown for its kernel and shell oil. Among commercial crops, cashew is one of the biggest foreign exchange earners for the country, and therefore, occupies a pre-eminent position in Indian export trade. Although India leads in cashew production, it is much short of requirement of even the local industry. Cashewnut is grown over an area of 4.2 lakh hectares in India (Anon., 1976). Presently, cashew is mostly confined to the coastal belt of southern region of the country, but is also found growing luxuriantly in some interior pockets. There is considerable extent of denuded forest land in the interior regions which can be brought under cashew cultivation. The bulk planting material raised from indiscriminately collected seed stock does not produce satisfactory yields, particularly in regions where the altitude is high and the rainfall heavy. The lower temperatures prevailing during winter at higher altitudes delay flowering and the late crop while undergoing maturity in the latter part of harvesting season is caught in the showers. With a view to locating a suitable selection, 13 types were selected at Cashew Research Station, Ullal, and subjected to field performance test in high rainfall areas of high altitude at the Regional Research Station, Mudigere, and the observations recorded during the years 1980-81 and 1981-82 are reported in this paper.

Materials and Methods

The Regional Research Station, Mudigere is located at 13° 25'N latitude and 75° 24'E longitude at an elevation of 975.6m above M.S.L. The average rainfall of 2540 mm is spread over a period of 8 months from April to November. The maximum and minimum temperatures recorded were 31.6°C in April, 1981 and 12.6°C in January, 1982 respectively. The air-layers of the 13 selections namely, 1/11 Ullal-Mysore, 6/19 Kanhangad-Kerala, 6/21 Moodabidri-Mysore, 4/43 Wynad-Kerala, 1/16 Alangudi-Madras, 2/61 Alangudi-Madras 4/61 Alangudi-Madras, 5/61 Alangudi-Madras, 4/62 Alangudi-Madras, 1/63 Chromepet-Madras, 4/63 Chromepet-Madras, 1/64 Maduranthakam-Madras, 2/64 Maduranthakam-Madras, were planted at a distance of 6m apart during 1972, in sandy-loam soils with a pH of 5.5. The different selections formed treatment plots, which were replicated four times in a randomized block design. Fertilizer mixture of 80, 100 and 80g of NPK was applied annually in two split doses. The plants were sprayed with 0.05 per cent Ekalux 25 EC, three times at an interval of 20 days, starting from the middle of December.

Results and Discussion

The flowering season was spread from November to January and harvesting commenced from beginning of April and continued upto the middle of June. The yield data for the two successive years presented in Table-1, would show that, 4/61 Alangudi-Madras recorded highest yield of nuts (0.791 kg/tree) during 1980-81 followed by 4/62 Alangudi-Madras (0.778), 5/61 Alangudi-Madras (0.727), 4/63 Chromepet-Madras (0.724) and these were found to be significantly superior to some of the selections. During

Table 1. Yield attributes of different cashew selections at Mudigere (Upghat area)

	Selections	No. of nuts/plant				Yield of nuts/plant (Kg)				No. of nuts/kg.	Average weight of nut (g)
		1980–81 T.V.*	1980–81 O.V.*	1981–82 O.V.	Mean O.V.	1980–81 T.V.	1980–81 O.V.	1981–82 O.V.	Mean O.V.		
1/11	Ullal–Mysore	8.64	92.44	152.75	122.60	1.163	0.369	0.794	0.581	213	4.69
6/19	Kanhangad–Kerala	5.34	29.04	112.92	70.98	1.061	0.129	0.489	0.309	149	6.71
6/21	Moodabidri–Mysore	3.67	14.42	29.04	21.73	1.038	0.079	0.198	0.198	131	7.63
4/43	Wynad–Kerala	5.91	49.23	32.35	40.79	1.205	0.240	0.130	0.185	256	3.90
1/61	Alangudi–Madras	7.78	74.96	242.27	158.62	1.139	0.404	0.740	0.572	310	3.22
2/61	Alangudi–Madras	10.76	153.66	339.50	246.58	1.208	0.642	1.277	0.959	267	3.74
4/61	Alangudi–Madras	13.78	223.88	300.19	262.04	1.323	0.791	0.978	0.884	292	3.42
5/61	Alangudi–Madras	12.64	190.50	442.63	317.07	1.297	0.727	1.489	1.108	281	3.55
4/62	Alangudi–Madras	11.56	191.44	314.25	252.85	1.305	0.788	1.025	0.906	277	3.61
1/63	Chromepet–Madras	9.42	107.94	469.27	238.61	1.205	0.629	1.510	1.069	264	3.78
4/63	Chromepet–Madras	11.39	105.75	316.13	230.94	1.304	0.724	1.663	1.193	193	5.18
1/64	Maduranthakam–Madras	9.63	114.56	153.67	134.12	1.240	0.560	0.751	0.655	201	4.97
2/64	Maduranthakam–Madras	10.80	163.48	234.48	198.98	1.248	0.608	0.867	0.737	257	3.29
C.D.	at 5 per cent	5.23		118.59		0.197		0.226		84	1.03

*T.V.=Transformed valus; O.V.=Observed values

1981-82, 4/63 Chromepet-Madras yielded highest nut-weight (1.663 kg/ tree), followed by 1/63 Chromepet-Madras (1.510), and 5/61 Alangudi-Madras (1.489).

When the average yield of two years was considered, 4/63 Chromepet-Madras topped the list with an yield of 1.193 kg of nut per tree followed by 5/61 Alangudi-Madras (1.108) and 1/63 Chromepet-Madras (1.069). In the earlier reports of this study also, it was found that the three selections, 4/61 Alangudi-Madras, 4/63 Chromepet-Madras and 1/63 Chromepet-Madras have performed well (Kololgi *et al.*, 1977). In a similar trial consisting of fifteen selections at Ullal, Chromepet-Madras has again performed well (Anon. 1967). The lowest average yield of nuts was recorded in 6/21 Moodabidri-Mysore (0.138 kg/tree), followed by 4/43 Wynad-Kerala (0.185), and 6/19 Kanhangad-Kerala (0.309). The yield of these selections was poor in both the years. The average fresh weight of nut was maximum in 6/21 Moodabidri-Mysore (7.63 g) followed by 6/19 Kanhangad-Kerala (6.71 g), and in these two selections, the average size of nut was more compared to other selections.

Table 2. Harvesting period in different selections of cashewnut (%) at Mudigere

Selections	First fortnight of April	Second fortnight of April	May	June
1/11 Ullal-Mysore	6.4	54.2	34.2	5.2
6/19 Kanhangad-Kerala	9.0	66.8	17.8	6.5
6/21 Moodabidri-Mysore	0.9	68.1	22.7	8.3
4/43 Wynad-Kerala	6.4	49.7	28.3	15.5
1/61 Alangudi-Madras	46.8	45.6	6.2	1.5
2/61 Alangudi-Madras	31.9	38.2	29.5	0.5
4/61 Alangudi-Madras	33.6	48.3	15.5	2.6
5/61 Alangudi-Madras	41.5	54.3	3.3	1.0
4/62 Alangudi-Madras	31.2	64.7	2.3	1.9
1/63 Chromepet-Madras	24.5	50.3	22.0	3.1
4/63 Chromepet-Madras	56.8	34.8	7.4	1.0
1/64 Maduranthakam-Madras	39.8	36.2	21.1	2.9
2/64 Maduranthakam-Madras	32.7	46.2	18.6	2.5

Earliness in maturity is one of the important criteria for evaluating different selections in upghat areas, where the delayed crop is generally damaged by premonsoon showers. In this trial, out of 13 selections tried, 4 selections namely, 4/62 Alangudi-Madras, 5/61 Alangudi-Madras, 1/61 Alangudi-Madras, and 4/63 Chromepet-Madras have yielded more than 90 per cent of the crop before April (Table-2). From Table 2, it can also be observed that nearly 50 per cent of the crop was harvested by the first fortnight of April, in 4/63 Chromepet-Madras (56.84 per cent), and 1/61 Alangudi-Madras (46.80), while in 4/43 Wynad-Kerala, only 56.15 per cent of the crop was harvested by April end.

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AN EVALUATION OF CERTAIN CASHEW TYPES FOR YIELD AND NUT CHARACTERS

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ABSTRACT

An evaluation of 38 accessions in the germplasm assemblage of cashew, was made for yield of raw nuts and quality characters of the nut and kernel revealed a high degree of variation in individual tree yields. There was considerable variation among the types in the percentage recovery of whole kernels. Among the types tested, the entry M 10/4 from Tamil Nadu emerged as the best selection, in terms of yield of nuts as well as kernel quality, high shelling percentage, least testa weight, high percentage of whole kernel recovery, and high kernel weight.

INTRODUCTION

Research on crop improvement in cashew has been launched in India only in recent times and a few superior types with high yield potential have been identified in the different States (Anon. 1981a and b), which are in pre-release multiplication stage. Practically little work has been done so far on the quality characteristics of the nut and kernel. With the object of identifying cashew types possessing high yield as well as superior kernel qualities, a detailed evaluation of the cashew germplasm for the above characters, was undertaken at Vridhachalam centre in Tamil Nadu. The results obtained in this study are presented in this paper.

MATERIALS AND METHODS

The studies were made on the germplasm assemblage maintained at the erstwhile Cashew Research Station in Vridhachalam, South Arcot District, during the cropping season of 1981. A total of 38 entries which recorded flowering and fruiting during the season provided the experimental population for the study. The individual trees were scored for the following characters: (1) yield of raw nuts/tree; (*ii*) 100-nut weight; (*iii* shelling percentage:

(*a*) weight of shell (per cent), (b) weight of testa (per cent), (c) weight of whole kernels (per cent), (*d*) weight of broken kernels (per cent), and (*iv*) 100 - kernel weight.

The statistical parameters, like mean, range, variance and coefficient of variation were also worked out as per Panse and Sukhatme (1967).

RESULTS AND DISCUSSION

The data on tree yield, nut and kernel characters are presented in Table 1.

(i) Tree yields: The tree yields ranged from 0.525 kg/tree to 25.3 kg/tree the lowest being on M 2/2 and the highest in M 15/4. The other entries noteworthy for yield were, M 5/4 (17.625 kg), N 10/4 (16.1 kg) and M 26/1 (23.025 kg). Among the 38 entries, five recorded yields exceeding 10 kg/tree, ten recorded yields exceeding 5 kg/tree and the rest less than 5 kg/tree. These observations are in agreement with the findings earlier reported (Aiyadurai and Koyamu, 1957; Anon. 1981a and b; Damodaran *et al.*, 1979; Northwood, 1966; Nair *et al.*, 1979; Ohler, 1979; Falade, 1981). Ohler (1979) attributed this wide variation in tree performance to the differences in the genetic make-up of the trees. Considerable tree-to tree variability for yield is also evident (Table 2), and hence crop improvement through selection on the basis of tree yield appears to be promising. In the present study, M 15/4, M 26/1, M 5/4 and M 10/4, all from Tamil Nadu, and ME 5/4 from Karnataka have emerged as high yielders. The local types generally appeared to possess higher yield potential, attributable to their better acclimatization to the local agro-climatic environs.

(ii) Nut size: The 100-nut weight showed a range from 252 to 667g as against 300 to 2000g reported by Nair *et al.* (1979). The lowest weight was in ME 5/4 and the highest in M1/4. It is interesting to note that the variation in nut size among the Tamil Nadu types was relatively narrow ranging from 387 to 667g, and all except one registered more than 400g. Among the ex-state introductions, which numbered eight, in only four, the individual nut weight exceeded 4g. The best nut size was recorded in M 1/4,

Table 1. Tree yield, nut and kernel characters of certain cashew types

Type No.	Yield Kg/Tree	100 nut weight (g)	Shell (%)	Testa (%)	Kernels (W) (%)	Kernels (B) (%)	Shelling %	100-Kernel weight (g)
M 1/3	8.150	479	71.2	3.6	16.6	8.6	25.2	124
M 1/4	8.670	667	72.0	2.8	21.0	4.2	25.2	184
M 2/1	2.100	589	68.8	3.2	20.8	7.2	28.0	172
M 2/2	0.525	463	75.4	2.4	13.4	8.8	22.2	116
M 4/1	5.100	530	67.4	3.6	20.6	8.4	29.0	166
M 5/4	17.625	482	72.0	3.4	16.6	8.0	24.6	126
M 6/1	0.730	531	68.0	2.8	6.4	22.8	29.2	155
M 10/2	2.090	486	72.6	4.0	10.4	13.0	23.4	128
M 10/3	3.450	576	68.4	3.0	13.6	15.0	28.6	168
M 10/4	16.100	500	69.5	1.5	27.0	2.0	29.0	200
M 11/2	5.200	408	67.2	3.0	7.4	22.4	29.8	120
M 13/4	2.350	485	68.0	6.2	7.8	18.0	25.8	156
M 15/4	25.300	614	70.6	2.8	2.0	24.6	26.6	167
M 17/1	5.400	596	69.4	4.2	8.4	18.0	26.4	200
M 17/4	0.850	595	68.6	4.0	18.4	9.0	27.4	171
M 18/4	2.450	511	70.6	7.4	8.4	13.6	22.0	144
M 20/4	1.380	524	68.8	2.8	15.6	12.8	28.4	150
M 21/1	0.700	552	68.0	3.2	28.8	—	28.8	170

M 21/2	0.900	514	74.4	4.4	16.6	4.6	21.2	126
M 21/4	8.100	520	67.6	3.8	10.4	18.2	28.6	160
M 24/2	2.050	580	67.4	2.8	10.4	19.4	29.8	170
M 24/3	2.425	563	67.8	4.2	15.8	12.0	28.0	160
M 26/1	23.025	387	66.4	7.6	1.0	25.0	26.0	125
M 26/2	8.350	630	66.4	4.2	9.8	19.6	29.4	196
M 35/3	1.380	532	67.2	4.0	6.8	22.0	28.8	170
M 36/2	0.850	500	74.0	5.6	2.8	17.6	20.4	88
M 45/4	1.490	500	67.2	3.2	7.0	22.6	29.6	155
M 55/4	9.660	480	66.6	4.4	2.2	26.8	29.0	160
M 59/1	0.800	492	70.0	5.2	24.8	—	24.8	145
M 56/1	1.300	504	68.8	4.0	4.0	23.2	27.2	160
ME 5/4	10.350	252	68.0	4.0	7.6	20.4	28.0	68
ME 6/1	9.150	542	68.0	4.4	17.0	10.6	27.6	158
ME 6/2	0.550	462	66.8	3.2	6.4	23.6	30.0	160
ME 13/1	7.150	371	64.6	6.0	5.6	23.8	29.4	125
ME 15/4	2.600	525	68.8	4.4	12.2	14.6	26.8	153
ME 16/2	1.000	420	68.4	5.6	12.0	14.0	26.0	124
A 16/1	2.050	375	66.0	6.4	1.4	26.2	27.6	140
A 20/4	0.750	372	64.0	4.4	2.8	28.8	32.6	116

M. Madras (Tamil Nadu) type; ME—Mysore (Karnataka) type; A—Andhra type; W—Whole; B—Broken

M 15/4 and M 26/2 with individual weights of 6.67g, 6.14g and 6.30g, respectively. Among the rest, the individual nut size was 5g and more in 20 entries of which all except two were from Tamil Nadu. The coefficient of variation being small, scope for selection based on this character nevertheless, seems limited.

Table 2. Mean, range, and coefficient of variation for yield, nut, and kernel characters

Characters	Range	Mean	Variance	CV
Tree yield(kg/ha)	0.525—23.025	5.3	37.8	115.4
100-nut weight (g)	2.52 —667	502.9	6612.9	16.2
Shell weight (percent)	64.0 —75.4	68.8	6.3	3.6
Testa weight (percent)	1.5 — 7.6	4.1	1.9	34.0
Whole kernel recovery (per cent)	1.0 —28.8	11.6	52.0	62.3
Broken kernel (per cent)	0.0 —28.8	15.5	61.5	50.6
Shelling (per cent)	21.2 —31.6	27.1	6.8	9.6
100-kernel weight (g)	68—200	149.4	791.9	18.9

(iii) Shelling percentage: The kernel recovery from raw nuts ranged from 20.4 per cent in M 36/2 to 31.6 per cent in A 20/4. The shelling percentage generally varied from 15 to 30 per cent (Morada, 1941; Rao and Hassan Vazir, 1956; Aiyadurai and Koyamu, 1957; Nair, *et al.*, 1979). Among the types tested, 28 out of 38 entries scored a good shelling percentage. Of the two components viz., shell and testa, the variation among the types was from 64.0 to 75.4 per cent in the former, which is quite low, and from 1.5 to 7.6 per cent for the latter, which may be considered as high (CV=33.99). From the recorded information available, this appears to be the first report on a study of the variations in the testa and shell components of raw cashewnut, carried out with a good sized population of cashew trees. It is interesting to note that M 10/4 registered the least testa weight. With the fair amount of variability exhibited, selection based on testa weight for quality improvement of cashew appears feasible.

(iv) Kernel grades: In cashew, the best market grade is the whole kernel and the importance of a high percentage recovery of whole kernels need not be overemphasized. The results of the present study provided a few interesting findings in this respect. The percentage recovery of wholes varied from as low as 1.0 per cent to as high as 28.8 per cent. The entries M 21/2, M 10/4 and 59/1, were the best with a high recovery of 24.8 to 28.8 per cent. Six of the entries gave a recovery exceeding 20 per cent. Another interesting finding is that in some of the entries such as M/21/2 and M 59/1, the wholes were as high as one hundred per cent on total kernel recovery. With a coefficient of variation of 62.32 (Table 2), this parameter emerged as one of the best as a selection criterion for quality improvement in cashew. As expected, the percentage recovery of broken kernels also showed wide variation (CV=50.55). There is no previous information on the above aspects as far as the authors are aware.

(v) **Kernel weight**: The hundred kernel weight of the types varied from 69 to 200g with a coefficient of variation of 18.94 per cent. As such, this trait does not offer scope for selection. In trade, a kernel size of about 2 to 2,5g conforms to the top grade kernels in the export market (Nair *et al.*, 1979). In the present study, the types M 10/4 and 17/1 have secured the highest scores and stood out as outstanding with export quality kernels.

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SESSION III

Plant Physiology and Biochemistry

Chairman : Dr M. R. Sethuraj

Rapporteurs : Shri D. Venkataramanan

Dr V. Rajagopal

GROWTH AND DEVELOPMENT OF TEA SHOOTS IN RELATION TO PLUCKING STYLES

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ABSTRACT

This paper reports the results of observations on shoot production as affected by different styles of plucking in tea. Growth of axillary buds of a normal leaf was found to be faster than that of fish and scale leaves. In all cases, the linear growth was found to be at the minimum level till the emergence of scale leaf, and a steady increase occurred with the formation of each of the successive leaves. The greatest growth occurred after the unfolding of mother leaf. The time interval to produce a pluckable shoot from the axils of different leaves varied with the climatic fluctuations. Plucking to scale leaf during lean season resulted in dieback of its axillary bud. Scale leaf plucking also failed to add any maintenance foliage. The position of developing shoots on the bush, whether it be periphery or centre, had no effect on its development.

INTRODUCTION

Shoot growth in tea, as in many other tropical and subtropical perennials, is a rhythmic process caused by the successive phases of cessation and active growth of shoot apex. The phenomenon on periodicity of growth was examined by Bond (1942) in great detail. In a tea bush under plucking, a proportion of shoots will be actively growing while other shoots remained temporarily dormant. The former are usually called 'flush shoots' and the latter 'banji shoots'. The active growth of a terminal bud prevents the growth of buds which occur in the axils of all the leaves lower down the stem. When the harvestable shoot is plucked off, the apical dominance is temporarily removed and generally, the bud in the axil of the topmost leaf remaining on the stem develops into a new shoot. This bud is at first very small, and during its development, the first to appear are two scale leaves (cataphylls), which were protecting the leaf primordia in the bud. The first scale leaf usually drops off but the scar can be seen at the base of every shoot. The scale leaves are folowed by a malformed leaf often growing like an ordinary leaf. It is called 'fish leaf', and it has smooth margins and an oval shape often without a prominent tip. Next, the normal leaves unfold in sequence from the growing bud.

Tea is unique in that the tender shoots and foliage harvested at short intervals perpetually form the crop. As yield in tea consists of leaf shoots, the time taken for a new shoot to develop to a pluckable stage is of great importance. Although many factors affecting shoot production were studied by a number of workers (Tubbs, 1939; Portsmouth and Rajiah, 1957; Visser, 1960; Nathaniel, 1976), the variations in the rate of shoot growth and development from the axils of scale leaf, fish leaf and normal leaf of tea plant in relation to plucking have not received much attention. This basic knowledge will help in formulating a sound and profitable plucking policy to harvest all the crop, at the same time ensuring bush health. The present paper reports the results of a series of observations made in different tea growing areas of South India, on crop shoot production in clonal tea bush as affected by different styles of plucking.

Materials and Methods

Plants of the following tea clones which were under regular plucking were used in the present study:

TRI 2024, TRI 2025, ATK-1, KM/19/14.	Madupatty Estate, High Ranges Altitude: 1680 m
UPASI-2, 3 and 6,	Brooklands Estate,
UPASI-9, 10, and 15	Nilgiris Altitude: 1825 m
UPASI-3, ATK-1, AK-1	Chembra Peak Estate, Wynad Altitude: 1150 m
UPASI-2, 3, 8 and 10	UPASI Tea Research Sub-Station; Vandiperiyar, Central Travancore Altitude: 930 m

At the start of the observations, 30 shoots which had reached the pluckable stage from 2 bushes (15 shoots/bush) in each clone were marked by tagging, and plucked to: (*a*) Scale leaf, (*b*) Fish leaf, and (*c*) Normal leaf, hereafter referred to as Mother leaf.

Care was taken to remove both 'banji' shoots and flush shoots from the centre as well as periphery of the bush. Observations were recorded at three-day intervals on the following:

(*a*) When the bud broke open (i.e., unfolding of scale leaf)

(*b*) When the fish leaf became clear of bud

(*c*) When the mother leaf became clear of bud

(*d*) When two leaves and a bud formed

(*e*) When the shoot became ready for plucking

(*f*) The linear growth from the time of emergence of scale leaf to pluckable stage.

When the shoot reached the pluckable stage, it was removed either as 'flush' or as 'banji', as the case may be, for measurement of weight and length. During the observations, the unmarked harvestable shoots produced by the experimental bushes were also harvested regularly to ensure that the bushes remained under normal growth conditions. The experiment was conducted for one year.

Results and Discussion

I. Rate of development: After plucking a shoot, no visible growth was noticed in the axil for about 30 days. Sprouting of the axillary bud and unfolding of the scale leaf in most cases were observed between 34th and 40th day under High Range conditions. During the sixth week, unfolding of the fish leaf was noticed. Thereafter, the growth was very fast depending on the type of plucking (Table 1).

Table 1. Shoots developing into new pluckable shoots (Madupatty Estate-High Ranges) Clone TRI 2025

Month of plucking	Number of days taken to								
	Bud sprout			Unfolding of fish leaf			Pluckable stage		
	MLP	FLP	SLP	MLP	FLP	SLP	MLP	FLP	SLP
January	36	38	43	43	46	48	62	66	67
February	36	37	40	43	45	46	60	63	65
March	34	35	36	40	41	41	57	59	61
April	36	36	36	42	43	46	62	60	63
May	34	36	38	40	42	44	65	69	70
June	37	41	38	45	48	51	69	72	75
July	39	40	41	47	45	47	64	68	72
August	38	38	41	44	44	49	61	63	69
September	30	30	34	43	41	43	59	59	61
October	29	32	37	43	45	50	63	71	75
November	37	38	42	46	50	53	70	77	81
December	42	37	44	48	51	52	64	70	73
Average:	35.6	36.6	39.2	43.6	45.1	47.5	63.8	66.4	69.3

MLP—Mother Leaf Plucking FLP—Fish Leaf Plucking
SLP—Scale Leaf Plucking

In all cases, growth of buds from mother leaf axil was faster than those in the axils of fish leaf and scale leaf. The mean time in days recorded in Wynad, Nilgiris and Central Travancore, are given in Tables 2, 3 and 4 respectively.

Table 2. Average number of days taken to produce Two and a Bud-Average for 3 clones (Chembra Peak Estate-Wynad)

Type of plucking	Dry weather Jan.-Mar.	Wet weather July-Aug.	Growing period Apr.-June Sept.-Nov.
Mother leaf	100	62	61
Fish leaf	Not recorded	67	74
Scale leaf	122	77	77

Table 3. Average number of days taken to develop pluckable shoot (Brooklands Estate-Nilgiris)

Clone	Type of plucking	Time taken
UPASI-2	Mother leaf plucking	91
	Fish leaf plucking	104
	Scale leaf plucking	106
UPASI-9	Mother leaf plucking	88
	Fish leaf plucking	91
	Scale leaf plucking	95
UPASI-10	Mother leaf plucking	103
	Fish leaf plucking	110
	Scale leaf plucking	105
UPASI-15	Mother leaf plucking	98
	Fish leaf plucking	98
	Scale leaf plucking	105
UPASI-3	Mother leaf plucking	95
	Fish leaf plucking	109
	Scale leaf plucking	114
UPASI-6	Mother leaf plucking	79
	Fish leaf plucking	87
	Scale leaf plucking	91

Table 4. Time taken to grow into a pluckable shoot (Central Travancore)

Clone	Mother leaf plucking	Fish leaf plucking	Scale leaf plucking
UPASI-2	52	54	55
UPASI-3	56	60	61
UPASI-8	55	57	59
UPASI-10	60	66	66

With a rigidly controlled method of plucking, it was noticed that the time interval did not remain constant throughout the year, but varied to a considerable extent with the fluctuations in weather (Tables 2 and 5). Therefore, the growth rhythm of shoots depended upon the climatic conditions.

Table 5. Number of days taken during different periods (Madupatty Estate-High Ranges)

Clone	Type of plucking	Dry weather period	Wet weather period	Growing season	Towards end of growing season
TRI 2025	MLP	69	69	57	63
	FLP	72	72	59	71
	SLP	73	75	61	75
ATK-1	MLP	66	73	58	67
	FLP	72	79	63	77
	SLP	78	85	64	77
KM/19/14	MLP	67	72	57	68
	FLP	70	76	61	71
	SLP	77	83	64	73

II. Shoot growth as measured by length and weight: Shoot developing from mother leaf axil was generally large-leaved with longer internodes than fish leaf and scale leaf axils. The weight of the mother leaf axillary shoot was always more than the other two (Table 6). The average extension growth per day of axillary buds of different leaves of various clones under Nilgiris conditions is given in Table 7.

Table 6. Growth as measured by length and weight (Madupatty Estate-High Ranges)

Clone	Average length of the shoot (cm)			Average fresh weight of the shoot (g)		
	MLP	FLP	SLP	MLP	FLP	SLP
TRI 2024	13.3	11.5	10.2	1.8	1.5	1.4
TRI 2025	15.5	11.5	9.3	2.2	1.7	1.3
ATK-1	14.0	12.2	10.0	1.6	1.2	1.0
KM/19/14	14.3	11.9	8.9	1.6	1.4	1.0

Table 7. Average growth rate of 'Two and a Bud' in mm/day (Brooklands Estate-Nilgiris)

Plucking	UPASI-2	UPASI-3	UPASI-6	UPASI-9	UPASI-10	UPASI-15
MLP	2.3	2.4	2.1	2.7	1.8	1.7
FLP	1.9	1.9	1.8	2.4	1.8	1.9
SLP	1.8	1.8	2.0	2.4	1.8	1.5

The linear growth was found to be at the minimum level till the emergence of scale leaf and a steady increase occurred with the formation of each of the successive leaves. The greatest growth occurred after the unfolding of mother leaf (Table 8).

III. Die-back of shoots: Scale leaf plucking often resulted in die-back of shoots from the point of plucking extending below the scale leaf. During wet weather this was pronounced in clone TRI 2024 particularly after scale leaf plucking (Table 9).

IV. Occurrence of 'banji' shoots: When adverse weather conditions prevailed, irrespective of the styles of plucking, a majority of shoots turned into 'banji' shoots at the plucking table (Table 9). In the case of scale leaf plucking, even under normal conditions, about 90 per cent of the shoots turned 'banji' after formation of second or third leaf and rarely grew into fourth leaf. It was noticed that fish leaf and mother leaf axils turned into 'banji' shoots after unfolding of third or fourth leaf.

V. Effect of type of shoot removed and position of shoot: The type of shoot plucked ('banji' or 'flush') had no effect on the development of subsequent buds. Though the centre of the bush is more productive than periphery due to higher shoot density, the position of the developing shoots had no effect on its development.

VI. Other observations: In some cases, mother leaf and fish leaf plucking activated buds below these leaves which invariably turned into 'banji' shoots. Multiple shoot growth was observed from the axil of mother leaf. This was more pronounced in clone TRI 2025. These buds ranging from 1 to 3, invariably produced small-leaved 'banji' shoots.

In conclusion, the practical implications of this study may be brought out by comparing the time taken by the axillary buds of different leaves to reach pluckable stage. The observations clearly indicate the advantages of mother leaf plucking, such as development of vigorous shoots from its axil, and less time taken to reach harvestable stage, besides adding sufficient maintenance foliage to the bush to meet its carbohydrate requirements. However, continual light plucking will certainly lead to problems such as

Table 8. Average linear growth rate in mm of shoots during growing and lean seasons-Clone TRI 2025 (Madupatty Estate-High Ranges)

Stage of development	M. L. Plucking		F. L. Plucking		S. L. Plucking	
	Extension in length	Average growth rate/ day	Extension in length	Average growth rate/ day	Extension in length	Average growth rate/ day
Growth season						
Scale leaf emergence	8	0.22	8	0.20	6	0.15
Fish leaf emergence	14	2.50	14	2.30	14	2.30
Mother leaf emergence	25	5.40	26	5.20	17	4.90
Two & a bud	58	10.50	42	10.00	29	6.40
Lean season						
Scale leaf emergence	10	0.26	7	0.18	7	0.18
Fish leaf emergence	13	2.10	10	1.40	10	1.30
Mother leaf emergence	22	3.70	20	3.40	24	3.00
Two & a bud	42	4.70	34	4.60	26	4.10

Table 9. Die-back of shoots and occurrence of "banji" shoots after plucking (Madupatty Estate-High Ranges)

Clone	Type of plucking	% shoots dried Wet weather	Dry weather	Growing season	% "banji" shoots formed Wet weathers	Dry weathers	Crouing Season
TRI 2024	MLP	Nil	Nil	Nil	80	30	20
	FLP	30	10	10	90	30	30
	SLP	90	30	20	100	90	90
TRI 2025	MLP	Nil	Nil	Nil	30	40	20
	FLP	Nil	Nil	Nil	80	60	50
	SLP	10	Nil	10	90	90	100
ATK-1	MLP	Nil	Nil	Nil	60	80	40
	FLP	Nil	Nil	10	70	100	60
	SLP	20	Nil	Nil	100	100	90
KM/19/14	MLP	10	Nil	Nil	80	50	20
	FLP	10	Nil	Nil	90	70	20
	SLP	20	10	Nil	90	90	70

the rapid increase in height of the bush, depending on the type of jat, elevation of the area, and difficulty in maintaining uniform plucking surface due to axillary buds left at different heights. The investigation also reveals the disadvantages of continual scale leaf plucking (hard plucking), such as production of small 'banji' shoots and die back of axillary buds during lean seasons. The severe style of plucking obviously fails to add any maintenance foliage.

On the basis of data emerging from this study, our present recommendation on plucking namely, mother leaf plucking during lean seasons, and plucking to any leaf on the existing level during growing period, seems to be justified.

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PENETRATION OF RADIOPHOSPHORUS THROUGH LEAF CUTICLE IN COFFEE PLANTS

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Abstract

In 48 hours after the application of radiophosphate (^{32}P) to the upper surface of leaves, considerable quantity of phosphate penetrated through cuticle and entered into the plants of *Coffea arabica* L. and *Coffea canephora* Pierre. In both the coffee species, with increase in their age, the foliar absorption of radiophosphate also increased. The initial cuticular penetration of radiophosphate was extremely rapid, which later slowed down in the two species, during a period of 96 hours. Irrespective of age and duration of absorption, the penetration of radiophosphate was considerably more in *robusta* than in *arabica*.

Introduction

Many cultivated plants are fed with aqueous solutions of inorganic fertilizers through leaves. The foliar method of feeding mineral nutrients is gaining wider application in agricultural economy and crop production. Iyengar and Awatramani (1975) reported that foliar feeding of mineral nutrients in coffee, particularly N and P, was more efficient than soil application. The benefit of foliar sprays of these nutrients to *arabica* coffee was further stressed by Krishnamurthy Rao *et al.* (1976).

Using sodium dihydrogen orthophosphate and monocalcium phosphate (single superphosphate) labelled with radioactive ^{32}P as sources of P, and with 8–, 15–, 25– and 50-month-old *arabica* S.795 and *robusta* S.274 coffee plants, it was found that absoprtion of phosphate through foliage was considerably higher than soil application in all the four age groups of both the species (Gopal and Balasubramanian, 1975; Gopal *et al.*, 1977). The capacity for

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absorption of foliar applied P by leaves in *arabica* and *robusta* is not only dependent on the inherent morphological features of the two coffee species, but also influenced by the quantitative needs of P-requiring metabolic processes associated with different phases of annual growth (vegetative and reproductive) in the plants (Gopal *et al.*, 1976). The present study was carried out to gather data on penetration of phosphate through the cuticle of leaves in *arabica* and *robusta* coffee plants.

MATERIALS AND METHODS

Two experiments were carried out using *C. arabica* S.795, and *C. canephora* S.274 plants, grown in polythene nursery bags (15+23 cm) filled with equal quantities of a mixture of jungle soil+ farmyard manure+sand (6:2:1 proportion). The plants were supplied with N, P and K through soil and watered once a day approximately up to the field capacity.

Feeding of radiophosphate (^{32}P)

In the first experiment, 12–, 18– and 24-month-old plants were selected for phosphate application. Sodium dihydrogen orthophosphate (NaH_2PO_4) labelled with ^{32}P (Code PHS 8) was obtained from Bhabha Atomic Research Centre, Trombay, Bombay. To each of the top six leaves, avoiding the terminal tender leaves (on the main stem in the case of 12-month-old plants, and on one of the top primary branches in the 18-and 24-month-old plants) a total of 0.2 ml containing 50 μCi of ^{32}P was applied to each plant at the rate of two drops per leaf on its upper surface. Before foliar application. the pH of the $^{32}PO_4$ solution was adjusted to 6.5 with a dilute solution of spray lime (70 per cent calcium). There were three replications for each age group of the two species.

In the second experiment, 0.2 ml containing 50 μCi of ^{32}P was applied to the leaves of 24-month-old plants following the above technique. There were 12 plants for each species.

Sampling of plant material

In the first experiment, 48 hours after ^{32}P was fed, the plants were removed from nursery bags, and the root system was washed free from soil with tap water. The whole plant was then washed with tap water followed by 10 per cent teepol, and finally with three fresh changes of deionized water, and the adhering water was removed by blotting. The plants in the second experiment were sampled at 1, 6, 12, 24, 48 and 96 hours after ^{32}P was fed, and washed similarly. In both the experiments, the plants were separated into total roots, wood of main stem, wood of primary branches, mature leaves and young leaves, and dried in an oven at 100° C for 24 hours. The weights of the oven-dried samples as well as of each plant were recorded.

Counting of ^{32}P radioactivity

The radioactivity of the dried plant tissue was monitored using Geiger Counter (1280 V) as described by Gopal and Balasubramanian (1975) and Gopal *et al.* (1977). The percentage of ^{32}P out of the total applied activity, the ^{32}P content (μg P), and ^{32}P activity (in terms of μCi) that entered into the whole plant (on actual oven-dry weight of the plant), were calculated using the radioactivity of the different plant parts and their individual oven-dry weights.

RESULTS AND DISCUSSION

Experiment No. 1.

About 10 per cent of ^{32}P, out of the total phosphate applied had penetrated through cuticle of the upper surface of leaves in 12-month-old *arabica* plants, whereas it was about 13 per cent in *robusta*, in 48 hours after the radioisotope was fed (Table 1). With progressive increase in age upto 18 months, the absorption of

Table 1. Entry of ^{32}P (as % of total applied activity, and ^{32}P content in μg) through cuticle in *arabica* S. 795 and *robusta* S. 274, 48 hours after application (Mean of 3 replications)

Age of plants (months)	*Arabica* S. 795		*Robusta* S. 274	
	Percentage	μg	Percentage	μg
12	10.02±0.26	60.2	13.24±0.04	79.5
18	17.46±0.54	104.8	25.68±1.22	154.2
24	28.68±0.42	172.2	36.44±1.18	218.8

radiophosphate through leaf cuticle was also more in both the species. In 24-month-old plants 172.2 μg (29 per cent) and 218.8 μg (36 per cent) of P entered through leaf cuticle in *arabica* and *robusta* respectively. In all the three age groups, *robusta* leaves absorbed considerably more phosphate than *arabica*.

Experiment No. 2.

The results on cumulative entry of radiophosphate as percentages of total applied activity in the whole plant of the two species during a period of 96 hours are presented in Text Fig. 1. These percentage values calculated in terms of μCi of ^{32}P, and ^{32}P content in μg P are given in Table 2. In one hour, after the ^{32}P

Table 2. Cumulative entry of ^{32}P (as μCi of total applied activity, and ^{32}P content in μg) *arabica* S. 795 and *robusta* S. 274 (oven-dry weight, per plant) during 96 hours after radiophophate application (Mean of biological duplicates)

Hours after ^{32}P application	*Arabica* S. 795		*Robusta* S. 274	
	μCi	μg	μCi	μg
1	2.0	24.0	3.0	36.0
6	5.5	66.0	7.5	90.0
12	9.0	108.0	12.0	144.0
24	12.0	144.0	15.5	186.0
48	14.0	168.0	18.0	216.0
96	17.5	210.0	22.0	264.0

was fed, the leaves absorbed 4 per cent and 6 per cent of the total applied activity respectively, in *arabica* and *robusta*. By 24 hours (cumulative), about one fourth (24 per cent) of the total applied activity of 32P was found in the whole plant of *arabica*, whereas in *robusta* the uptake ot ^{32}P was 31 per cent (Fig. 2.) At the end of 96 hours, the penetration of ^{32}P was about one-third (35 per cent) in *arabica* and 44 per cent in *robusta* (Fig. 1), out of the total quantity of radiophosphate applied to the foliage. The initial uptake of ^{32}P atter the radiosiostope was fed to the leaves was very quick, and later it was slow in both the coffee species during the 96-hour-period (Fig. 1). Between successive intervals of 12-24 hours, the foliar absorption (mean per hour) of radiophosphate was 0.50 and 0.58 per cent, and it was only 0.15 and 0.17 per cent between 48-96

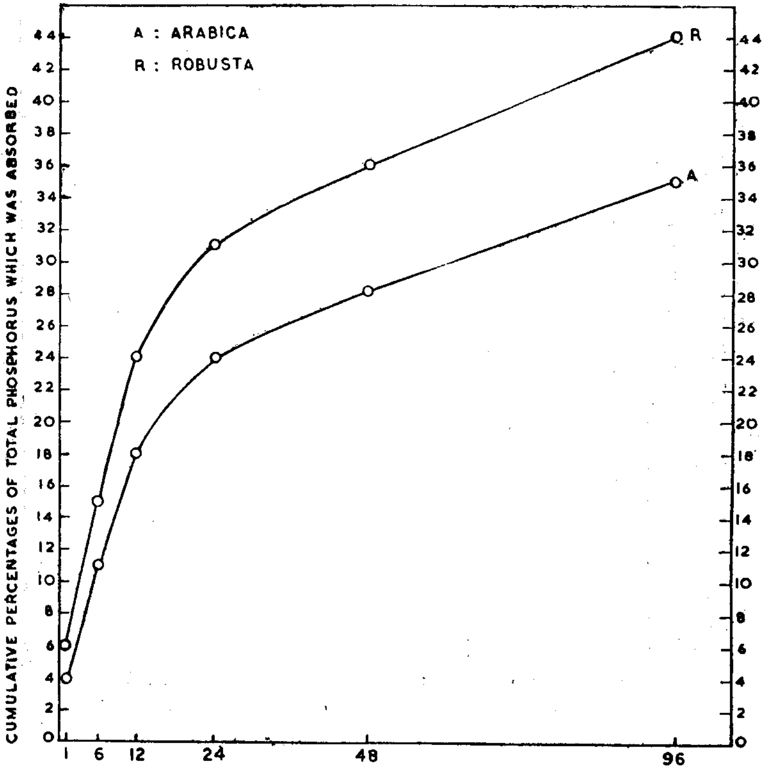

Fig. 1. Cumulative percentages of phosphorus (^{32}P) absorbed and accumulated (per plant) in *arabica* S. 795 and *robusta* S. 274 coffee, at various time intervals.

hours, out of the total ^{32}P applied in *arabica* and *robusta* respectively (Fig. 2). However, the foliar absorption of radiophosphate was higher in *robusta* than in *arabica* at all time intervals.

With application of radiophosphate (32P) on the upper surface of leaves, considerable quantity of phosphate entered into the plants of *arabica* S.795 and *robusta* S.274, in 48 hours after the radioisotope was fed. All the radiophospate found in the plants of both the coffee species had penetrated only through cuticle of the upper surface of the foliage, as the leaves of coffee are hypostomal.

The rate of entry of mineral nutrients into leaf tissue through cuticle is controlled by a number of factors, and experimentally

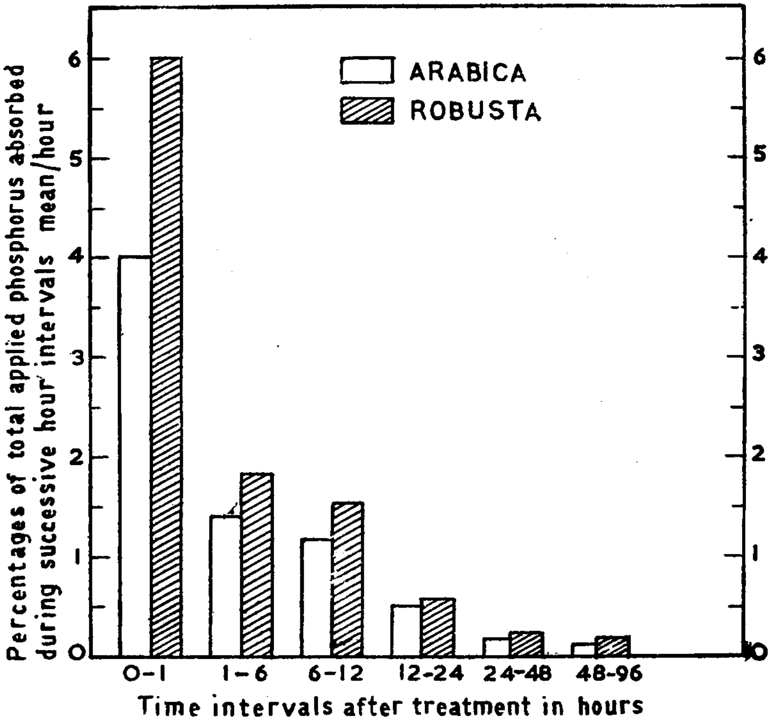

Fig. 2. Percentages of phosphorus (^{32}P) absorbed (mean/hour/plant) in *arabica* S.795 and *robusta* S.274 during successive hourly intervals.

stomatal penetration of compounds can be obtained through aqueous sprays, but this is rarely achieved in nature (Dimon, 1962). The consensus of opinion is that stomatal penetration of aqueous solutions is relatively unimportant, and the main route of entry of both water and lipid soluble materials is through the cuticle (Martin and Juniper, 1970).

From the existing knowledge and the data from present studies, it may be tentatively concluded that, when mineral nutrients alone are to be supplied, sprays of water-soluble inorganic fertilizers may be given to the upper surface of foliage of coffee plants for efficient absorption and physiological action. However, when mineral nutrients are supplied to plants along with Bordeaux mixture, the sprays should be directed towards the lower surface of the leaves to efficiently control leaf rust disease.

ACKNOWLEDGEMENT

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DISCUSSION

V. S. SHARMA (UPASI, Cinchona): Age of the leaf should be having a bearing on the absorption of the nutrients; in your results, you have not indicated as to which leaf is more effective in absorption, though three pairs of leaves from the top were studied.

N. HARIGOPAL: Since this research work is aimed at only to find out whether phosphate penetrates through the cuticle of the upper surface of leaves, no distinction is made between leaves at different positions on the coffee plant.

K. RAMAN (UPASI, Cinchona): Did you count the radioactivity in the washings?

N. HARIGOPAL: Yes, but no radioactivity was detected in the last fresh change of deionized water used that interferes in the monitoring of radioactivity of the experimental samples of the plants.

M. LAKSHMANAN (Madurai Kamaraj Univ. Madurai): 1. What is the significance of your work since foliar absorption of urea and phosphorus is already known?

2. How do you account for lower uptake with time?

N. HARIGOPAL: (1) This research work is specifically intended to find out the entry of phosphate through cuticle of the upper surface of leaves using radioactive phosphate-32. This study gives the data to distinguish entry of phosphate into the leaf tissue through cuticle from that of stomatal penetration, which are totally absent on the upper surface of coffee leaves.

(2) The existing literature indicates that the rapid initial uptake of mineral nutrients from foliar sprays is a non-metabolic passive process, and the second phase is slow and metabolically controlled.

COMPARATIVE PHYSIOLOGY OF SUN AND SHADE LEAVES OF CASHEW*

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ABSTRACT

Leaves well exposed to sunlight showed greater specific leaf weight (SLW), nitrate reductase activity (NRA), and content of total phenols than shaded leaves in cashew (*Anacardium occidentale* L.) Though the shade leaves had more chlorophyll with a lower chlorophyll a/b ratio which might compensate for the limiting sunlight, the adaptation was not maximal as their surface areas were similar to those of sun leaves.

INTRODUCTION

Many aspects of tree growth and productivity are influenced by light intensity (Jackson 1975; Diedda *et al.* 1981). A previous report has shown that in cashew, fruit-set and development in a panicle or a whole tree are dependent on the degree of their exposure to photosynthetically active radiation (Subbaiah, 1982b). The present study concerns the morphological and physiological responses of leaves to limiting light intensity since it is the ability of the photosynthetic machinery to adapt to varying light regimes that determine the tree growth and yield.

MATERIALS AND METHODS

Samples were collected from 9 year old cashew trees grown in the experimental plots of our Station. The experimental site and cultural conditions were as described previously (Subbaiah, 1982b).

Fully expanded leaves were collected from:

(*a*) Well exposed canopy zones of border trees

(*b*) heavily shaded portions of border trees, and

(*c*) from the interior trees that were generally shaded.

*Contribution No. 255, CPCRI, Regional Station, Vittal-574 243, Karnataka

Photosynthetically active radiation (PAR) was recorded on all the sampling sites using a Li-Cor quantum radiometer.

Leaf areas were computed by substituting the values of linear measurements in a regression equation (Murthy *et al.* 1978). After recording the fresh weights, leaves were oven dried at 60°C for dry weight determination.

Nitrate reductase activity was assayed by the *in vivo* method (Jaworski, 1971) with a few modifications in the assay medium (Subbaiah, 1982a). Chlorophylls were extracted in acetone and determined spectrophotometrically (AOAC, 1975). Phenolic content was assayed using Folin-ciocaliteau reagent (Farkas & Kiraly 1962). All the parameters were expressed per gfr. wt. per leaf and per dm^2 leaf area.

All the determinations were repeated with sun and shade leaves from seedlings grown in the open field and under artificial shade.

RESULTS AND DISCUSSION

The light intensities (PAR), growth characteristics, chlorophyll and phenolic contents, and NRA, of the three sampling sites are given in Table 1.

The shade leaves were thinner with lower specific leaf weights. This reflects the limited photosynthetic activity of these leaves because specific leaf weight was shown to correlate with the rate of photosynthesis in the leaves of many annual and perennial crops (Dornhoff & Shibles, 1976; Barden, 1978) including cashew seedlings (Subbaiah & Aggarwal, unpublished). However, because of the lesser mechanical tissue per unit leaf area (as reflected by their smaller specific leaf weights) the respiratory losses also would be minimal in the shaded leaves. However, as the absolute leaf area did not differ in the two types of leaves, the leaf acclimatization to shade appears to be partial in cashew

As well documented in the literature, the shade leaves showed higher chlorophyll content per unit weight in cashew too However, the amount of chlorophyll per unit area of leaf surface was lower than that of the sun leaves, in the case of border trees. This might be because of the fewer chloroplasts per unit area of lamina. But in the case of interior trees, the leaf pigment content was always higher either on the weight or area basis than that of the sun leaves and thus they might be more efficient in tapping light. The ratio of chlorophyll a/b was lower in the shade leaves. This facilitates greater absorption in the green wave length and thus has an adaptive advantage, in view of the availability of filtered light rich in green region, to the shade leaves.

Table 1. PAR, growth characteristics, chlorophyll and polyphenolic contents and NRA of sun and shade leaves cashew.

Character	Leaf type/sampling site			C.D.
	Border Trees		Interior Trees	
	Sun Leaves	Shade Leaves		(P=0.05)
1. (PAR) (μ-insteins/ cm^2/sec)				
at 10 AM	1100	80	150	—
at 3 PM	1140	150	175	—
2. Growth characteristics				
SLW (mg/cm^2) Fresh wt.	29.70	22.13	21.14	1.65
,, Dry wt.	13.10	8.58	8.67	0.89
Area (cm^2)	55.91	60.64	51.75	NS
water content (% dry wt.)	132.20	155.76	157.76	10.40
3. Chlorophyll content:				
a + b mg/g/fresh wt.	0.58	0.69	0.86	0.21
,, mg/leaf	0.93	0.83	0.98	NS
,, mg/dm^2	1.72	1.38	1.88	NS
a/b ratio	3.32	2.91	3.05	0.21
4. Phenolic contents (mg)$^{-1}$				
g/fresh wt.	17.59	14.89	—	NS
leaf^{-1}	26.12	18.22	—	4.5
dm^{-2}	49.49	30.74	—	9.39
5. NRA (μ moles NO_2)	**Border trees**			
g^{-1} fresh wt.	0.43	0.39		NS
leef^{-1}	0.77	0.56		NS
cm^{-2}	1.22	0.88		NS

The activity of nitrate reductase (NR), a key enzyme in plant nitrogen metabolism was also lower in the shade leaves. The role of light in the induction and maintenance of NR is well-known (Beevers & Hageman, 1972). Besides, the reductive potential necessary for this enzyme activity might also be limiting because of the low light intensity.

Thus, shade leaves in their adaptation for economical use of available sunlight had to invest a greater portion of their synthetic capacity in the synthesis and maintenance of the light harvesting system, as reflected by the enhanced chlorophyll content, but had to sacrifice the levels of essential enzymes like NR. Even this type of acclimatization to low light intensity appears to be limited in cashew as exemplified by the low leaf areas. Besides, in many instances, severe shading was found to result in self-pruning in cashew (unpublished). Such a poor adaptability to shade in this crop was found to influence its fruiting and yield also (Subbaiah, 1982b).

The total phenolic content was also found to be lower in the shade leaves. Light is known to promote the biosynthesis of phenols in plants (Engelsma & Meijer, 1965). The thin shade leaves with their low phenolic content might render themselves susceptible to pests. In fact, the fruit loss due to tea mosquito damage in cashew was found to be more in the shaded zones of the canopy (Subbaiah 1982b).

Thus, these studies clearly point out that cashew has an obligate need for high light intensity and shows only limited capacity for shade adaptation. However, detailed and systematic shading experiments are necessary to quantify the optimum light requirement for growth and productivity of cashew trees.

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Discussion

N. VASUDEVA (CCRI, Chikmagalur): What type of shade was used for studying NR activity?

C. CHENCHU SUBBAIAH: Only the natural shade available within the tree and in the plantation, was considered.

M. LAKSHMANAN (Madurai Kamaraj Univ., Madurai): You made a statement that the shaded leaves with higher chlorophyll content compensate for the less light availability. Is this true? Is there a correlation between chlorophyll content and photosynthetic activity beyond a certain concentration? An in vitro experiment if done at the concentration of chlorophyll and light intensity available in the leaf would confirm/contradict your assumption.

C. CHENCHU SUBBAIAH: Higher chlorophyll means better light harvesting system under shade conditions. I do not hold the view that chlorophyll has a direct correlation with photosynthetic rate. Higher chlorophyll helps in better trapping of light only.

LEAF GROWTH AND ASSOCIATED PHYSIOLOGICAL CHANGES IN SIX CACAO ACCESSIONS UNDER WATER STRESS*

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ABSTRACT

Leaf growth rate was compared in seedlings of six accessions of cacao (*Theobroma cacao* L.) differing in their drought tolerant characteristics subjected to water stress. The leaf elongation rate was severely inhibited under drought but failed to indicate any positive relationship with their drought tolerance. Under stress, relative water content of leaf decreased, accompanied by an accumulation of free proline and reduction in nitrate reductase activity. This was more pronounced in drought-susceptible accessions. Epicuticular wax content was generally higher in drought tolerant accessions and did not change appreciably due to stress, while in susceptible accessions the wax content increased considerably. The specific leaf dry weight did not show significant changes.

INTRODUCTION

Cell growth and elongation are adversely affected due to water deficits. One of the first physiological responses to water stress to be affected is leaf elongation rate (Acevedo *et al.*, 1971; Hsiao *et al.*, 1970). Cacao is sensitive to water stress and various physiological parameters are affected (Balasimha, 1981). However, most of the metabolic changes occur only after the leaves are desiccated considerably (below –15 bars or 70 per cent RWC). This study examined the leaf growth rates under increasing stress conditions and associated physiological changes in six cacao accessions.

MATERIALS AND METHODS

Seedlings of six cacao (*Theobroma cacao* L.) accessions were raised in polyethylene bags containing 1:1 mixture of garden soil

*Contribution No. 254, CPCRI, Regional Station, Vittal.

and farmyard manure, and 4-month old plants were used for the experiments. Leaf elongation rate was measured in first three young leaves in 6 replicates. All other determinations were done in 3 replicates. Water stress was induced by withholding irrigation.

For analyses, fully expanded leaves were sampled. Relative water content (RWC) was estimated by floating 1 cm^2 leaf discs in distilled water for 6 hr (Weatherely, 1950). Epicuticular wax was extracted in chloroform, evaporated to dryness at room temperature and determined gravimetrically. The *in vivo* assay procedures were employed for nitrate reductase (NR) activity with 0.1M KNO_2, 20 mM K-phosphate buffer and 0.25 per cent n-propanol (Jaworski, 1971). Proline was extracted in 3 per cent sulfosalicylic acid, centrifuged and supernatant used for estimation (Bates *et al.*, 1973).

RESULTS AND DISCUSSION

There were differences in leaf elongation rates among the six cacao accessions under irrigated and stress environments (Table 1). The elongation rates did not show significant variations among 1st, 2nd and 3rd leaves. However, due to water stress the elongation was inhibited significantly. There was, however, no difference in elongation rates among accessions (NC 29, 31, 32 and 43) which possess some drought tolerant characteristics (Balasimha *et al.* 1982) as compared to susceptible ones (ICS 6 and IMC 67) under stress. Similar varietal differences in growth of leaf among annual crops have been reported (Acevedo *et al.* 1971; Boyer, 1970;, Parameshwara & Krishna Sastry, 1982). After rewatering, the leaf growth recovered after 4 days to prestress levels. The metabolic parameters like proline accumulation and reduction in NR activity changed only after irrigations were stopped for some time and when RWC reached below 70 per cent (Tables 2, 3; Fig. 1). It is apparent that leaf growth is much more sensitive to drought as compared to other parameters. There is increasing evidence for this contention (Hsiao *et al.*, 1970; Acevedo *et al.*, 1971; Boyer, 1970).

After 7 days of drought, the RWC decreased to a great extent in susceptible accessions (Table 2). This was associated with retention of high NR activity (Table 2) and low proline accumulation in drought tolerant accessions (Fig. 1). It is interesting to note that proline accumulated only when the plants were severely wilted and was negatively correlated with the relative water content (r= −0.68). As RWC was low in ICS 6 and IMC 67, proline content also was high. It is pertinent to view their relationship in the light of better utilization of metabolites like proline as leaf turgidity was maintained. Similarly, nitrate reduction could occur more efficiently because of higher energy pools available.

Table 1. Leaf elongation rates (cm/day)

Accession No.	Prestress	Stress (days)			Recovery*
		2	3	4	
			1st leaf		
ICS 6	2.92	1.92	1.56	0.80	1.00
IMC 67	2.02	2.15	0.78	1.00	1.50
NC 29	1.18	1.88	1.37	0.85	ND**
NC 31	1.33	1.45	1.18	0.75	1.70
NC 32	1.57	2.10	1.30	0.44	1.25
NC 42	1.89	1.70	1.35	0.63	1.15
		CD (P=0.05)=0.4295			
			2nd leaf		
ICS 6	2.44 ± 0.91	2.00 ± 0.86	1.32 ± 1.27	1.05 ± 1.84	1.40
IMC 67	2.32 ± 0.28	2.87 ± 2.04	1.63 ± 2.09	1.12 ± 1.13	2.10
NC 29	1.94 ± 0.64	1.05 ± 0.89	0.77 ± 0.87	0.33 ± 0.53	ND
NC 31	1.83 ± 0.84	2.10 ± 0.95	1.05 ± 1.12	0.78 ± 1.22	2.50
NC 32	2.61 ± 0.83	1.48 ± 1.12	1.35 ± 1.35	0.95 ± 0.88	2.70
NC 42	3.15 ± 1.90	2.18 ± 1.16	2.12 ± 1.48	1.44 ± 0.46	2.50
			3rd leaf		
ICS 6	3.35 ± 1.10	0.35 ± 0.21	0.25 ± 0.35	0.23 ± 0.40	4.40
IMC 67	2.54 ± 0.63	1.85 ± 1.77	0.55 ± 0.47	0.30 ± 0.38	2.50
NC 29	1.66 ± 0.56	1.30 ± 1.56	0.62 ± 1.02	0.58 ± 1.30	ND
NC 31	2.20 ± 0.30	1.70 ± 1.73	1.26 ± 0.97	0.28 ± 0.49	ND
NC 32	2.54 ± 0.83	1.55 ± 1.20	0.07 ± 0.12	0.00	ND
NC 42	2.91 ± 0.95	1.23 ± 1.24	1.28 ± 1.65	0.18 ± 0.35	3.00

*4 days after rewatering

**ND, New flushing leaf not present for measurement

Table 2. Changes in relative water content (%) after 7 days' stress

Accession No.	Relative water content	
	Control	Stress
ICS 6	82.7	50.3
IMC 67	84.7	57.6
NC 29	84.7	69.5
NC 31	83.3	75.0
NC 32	82.7	71.3
NC 42	83.7	69.3

CD (P=0.05): Accessions 8.8; Treatments=3.6; Interactions=5.13

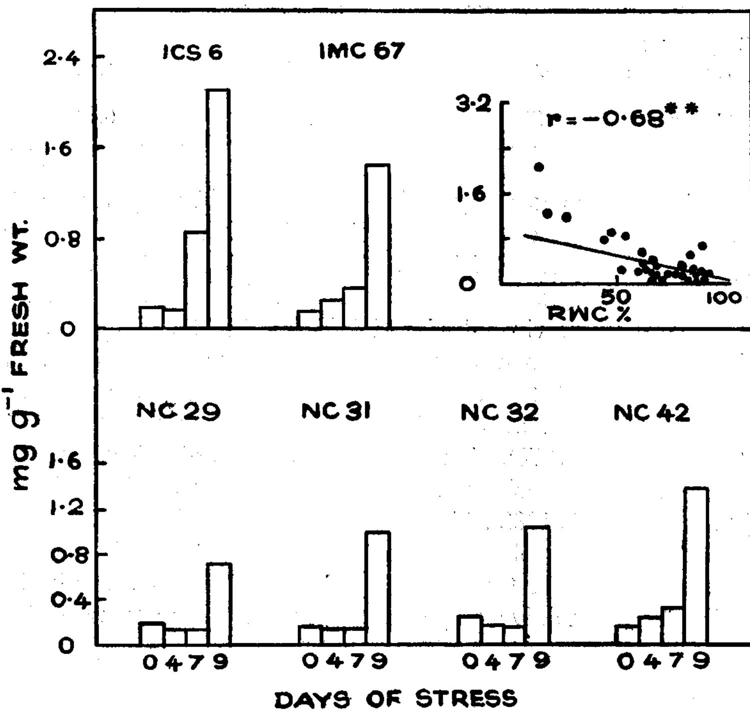

Fig. 1. Changes in proline content during stress; CD (P=0.05): Accessions =0.464 mg g^{-1} Treatments=0.184 mg g^{-1}. Inset shows the regression curve for proline content *vs* relative water content.

Table 3. Specific leaf weight, epicuticular wax content, and NR activity in leaves after 7 days' stress

Accession No.	Specific leaf weight (mg/cm^2)		Epicuticular wax ($\mu g/cm^2$)		NR activity NO_2 g^{-1} hr^{-1})	
	Control	Stress	Control	Stress	Control	Stress
ICS 6	3.37	3.70	149.5	197.5	8.27	3.27
IMC 67	4.25	4.20	56.7	198.7	7.60	3.33
NC 29	4.55	3.63	174.2	188.5	8.53	6.07
NC 31	3.48	3.52	203.3	164.6	8.00	5.93
NC 32	4.20	3.77	33.1	229.8	8.80	3.47
NC 42	3.48	3.77	153.9	151.6	6.93	6.27
CD(P=0.05)						
Accessions	0.24		38.04		1.18	
Treatments	NS		21.96		0.68	

The specific leaf dry weight varied significantly among the accessions but not due to stress. The epicuticular wax content was significantly higher in NC-29, 31, and 42 which did not show any changes on being subjected to water stress (Table 3). However, in other accessions, viz. ICS-6, IMC-67 and NC-32 there was considerable increase in wax contents during stress. Epicuticular wax plays an important role in the plant's ability to withstand water deficits, and is known to increase due to stress (Baker, 1974; Bengston *et al.*, 1978). In fact, higher contents of epicuticular wax content may be associated with drought tolerant accessions of cacao (Balasimha *et al.*, 1982). This increased wax deposition may provide an ability to the plants for reflecting sunlight, thereby reducing transpiration rather than a direct effect on cuticular transpiration, which may form only a very small portion of total water transpired.

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Discussion

P. S. SREENIVASAN (Palghat): This study, I think, refers to soil drought. How far the findings will hold good for aerial drought? What is the type of proline accumulation, water content of leaf, wax content etc.?

D. BALASIMHA: This study was done with increasing soil drought conditions at atmospheric humidity. The crop response would change at varying humidity levels.

V. S. SHARMA (UPASI): While calculating any physiological character like drought, no single factor should be judged in isolation but in conjunction with several other factors responsible for the particular physiological function under study.

D. BALASIMHA: Yes, in fact I have made this point very clear in my paper that no single parameter should be evaluated while dealing with drought tolerance.

N. VASUDEVA (CCRI, Chickmagalur): Apart from proline, is there any other biochemical character responsible for drought tolerance/ resistance in coffee?

D. BALASIMHA: No single growth or metabolic parameter can be considered in isolation, but studied *in toto*. To my knowledge, RWC and NR activity have been shown to be influenced by drought in coffee.

COMPARATIVE STUDY OF COCONUT GENOTYPES FOR COMPONENTS OF PHOTOSYNTHESIS AND RESPIRATION

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ABSTRACT

The three coconut genotypes, West Coast Tall (WCT), Chowghat Dwarf Orange (CDO) and the hybrid WCT×CDO (T×D) were compared for the rate of apparent photosynthesis, dark respiration, chlorophylls *a* and *b*, total carotenoids, relative assimilation rate (RAR), leaf area, and stomatal frequency. With the exception of WCT, the rate of photosynthesis was not correlated with yield, There was significant difference in the rate of photosynthesis between T×D and WCT. CDO exhibited higher dark respiration as compared to WCT and T×D. T×D had significantly higher amounts of total chlorophylls than WCT and CDO. Stomatal frequency was not related with the rate of photosynthesis. The total leaf area of T×D was the highest followed by WCT and CDO. The results indicate that the total leaf area might be an important factor determining productivity.

INTRODUCTION

The coconut palm exhibits wide variability in the production of nuts. Of the common cultivars of India the West Coast Tall (WCT), Chowghat Dwarf Orange (CDO), and the hybrid between WCT and CDO (T×D), the T×D is superior in yield.

Chacko Mathew and Ramadasan (1975) reported a significant positive correlation between the rate of apparent photosynthesis and annual yield of nuts in WCT. The present paper reports the results of a comparative study of photosynthetic rate, rate of dark respiration, stomatal frequency, relative assimilation rate, and the chlorophylls, in WCT, CDO and T×D genotypes.

MATERIALS AND METHODS

Adult coconut palms (35-50 years of age) growing in the Institute campus under similar soil conditions were selected for the study. Twenty palms each of WCT, CDO and T×D including low, medium

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and high yield groups were chosen, on the basis of their mean yield during the past ten years. The study was carried out between October and November, 1981.

The youngest fully expanded leaf was sampled at 8.30 a.m. daily and apparent photosynthesis was determined manometrically (Chacko Mathew & Ramadasan, 1974). Measurement of dark respiration was done by Warburg's direct method (Umbreit, Burris & Stauffer, 1972). Chlorophylls *a* and *b* were determined spectrophotometrically following the method of Mackinney (1941). Carotenoids were estimated in the same extract according to Jensen and Jensen (1971). The stomatal frequency and stomatal index were determined after peeling off the eipdermis by boiling the leaf bits in 10 per cent nitric acid in the presence of potassium perchlorate (oxygen salt). Staining was done in safranin for microscopic, observations. The mean stomatal count of ten fields was used for estimating stomatal frequency. Relative assimilation rate was estimated by collecting leaflet samples from the youngest fully opened leaf at intervals of one month (Ramadasan *et al.*, 1984) and determining growth by using the formula of Watson (1947). Leaf area estimation was done using Li-3000 Li-Cor electronic leaf-area-meter.

Results and Discussion

The photosynthetic rate was significantly higher in T×D than in WCT and CDO. Although CDO exhibited a higher rate of photosynthesis as compared to T×D, it showed a higher of dark respiration also, thereby nullifying the advantage of the high rate of photosynthesis. This was reflected in the annual yield of nuts. In the case of T×D, not only was the photosynthetic rate higher but also the dark respiration was relatively less resulting in higher relative assimilation rate. Further, it may be noted that the T×D possesses a larger photosynthetic area (6.8 m^2/leaf) as compared to WCT (4.5 m^2/leaf) and CDO (3.6 m^2/leaf), resulting in higher rates of dry matter production (Table 1).

Data on chlorophyll pigments presented in Table 1, would show that T×D recorded significantly higher values than both WCT and CDO.

Table 1. Rate of apparent photosynthesis, dark respiration, relative assimilation rate and other characters in three coconut genotypes

	WCT		CDO		T×D	
	Mean	CV%	Mean	CV%	Mean	CV%
Rate of apparent photosynthesis (μlO_2/evolved/cm^2/h)	28.11	22.0	32.82	30.2	33.98*	14.0
Dark respiration ($\mu l/O_2$ consumed/cm^2/h)	4.23	24.4	6.31	11.8	5.02**	21.5
Relative assimilation rate (g/m^2/week)	2.83	44.1	2.63	38.8	4.7**	23.4
Total chlorophylla (mg/cm^2)	0.05	30.0	0.04	15.0	0.06**	16.0
Total carotenoids (mg/cm^2)	0.02	36.0	0.02	20.0	0.03**	17.0
Stomatal frequency (No./mm^2)	199.06	10.3	189.50	19.3	203.59	14.0
Leaf area (m^2/leaf)	4.5	—	3.6	—	6.8**	—
Mean yield (No. of nuts/palm/year)	58.3	26.4	48.6	33.3	93.1	51.5

**Significant at 1% level.
*Significant at 5% level.

No significant variability was noted in the stomatal frequency among genotypes.

The T×D stands out in two important components, namely, the Relative Assimilation Rate (RAR) and the leaf area. The RAR has shown a significant positive correlation with yield in WCT also (Ramadasan *et al.*, 1984).

The importance of using the rate of dry matter accumulation and leaf area in the selection of one-year-old seedlings of WCT was shown by Ramadasan *et al.* (1980). The results show that T×D is superior to both its parents in all the components studied. The possibility of using these parameters for early identification of T×D hybrids, is being examined.

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EFFECT OF EXPLOITATION METHODS ON BIOMASS PRODUCTION, HARVEST INDEX AND YIELD IN *HEVEA*

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ABSTRACT

Effect of different expolitation systems on yield, harvest index and biomass increment was studied for five years in clone RRIM 600. Effect of exploitation systems of biomass loss unaccounted by rubber yield (factor K) was found to vary with exploitation systems. Relationship of biomass production and yield as regulated by harvest index and factor K has been elucidated.

INTRODUCTION

Exploitation of rubber trees for extraction of latex is an abnormal physiological process induced by tapping. Only a portion of the annual biomass increment of the tree is diverred to rubber yield. Annual biomass increment in a tapped tree is substantially less than that of an untapped tree. This biomass loss is not completely explained by the rubber yield even when the higher energy content of rubber, 2.5 times that of carbohydrate (Templeton 1969), is taken into account. Simmonds (1982) has, theretore, suggested that the energy required for rubber production is much more than what can be accounted for by higher energy content of rubber. Sethuraj (1982) has, however, analysed the biomass loss in a model in which the effect of tapping on biomass loss unaccounted by rubber yield and biomass loss equivalent to the energetic value of rubber yield were separately treated. The proportion of biomass potential (1-k) that is unrealized because of tapping, may vary according to the systems of exploitation. Exploitation systems, in addition, may also influence the harvest index (C). In the present study, an attempt was made to elucidate the effect of different systems of exploitation on factors 'K' and 'C'.

MATERIALS AND METHODS

The experiment was started in 1977 at the Central Experiment Station, Chethackal, on clone RRIM 600 planted in 1968, and brought under tapping in 1976. Sixty trees were selected and randomly allotted to the following five treatments:

(1) S/4 d/2.

(2) S4 d/2+Ethephon 10 per cent.

(3) S/2 d/2.

(4) S/1 d/2.

(5) No tapping.

The existing tapping cuts were converted into S/4 and S/1 cuts as per the need of the treatments and the trees were tapped under alternate daily system. Ethephon (10 per cent) was applied, by bark application method, on trees in treatment No. 2, every alternate month. Yield was recorded on all tapping days by cup-coagulation method. Dry matter increment was calculated from the girth data collected annually by using the formula of Shorrocks *et al.* (1955). Harvest index was calculated by the formula $\frac{Y+2{\cdot}5}{(Y\times2.5)+G}$ where Y is the rubber yield and G the dry matter increment (both in kg/tree/annum).

Results and Discussion

The data on dry matter increment (Table 1) shows that all exploitation systems depressed dry matter production as compared to untapped trees. This biomass loss is most drastic with S/1 d/2 system. Quarter spiral and half spiral systems recorded an increasing trend for the first three years followed by a reduction in the fourth year whereas the untapped control trees showed a progressively upward trend. The full spiral system, however, indicated a declining trend in the dry matter increment. The dry matter increment in this system in the third and fourth years was practically negligible.

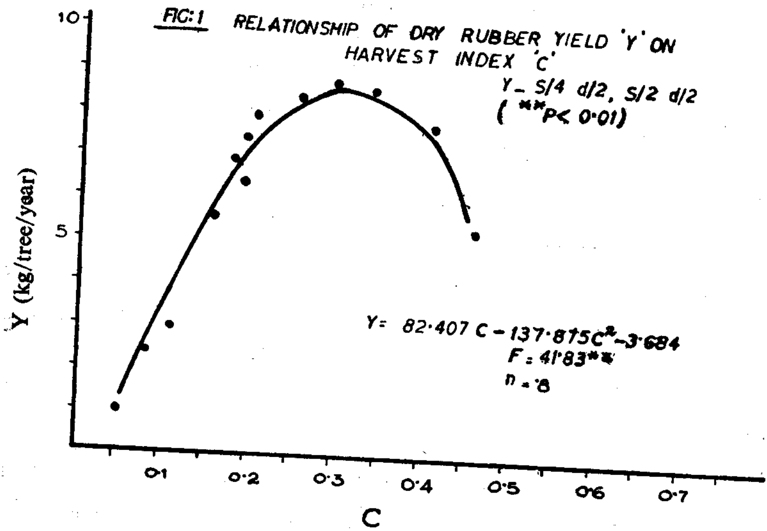
During the first year of experimentation, the yield increased with the intensity of tapping achieved by the lengthening of the tapping cut. The yield from trees under full spiral tapping declined, and was lower compared to that under the other systems. This was evidently due to the low dry matter production resulting in low girth increment. Application of Ethephon in quarter sprial system resulted in a higher yield compared to other higher intensity systems.

Table 1. Effect of different systems of exploitation on biomass production, harvest index and yield in *Hevea brasiliensis*.

Character	Exploitation system	1977–78	1978–79	1979–80	1980–81
1. Dry matter increment (kg/year)	S/4 d/2	68.85	69.05	80.68	59.89
	S/4 d/2+E	50.47	61.48	80.61	64.70
	S/2 d/2	60.74	76.62	79.89	34.01
	S/1 d/2	46.87	40.53	2.51	8.87
	No tapping	73.51	80.97	128.47	135.84
2. Dry rubber yield (kg/tree/year)	S/4 d/2	2.35	6.41	7.42	7.41
	S/4 d/2+E	2.72	7.54	8.46	8.44
	S/2 d/2	2.99	6.84	7.96	7.60
	S/1 d/2	3.58	6.71	5.59	5.88
3. Harvest Index 'C'	S/4 d/2	0.078	0.188	0.186	0.236
	S/4 d/2+E	0.118	0.234	0.207	0.245
	S/2 d/2	0.109	0.182	0.199	0.358
	S/1 d/2	0.160	0.292	0.847	0.623
4. Factor 'K'	S/4 d/2	0.063	0.147	0.372	0.559
	S/4 d/2+E	0.313	0.240	0.372	0.523
	S/2 d/2	0.173	0.053	0.378	0.749
	S/1 d/2	0.362	0.499	0.980	0.934

The data presented in Table 1 clearly indicate that harvest index increases with the length of the cut and age of the tree (year of tapping). In the full spiral system where the dry matter production was drastically affected, the harvest index became unusually high during the third and fourth years. Relationship between yield and harvest index was observed only during the first year. In later years, the harvest index was influenced by the total dry matter production rather than the yield and became high when the dry matter production decreased. During the third and fourth years, harvest index increased with the length of the cut though the yield recorded a reverse trend. Application of Ethephon resulted in a higher harvest index which was totally accountable by the higher yield obtained.

The biomass loss due to tapping was very pronounced in full spiral system. Over 90 per cent of the potential bimass increment was lost under full spiral tapping system. Application of Ethephon in combination with quarter spiral tapping did not show any significant adverse effect on biomass production except during the first year. These results conclusively show that it is the length of the cut that determines the biomass loss and not the amount of latex extracted *per se*. As the economic life span of *Hevea* trees is more than thirty years, the necessity for maintaining a high growth rate needs no emphasis, especially as the length of the cut is one of the factors that determines the yield (Sethuraj, 1981). A system of exploitation in which the biomass loss can be kept at the lower level combined with a reasonably high harvest index is to be desired. The present data indicate that rubber yield decreases after a certain level of harvest index (Fig. 1). Further investigations in shorter cut systems with stimulation, with these objectives in view, merit priority attention.



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DISCUSSION

P. S. SREENIVASAN (Palghat): How to maintain high growth rate and thereby obtain steady latex yield at the optimum level?

M. J. GEORGE: All the popular exploitation systems will retard the biomass increment. The only way to maintain high growth rate and sustained yield is to adopt less intensive exploitation systems.

CLONAL AND SEASONAL VARIATIONS IN OSMOTIC CONCENTRATION OF LATEX AND LUTOID SERUMS OF *HEVEA BRASILIENSIS* MUELL.-ARG.

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ABSTRACT

The osmotic concentrations of latex serum (C-serum) and lutoid serum (B-serum) of latex were determined using Vapour Pressure Osmometer for two seasons, during August-September when soil moisture level was adequate and during December-January when the soil moisture level was low. It was found that the clones differed markedly in the osmotic concentration of B-and C-serum of latex. There was an appreciable increase in the osmotic concentration of C-serum following the depletion of soil moisture level thereby showing the osmotic adjustment. There was a positive correlation between C-serum concentration and initial flow-rate, thereby showing its relationship with yield. The osmotic concentration of B-serum was found to be higher than that of C-serum. This difference which is related to the dilution of latex while tapping, was found to be related to the yield.

INTRODUCTION

Hevea latex is a hydrasole in which the dispersed particles are strongly protected by a complex film made of protein, neutral lipids and phospholipids. The dominant particulate phase of freshly collected latex is the rubber hydrocarbon. Next in abundance are lutoid particles amounting to 10-20 per cent of the volume. The lutoids are sub-cellular membrane bound bodies. The membrane encloses a fluid serum, referred to as lutoid serum (B-serum). Latex can be divided into three main fractions by centrifugation, an upper layer of rubber particles, middle aqueous serum (C-serum) and the bottom fraction comprising lutoid and other heavy particles. The lutoids are involved in the mechanism of cessation of latex flow. When a tree is tapped, latex vessels are cut open and due to hydro static pressure, latex is expelled out. Simultaneously, water from the surrounding tissue enters into the latex vessel making it more dilute. The drop in the tonicity of C-serum upsets the osmotic balance of

B-serum and C-serum. Water enters lutoids, and ultimately lutoids swell and burst, releasing the positively charged cationic proteins and other cations like Magnesium and Calcium. This results in the formation of a floc of rubber particles by charged neutralization culminating in latex vessel plugging and cessation of flow. Osmotic concentration of C-Serum and B-serum are thus related to the mechanism of the plugging process. This study was initiated to elucidate the relationship between osmotic concentration of C-serum and B-serum, and the mechanism of latex flow, and the present report forms the first part of this study.

MATERIALS AND METHODS

Ten different *Hevea* clones were selected for the present study with three trees each. The study was conducted during the periods of August-September and December-January when the soil moisture content was above 90 and below 40 per cent of the field capacity, respectively.

Latex samples from these trees were collected upto first 5 minutes of tapping in ice-cold containers. The samples were centrifuged at 18,000 rpm for 2h. The central clear serum of the centrifuged latex, which constituted the latex serum (C-serum) was collected. The bottom fraction (lutoid fraction) was dispersed in 0.4M Mannitol and centrifuged at 5000 rpm for 45 min. The supernatant was discarded. Lutoid serum (B-serum) was collected after subjecting the lutoid fraction to continuous freezing and thawing (Hsia, 1958).

The osmotic concentration of latex and lutoid sera was determined by adopting Vapour Pressure Osmometry technique using Wescor 5100-C Vapour Pressure Osmometer.

Initial flow rate (Ifr) is the average flow rate per minute during first five minutes after tapping. Plugging index (P) was determined as per the method of Pardekooper and Somosorn (1969). Yield (g tree^{-1} tap^{-1}) was calculated by multiplying the volume of latex collected with its dry rubber content (Cr, per cent rubber content, w/v).

Results and Discussion

There was a marked increase in the osmotic concentration of C-serum of different *Hevea* clones during December-January, following the depletion of soil moisture level in this period (Table 1), thereby showing osmotic adjustment by increasing the solute concentration inside the tissue during water deficit. Such type of osmotic adjustment had been reported for different crops like wheat (Rana Munns and Weir, 1981) and soybean (Meyer and Boyer, 1981). It was found that the high yielding clones like RRII-105 and RRII-102 were able to maintain a high osmotic concentration during both the periods.

Table 1. *Osmotic concentration of latex serum (C-serum) of Hevea clones*

Clone	Osmotic concentration (mOs)			
	Aug.-Sept.	±S.E.	Dec.-Jan.	±S.E.
RRII 105	385	12.7	450	21.0
RRII 102	433	7.7	484	7.3
Tjir 1	328	4.8	388	5.9
HP 267	362	29.6	424	11.9
HP 115	353	16.5	419	7.8
HP 14	294	16.7	408	2.9
HP 39	320	25.1	395	2.9
HP 268	327	20.8	423	4.0
HP 201	379	12.8	435	9.6
HP 218	376	4.5	431	10.8

The osmotic concentration of B-serum also increased in the summer months (Table 2), but the increase was not so pronounced as in the case of C-serum. It was observed that the osmotic concentration of B-serum was generally higher than that of C-serum in both the periods; while this difference (B-C serum concentration) was marked during the rainy months, it was negligible during the summer months, thereby showing a higher dilution of latex during the period of adequate soil moisture level (Fig. 1). The clones which had shown a higher C-serum concentration registered a higher B-serum concentration also.

Table 2. *Osmotic concentration of lutoid serum (B-serum) of Hevea clones*

Clone	Osmotic concentration (mOs)			
	Aug-Sept	±S.E.	Dec-Jan.	±S.E.
RRII 105	421	5.0	445	7.4
RRII 102	449	19.1	470	6.0
Tjir 1	413	4.2	400	5.8
HP 267	400	2.1	423	7.6
HP 115	417	18.0	428	4.7
HP 14	397	7.0	410	1.2
HP 39	405	7.5	402	1.2
HP 268	401	4.3	427	1.5
HP 201	420	8.1	434	4.7
HP 218	424	11.1	431	5.4

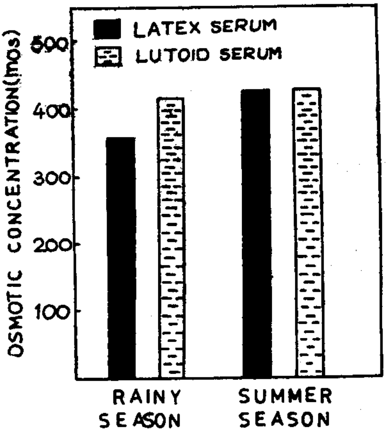
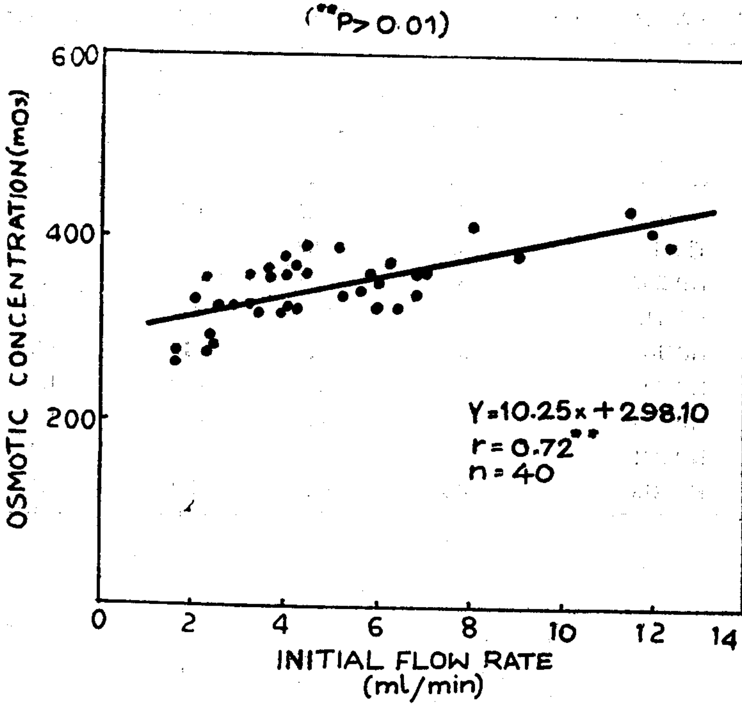


Fig. 1. Seasonal variations in osmotic concentrations of latex and lutoid serums

Pakiananthan (1967) reported that the presence of rubber hydrocarbon would not affect the osmotic cocentration of latex, thereby showing that the osmotic concentration of C-serum really represents that of the latex. A study of the relationship of C-serum concentration with major yield components, like initial flow rate and plugging index, revealed a significant positive correlation.



Fig, 2. Relationship of osmotic concentration of Latex serum with intial flow rate

Table 3. Effect of dilution of latex on yield of *Hevea* clones

Clone	Dilution B-C Serum Conc: (mOs)		Yield (g/tree/tap)	
	Aug-Sept	Dec-Jan.	Aug-Sept	Dec-Jan
RRII 105	36	–5	58.9	93.7
RRII 102	16	–14	61.9	70.5
Tjir 1	85	12	21.6	20.6
HP 267	38	–1	67.4	90.9
HP 115	64	9	52.2	42.1
HP 14	103	2	27.8	35.1
HP 39	85	7	38.1	26.2
HP 268	74	4	14.9	11.7
HP 201	41	–1	52.3	51.2
HP 218	48	0	60.4	58.9

between C-serum concentration and initial flow rate (Fig. 2). This may be due to the fact that a higher inherent osmotic concentration of the sap would facilitate a higher turgor pressure of the laticiferous system, resulting in higher initial flow rate. Since an inverse relationship between initial flow rate and plugging index has already been established, the negative correlation between osmotic concentration of C-serum and plugging index is expected (Fig. 3). These results showed that the high osmotic concentration of latex was directly related to high yield. It was also found that the clones which had recorded lesser dilution of latex by tapping were also capable of maintaining appreciably higher yield during both the periods of the study (Table 3). Further studies related to the osmotic adjustment of different clones during the periods of progressive development of soil moisture stress might prove rewarding.

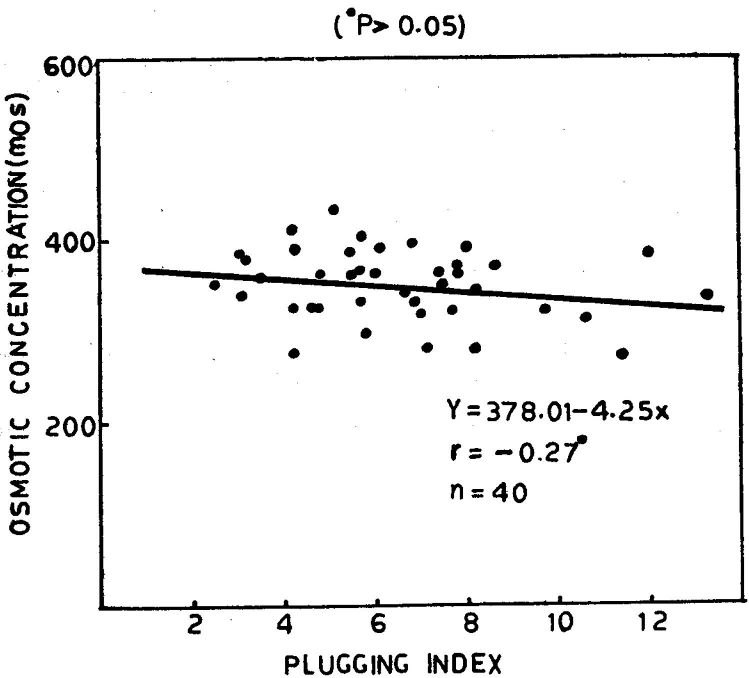


Fig. 3- Relationship of osmotic concentration of latex serum and Plugging Index

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DISCUSSION

P. S. SREENIVASAN (Palghat): High osmotic concentration is highly correlated with latex yield (r= + 0.71, i.e. 50% of total variation in yield). What are the other physiological and environmental factors influencing the latex yield directly or indirectly?

K. V. SATHEESAN: The osmotic concentration of latex is found to be positively correlated with initial flow rate (r = + 0.71), and negatively correlated with plugging index (r=0.27) thereby showing its relationship with yield. The contribution of other yield components has not been taken into account in this study.

V. RAJAGOPAL (CPCRI, Kayangulam): What is the difference in the osmotic concentration of leaves of different clones between seasons?

K. V. SATHEESAN: We have not studied the osmotic concentration of leaves.

EUPATORIUM ODORATUM L. IN PLANTATIONS—AN ALLELOPATH OR A GROWTH PROMOTER?

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ABSTRACT

***Eupatorium odoratum* L. is an aggressive weed which invades the nurseries and forest area freshly cleared for growing plantation crops. In the forests of Kerala and Karnataka the weed has established over very large areas causing the failure of new plantations. The different parts of the weed contain phytotoxins which are allelopathic. In nature, the inhibitors get leached out from the fresh and dried leaves when rainsoaked or during decay. The phytotoxicity is high in the initial stages of decay, but after eight weeks the medium promoted the growth of the test species. Thus, if the leaf materials from the annual weeding operation in the forest, is allowed to compost for atleast 8 weeks it can be used as a good manure in the cultivated fields. However, in the forest as the perennial weed continues to produce new leaves during most part of the year, and the release of allelochemicals would be continuous, only its alleopathic effect would be prevalent.**

INTRODUCTION

Eupatorium odoratum L. is an aggressive, perennial weed posing serious problem to many plantation crops like teak, rubber, banana coconut, softwood, oil palm, coffee, cocoa and others. It is also a problem in the nurseries and freshly cleared forest areas. Our survey of the forests of Shimoga (Karnataka) revealed that the young plantations of teak and softwood were completely suppressed by this weed, and further investigation showed that the weed exerted allelopathic influence (Ambika and Jayachandra, 1980). Different parts of the weed were found to contain toxins which inhibited the crop growth.

There have been reports that *E. odoratum* could be evaluated as an organic amendment to improve yields of lowland rice, manioc and black pepper when applied as a mulch or incorporated into the soil before ploughing (Litzenberger, 1961), and that the weed returns about 4000 kg/ha of litter annually to the soil, and the litter decomposes very fast (Olaoye, 1976). Hence, it was considered necessary to examine whether the litter of the weed at the advanced stages of decomposition could promote crop growth, and also to consider the question of the dominating influence of allelopathy/ growth promotion in forests due to *Eupatorium* weed.

Materials and Methods

Leaf material of *Eupatorium* weed used for the studies on the allelopathic effects, decomposition and for the effects on crop growth, was collected from the weed stand in teak plantations located near Shimoga (Karnataka). Seeds of wheat (*Triticum aestivum* L. var. UP 301), and fenugreek (*Trigonella foenum-graecum* L. var. PEB) used as test crops, were obtained from the National Seeds Corporation, Bangalore.

Test 1. Allelopathic effects of the aqueous leachate and alkaloids from the weed: This test was carried out following the procedure described earlier (Ambika and Jayachandra, 1980).

Test 2. Effect of the rhizosphere soil on growth of the test plants: 100 g of the air-dried rhizosphere soil of *Eupatorium* weed was extracted with 250 ml of distilled water, concentrated in vacuum to $\frac{1}{8}$ the volume and tested on the growth of the test seedlings in petri dish as under Test 1. The test plants grown in the distilled water extract of soil from teak plantation devoid of *Eupatorium* served as the control. The 96 hour old test seedlings were used for determining the dry weight.

Test 3. Decomposition of the leaf material: *Eupatorium* leaves were set for decomposition in shallow pits of 15 cm depth and 23 cm diameter. The pots were filled with fresh red soil to a depth of 13 cm, and charged with 20g of air-dried leaves of the weed mixing partly with the soil and sprinkled with water (260 ml/pot) daily. The whole set of 120 pots was kept in the open, where the temperature varied from a mean maximum of 40±2°C to a mean minimum of 25°±2°C, and the mean relative humidity ranged between 65 and 44 per cent. At intervals of 15 days, wheat and fenugreek seedlings were raised in these and control pots, in 3 replications. The 15 day-old test plants were screened for linear growth and dry matter production.

Test 4. Changes in the number of total microbes and MPN of *Nitrosomonas* in the decomposing leaf material of the weed: *Eupatorium* leaves were set to decompose in 2 litre capacity Erlenmeyer flasks kept at 24°±2°C in dark. Samples were removed at 20, ?5, 45, 65, 95 and 135 days for determining the total microbial count and M.P.N. of *Nitrosomonas*, following the method of Alexander and Clark (1965).

Test 5. Chemical changes during decomposition: Three replications of 5g samples from the pots set as in Test 3, were collected after 1, 2, 4 and 6 months and used for the various analyses. The Kjeldahl digests of the soil samples prepared following Jackson's (1967) method were used for the estimation of total nitrogen following Umbreit and Burries (1972). The samples were also analysed for nitrate nitrogen by phenol-disulphonic acid method (Bremner, 1965), for hydroxyl and carbon extractable phosphorus following Oslen *et al.'s* (1954) method, available potassium by cabaltinitrite method (Jackson, 1967), pH using glass electrode in a 1:1 soil: water suspension (Piper, 1966), total soluble salts , by measuring the electrical conductivity, following Jackson (1967), total phenolics, using Folin- Denis reagent following A.O.A.C. (1960) and amino acids, following Moore and Stein (1948).

The data of all the above tests were analysed using t-test and F-test following the procedure described by Sokal and Rohlf (1973).

Results and Discussion

The data in Figs. 1, 4 and 5 show that the aqueous leachate, alkaloid and the rhizosphere soil of the weed inhibitied the growth of the test seedlings to varying degrees. Leaf leachate was found to inhibit the crop growth to the maximum and was followed by those of seed, stem and root. In fenugreek, though the grains germinated, they failed to grow further. The inhibition caused by the rhizosphere soil was not statistically significant.

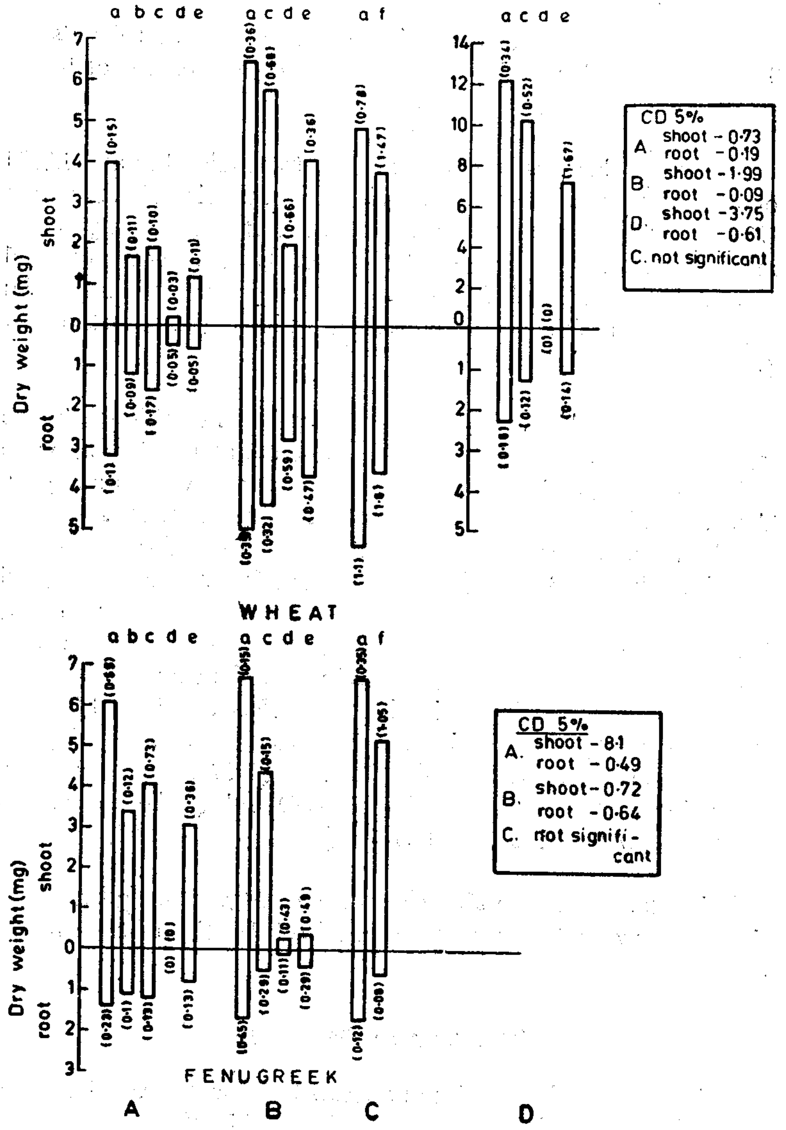

Fig. 1 Growth inhibition in wheat (*Triticum aestivum L.* Var. UP 301) and fenugreek (*Trigonella foenum-graecum* L. var. PEB) seedlings due to *Eupatorium odoratum L.*)

Growth for 72h in the aqueous leachate (A), for 96h in the alkaloid medium and the extract of the rhizosphere soil (B and C) and for 120h in the soil fed with the leachate (D)

a-Control, b-f: stem, root, leaf, cypsella and rhizosphere soil of the weed, respectively.

Figures in parentheses refer to standard deviation.

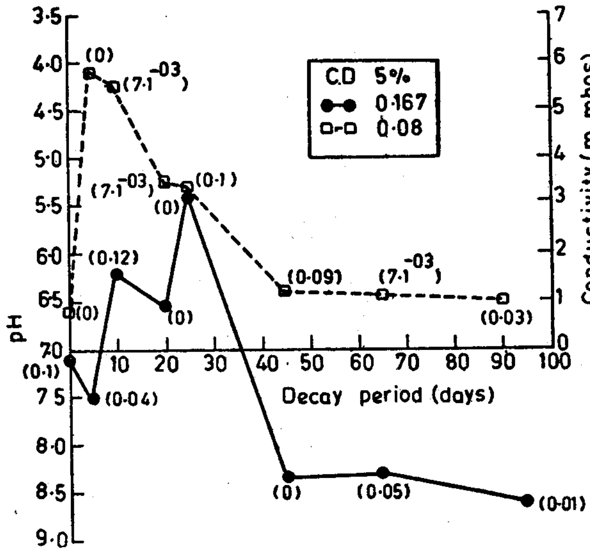

Fig. 2 Changes in pH and Electrical Conductivity of the medium with the decomposing leaves of *Eupatorium odoratum* L.

Figures in parentheses refer to standard deviation.

●–● pH Value; □–□ Electrical conductivity.

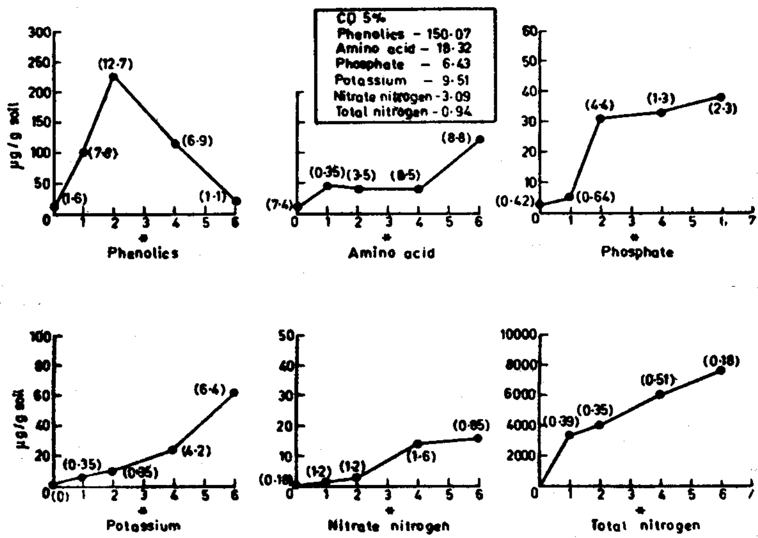

Fig. 3 Analytical data of the soil with the decomposing leaves of *Eupatorium odoratum L.*

* Decomposing period in months. Figures in parentheses refer to standard deviation.

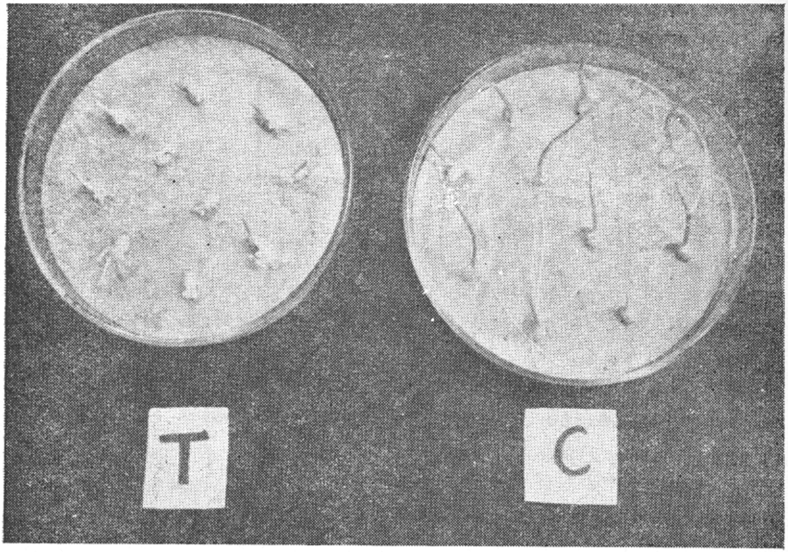

Fig. 4

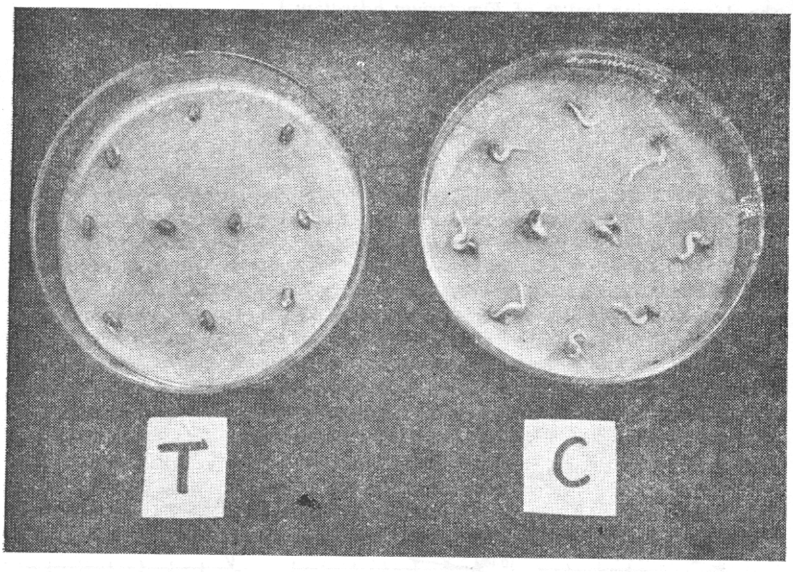

Fig. 5.

Inhibition of 72h-old seedlings of wheat (Fig. 4) and fenugreek (Fig. 5) due to aqueous leachate of *Eupatorium* weed. T—treated; C—control.

As per data in Tables 1 and 2, the medium with *Eupatorium* leaves proved highly allelopathic in the initial stages upto 60 days, and in the test plants, the root growth was inhibited more than that of the shoot. Subsequently, at 75 and 90 days of decomposition, the medium caused significant promotion of growth of the test plants.

Data in Table 3 show that the total microbial count changed with the stage of decomposition. The maximum number of microbes was found on the 20th day, and thereafter it declined. However, the *Nitrosomonas* count increased gradually in the medium and the maximum was reached on 45th day.

The soil with an initial pH of 7.2 became highly acidic (pH 4.9) in 25 days with the leaves decomposing, but later, the pH increased. The total soluble salt content (electrical conductivity) of the medium was found to increase upto 25 days, decline upto 45 days and remained stationary thereafter. The total phenolics and amino acids increased in the medium upto two months, declining later. By six months, the phenolic content was 20μg and amino acid level 30 μg perg soil. The levels of phosphate, potassium, nitrate nitrogen and total nitrogen in the medium kept on increasing with time, and by six months, phosphate was 38μg, potassium 60μg, nitrate nitrogen 16μg, and total nitrogen 7670μg per g soil.

During the initial stages (i.e., upto sixty days) of decomposition of *Eupatorium* leaves, the medium being rich in amino acids and phenolics (Fig. 3) was allelopathic (Fig. 1). Subsequently, with the increased microbial activity (Table 3) there was a steep fall in the level of total phenolics and a signficant rise in the nutrient content (Fig. 3) released obviously from the decomposing weed leaf material, and hence the medium promoted the growth of the test crops (Tables 1 and 2).

In the forest floor, though one would expect a rapid decomposition of the weed material and consequent growth promoting effect on the plantation, during the rainy season, there would be a continuous rain wash of the growth inhibitors from the intact leaves and release of inhibitors from the decomposing leaves of *Eupatorium*.

Table 1. Growth response of 15 day-old seedlings of wheat (*Triticum aestivum* L. var. UP 301) in soil holding decaying leaves of *Eupatorium odoratum* L.

Treatment		Shoot length (cm)	Per cent of control	Shoot dry wt. (mg)	Per cent of control	Root length (cm)	Per cent of control	Root dry wt. (mg)	Per cent of control
Soil without *Eupatorium* leaves (control)		14.39 (0.56)	—	30.41 (7.2)	—	27.33 (3.3)	—	29.20 (4.4)	—
Soil holding *Eupatorium* leaves decayed for different durations (days)	15	11.22 (0.25)	77.97	17.72 (1.3)	58.27	12.67 (1.9)	46.36	13.01 (2.2)	64.12
	30	15.93 (0.73)	110.70	27.0 (2.4)	88.79	19.0 (1.1)	69.52	14.62 (0.22)	72.05
	45	16.92 (0.11)	117.58	27.8 (0.8)	91.42	22.91 (2.9)	83.83	15.68 (2.3)	77.28
	60	17.11 (0.03)	118.90	28.23 (1.9)	92.83	23.95 (3.2)	87.63	16.40 (3.3)	80.83
	75	21.35 (0.49)	148.37	35.08 (0.37)	115.36	23.92 (3.6)	87.52	21.08 (0.18)	103.89
	90	22.62 (0.18)	157.19	39.34 (5.17)	129.36	24.99 (0.06)	91.44	24.01 (5.2)	118.33
	CD 5%	1.01		8.83		5.84		7.61	

Figures in parentheses refer to standard deviation

Table 2. Growth response of 15 day-old seedlings of fenugreek (*Trigonella foenum-graecum* L. var. PEB) in soil holding decomposing leaves of *Eupatorium odoratum* L.

Treatment		Shoot length (cm)	Per cent of control	Shoot dry wt. (mg)	Per cent of control	Root length (cm)	Per cent of control	Root dry wt. (mg)	Per cent of control
Soil without *Eupatorium* leaves (control)		5.72 (0.6)	—	7.96 (0.96)	—	10.61 (1.1)	—	2.69 (0.07)	—
Soil holding *Eupatorium* leaves decayed for different durations (days)	15	4.46 (0.13)	77.97	6.76 (0.44)	84.92	6.43 (0.18)	60.60	2.26 (0.07)	84.01
	30	6.01 (0.27)	105.07	8.25 (0.64)	103.64	8.25 (0.49)	77.76	2.36 (0.54)	87.73
	60	6.74 (1.3)	117.83	9.42 (1.9)	118.34	9.32 (1.2)	87.84	2.45 (0.03)	91.08
	75	6.34 (0.4)	110.84	10.02 (0.46)	125.88	10.18 (0.12)	95.95	3.30 (0.09)	122.68
	90	6.62 (0.56)	115.73	10.75 (0.35)	135.05	10.59 (1.63)	99.81	4.49 (0.39)	166.91
	CD 5%	1.66		2.42		2.44		1.74	

Figures in parentheses refer to standard deviation

Table 3. Total microbial count and the most probable number of *Nitrosomonas* in the decomposing leaf material of *Eupatorium odoratum* L.

Treatment		Total microbes per g soil	Per cent of control	MPN of *Nitrosomonas*	Per cent of control
Forest soil without *Eupatorium* leaves (control)		82×10^5 (8.2)	—	62×10^3 (2.3) (0.16)	—
Soil with *Eupatorium* leaves decayed for different durations (days)	20	157×10^5 (24.4)	191.00	68×10^2 (0.26) (0.018)	10.97
	45	102×10^5 (13.6)	124.39	62×10^5 (2.3) (0.16)	10.00
	65	30×10^4 (6.43)	3.66	34×10^5 (1.3) (0.09)	5483.87
	95	None	0.00	22×10^3 (0.84) (0.06)	35.48
	CD 5%	103.11×10^{12}			

Figures in parentheses refer to standard deviation in total microbes and those in MPN of *Nitrosomonas* refer to—
right—upper confidence limit at the 95% level
left—lower confidence limit at the 95% level

During the early part of spring, the weed starts shedding its older leaves culminating in the total leaf shed by April. As *Eupatorium* weed is perennial, its contribution to the inhibitor reserve of substratum through leaf shed, is very high. Thus, its allelopathic influence is more likely to dominate in forests, and hence the observed suppression of growth of the forest trees. However, the compost of *Eupatorium* leaves prepared separately in pits would serve as a good manure to any cultivated crop.

Acknowledgement

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DISCUSSION

V. S. SHARMA (UPASI, Cinchona): What is good for wheat need not be the same for the forest crops. While wheat was your test plant, how could you conclude that *Eupatorium* is allelopathic to plantation or forest crops?

AMBIKA: True. The conclusion is not only based on this present study. Our vast survey of the Shimoga forests, have given us proof that the plantation crops are completely suppressed by this weed and that made us examine the different parts of the weed for growth inhibitors and we found phenolic acids and alkaloids in different parts and their concentration was maximum in the leaf, followed by other parts. Since the study was taken up only after observving the plantation crop suppression, the data we got very well point to the fact that *Eupatorium* is allelopathic to plantation crops.

N. VASUDEVA (CCRI, Balehonnur): How to control *Eupatorium* growth under field condition?

AMBIKA: This was not the objective of my paper. However, under field conditions, *Eupatorium*, can be controlled by herbicidal spray. Unpublished data show that 'Weedone' concentrate 48% at 16 kg/ha could completely destroy this plant.

R. GOPALAN (Kerala Agrl. University): Of course *Eupatorium odoratum* is a noxious weed especially in forest areas. But how can you come to the conclusion that it is allelopathic to perennial trees? Do you have any personal experience to cite?

AMBIKA: From our studies as well as our vast survey of Shimoga forests with *Eupatorium* infested plantations, we have come to this conclusion. Please refer to our present paper and the earlier paper (Ambika and Jaya chandra, 1980 in *Curr. Sci.* **49**: 874-875).

R. D. IYER (CPCRI, Kasaragod): Have you studied the effect of the root or leaf exudates of *Eupatorium* weed on the soil microflora in the rhizosphere? The stimulatory effect you have observed could be an indirect action *via* mycorrhizae, and other micro-organisms.

AMBIKA: No. Here, in our studies we have used only the leaf material of *Eupatorium* for decomposition and not the intact plants. So, the question of promoting effect of *Eupatorium* root exudates on the soil microflora does not arise.

V. RAJAGOPAL (CPCRI Kayangulam): What are the growth promoters observed? Inhibitors have been identified as phenolic acids.

AMBIKA: We have not carried out any analysis for the growth promoters but we have analysed the soil with the decomposing leaf material for the nutrient contents.

POSTER SESSION

EFFECT OF SOME PLANT GROWTH REGULATOR (PGR) FORMULATIONS ON TEA BUSH PRODUCTIVITY

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ABSTRACT

Effect of triacontanol, a naturally occurring plant growth regulator, and "Miraculan, a commercial formulation containing triacontanol, was studied on a number of parameters like yield, banji formation, and seasonlity of response, in mature clonal teas. With respect to yield, all clones responded very favourably. However, of the two clones in which triacontanol effect was studied, flush shoots showed a slight decline in one clone, whereas in the other, it increased by 15% in the harvest following the treatment. 'Miraculan' and another different commercial formulation Cytozyme was marginally effective in enhancing productivity in mature seedling teas. 'Miraculan' treatment was more effective in clonal teas compared to seeding teas. All these chemicals showed clonal and seasonal variations in their effects.

INTRODUCTION

A number of plant growth regulators have recently been used to increase crop productivity besides regulating a number of other physiological attributes (Nickell, 1982). Of late, a number of commercial formulations have surfaced in the market, some of which have displayed promising potential to be employed in commercial agriculture for a variety of beneficial purposes.

In tea, triacontanol, a naturally occurring growth regulator and a commercial formulation, containing triacontanol, marked as as "Miraculan", showed some promise in enhancing the yield of certain clones, in our preliminary trials (Raman, 1981; 1982). This paper further discusses the effect of triacontanol called 'Miraculan', and another entirely different commercial product "Cytozyme", on mature seedling and clonal teas.

Materials and Methods

Two clones namely, UPASI-9 (B/6/71) and UPASI-10 (B/6/62) planted in 1964 at UPASI Tea Research Institute Experimental Station, were used. About 200 ml/bush, adequate to wet the upper foliage completely, in which the chemical concentration was 0.1 mg/l with 0.05 per cent Teepol, was sprayed. The trials were conducted on 5 bushes each, replicated 6 times. Plucking was carried out at weekly intervals, and the weights of flush and banji shoots in the harvest were monitored individually.

'Miraculan' was used at concentrations of 0.4, 4.0 and 40.0 ml in 175–200 litres of water per hectare (Raman, 1982). It was sprayed by pressure-retaining knapsack sprayers or Back-pack sprayers. Four clones, 2024, UPASI-3 (B/5/63), UPASI-12 (B/6/129) and UPASI-15 (SP/4/5), with 5 bushes per treatment and replicated 5 times (except in the case of UPASI-3, where it was replicated only thrice), were employed. In this trial also, the plucking was done at weekly intervals.

'Miraculan' at similar concentrations was also tried on mature seedling teas in a neighbouring estate in the Anamallais. In the same estate another trial was conducted to study the effect of Cytozyme. The latter was applied in two concentrations of 250 and 450 ml in 200 litres of water per hectare. The plots consisted of 100 bushes each replicated 6 times. Plucking was done according to the estate practice and the average interval was between 10 to 14 days.

During the experimental period, 4 rounds of chemical sprays, at an interval of 3-4 months, were effected.

All the data collected were analysed statistically.

Results and Discussion

Both clones, UPASI-9 and UPASI-10 responded favourably to triacontanol treatment. In either clone, the treated plots yielded 15 per cent more green leaf than untreated ones (Fig. 1). Further, the treatment also affected the composition of flush and banji buds in the harvest. For example, over the period, a marginal decrease of about 2 per cent in the flush shoots occurred following

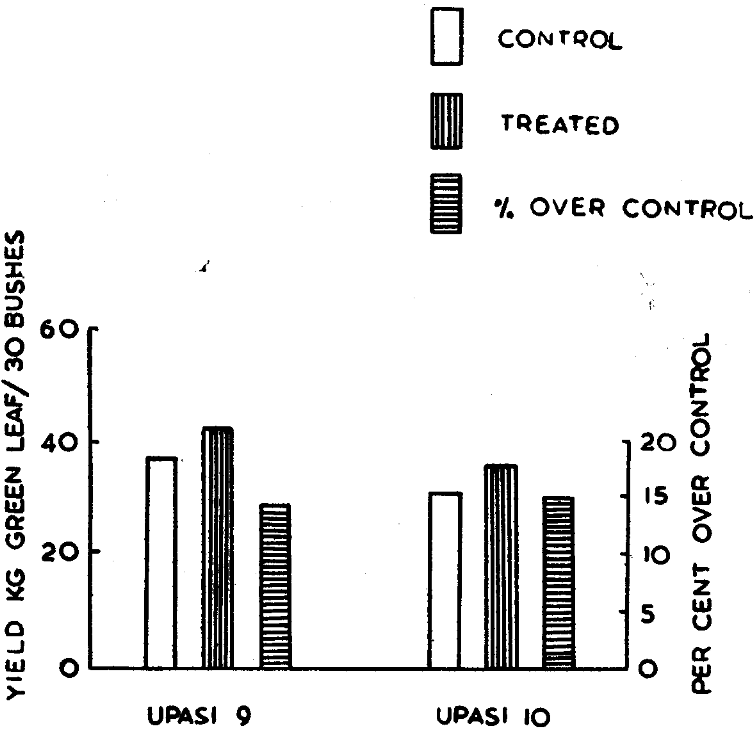

Fig. 1. Effect of triacontanol on yield of two UPASI tea clones (Mean green leaf weight in kg/30 bushes; July 1981–June 1982).

treatment in UPASI-9, whereas in UPASI–10, the flush shoots increased by 15 per cent (Fig. 2). Seasonally, the banji composition showed an increase during the drought season (mid-December to mid-April) in the Anamallais. The triacontanol treatment was effective especially during the drought season, in reducing the banji percentage (Table 1). These results generally agree with our earlier observations (Raman, 1981). In our previous trial, which was carried out only for a short duration, the treatment did not affect the yield in UPASI-9; in fact, there was a slight decline. However, in the trial reported here, even this clone, showed a beneficial response in the sense that the treated plots yielded 15 per cent more crop. This may be due probably to the slow acting nature of the chemical in this particular clone, or due to the influence of environmental factors.

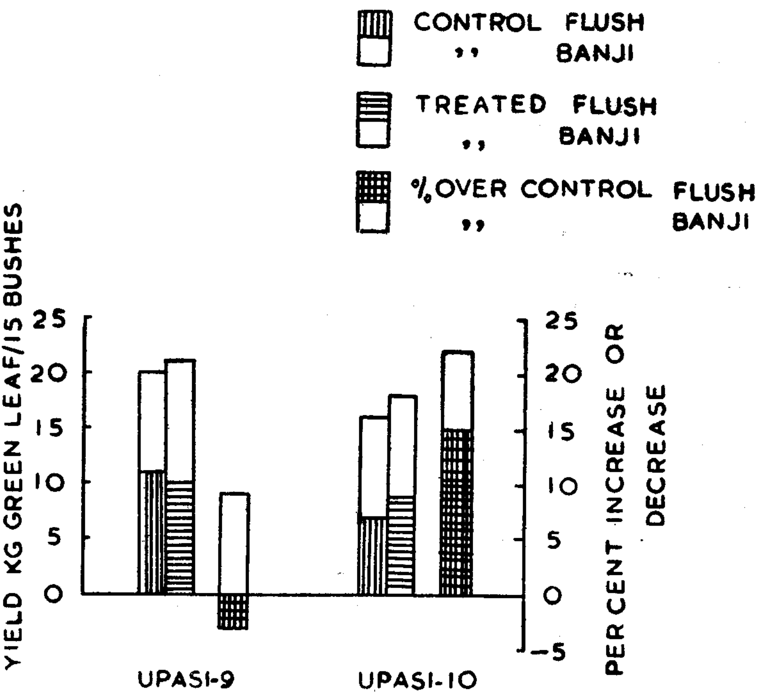

Fig. 2. Effect of triacontanol on yield components in two UPASI Tea clones (Mean green leaf weight in kg/15 bushes; July 1981–June 1982).

Table 1. Effect of triacontanol on the percentage of banji shoots in two UPASI tea clones

(Mean green leaf weight in Kg/15 bushes)
(July 1981–June 1982)

Months	B/6/61				B/6/62			
	Control		Treated		Control		Treated	
	A	%B	A	%B	A	%B	A	%B
1981:								
July	1808	32.2	1575	34.8	577	48.7	1109	42.2
August	554	46.3	626	51.2	514	53.7	428	57.6
September	1081	33.2	1106	35.8	1606	36.1	1046	43.8
October	1745	40.4	1557	42.3	1188	42.1	1538	43.5
November	736	59.2	769	60.2	659	60.7	835	57.2
December	970	54.6	1142	51.7	1082	52.3	1188	52.0
1982:								
January	178	79.6	397	67.1	333	70.0	316	64.5
February	380	53.8	496	51.6	358	52.9	386	48.1
March	594	53.3	710	52.7	367	59.2	564	50.7
April	485	51.0	516	56.1	239	69.4	213	68.3
May	1703	40.4	1053	53.7	756	53.1	1170	45.1
June	533	51.6	479	52.9	302	57.0	381	57.5

A=Flush Shoots
%B=Percent Banji

I spray 29–5–1981
II spray 15–9–1981
III spray 24–12–1981
IV spray 17–4–1982

All the four concentrations of Miraculan were effective in increasing the yield of mature clonal teas compared to the control (Fig. 3). The clone 2024 responded most to the chemical treatment. In this clone, the maximum yield was realized from plots sprayed with 4.0 ml, followed by 40.0 ml Miraculan per hectare. In the other three clones, there was no difference in the effectiveness of the lower two concentrations, 0.4 and 4.0 ml/ha. In these clones, the highest concentration was more effective in boosting the productivity. In addition, the interactions between treatment and months and between clones and treatments were highly significant.

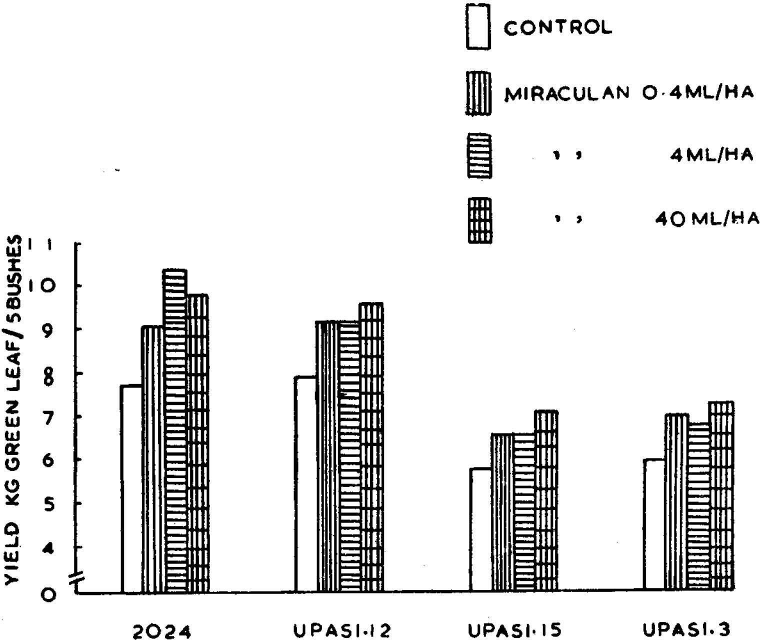

Fig. 3. Effect of four concentrations of Miraculan on the yield of four mature tea clones (Mean green leaf weight kg/15 bushes; July 1981–June 1982).

The chemical treatment boosted the yield to the maximum per cent over control in 2024. The next higher increase (Fig. 4) was in UPASI-15 followed by UPASI-3 and UPASI-12. This observation is highly significant in that UPASI-15 is a quality clone and UPASI-3 is both a quality clone and a high yielder. These observations agree with our earlier report (Raman, 1982), and also brings out the clonal differences and differences in optimal concentrations of chemical for these 4 clones.

In seedling teas, eventhough Miraculan and Cytozyme treatments resulted in increased yield, the magnitude of response was much lower compared to clonal teas, and also seasonal (Fig. 5). For example, during July-September 1982, the crop in all the treated plots declined compared to control, eventhough in other periods the yield was higher.

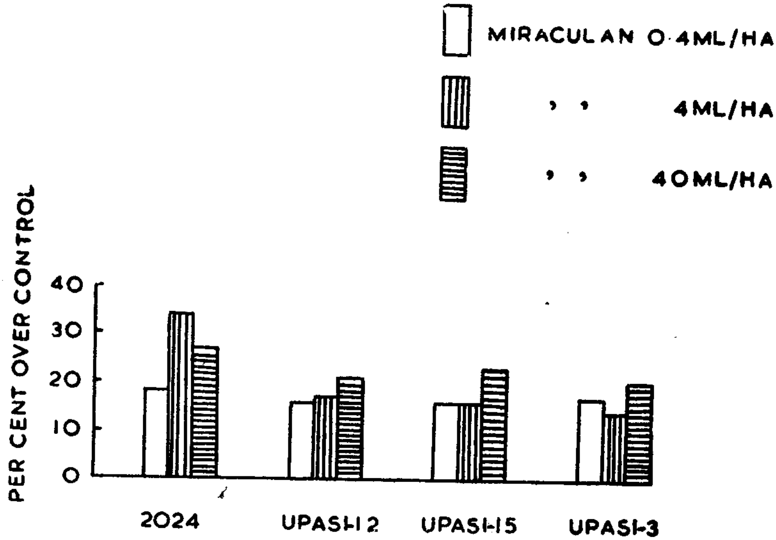

Fig. 4. Effect of three concentrations of Miraculan on yield increase over control.

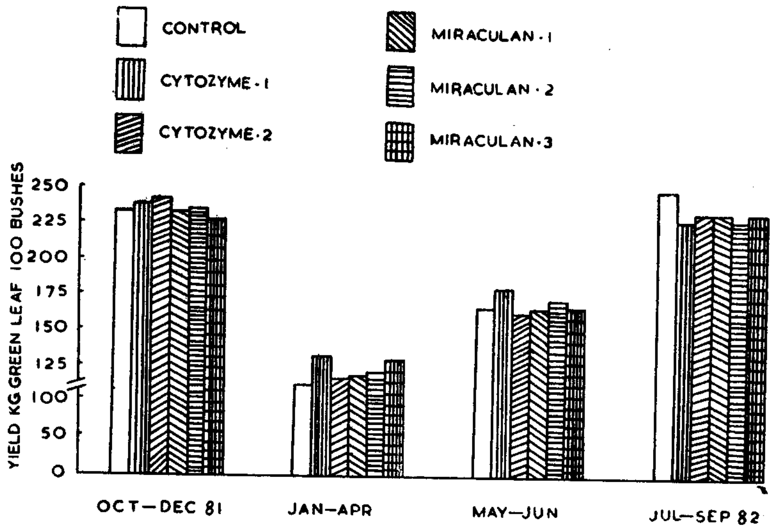

Fig. 5. Effect of two plant growth regulator formulations on seasonal yield of mature seedling tea(Mean green leaf weight in kg/100 bushes).

In spite of the beneficial effect of these chemicals noted in this study, information on their long-term effects has to be generated befor recommending their use on an extensive scale.

In tea, this is the first comprehensive report on the use of indigenous commercial plant growth regulators for realizing higher productivity. These chemicals have shown high potential for wider adoption in the tea plantations, after thorough preliminary trials in various ecoclimatic regions.

ACKNOWLEDGEMENT

The author is grateful to Dr. C. S. Venkata Ram for his constant inspiration and guidance throughout the course of this work.

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FIELD EVALUATION OF THE EFFECT OF SOME GROWTH REGULATORS, MICRONUTRIENTS, FUNGICIDES AND NEMATICIDES IN THE CONTROL OF IMMATURE CAPSULE SHEDDING IN CARDAMOM

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ABSTRACT

A field experiment initiated in 1980 is being continued in a plantation situated in North Wynad, Kerala State, to find out control measures for abnormal fruit-shedding in cardamom. Various growth regulators (IAA, GA_3, NAA, 2,4-D, 2,4,5-T, Cycocel, Planofix and Miraculan), micronutrients (Zn, Cu, B) and fungicides (Aliette, Brassicol, Bordeaux Mixture, Bavistin and Dithane M-45) were applied at monthly intervals commencing from April 1982. One round of biofertilizer (Azovigor) and nematicides (Temik 10 G), were also given as treatments. Daily hand-pollination was included as one of the treatments. The number of flowers that opened till 20th August and the number of capasules that dropped till 25th August were recorded daily. Significant reduction in capsule shedding was observed in plots where 'Azovigor' was applied in the soil. Other treatments which recorded relative reduction in fruit drop were IAA (25 ppm and 50 ppm), Copper (100 ppm), Azovigor (foliar application), and hand-pollination. Significantly higher drop was recorded in treatments with GA_3 (20 ppm), NAA (20 ppm) 2,4-D (20 ppm) and IAA + GA_3 + NAA (50 + 20 + 20 ppm) in comparison to control.

INTRODUCTION

Till the recent past cardamom plant was either grown wild under forest canopy or raised in semi-wild condition. Price hike of this spice in the international market resulted in intensive cultivation of the plant in man-made habitats. This has invited many of the present day maladies for the spice, and immature capsule shedding is one among them.

Though the phenomenon is common throughout the cardamom tract, certain localities of Kerala, like N. Wynad and Kallar (Pallivasal village) recorded the highest shedding. From a preliminary evaluation conducted in those areas, no precise conclusion could be drawn about its actual cause. However, it was felt that, in general, the abnormal feature of the plants can either result from ecological aberration, hormonal imbalance, nutritional disorder, fungal and/or nematode infestation, inadequate pollination or due to a combined action of some of these factors. A field trial was therefore, initiated to unravel the real reason for the malady, and some preliminary observations are presented here.

MATERIALS AND METHODS

The trial is being conducted at Harryland estate, Periya, N. Wynad from 1980 onwards. The details of the experiment are as follows:—

Number of major treatments	:	2
Number of minor treatments	:	30
Number of replications	:	2
Design	:	Randomized Block Design
Plot size	:	Five plants/plot

The rhizomes of *Elettaria cardamomum* (L.) Maton cv. 'Vazhukka' selected from the same site, were used for planting. A single unit having 3-5 tillers was planted upright in each pit and irrigated for good establishment. Normal cultural practices and plant protection measures were followed, Though a few plants came to bear in the succeeding season, uniform bearing was recorded only during 1982–83 crop season.

The two major treatments are, the plants which exhibited maximum capsule shedding (susceptible), and those recording least shedding (resistant). They were planted in alternate blocks. The minor treatments included foliar application of some plant hormones, fungicides, micronutrients and biofertilizer, soil application of nematicides and biofertilizer, and hand-pollination (Table 1).

The first round of minor treatments was done in early April, 1982, followed by two rounds at monthly intervals. While some of

Table 1. Effect of various treatments on flowering, capsule-set, immature shedding and yield

Treatment No.	Particulars	No. of flowers	% capsule-set	Dropping as % of capsule set	Dropping as % of total flowers	Yield as % of flowers opened
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1.	IAA 25 ppm	918.3	59.4	34.7	20.3	39.1
2.	IAA 50 ppm	884.3	56.6	37.0	20.5	36.1
3.	GA_3 10 ppm	1285.3	58.5	47.5	27.5	31.0
4.	GA_3 20 ppm	1091.8	56.0	51.0	28.4	27.7
5.	NAA 10 ppm	1163.0	63.0	43.3	27.2	35.9
6.	NAA 20 ppm	978.8	62.6	52.1	32.8	29.9
7.	Cycocel 0.01 A.S.	1209.0	58.9	40.9	24.1	34.8
8.	Cycocel 0.02 A.S.	1007.0	54.5	45.9	24.5	30.0
9.	2,4-D 10 ppm	1157.5	70.3	46.5	32.2	38.2
10.	2,4-D 20 ppm	740.8	68.4	59.8	40.8	27.7
11.	2,4,5-T 10 ppm	893.8	61.1	40.7	25.0	36.2
12.	2,4,5-T 20 ppm	1023.5	69.9	47.0	32.6	37.0
13.	Aliette 0.1%	1080.5	60.0	41.5	23.5	36.5
14.	Brassicol 0.4%	938.5	54.9	43.8	24.2	30.8

Contd.

(1)	(2)	(3)	(4)	(5)	(6)	(7)
15.	Bordeaux Mixture 1%	1070.3	53.0	47.5	24.7	28.3
16.	Bavistin 0.05%	1070.75	55.1	43.4	23.9	31.3
17.	Planofix 10 ppm	1002.5	65.0	39.2	25.4	39.6
18.	Miraculan .5 ml/ciump	1144.5	63.3	39.2	24.7	38.6
19.	Dithane M-45 0.3%	1058.3	59.9	46.8	27.9	32.0
20.	Temik 10G 25/g clump	1110.5	55.9	44.0	24.3	31.7
21.	Zinc 500 ppm	751.3	61.7	38.4	23.8	35.4
22.	Boron 200 ppm	1020.8	57.7	45.4	26.3	31.6
23.	Copper 100 ppm	1054.0	61.3	31.8	19.5	41.8
24.	IAA+GA_3+NAA (25+10+10 ppm)	1368.8	65.8	48.1	31.4	34.4
25.	IAA+GA_3+NAA (50+20+20 ppm)	839.0	61.9	65.5	40.5	21.3
26.	Zinc+Boron+Copper (500+200+100 ppm)	1099.3	56.1	45.5	25.0	31.0
27.	Azovigor (Soil application 10g/plant)	770.0	60.4	24.1	14.4	45.3
28.	Azovigor (Foliar application 10g/plant)	983.5	59.6	33.0	19.4	41.2
29.	Hand-pollination	792.5	60.7	34.8	21.1	39.5
30.	Control	1153.3	58.8	37.9	22.1	36.7
	S.F./Plot	336.2	5.9	9.3	4.0	7.4
	Gen. Mean	1022.0	60.3	43.2	25.9	34.3
	F. Test	N.S.	**	**	**	*
	C.V.%	32.9	9.8	21.6	19.4	21.5
	C.D. (P=0.05)	—	8.3	13.1	11.1	10.4

**Significant at 1% level *Significant at 5% level

Table 2. Effect of various treatments on morphological characters

Treatment No.	No. of tillers	No. of panicle-bearing tillers	Height of tillers	No. of panicles	Length of panicles (cm)	No. of spikes/ panicle	Av. no. of flowers/panicle
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1.	129.8	34.9	212.3	51.7	34.8	13.8	62.3
2.	121.5	28.9	200.0	43.9	34.0	14.3	65.0
3.	97.4	36.3	221.8	58.0	42.0	15.8	86.0
4.	99.8	31.3	223.5	42.1	47.0	15.0	73.3
5.	119.2	33.0	218.3	47.4	37.8	16.0	75.5
6.	126.1	34.4	200.0	48.2	36.3	15.3	69.5
7.	121.0	32.7	205.7	55.4	37.8	15.0	72.8
8.	117.8	30.6	205.7	47.7	42.0	16.8	71.0
9.	11.9	33.9	222.8	51.5	43.5	16.3	68.8
10.	116.2	36.7	213.6	55.1	35.0	15.3	57.5
11.	117.2	32.0	208.5	48.2	33.0	14.0	67.8
12.	112.1	28.9	209.8	46.7	33.5	15.0	67.3
13.	115.0	32.4	212.0	44.6	42.0	16.0	70.0
14.	128.1	30.7	199.0	50.7	33.8	14.8	66.0
15	121.7	36.8	209.8	55.8	31.8	14.3	61.3
16.	116.6	31.0	196.3	47.0	29.3	14.3	73.3

Contd.

17.	121.9	31.3	210.0	49.9	40.0	14.8	67.8
18.	107.7	27.8	196.0	51.0	40.8	15.0	74.3
19.	131.1	32.0	206.3	55.3	35.8	15.8	71.3
20.	122.1	32.4	211.0	52.8	38.5	15.0	76.0
21.	114.8	30.6	202.3	44.7	36.3	13.8	57.3
22.	131.2	34.4	200.5	50.4	31.5	14.3	65.5
23.	123.9	33.8	203.2	41.7	46.3	17.0	76.5
24.	106.8	33.1	220.7	58.6	49.3	16.8	80.5
25.	105.8	32.4	231.3	48.0	41.0	13.5	54.3
26.	118.0	34.3	205.3	51.8	39.5	16.3	73.0
27.	113.3	35.1	205.9	54.9	34.8	13.3	62.8
28.	125.0	32.1	205.1	54.2	44.5	16.8	75.8
29.	125.6	37.6	216.1	60.4	38.3	13.8	63.8
30.	129.9	32.2	202.8	49.8	39.0	16.0	79.3
S.E./plot	11.0	5.5	11.4	7.4	8.8	2.3	14.1
Gen. Mean-x	75.0	24.4	188.5	34.9	—	—	—
Gen. Mean-y	118.3	32.8	209.3	51.0	38.3	15.1	69.9
C.V.%	9.3	16.7	5.4	14.5	23.0	15.0	20.1
F. Test	**	NS	**	NS	—	—	**
C.D. (P=0.05)	15.6	—	16.1	—	—	—	19.8

x=Pre-treatment; y=Post-treatment **Significant at 1% level them (Nos. 20, 27 and 28) were limited to the first round, hand-pollination (No. 29) was done daily morning.

Five panicles from each of the plants were marked for recording observations on the number of blossoms opening daily and the capsules that aborted on alternate days, from 18th April to 20th August. Total capsule-set in these panicles was recorded which gave the actual yield (Table 1). Pre-as well as post-treatment vegetative growth data of plants such as, number of tillers, number of panicle-bearing tillers, height of tillers, and number of panicles were recorded. The values of adjusted means (after univariant analysis), for the length of panicles, average number of spikes per panicles and average number of flowers opened per panicle are presented in Table 2.

Results and Discussion

In the trial area, initial showers of the season were received in the last week of March (15 mm), and April (15 mm), regular light rains from the second half of May, and continuous downpour during June, and August.

Stray flowering was observed during April and the rate of flowering increased as the season advanced. Maximum flowering was recorded during June and first fortnight of July. Between the two major treatments, when the data were collected, no significant difference could be noted. In general, the average number of flowers per panicle that opened during the period of observation was lower for plants under treatment (69.9 than the control (79.3). However, maximum flowering (86 and 80.5 per panicle) was recorded under treatments 3 and 24 in which GA_3 (10 ppm) was common. Significant reduction in flowering was recorded under treatments 10 (2,4-D 20 ppm) and 21 (Zinc 500 ppm). A lower number of flowers than control was also recorded under treatments 1 (IAA 25 ppm) and 15 (Bordeaux mixture 1 per cent).

Percentage of capsule-set was found to be significantly higher under treatment numbers 9 (2, 4-D 10 ppm), 10 (2, 4-D 20 ppm), 12 (2,4,5-T 20 ppm), 17 (Planofix) and 24 (IAA+GA_3+NAA, 25+10+10 ppm). NAA is common for treatments 17 and 24.

Though the values are not statistically significant, the same is true with the other treatments (5 & 6) where NAA (10 and 20 ppm respectively) was used. The lowest percentage of capsule-set was recorded under treatments 14 (Brassicol 0.4 per cent) and 15, (Bordeaux mixture 1 per cent).

Capsule shedding, whether as percentage of total flowers opened or total flowers fertilized or as actual number shed from the panicle showed similar trends, and the treatment effects were highly significant. Maximum and highly significant reduction in shedding was recorded under treatment No. 27 (Azovigor, soil application). This was followed by treatment Nos. 28 (Azovigor, foliar application), 23 (Copper 100 ppm), 1 (IAA 25ppm), 2 (IAA 50ppm), and 29 (hand-pollination), respectively. Significantly higher rate of shedding was recorded under treatments 6 (NAA 20ppm), 9 (2,4-D 10ppm) 10 (2,4-D 20ppm), and 25 (IAA+GA_3+NAA 50+20+20 ppm). Increased shedding was also recorded under treatments 12 (2,4 5-T 20ppm), 15 (Bordeaux mixture), 19 (Dithane M-45), 22 (Boron 200 ppm) and 24 (IAA+GA_3+NAA 25+10+10 ppm).

Yield, recorded as number of capsules, did not vary significantly between treatments. However, when considered as percentage of total flowers that opened, it showed significant effects. Significantly higher yield was recorded under treatment 27, followed by treatments 28 and 23. Though not statistically significant, low yield was recorded under treatments 3, 4, 6, 8, 10, 15 and 25.

The increased flowering observed under treatments 3 and 24 has not led to high yield owing to the very high rate of shedding recorded under these treatments. Increased capsule-set recorded under treatments 9, 10, 12 and 24 has not resulted in high yield due to the same reason. Poor yield was recorded under treatments 8, 10 and 15 owing to low percentage of capsule-set.

None of the hormones or hormone formulations or the fungicides have helped in reducing the shedding and thereby increase the yield. On the contrary, spraying of certain fungicides has reduced the yield by lowering percentage of capsule-set as well as by increasing shedding.

Among the micro-nutrients applied, copper at the rate of 100 ppm has recorded maximum yield, by reducing the shedding, whereas Boron (200 ppm) increased shedding.

Biofertilizer, both as soil and foliar application, was effective in increasing yield by reducing shedding. Hand-pollination also recorded higher yield as a result of reduced shedding.

The data obtained so far from the experiment indicate that the genetic make-up of the plant has little effect on the rate of variation of immature capsule shedding in cardamom. Indiscriminate use of many chemicals in cardamom plantations adversely affects the flowering and fruiting habit of the plant. Positive effects of biofertilizer (soil application), can be attributed to increased microbiological activity in the root zone of the plants and consequent improvement of structure and fertility of soil.

Acknowledgement

The authors are thankful to Dr M.R. Sethuraj, Director, R.R.I.I., Kottayam and Prof. M. Lakshmanan, Madurai Kamaraj University, Madurai, for their valuable suggestions in the conduct of the trial. The statistical analysis of the data was done at CPCRI, Kasaragod, and this is thankfully acknowledged. We are also grateful to Sri K. V. George, Director, Cardamom Board, Cochin, for the facilities provided and we also thank Sri P. K. Harris, Harryland Estate, Periya for all the help rendered during the studies.

Discussion

R. CHANDRASEKARAN (UPASI, Vandiperiyar): What is the age of the panicle that was taken for observation?

K. J. MADHUSOODANAN: The panicles which emerged during January to March, were used for the study.

M. K. NAIR (CPCRI, Calicut): This seems to be a comprehensive trial consisting of two major treatments, thirty minor treatments and two varieties. Chemicals have been applied on the leaves and below soil. I would like to know the methodology followed in analysing the data and drawing the conclusion.

K. J. MADHUSOODANAN: Analysis of variance between treatments only have been worked out.

T. THANGARAJ (TNAU, Coimbatore): I would like to know the physiological effect of Cycocel in preventing capsule-shedding The results obtained indicate its negative effect in reducing capsule-shedding.

K. J. MADHUSOODANAN: Since the actual cause of fruit shedding is not clear, a growth retardant, Cycocel, has also been included as one of the treatments. The results indicate its negative effect in reducing capsule-drop.

P. RETHINAM (CPCRI, Kasaragod): (1) What are the physiological aspects studied in this trial to say that Azovigor is preventing shedding and increasing the yield?

(2) More thrust is being given by Cardamom Board research workers for Azovigor, with inadequate research results.

K. J. MADHUSOODANAN: (1) Number of flowers opened, percentage set of capsules, number of droppings etc. were recorded daily, and under this treatment shedding was minimum with consequent increase in yield.

(2) Question is irrelevent with the context. Only the data obtained so far from the trials conducted have been presented. The results are not at the recommendation stage for the farmers.

EAPEN GEORGE (A.V. Thomas & Co. Ltd., Cochin): Please verify the trial before arriving at firm conclusions.

C. KUNHIKRISHNAN NAIR: Only preliminary observations have been reported, and the trial is being continued; final conclusions will be drawn only after further critical studies.

STUDIES ON THE EFFECT OF CHEMICAL TREATMENT ON THE GERMINATION OF CARDAMOM SEEDS

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ABSTRACT

Effect of pre-soaking of cardamom seeds in acetone, conc. hydrochloric and nitric acids for various durations, on germination, was studied. Periodical observations recorded on germination of seeds indicated that pre-soaking the cardamom seeds for 10 minutes in Acetone and for 5 minutes in concentrated hydrochloric and nitric acids gave increased germination compared to control. Increased exposure of cardamom seeds for over 5 minutes in concentrated hydrochloric and nitric acids had resulted in a decline in or no germination depending upon the durations tried. Among the treatments tried, acetone gave the maximum germination and also proved safer compared to conc. hydrocholric and nitric acids for cardamom seed treatment.

INTRODUCTION

Hastening and enhancing seed germination, particularly in commercially important crops like cardamom (*Elettaria cardamomum*) has many agronomic advantages. Several methods like mechanical and chemical scarification, are employed to improve the germination of crop seeds that are inherently poor in germination. Different chemicals have been tried in various crops to improve the germination (Akeson *et al.*, 1981). Organic chemicals like acetone were tried as carriers for growth regulators for treating the seeds to improve the germination of bean seeds (Muchovej *et al.*, 1980). Prasad *et al.* (1974) had successfully tried conc. hydrochloric and nitric acids, to improve the germination of cardamom seeds. Since conc. hydrochloric and nitric acids were found to be inconvenient to handle, particularly by the farmer, and also any prolonged treatment for over 5 minutes with the above acids resulted in poor or no germination, investigations were taken up to find out suitable alternate chemicals for cardamom seed treatment, and the results are reported in this paper.

MATERIALS AND METHODS

Germination trials were conducted between September and December in 1980 and 1981 at the UPASI Tea Research Sub-Station, Vandiperiyar.

Mature cardamom seeds were extracted from ripe capsules harvested from semi-erect type of cardamom plants. After extraction, the seeds were dried under shade in the laboratory. These seeds were kept in sealed polythene bags, for two months, before they were used for the germination studies.

Nursery beds brought to fine tilth, under an overhead shade of coir mats, were used for germination studies. Cardamom seeds, 200 per treatment, of uniform size and weight, were soaked in concentrated hydrochloric acid (sp. gr.=1.18), nitric acid (sp. gr.=1.41) and in acetone (purity 99 per cent) for 5, 10 and 30 minutes. The seeds were placed in glass beakers along with the treatment chemicals and soaked for the prescribed duration. Seeds were washed immediately in running water under a tap, dried in shade for about 6-8 hours, and sown on the same day along with untreated control. The beds were covered with a transparent polythene tent under an over-head coir-mat shade. Watering was done as and when necessary. Germination was recorded 40, 50, 60 and 70 days after sowing.

RESULTS AND DISCUSSION

Treatment details and germination count are given in Tables 1 and 2.

The overall germination at the end of 70 days was better when the seeds were pre-soaked for 10 minutes in acetone and for 5 minutes in conc. hydrochloric acid and conc. nitric acid in that order compared to control (Table 1.) Early germination was observed when seeds were treated with hydrochloric acid for 5 minutes. From the data given in Table 1, it could be observed that the pre-soaking treatment involving durations longer than 5 minutes in respect of conc. hydrochloric and nitric acids had resulted in poor or no germination. Pre-soaking in conc. hydrochloric and nitric acids for 10 minutes had reduced the germination by 15 and

14.5 per cent respectively, compared to pre-soaking for 5 minutes in the same chemicals, and the results were on par with control. Further, when pre-soaking was carried out for 40 minutes the seeds completely failed to germinate. However, no such deleterious effect was noticed in the treatment with acetone, though the percentage of germination had marginally dropped in 30 minutes soaking compared to 10 minutes soaking.

Table 1. Cardamom seed germination

Treatment	Pre-soaking time (min)	Percentage germination Days after sowing			
		40	50	60	70
Conc. Nitric acid	5	7.0	30.0	36.0	36.5
Conc. Nitric acid	10	1.5	15.5	21.5	27.0
Conc. Nitric acid	30	—	—	—	—
Conc. Hydrochloric acid	5	15.5	31.0	36.0	37.5
Conc. Hydrochloric acid	10	5.0	16.0	19.5	20.0
Conc. Hydrochloric acid	30	—	—	—	—
Acetone	5	5.0	22.0	32.0	36.5
Acetone	10	6.5	30.5	38.0	41.5
Acetone	30	6.0	29.0	35.5	37.5
Control	—	2.0	16.5	21.0	24.5
C.D. ($P=0.05$)	—	5.13	7.74	6.76	1.73

But for the earliness in germination and consequent initial advantage for growth, no appreciable visible difference in vigour was observed in the growth of the seedlings under different treatments, as judged by the time taken to produce the first leaf from emergence and also the height at which the first leaf was produced.

Although the action of the above chemicals on cardamom seeds is not fully understood, it appears that these chemicals soften the seed coat thereby favouring ready imbibition of water, which might have helped in early and improved germination.

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The authors wish to record their gratitude to Dr. C. S. Venkata Ram, Director, UPASI Tea Research Institute, for his guidance and encouragement in carrying out the investigations.

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SESSION IV

Technology and Processing

Chairman	:	**Dr EV Thomas**
Rapporteurs	:	**Dr S Ramaswamy**
		Shri SJK Annamalai

ALTERNATIVE MATERIALS FOR PACKING TEA

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ABSTRACT

Investigations were carried out to find out the suitability of "MM Wrap" (biaxially oriented polypropylene film) and "Teagard" (9 micron aluminium foil laminated to tissue paper) as tea chest inner lining materials and "Rubsteel" boxes (reinforced paper carton) as tea chest, in comparison with conventional lining material and plywood chests, respectively. Both the test lining materials compared favourably with the standard when tea packed over a period of one year was assessed for moisture pick-up, and organoleptic value and assayed for theaflavin content. "Rubsteel" box as possible substitute for plywood chest was also satisfactory.

INTRODUCTION

The present system of bulk packaging of black tea involves packing black tea in plywood chests containing inner lining material to minimize moisture pick up and to retain the characteristic flavour of tea. Traditionally, the lining material in use has been aluminium foil juxtaposed with tissue paper. Plywood chest and its components have been approved under ISI certification mark IS:10 (Part I-V) 1976 (Anon. 1976) for packing teas that are exported from India. Due to the high cost and shortage of plywood panels and other components, it was necessary to find out alternative materials for packing tea.

Various alternative materials, such as, corrugated paper board chests, jute hessian bags, etc., have been tried as substitutes to plywood chest by the Indian Institute of Packaging (Narayanan, 1976). But, none of them have been approved by ISI for packing tea for export purposes.

In the extensive storage trials carried out by Stephen Thanaraj and Ramaswamy (1980) involving 2 types of lining materials, viz., 300 MXXT cellophane film supplied by M/s. Travancore Rayons Ltd., Madras and metallized polyester film supplied by M/s. Garware Plastics and Polyester Ltd., Bombay, it was observed that 300 MXXT cellophane film and metallized polyester film compared satisfactorily with the conventional lining material, aluminium foil backed with tissue paper, and have subsequently been amended in IS:10 (Part I) 1976.

The present investigation was undertaken to find out the suitability of 2 lining materials and one tea chest for packing tea. The lining materials tested were "MM Wrap" (Biaxially oriented polypropylene film) supplied by M/s. M. M. Rubber Co. Ltd., Madras and "Teagard" (9 μ aluminium foil laminated to tissue paper) supplied by M/s. India Foils Ltd., Calcutta. The material tested as substitute for plywood chest was "Rubsteel", a reinforced paper carton, supplied by M/s. Steelsworth Ltd., Calcutta.

Materials and Methods

This experiment was carried out in Sirikundra Tea Factory in the Anamallais during 1981–82. CTC-Fine Dust (CTC-FD) tea was packed in plywood chests of the size $40 \times 40 \times 50$ cm, conforming to ISI specifications, lined with either "MM Wrap" or "Teagard" or aluminium foil backed with tissue paper, and also in "Rubsteel" chests of $40 \times 50 \times 60$ cm size with and without aluminium foil-tissue as liner.

From the date of commencement of the experiment over a period of 365 days, the chests were periodically opened, on 13 occasions, and three replicates of samples were drawn, namely, from one of the top corners of the chest, middle of the chest, and the bulk after mixing. These samples were individually analysed in duplicates for moisture by the ISI oven method (Anon., 1973), and theaflavins (TF) by modified Roberts' spectrophotometric method as employed by Takeo and Oosawa (1976) and Ramaswamy (1977). Parallel sets of tea samples were sent to professional tea tasters for their evaluation and particularly for remark on "taint" if any. At the time of packing, the moisture content of CTC-FD tea was found to be 4.441 per cent.

Results and Discussion

The comparative properties of three tea-chest-lining, materials used in the present investigation, namely, aluminium foil, "MM Wrap" and "Teagard" are given in Table 1. "MM Wrap" seems to possess higher mechanical properties, such as, tensile strength, burst strength and elongation compared to that of aluminium foil and "Teagard". Based on moisture vapour transmission rate (MVT rate) of the materials in test it appears to indicate that aluminium foil and "Teagard" have better moisture barrier property when used as lining material in tea chest. However, the relative merits of these lining materials remain to be seen from the experimental evidences.

Table 1. Comparative properties of different Tea chest lining materials

Properties	Aluminium	"Teagard" foil	"MM Wrap"
Thickness (Microns)	20	9	18
Tensile Strength (kg/cm^2)	875	1738	2000
Burst Strength (kg/cm^2)	0.95	N.A.	5
Elongation (%)	1.5	1.2	85
MVT Rate (g/m^2/24h at 38°C, 90% RH)	0.1	0.6	7.3
Yield (m^2/kg)	19	39	44

N.A.: Not available.

In the present investigation, analysis of black tea was restricted to the determination of moisture and theaflavin contents, because the decline in value of tea during storage is attributed to the effect of moisture gain in tea, and the theaflavins which are responsible for briskness, brightness, and quality of tea liquor are also affected by moisture during storage of tea (Dougan, Glossop, Howard and Jones, 1978).

Moisture pick-up of CTC-FD tea packed in plywood chests with different liners during storage for 365 days is given in Fig. 1. From the date of commencement of the experiment over a period of one year, the respective moisture gains of CTC-FD tea packed in chests lined with aluminium foil-tissue, "MM Wrap" and "Teagard" were 2.358 per cent, 1.870 per cent and 2.625 per cent. It will be evident from Fig. 1 that "MM Wrap" resisted moisture better than "Teagard" and even aluminium foil-tissue. Although aluminium foil has got low MVT rate (Table 1), it did not exhibit better moisture barrier properties than "MM Wrap". It may be due to the fact that tight packing of tea in chests could have resulted in damage to the aluminium foil by way of increasing number of pin holes per unit area. But, in the case of "MM Wrap", the possible damage was very less, probably because of its better mechanical properties such as, tensile strength, burst strength and elongation.

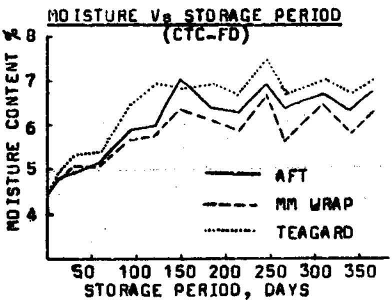
The relationship between storage period and moisture absorption of CTC-FD tea packed in "Rubsteel" chests, with and without liner, and plywood chests during storage is shown in Fig. 2. "Rubsteel" chests when used without lining material for packing tea showed poor moisture barrier property compared to using aluminium foil liners in "Rubsteel" chests. The use of aluminium foil liners in "Rubsteel" chests, however, restricted moisture pick-up of tea during storage better than that of the conventional plywood chest with aluminium foil liners.

Theaflavin content of CTC-FD tea packed in plywood chests lined with different lining materials are given in Fig. 3. The TF content of tea in all cases of packing showed an initial increase upto 30 days and a decline upto 60 days of storage followed by another rise upto 110 days and thereafter, a declining trend till the end of the trial. These findings confirm the observation reported earlier by Stephen Thanaraj and Ramaswamy (1980), and Cloughley (1981). However, teas packed in chests with aluminium foil-tissue, "MM Wrap" or "Teagard" did not show any significant difference in TF levels during storage.

On comparing the performance of "Rubsteel" chests with that of conventional plywood chests, from the illustration shown in Fig. 4, TF content of tea packed in "Rubsteel" chests with aluminium foil liners did not show appreciable change in their levels during storage compared to that of tea packed in plywood chests with alumium foil liner. However, tea packed in "Rubsteel" boxes without liner showed greater loss in TF levels during storage. This investigation suggests that incorporation of lining material with

"Rubsteel" chests could be of greater advantage in keeping the tea from chemical deterioration during storage.

The report from the tasters did not show either significant quality variation or any trace of taint in tea except in the case of



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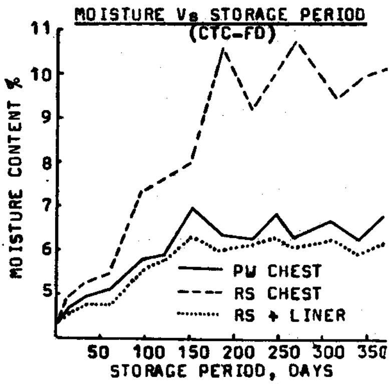

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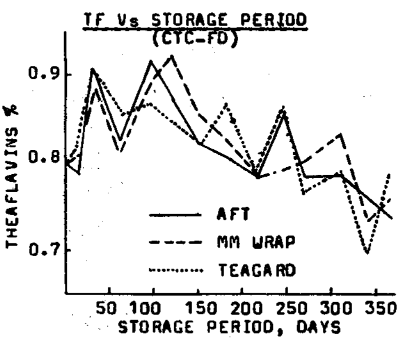

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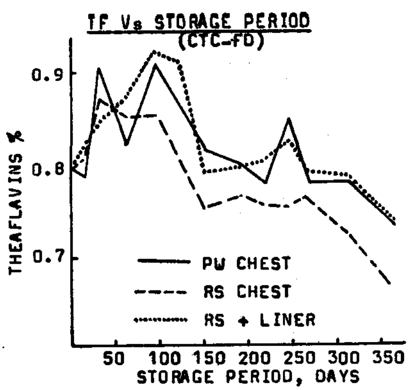

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Fig. 1. Moisture levels of CTC-FD tea during storage in plywood chests with different lining materials. Fig. 2. Moisture levels of CTC-FD tea during storage in plywood and "Rubsteel" chests Fig. 3. Theaflavin content of CTC-FD tea during storage in plywood chests with different lining materials. Fig. 4. Theaflavin content of CTC-Fine Dust tea during storage in plywood and "Rubsteel" chests.

(AFT=Aluminium Foil-Tissue). (PW=plywood) (RS=Rubsteel) tea packed in "Rubsteel" chests without liner, which was not preferred in any occasion.

Cost breakup of standard tea chests with different lining materials are given in Table 2. Comparing the cost of "MM Wrap" and "Teagard" with that of approved lining material such as aluminium foil-tissue, metallized polyester and cellophane film, the former is cheaper. "MM Wrap" alone shows 61-65 per cent saving if used in place of aluminium foil tissue, as against 35-39 per cent saving in case of "Teagard".

Table 2. Ruling prices of Tea chest components

Tea chest component	Price (Rs.)		
	40×50×60 cm	40×40×60 cm	40×40×50 cm
1. Panels	17.75	16.85	15.50
2. Battens	3.40	3.35	3.25
3. Fittings, Nails & Batten Covers	5.65	5.40	5.15
4. Liners:			
(*a*) Aluminium foil	5.20 (32.00)	4.60 (30.20)	4.10 (28.00)
(*b*) "MM Wrap"	2.02 (28.82)	1.63 (27.23)	1.43 (25.33)
(*c*) "Teagard"	3.38 (30.18)	2.91 (28.51)	2.50 (26.40)
(*d*) Cellophane 300 MXXT	3.78 (30.58)	3.29 (28.89)	2.89 (26.79)
(*e*) Metallized Polyester	4.65 (31.45)	4.03 (29.63)	3.54 (27.44)

Total costs of the Tea chests are given in parentheses.

Costs of different sizes of "Rubsteel" chests in comparison with that of plywood chests are given in Table 3. Eventhough "Rubsteel" chest costs more compared to plywood chests, it could be used as tea chest on the merit that "Rubsteel" chest requires less labour for assembling, occupies less space during storage before assembling, and could be recycled or reused.

Table 3. Cost of Plywood and "Rubsteel" Chests

Chest	Sizes		
	40×50×60 cm	40×40×60 cm	40×40×50 cm
	Rs. P.	Rs. P.	Rs. P.
Plywood chest	32.00	30.20	28.00
Rubsteel*	35.50	32.50	30.50

*Rubsteel chests can be reused or recycled.

Based on the above results, it is concluded that "MM Wrap" or "Teagard" can be used as alternative material to conventional aluminium foil-tissue as inner tea chest liners and "Rubsteel" chests with any of the approved lining material could be used for packing tea.

ACKNOWLEDGEMENT

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FORMATION OF TRICETINIDIN DURING TEA PROCESSING

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ABSTRACT

Formation of tricetinidin in clonal teas during fermentation and drying stages of processing was studied. Pattern of tricetinidin level in fermenting dhool was found to be similiar to that of theaflavins, the most important constituents of tea. During drying, appreciable increase in tricetinidin content was observed. Effect of drying on the levels of tricetinidin and theaflavins in made tea as influenced by temperature and aeration was also studied. The results indicated that tricetinidin is formed enzymically during fermentation and non-enzymically during drying stages of black tea processing.

INTRODUCTION

Anthocyanins lacking a 3-hydroxy group are very rare and they have been found in only four families of plant kingdom, namely, *Bignoniaceae*, *Gesneriaceae*, *Sterculiaceae* and *Theaceae* (Harborne, 1963). A delphinidin analogue in this series, tricetinidin (Fig. 1), had been found in processed tea leaves by Roberts

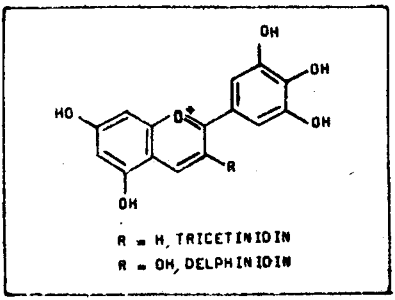


Fig. 1. Molecular structure of Tricetinidin.

and Williams (1958) who claimed that it was formed during processing by auto-oxidation of 1-*epi*gallocatechin gallate. Fresh tea leaves were reported to contain two anthocyanins, one of which appeared from its Rf values and spectral properties to be a derivative of tricetinidin (Vuatez, Brandenberger and Egli, 1959), While identifying the substrates of tea polyphenol oxidase using paper chromatographic techniques, Perera and Wickremasinghe (1972) observed that tricetinidin was formed on aerial oxidation of (–) *epi*gallo-catechin gallate even in the absence of enzyme. However, there is no information available on the extent of formation of this compound during tea processing. This paper presents the results of the investigation on the formation of tricetinidin in clonal teas during fermentation and drying stages of tea processing.

Materials and Methods

Experimental tea manufacture

Freshly plucked clonal tea leaves were spread at the rate of 10 kg/m^2 on a withering trough and allowed to wither artificially by means of warm air at 30°C and 45 per cent RH for 16-18 h. to achieve 70 per cent wither. The withered leaf was passed twice through a duplex CTC (crush, tear and curl) machine to bring about adequate physical damage. Suitable portions of the CTC processed leaf (dhool) were allowed to ferment for desired period at 25°C and 95 per cent RH, and dried using hot air at 100°C at the rate of 15000 M^3/min for 25 minutes in a 3–feet Sirocco Endless Chain Pressure (ECP) drier, to a final moisture of 3 per cent.

The drying was carried out without aeration in a Kaybee Moisture Tester by irradiating 25 g of dhool with 250W Infra Red lamp from a distance of 15 cm for a period of 15 min, to achieve 3 per cent moisture.

By controlling the damper at the hot air inlet chamber of the drier, the temperature and airflow were regulated to achieve required conditions of drying.

To achieve aeration during fermentation the airflow from an ½ H.P. axial fan was directed towards the dhool.

Preparation of brew

Four grammes of dry tea, or dhool equivalent to 4 g of dry tea was brewed with 200 ml boiling distilled water over a steam bath for a period of 10 min, filtered hot through glasswool and cooled.

Isobutyl Methyl Ketone Extract

To 50 ml of the cooled extract taken in a separating funnel, was added equal volume of isobutyl methyl ketone (IBMK) and shaken for a minute. The IBMK layer was separated and used for tricetinidin and theaflavin estimation.

Estimation of tricetinidin and theaflavin

Ten ml of IBMK extract was passed through a $2 \times \frac{1}{2}$cm cellulose acetate column and eluted with 1 per cent ethanolic HCl. The final fraction containing the tricetinidin was collected in a 10 ml volumetric flask (Lakshminarayanan and Ramaswamy, 1982). The optical density of the eluate was measured at 510nm using Spectronic-20 colorimeter and the tricetinidin content was expressed as cyanidin (Schou, 1927).

The estimation of theaflavins was carried out by following Roberts' method as employed by Ullah (1977), Ramaswamy (1977) and Takeo and Oosawa (1976). Tricetinidin and theaflavin contents were expressed on dry matter basis.

Results and Discussion

Analyses of tricetinidin and theaflavins in some clonal teas are shown in Table. 1. Though the level of tricetinidin is about one hundredth of theaflavins, its contribution to the colour in the long

Table 1. Tricettnidin and theaflavin contents of clonal teas

Clone	Tcn mg %	TF %
UPASI—3	20.93	1.35
UPASI—10	19.24	1.26
UPASI—15	18.75	1.40
UPASI—17	17.02	1.45
UPASI—22	12.49	1.07

Tcn: Tricetinidin
TF: Theaflavins
Ttricetinidin expressed as Cyanidin.

wavelength region of the visible spectrum is found to be appreciably high.

Tricetinidin and theaflavin levels in termenting dhools and in black teas made at different stages of fermentation are illustrated in Figures 2 and 3 for clones UPASI-3 and UPASI-10 respectively. Formation of tricetinidin and theaflavins in dhools and black teas of UPASI-3 has shown an increase upto an opitmum fermentation period of 45 min and a decline thereafter. Tricetinidin levels in black teas were found to be appreciably higher than that in the corresponding dhools at all stages of fermentation, whereas theaflavin levels in black teas and corresponding dhools did not show a considerable difference. For instance, at 45 min of fermentation an increase of 115 per cent in tricetnidin level was observed in black teas when compared to the dhool, whereas the increase was only 11 per cent in case of theaflavins. It is observed from the results shown in Figures 2 and 3 that 46 per cent of tricetinidin and 90 per cent of theaflavins found in black tea are formed during fermentation in case of clone UPASI-3, and 44 per cent of tricetinidin

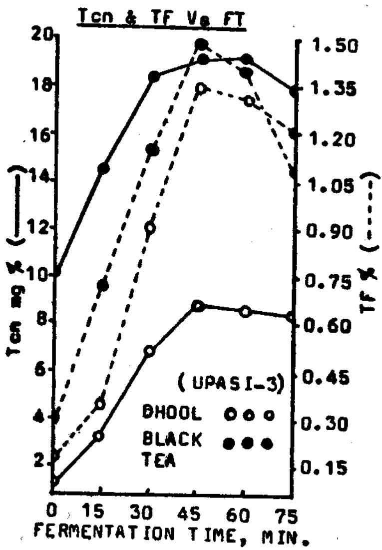


Fig. 2. Tricetinidin and theaflavin profiles during fermentation in dhools and black teas (UPASI-3)

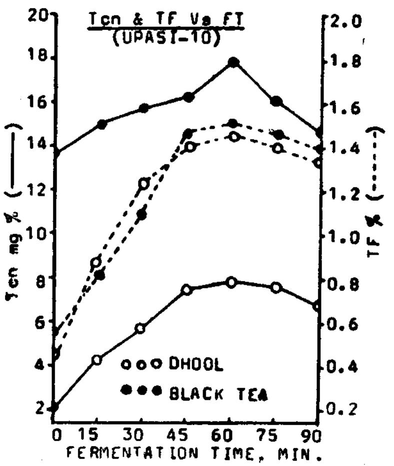


Fig. 3. Tricetinidin and theaflavin profiles during fermentation in dhools and black teas (UPASI-10)

and 96 per cent of theaflavins in case of UPASI-10, indicating that the extent of tricetinidin formation is greater during drying than during fermentation, quite contrary to the trend shown by theaflavins which are essentially formed during fermentation.

Earlier reports (Roberts, 1958; Ullah, 1977) have indicated that theaflavins are formed during fermentation and these pigments are closely associated with all the liquor characteristics viz. colour, strength, briskness and taster's quality. Although the role of tricetinidin in determining the quality of black tea is not known, it is seen from the present investigation that tricetinidin formation follows a pattern similar to that of theaflavins during fermentation, both showing maximum at the optimum fermentation periods of 45 min and 60 min for UPASI-3 and UPASI-10 respectively.

The pattern of tricetinidin and theaflavins formation during drying of dhools of UPASI-3 fermented for periods varying from 0 to 75 min is shown in Figures 4 and 5. It is observed that tricetini-

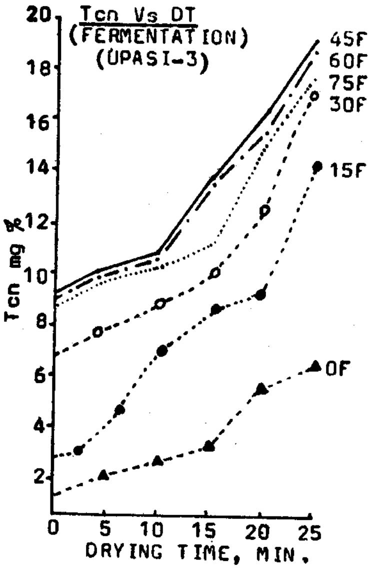


Fig. 4. Effect of fermentation period on tricetinidin formation during drying. (UPASI-3)

F. Period of fermentation (minutes)

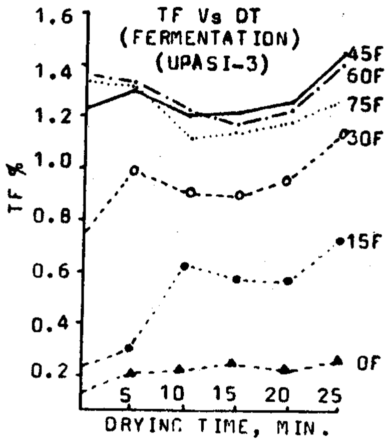


Fig. 5. Effect of fermentation period on theaflavin level during drying. (UPASI-3)

F. Period of fermentation (mins)

din level increased progressively throughout drying (Fig. 4), whereas theaflavin level showed a small initial rise upto 5 min., a steady state up to 20 min. and a gradual rise during final stage of drying (Fig. 5). Tricetinidin and theaflavin levels are found to be maximum in optimally fermented and fully fired teas.

A comparison was made between UPASI-3 and UPASI-17 with respect to the formation profiles of tricetinidin and theaflavins in optimally fermented dhool during drying (Fig. 6). While UPASI-3 showed a slow rise in tricetinidin level upto initial 10 min. of drying followed by a steep rise till completion of drying, UPASI-17, behaved just the opposite. As far as theaflavin profile during drying is concerned, UPASI-17 did not show an increase during drying, but UPASI-3 exhibited a small increase. At this stage, it can be surmised that tricetinidin formation is effected enzymatically during fermentation and nonenzymatically during drying.

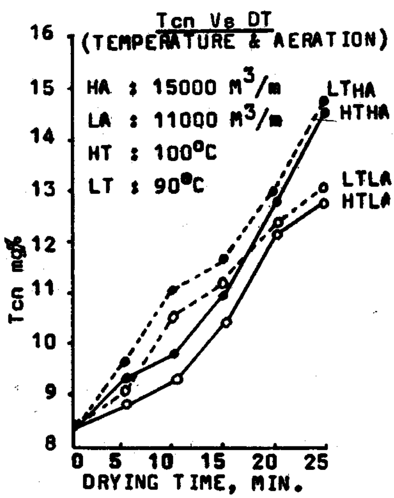


Fig. 6. Tricetinidin and theaflavin profiles during drying of optimum fermented dhools of clones UPASI-3 and UPASI-17.

Normally during drying enormous quantity of air is used at 100°C. This condition might help in aerial oxidation reaction and hence enhanced tricetinidin formation. The effect of aeration during fermentation and drying on tricetinidin and theaflavin contents of black tea of UPASI-3 given in Table 2, would reveal

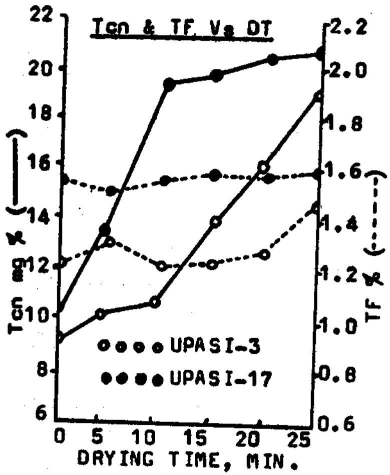
Table 2. Effect of aeration during processing on tricetinidin and theaflavin contents of black tea (UPASI-3)

AERATION (+ OR —) FERMENTATION	DRYING	Tcn mg %	TF %
—	—	7.95	1.15
—	—	7.95	1.27
+	+	15.89	1.58
—	+	18.16	1.47

(+) indicates the use of aeration
(−) indicates no aeration

that aeration during fermentation has not helped in increasing the tricetinidin, but has resulted in an increase of 10.4 per cent in theaflavin level. When aeration was employed only during drying, the increase in tricetinidin and theaflavin contents was observed to be 128 per cent and 27.8 per cent respectively over no aeration at all. The moment aeration was provided during fermentation in addition to drying, the increase in tricetinidin level was brought down to 99.9 per cent with concomitant improvement in theaflavin to 37.4 per cent. This may be due to greater conversion of catechins to quinones leading to theaflavin formation than transformation reactions leading to tricetinidin. The important observation from this experiment is that aeration during fermentation favoured only theaflavin formation, and aeration during drying greatly favoured the tricetinidin formation.

The effect of airflow rate and temperature during drying on tricetinidin and theaflavin levels is shown in Figures 7 and 8 respectively for clone UPASI-3. Conventionally, tea drying involves drying of dhool at 100°C with an airflow rate of 15000 M^3/min., as one of the conditions employed in this investigation. By altering the airflow rate and the temperature during drying it was observed that low temperature (90°C) favoured high rate of tricetinidin formation during early stage of drying, and during the final stage high aeration favoured its formation. It is seen from Figure 8 that formation of theaflavins is favoured by low temperature and low aeration during initial stages of drying and high temperature and high aeration during final stages of drying.



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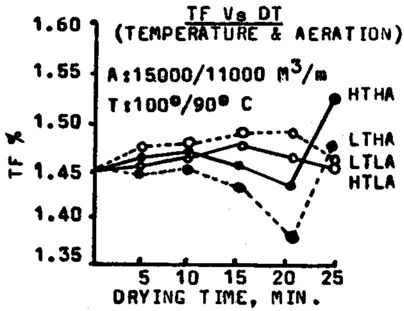

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Fig. 7. Effect of temperature and airflow rate during drying on tricetinidin level (UPASI-3).

HT - High temperature	- 100°C
LT - Low Temperature	- 90°C
HA - High Aeration	- 15000 M^3/min.
LA - Low Aeration	- 11000 M^3/min.

Fig. 8. Effect of temperature and air flow rate during drying on theaflavin level (UPASI-3).

HT - High Temperature	- 100°C
LT - Low Temperature	- 90°C
HA - High Aeration	- 15000 M^3/min.
LA - Low Aeration	- 11000M^3/min.

Conclusions arrived at from this study are: (1) tricetinidin formation is maximum at the optimum fermentation time; based on this, tricetinidin can be an index for determining the optimum fermentation period of tea clones, (2) tricetinidin formation is enzymic during fermentation and non-enzymic during drying stages of tea processing, and (3) the patterns of both tricetinidin and theaflavin formation during drying suggests the need for a modification in the present system of drying tea in ECP driers.

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SURVEY TO ASSESS THE QUALITY OF PROCESSED COCOA BEANS

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Abstract

The processed cocoa beans of monsoon and summer collected from the various processing centres in Karnataka and Kerala states were used to assess the quality. Bean acidity (pH and titrable acidity of the nibs), moisture content, shell per cent, bean weight and fat content were assessed. The pH of the samples ranged from 4.90 to 6.05 and the average bean weight varied from 0.62 to 1.20 gm. Smaller beans were more in monsoon crop, as compared to summer indicating the seasonal variation. The moisture content of the beans in different samples varied between 4.50 and 8.75 per cent. The shell and fat content of the processed beans ranged from 14-20 and 40.5-50.0 per cent respectively.

Cut test was carried out to evaluate the extent of fermentation of the beans (brown, brown/purple and purple beans). The percentage of defective beans such as germinated, flat, slaty, broken, moldy and insect-infested beans was recorded.

Introduction

Cocoa is mainly grown as a mixed crop in coconut and arecanut plantations covering an area of 28,000 hectares. The production is increasing in our country and the anticipated production is about 20,000 tonnes by 1985. After meeting the internal demand, the surplus produce has to be exported. Therefore, the quality of the beans should meet the international standards to fetch a good price. The prime interest of chocolate manufacturers in respect of quality of the cocoa beans lies in the flavour it develops after processing and roasting. Cocoa of marketable quality is required to be free from insects and broken beans. Grading in cocoa is done on the basis of limits to its content of particular defects, viz. moldy, slaty, flat and germinated beans. The manufacturer's needs with respect to quality of cocoa beans are outlined by Wood (1979). Mold is detectable in very small quantities (4 per cent) in the finished chocolate. So far no studies have been carried out to assess the quality of the processed beans, although there was a report on the inferior quality of the beans (Balasimha *et al.* 1980). In the present investigation the author reports on the survey conducted to assess the quality of the processed beans.

MATERIALS AND METHODS

Collection of beans: The processed cocoa beans were collected from the various processing units in Karnataka and Kerala states. The details regarding the fermentation and drying methods are given in Table 1. The samples included the processed beans of monsoon and summer season for comparison.

Table 1. Fermentation method, duration and drying of Cocoa at various processing units in Karnataka and Kerala States

Place	Method of fermentation	Mixing schedule	Duration of fermentation (days)	Drying
Puttur	box	1st, 2nd and 4th day	6	Samoan type (72-96 hrs)
Vittal	tray*/heap	2nd and 4th	6	Electric oven (72 hrs)
Kottayam	box/heap	2nd, 3rd and 5th day, or 2nd and 4th day	6	Electric oven (72 hrs) or Sundrying (96 to 144 hrs)
Tamarassery	heap	2nd and 4th day	6	Sun drying (96 to 144 hrs)
Wynad	box/tray*	2nd and 4th day	5/6	Samoan type/ Sun drying

*No mixing, and fermentation period is 5 days.

pH and moisture content: Ten gm of cocoa beans were ground to powder using pestle and mortar, transferred to 150 ml beaker, and 100 ml boiling water added to it. After cooling to room temperature, the pH was measured using digital pH meter. Another ten gm of beans were roughly crushed with the help of a cutter. The samples were kept in an oven regulated at 103±2°C for 16 hrs to determine the moisture content (per cent) of the beans (Anon. 1967). The 100–bean weight and shell content (per cent) were recorded.

Titratable acidity: Five ml extract, was made upto 100 ml with water, and titrated against 0.1N NaOH solution using phenolphthalein indicator. The amount of alkali used times 0.15 equals the titratable acidity.

Fat estimation: Twenty beans were powdered after removing the shell and 3 gm powder used for fat estimation using solvent petroleum ether (40-60°C grade) in a soxhlet extraction apparatus for 6 hrs. The solvent was evaporated in an oven to get a constant weight. The increased weight of the flask is the butter fat and percentage fat was calculated.

Visual method of assessment of processed cocoa (cut test): Cut test was carried out to evaluate the beans for the extent of fermentation (brown, brown/purple and purple beans). The moldy and insect infested beans were also recorded. For each sample, 25 beans were used for the cut test and 100 beans to record the defective beans. The percentage occurrence of germinated, flat, slaty and broken beans were recorded.

Results and Discussion

The observations revealed that different methods of fermentation (box, tray and heap) and drying (artificial and sun drying) were followed at the various processing units (Table 1). Further, there was variation in the mixing schedule adopted during the fermentation. However, the duration of fermentation remained same (6 days). No mixing was done in tray fermentation for a period of 5 days. The artificial driers include Samoan driers or electric ovens. Sun drying was given preference because of low cost and also results in superior quality beans.

The quality of processed beans in summer and monsoon season at different centres are presented in Table 2. Seasonal variation was observed in bean weight, indicating that bigger beans occurred in summer crop. The average bean weight varied from 0.62 to 1.20 g. The international standard requires a bean weight of one gram and above (maximum of 110 counts for 100 gm). Therefore, grading is required for the monsoon beans.

Table 2. Quality of the cocoa beans processed at different centres in Karnataka and Kerala states during summer and monsoon

Place	Season	100 bean wt. (gm)	Shell per cent	Moisture content (%)	pH	Titratable acidity (mg)	Butter fat (%)
Puttur	Summer	120.2	14.6	5.8	1.2	210	46.5
	Monsoon	80.4	15.4	4.5	5.2	210	40.5
Vittal	Summer	108.0	15.8	5.5	5.4	210	43.5
	Monsoon	85.0	18.9	6.0	5.4	225	48.0
Kottayam	Summer	104.5	14.2	6.2	5.4	225	42.6
	Monsoon	93.8	15.5	5.5	5.1	240	46.3
Tamarassery	Summer	109.1	14.7	5.6	5.6	210	48.9
	Monsoon	62.0	20.9	5.8	6.0	150	45.5
Wynad	Summer	110.7	15.8	6.0	5.6	225	44.5
	Monsoon	93.4	16.1	8.8	5.6	225	46.5
Nedumangad (Trivandrum)	Monsoon	75.3	18.5	7.2	4.8	285	42.6
Palghat	Monsoon	87.2	18.5	6.8	5.0	270	44.5
Trivandrum	Monsoon	83.3	16.5	6.2	5.2	195	45.5
Kottayam	Monsoon	73.3	17.8	5.9	5.2	210	48.0

The important parameters in the assessment of quality of the beans were pH and titratable acidity. The pH of the cocoa bean samples collected from different centres ranged from 4.80 to 6.05. Several samples collected from Central Arecanut Processing and Marketing Cooperatives Limited (CAMPCO) Cocoa Processing Unit, Puttur at different intervals showed a pH range of 4.90 to 5.35 (Table 3). Therefore, it indicates that standardization

Table 3. Variation in bean weight, shell per cent and pH of the processed bean at CAMPCO, Puttur, and CPCRI, Vittal

Place	100 bean weight (gms)	Shell per cent	pH
CAMPCO 1	80.4	15.4	4.9
CAMPCO 2	120.2	14.6	5.2
CAMPCO 3	70.3	19.2	5.3
CAMPCO 4	70.5	16.2	5.1
CAMPCO 5	110.4	15.5	5.1
CPCRI 1	108.0	15.8	6.1
CPCRI 2	89.9	15.9	5.4

is required in fermentation process. The survey indicated that many samples were in the limit of international standard (pH 5.3-5.5). The titratable acidity was in the range of 150 to 240 mg. The bean acidity is important in the preparation of chocolate, as it affects the quality by imparting acid taste.

The moisture percentage of the processed beans ranged from 4.5 to 8.8 (Table 2). The moisture content should be less than 7.5 per cent, as above 8 per cent moisture it encourages mold development during storage, thus affecting the quality (Wilbaux, 1965). The butter fat content of the processed beans varied from 40.5 to 49.0 per cent. The manufacturers are interested in bean size, shell per cent and butter fat content, but these factors are largely outside the control of growers.

Table 4 presents the results of cut test carried out to record the extent of fermentation, and moldy beans. The percentage occurrence of brown (fully fermented), brown/purple (partially fermented) and purple (unfermented) beans were recorded. The purple (violet beans are most undesirable with respect to quality. The partially fermented beans varied from 8-36 per cent. It has been shown that a certain proportion of fully fermented and partially fermented beans are required for the ideal flavour and aroma development in the products. Moldy beans were not observed in most of the samples. At the present time, in the absence of any other available objective method of assessing the degree of fermentation, the commonly used cut test for quality in relation to fermentation is recom-

Table 4. Cut Test—Extent of fermentation and moldy beans (per cent)

Place	Season	Brown	Brown/ purple	Purple	Moldy
Puttur	Summer	64	32	4	..
	Monsoon	60	30	4	..
Vittal	Summer	68	32	4	..
	Monsoon	60	32	8	..
Kottayam	Summer	64	32	4	..
	Monsoon	68	24	8	..
Tamarassery	Summer	60	28	12	..
	Monsoon	88	8	4	2
Wynad	Summer	56	32	12	..
	Monsoon	64	28	8	1

Table 5. Percentage of defective beans in processed cocoa at various units

Place & Season	Germinated beans	Flat beans	Slaty beans	Broken beans
Puttur				
Summer	..	2	2	3
Monsoon	..	3	3	1
Vittal				
Summer	1	1	3	..
Monsoon	..	2	3	2
Kottayam				
Summer	1	5	2	1
Monsoon	2	8	2	1
Tamarassery				
Summer	..	1	3	2
Monsoon	1	2	1	..
Wynad				
Summer	..	1	..	2
Monsoon	..	1	1	2

mended. The quality assessment is incomplete without the organoleptic evaluation by the expert taste panel either by paired comparison or triangular test (Rohan, 1963).

The percentage occurrence of germinated, flat, slaty and broken beans (defective beans) in processed cocoa at various centres is given in Table 5. Kottayam samples showed more number of flat beans. The flat, slaty and broken beans could be removed while grading the beans. Report of the Food and Agriculture Organisation's (FAO) Cocoa Study Group published in 1961 on cocoa has made some recommendations on quality and grading (Rohan, 1963). In conclusion, it may be said that the quality of the processed cocoa beans in our country is on par with that of Ghana or Nigerian beans. The slight bean acidity reported in a few samples could be easily overcome by manipulating the fermentation method.

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EFFECT OF INCORPORATION OF PEPTISERS AT LATEX STAGE ON PROPERTIES OF NATURAL RUBBER

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ABSTRACT

Peptisers when added to dry natural rubber during compounding help in reducing time for mastication. The effect of incorporation of various types of peptisers at latex stage on properties of natural rubber are studied in this paper. The peptisers are added at different dosages to NR latex and the resulting mixes are processed as crumb rubbers. The raw rubber properties, curing characteristics and technological properties of these rubbers are evaluated in comparison to those of conventionally processed block rubbers and viscosity stabilized rubbers.

INTRODUCTION

Natural rubber latex is processed into different marketable forms like Ribbed Smoked Sheet, Solid Block Rubber, Pale Latex Crepe and Concentrated Latex. Nearly 60 per cent of the rubber latex is converted into ribbed smoked sheets. Sheet rubbers especially the lower grades and the lower grades of block rubber are used by the tyre manufacturing industry for the production of different components of tyres like the tread and carcass. Higher grades of sheet rubber are used for the production of articles like inner tubes of automobile tyres, and non-tyre rubber goods manufactured for production of different coloured products.

Natural rubber undergoes hardening during storage (De Vries, 1927; Wood, 1952). Therefore, when it reaches the consumer's factory from producing estates, it will attain a Mooney Viscosity in the range of 80 to 90. This difficulty can be overcome by incorporation of hydroxylamine hydrochloride into latex at the time of processing (Sekhar, 1964). This procedure is adopted by some of the solid block rubber manufacturers in Malaysian estates and rubber is marketed as CV rubber (Chin Peng Sung, 1969). However, hydroxylamine hydrochloride is a costly chemical and is not freely available. Besides, hydroxylamine hydrochloride is not used as a compound ingredient in product manufacture. Therefore, it was thought appropriate to develop an alternate material which is readily available and used in rubber compounding operations for the purpose of preparing NR with low and controlled viscosity characteristics. Peptisers are a class of chemicals used in rubber compounding for reducing mastication time and viscosity of rubbers. Normally, they are added at the level of 0.4 to 0.5 phr at temperatures of 80-100°C during mastication. They function as promoters of oxidative breakdown of natural rubber during mastication (Michel Montu, 1953). The popular peptisers used in rubber mastication are, activated pentachloro-thiophenol (Renacit-7), and Mercaptobenzthiazole (MBT). Xylyl-mercaptan is used as a peptiser for rubber in certain applications.

Attempts to reduce the mooney viscosity of natural rubber by incorporation of petisers into ammoniated latex followed by heating of the latex at high temperatures have been reported (Marc Conte, 1954). However due to the presence of ammonia in latex, it was not able to get mooney values less than 85 in that experiment. The present study was taken up in this context to examine the effect of incorporation of peptisers into field latex followed by coagulation and processing into normal solid block rubber.

Materials and Methods

Natural rubber latex collected from the RRII Experiment Station was used as the starting material for the study. Two commonly used peptisers namely, Renacit-7 (manufactured by M/s. Bayer India, Ltd., Bombay) and MBT were used for latex stage peptisation of natural rubber. These chemicals were added to latex as a 33 per cent dispersion in water. Constant viscosity rubber was prepared by adding 0.15 phr or hydroxylamine hydrochloride into latex as a 10 per cent solution in water. The treated latexes were then acid coagulated and processed as normal solid block rubber in the pilot crumb rubber factory of Rubber Board.

To standardize the optimum concentration of peptisers which can be incorporated into NR latex, peptisers were added at different levels and properties such as mooney viscosity, initial wallace plasticity retention index and accelerated storage hardening (Anon., 1970) of the resulting rubbers were determined. Masticated natural rubber is having mooney Viscosity values in the range of 60-70. Hence peptised rubbers which give mooney viscosity values in this range were selected for comparing the raw rubber properties, processing properties and technological properties with that of CV and normally processed solid block rubbers (control). Raw rubber properties were evaluated as per IS methods (Anon., 1972). A treated mix (formulation given in Table 1) using polymerised 1,2-

Table 1. Formulation of Compound

Ingredients	Parts by weight			
	Mix 1	Mix 2	Mix 3	Mix 4
Latex stage Peptised Rubber (MBT-0.025 phr)	100	..	..	..
Latex stage Peptised Rubber (Renacit-7, 0.01 phr)	..	100	..	..
CV Rubber	..	..	100	..
Control	..	..	..	100
Zinc Oxide	3.5	3.5	3.5	3.5
Stearic Acid	2.0	2.0	2.0	2.0
Polymerised 1,2-Dihydro 2,2,4-Trimethyl Quinoline	1.0	1.0	1.0	1.0
Haf Black	50	50	50	50
Aromatic Process oil	5.0	5.0	5.0	5.0
Cyclohexyl Benz Thiazyl sulphenamide	0.6	0.6	0.6	0.6
Sulphur	2.5	2.5	2.5	2.5

dihydro 2,2,4-trimethyl quinoline as antioxidant was selected for comparing the processing and technological properties. Processing properties such as mastication time, scorch time and compound viscosity were evaluated. Cure characteristics of the samples were evaluated using Monsanto Rheometer R-100. Technological properties such as tensile strength, elongation at break, modulus (300 per cent), hardness, rebound resilience (Dunlop Trypsometer), Compression Set, abrasion resistance (Dupont Abradef) and Flex resistance (De Mattia flexing machine) were evaluated as per IS test methods for vulcanized rubbers (Anon, IS 3400). Heat build up of these samples were evaluated in Goodrich Flexometer as per ASTM,D 623-67 (Anon, ASTMD-623-67).

Latex stage peptised rubbers were also evaluated for flex resistance after compounding as per formulation given in Table 2 which contains an antiflex cracking agent N-(1,3-dimethyl butyl) N' phenyl p-phenylenediamine.

Table 2. Formulation of Compound

Ingredients	Parts by Weight			
	Mix 1	Mix 2	Mix 3	Mix 4
Latex stage Peptised Rubber (MBT-0.025 phr)	100	..	..	..
Latex stage Peptised Rubber (Renacit-7, 0.01 phr)	..	100	..	..
CV Rubber	..	..	100	..
Control	..	..	..	100
Zinc Oxide	3.5	3.5	3.5	3.5
Stearic Acid	2.0	2.0	2.0	2.0
Phenyl β–Naphthyl amine	1.0	1.0	1.0	1.0
N-(1-3 Dimethyl Butyl) N-phenyl p-phenylene diamine	1.0	1.0	1.0	1.0
Haf Black	50	50	50	50
Aromatic Process oil	5.0	5.0	5.0	5.0
Cyclohexyl Benz thiazyl sulphenamide	0.6	0.6	0.6	0.6
Sulphur	2.5	2.5	2.5	2.5

Results and Discussion

The results of trials for fixing the optimum concentration of peptisers are given in Table 3. It is seen that if MBT and Renacit-7 are added at levels above 0.15 phr, the resultant rubber becomes highly tacky due to excessive degradation. Mooney viscosity in the range of 60-70 was obtained when latex was treated with 0.025 phr MBT or 0.01 phr Renacit-7. PO and PRI values are slightly reduced for these rubbers compared to CV and control samples,

Table 3. Effect of varying concentration of peptisers on raw rubber properties

Treatment		Money viscosity ML (1+4) at 100°C	Initial Wallace Plasticity (PO)	Plasticity Retention Index (PRI)	Accelerated storage hardening (ΔP)
Peptiser	Conon. phr.				
MBT	0.5				
MBT	0.25	Rubber became tacky due to Excessive Degradation			
MBT	0.15				
MBT	0.1	49	22	54.5	+6
MBT	0.05	61	30	65.5	+10
MBT	0.025	62	30	65.5	+8
Renacit-7	0.5	Rubber became too much tacky			
Renacit-7	0.25		– do –		
Renacit-7	0.15		– do –		
Renacit-7	0.1	39	18	61.1	+4
Renacit-7	0.05	47	21	57.2	+6
Renacit-7	0.025	53	22	50	+6
Renacit-7	0.01	60	30	74	+4
Constant viscosity rubber	0.15 phr Hydroxyl-amine hydrochloride	71	39	76.9	+3
Control	Normal acid coagulated rubber	81	45	82.6	+12

but they fall within the specification limits prescribed for ISNR-5. Accelerated storage hardening of these peptised rubbers were less than the control, but higher than CV rubbers. Other raw rubber properties of these samples are given in Table-4. Nitrogen, ash content, volatile matter and dirt content of all these samples were within the limits specified for ISNR-5.

Table 4. Raw rubber properties

Treatment	Nitrogen (%)	Ash content (%)	Volatile matter (%)	Dirt content (%)
Rubber treated with 0.025 phr MBT	0.3721	0.3679	0.4812	0.0357
Rubber treated with 0.01 phr Renacit-7	0.3676	0.3655	0.5618	0.0381
CV Rubber	0.3918	0.4185	0.5272	0.0417
Control	0.3782	0.3504	0.4966	0.0393

Table 5. Processing properties

Properties	Mix 1	Mix 2	Mix 3	Mix 4
Mastication time (minutes)	4.5	5.5	7.0	8.5
Total Compounding time (minutes)	32.5	31	33.5	36.5
Scorch time at 120°C (minutes)	20.5	21.5	24.0	21.75
Optimum cure time at 150°C (minutes)	9.5	9.0	9.5	9.5

The processing properties of Mixes 1,2,3 and 4 are given in Table-5. The results show that the mastication time is reduced to an extent of 45 per cent for peptised rubbers compared to control samples. All other properties such as compound viscosity, scorch time at 120°C and optimum cure time at 150°C are comparable. This indicates an energy saving upto 50 per cent during rubber premastication processes.

The technological properties of Mixes 1,2,3 and 4 are given in Table-6. Tensile strength, modulus, tear strength, elongation at break, hardness, rebound resilience, properties after ageing, abrasion resistance, compression set and heat build up of all samples are comparable, However, flex resistance of peptised rubbers was inferior to CV and control rubbers (Table 7). It has been observed that with the incorporation of antiflex cracking agents during compounding, the flex resistance of peptised rubbers can be increased considerably and it becomes better than control and CV rubbers.

Table 6. Technological properties

Property	Mix 1	Mix 2	Mix 3	Mix 4
Tensile Strength (kg/cm^2)	240	240	230	240
Modulus (300%)	90	90	88	90
Elongation at Break (%)	610	610	600	610
Hardness (Shore A)	58	57	56	59
Resilience (%)	50.03	47.58	48.18	50.6
Tear Strength (kg/cm)	151.3	148.7	147.9	148.9
Abrasion Loss (cc/hour)	0.806	0.9633	0.9328	0.8264
Compression set (%)	45.4	42.5	49.8	38.5
Heat Build up ($\Delta T^\circ C$)	36	39	36	37
Flexing Initiation (K Cycles)	40.8	42.1	65.2	63
Failure (K Cycles)	98.8	98.8	135.6	117.1
After ageing at 70°C for 96 hrs.				
(a) Retention of tensile Strength (%)	100.8	93.7	104.3	99.2
(b) Retention of Elongation at Break (%)	86.9	85.2	90.0	86.06
(c) Retention of Modulus(%)	133.3	138.9	136.4	138.9

Table 7. Flex resistance

Property	Mix 5	Mix 6	Mix 7	Mix 8
Flexing Initiation (K Cycles)	75.88	60.01	60.01	65.80
Failure (K Cycles)	225.52	282.04	225.52	161.81

The incorporation of either of the two peptisers namely, MBT at 0.025 phr level or activated pentachloro-thiophenol at 0.01 phr level to natural rubber latex, reduces mooney viscosity of the resultant rubbers to the range of 60-70 which is the optimum viscosity for masticated rubber. The mastication time required for these rubbers is reduced to an extent of 45 per cent compared to control sample. The raw rubber, processing and technological properties of these rubbers are also comparable to CV and control samples.

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A NEW COAGULANT FOR NATURAL RUBBER LATEX

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ABSTRACT

Coagulant AC can be very safely used as coagulant for NR latex. The optimum dosage required for coagulation is 8 g per dry kg. rubber and coherent coagulum is obtained in about 2½ hrs. The rubber obtained with this coagulant has mooney viscosity about 4-6 units lower than conventional formic acid coagulanted rubber. The technological properties of the rubber processed with this coagulant is comparable to those obtained for conventionally processed rubbers.

INTRODUCTION

Coagulation of *Hevea* latex is the primary process in the conversion of latex to marketable forms of natural rubber viz., sheet, crepe or crumb. Field latex after dilution is conventionally coagulated with organic acids, usually formic or acetic acid. Formic acid is now the best available coagulant for NR latex. During the past years several other materials were tried and evaluated as coagulants for NR latex. Wiltshire (1932) suggested the use of sulfuric acid as a coagulant for latex. Later on further work on the use of sulfuric acid for coagulation was carried out by Martin and Davey (1934). They have reported that correct dosage of sulfuric acid for coagulation will not in any way affect the raw rubber properties or vulcanizate properties while excess quantity of sulfuric acid will deteriorate the properties of rubber. The findings of Martin and Davey was later confirmed by Van der Bie (1946) and Best and Morrel (1955). Other methods of coagulation have also been investigated. John (1966 a,b) reported the auto-coagulation of latex in about 48 hours by bacteria and yeasts. The time of coagulation can be further reduced to about 16 hrs by adding carbohydrates (John and New Sam, 1969). John and Pillai (1971) suggested the use of anionic surfactants for even speedy coagulation. In a later work John (1971) has reported the continuous coagulation of latex by the use of the surfactant dioctyl sodium sulfosuccinate and the salt calcium chloride at about neutral pH.

In the present paper attempts have been made to evaluate the suitability of coagulant AC, which is a derivative of sulphamic acid, supplied by M/s. Dharamsi Morarji Chemical Co., Ltd., Bombay. This chemical is a white free flowing solid, non-delequecant and highly soluble in water. The solid or the solution is non corossive and is less acidic than sulfuric acid.

Materials and Methods

The first part of the study was to find out the optimum dosage of this chemical for same-day coagulation and next-day coagulation. Field latex collected from the RRII experiment station was used for this study. Known weight of latex samples diluted to approximately 12.5 drc were coagulated by adding different quantities of coagulant AC ranging from 2-12 g/kg drc as one per cent solution with control samples coagulated with acetic acid and formic acid. Complete coagulation was observed within a period of 2-3 hours only in samples to which coagulant AC at the rate of 8 g/kg drc and above were added. Lower dosages of coagulant AC ranging from 5-7 g/kg drc were tried for next-day coagulation. Though coagulation was observed to be complete, air bubbles were observed on the lower surface of the wet coagulam. This coagulam on sheeting and drying had an unsatisfactory appearance. After fixing the optimum dosage of this chemical for the same-day coagulation of field latex, the percent recovery of rubber was evaluated. Known weight of latex samples were coagulated by adding coagulant AC, formic acid and acetic acid in the usual dosages for the same-day coagulation, the coagula were machined, washed, and dried at 70°C in an oven, determined the weight of dry sheets and calculated the percent of dry rubber content recovered. (Table 1).

NR latex was collected from 6 different sources. Each batch of latex was divided into two parts. One part from each batch was coagulated with formic acid as reference (4 ml per kg dry rubber). The other part was coagulated with coagulant AC (8 g per kg dry rubber). The pH of coagulation with formic acid and coagulant AC were 4.8 and 4.95 respectively. The latices for which formic acid was used as coagulant formed coherant coagulam in 3 hrs, while coagulant AC treated ones took only 2½ hrs. Of the six batches, 4 were processed into ribbed smoked sheet rubber and two

Table 1. Percent Recovery of Rubber

Coagulant AC	Formic Acid	Acetic Acid
8 gm/Kg. drc	4 cc/Kg. drc	8 cc/Kg. drc
36.67	36.65	36.68
36.64	36.67	36.69
41.03	41.08	41.04
41.04	41.00	40.91
40.42	40.30	40.43
40.38	40.36	40.48
40.37	40.37	40.35
40.33	40.35	40.35
40.27	40.25	40.25
40.25	40.24	40.29

into solid block rubber. These sheet rubber samples were subjected to visual examination, evaluation of raw rubber properties, acid retention in the raw rubber, cure properties and technological properties while the block rubber samples were subjected to evaluation of raw rubber and cure properties. Raw rubber properties were evaluated as per IS 3660 and technological properties as per IS 3400. The raw rubber properties studied were ash content, nitrogen content, initial plasticity (PO), plasticity retention index (PRI), accelerated storage hardening, Mooney Viscosity and acetone extractable materials. For evaluation of cure properties, with each sample a gum rubber compound as per ACS-I formulation and a tread compound were prepared. The formulations are given in Tables 2 and 3 respectively.

Table 2. ACS-1 Formulation

Natural Rubber	..	100
Stearic Acid	..	0.5
Zinc Oxide	..	6.0
MBT	..	0.5
Sulphur	..	3.5

Table 3. Tread Formulation

Natural Rubber	100
Stearic Acid ..	2.5
Zinc Oxide ..	3.5
HAF Black ..	50
Aromatic Oil ..	5
HSL Beads ..	1
CBS ..	0.6
Sulphur ..	2.5

Results and Discussion

Visual examination of the sheet rubber samples revealed that formic acid coagulated and those coagulated with coagulant AC belonged to the same grades. But the block rubber samples prepared by using coagulant AC possessed lighter colour over the control.

Raw Rubber Properties: From Table 4 and 5 it can be seen that the ash content, nitrogen content and acetone-extractable materials of the rubber obtained by using coagulant AC are comparable with those of the respective formic acid coagulated reference samples. Slightly softer rubber is obtained by coagulation with coagulant AC as evidenced by lower Po values and Mooney Viscosity. The response of the two types of rubber to accelerated storage hardening test is almost comparable. Tables 4 and 5 show slightly higher PRI values for the test samples over the control.

Evaluation of Cure Properties: Tables 6 and 7 give the data on cure characteristics. The gum rubber compounds prepared according to ACS-I formulation show an increase of 3-4 minutes at 150°C in cure time and about 15 minutes in scorch time at 120°C over the control compounds. But this difference is not observed in the case of the carbon black loaded tread rubber compound. Best and Morrel (1955) have reported that the tendency to scorch and the rate of vulcanization of rubber do not appear to be appreciably affected by the method of coagulation. This is found to be true only with the tread compound. The scorch safety of the compound suggests that the rubber coagulated using this material may be more advantageous in the production of products like tread rubber.

Table 4. Raw Rubber Properties of Sheet Rubber

Parameters	A1	B1	A2	B2	A3	B3	A4	B4
Ash Content %	0.339	0.328	0.271	0.287	0.261	0.311	0.226	0.297
Nitrogen Content %	0.413	0.429	0.382	0.405	0.411	0.425	0.418	0.446
Initial Plasticity (Po)	57	50	52	50	48	46	54	51
Plasticity Retention Index (PRI)	80.7	92.0	86.0	84.0	91.7	93.5	80.7	8[illegible]0
Accelerated Storage Hardening (No. of units hardened $\triangle$Po)	22	24	21	20	36	32	34	32
Mooney Viscosity (ML (1+4)100°C)	91	85	87	81	83	78	87	83
Acetone Extractable Materials %	2.57	2.47	3.64	3.33	2.42	2.20	2.47	2.48

A—Rubber Coagulated with Formic Acid

B—Rubber Coagulated with Coagulant AC

Table 5. Raw Rubber Properties of Block Rubber Samples

Parameters	A5	B5	A6	B6
Ash Content %	0.184	0.166	0.229	0.215
Nitrogen Content %	0.390	0.450	0.351	0.372
Initial Plasticity (Po)	53	51	51	48
Plasticity Retention Index (PRI)	77.0	80.0	79.0	82.0
Accelerated Storage Hardening (No. of units hardened, ΔPo)	19	20	20	18
Mooney Viscosity ML (1+4) 100°C	80	74	83	78
Accelerated Extractable Materials %	3.42	3.30	2.70	2.52

A—Rubber Coagulated with Formic Acid
B—Rubber Coagulated with Coagulant AC

Table 6. Cure Properties of Rubber Compound from Sheet Rubber

Sample	Gum Compound		Tread Compound	
	Cure time at 150°C)	Scorch time at 120°C	Cure time at 150°C	Scorch time at 120°C
A1	16′	18′30″	10′	28′
B1	20′45″	35′	10′	26′
A2	17′5″	22′30″	10′	27′
B2	20′	37′30″	10′	28′
A3	16′30″	21′	9′30″	26′
B3	20′	33′	9′30″	25′
A4	15′	20′	9′	24′
B4	18′30″	31′	9′30″	26′

A—Rubber Coagulated with Formic Acid
B—Rubber Coagulated with Coagulant AC

Table 7. Cure Properties of Rubber Compounds from Block Rubber

Sample	Gum Compound		Tread Compound	
	Cure time at 150°C	Scorch time at 120°C	Cure time at 150°C	Scorch time at 120°C
A5	16′30″	21′	10′	27′30″
B5	20′30″	36′30″	10′	27′
A6	16′	22′30″	10′	27′30″
B6	20′30″	35′	9′30″	28′30″

A—Rubber Coagulated with Formic Acid
B—Rubber Coagulated with Coagulant AC

Table 8. Evaluation of Technological Properties

Properties		A1	B1	A2	B2	A3	B3	A4	B4
Modulus 300% kg/cm²		85	82	77	77	87	85	95	90
Elongation at break %	Before	630	610	660	625	610	600	605	595
Tensile Strength kg/cm²	ageing	238	246	237	224	235	245	243	220
Modulus 300% kg/cm²		117	115	113	112	121	120	120	120
Elongation at break %	After	542	530	580	537	523	520	548	533
Tensile Strength kg/cm²	ageing	242	240	263	232	240	240	248	219
Hardness Shore A		57	55	55	55	56	58	59	55
Heat Build up $\triangle T^{c}F$		39	38	38	39	38	40	38	39
Compression Set %		31.16	31.75	39.13	41.80	35.57	33.55	33.89	36.39
Abrasion loss in Volume CC/hr.		1.664	1.545	..	..	..	..	1.521	1.406
Flex Cracking (Initiation Kilocycles)		32.23	32.23	32.23	32.23	32.23	32.23	32.23	32.23
Failure (Kilocycles)									
Tear Strength kg/cm		72.59	86.49	81.13	86.41	85.51	77.12	84.24	82.33
Ozone Resistance (% Retention of Property)		25	25	25	25	20	25	25	30

A—Rubber Coagulated with Formic Acid

B—Rubber Coagulated with Coagulaant AC

Evaluation of Technological Properties: The technological properties evaluated are modulus, elongation at break and tensile strength before and after ageing at 70°C for 96 hrs., hardness, heat build up, compression set, resilience, abrassion loss, flex cracking, tear strength and ozone resistance. The values obtained for all these parameters prepared from rubber obtained by coagulation with coagulant AC is comparable with those of the reference rubber compound.

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DESIGN AND DEVELOPMENT OF COPRA DRYER USING AGRICULTURAL WASTE AS SOURCE OF ENERGY

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ABSTRACT

Keeping in view the pressure on land in Kerala, the main coconut growing state in India which restricts the use of dryers needing permanent building and high initial investment, a small capacity dryer was designed and fabricated from materials such as MS angle, GI sheet, and AC sheets. This dryer consists of a drying chamber, plenum chamber and burning-cum-heat exchanging unit. A chimney is provided to control the rate of combustion and thus drying air temperature. An adjustable damper is provided to control the entry of fresh air for drying. The dryer could accomodate a maximum of 400 nuts per batch. Any dry agricultural waste could be used as fuel. The drying air temperature is kept at 70 to 80°C and time required for drying is 37.5 hours. The cost of the dryer is only Rs. 1000/- and it needs only 2m^2 area for housing.

INTRODUCTION

Fresh coconut meat contains about 45-50 per cent moisture on wet basis and it has to be dried to 6 per cent moisture for safe storage and further processing. A dryer for use during rainy season, when conventional practice of sun drying is not possible, has been a long felt need. Copra being easily susceptible to infestation by micro-organisms, cannot be dried even with intermittent supply of solar energy in the beginning and at the end of the monsoon season. The average land holding being 0.2 ha and about 90 per cent farmers holding less than 1 ha of land (Thampan, 1981), makes the other highly developed copra dryers (Grimwood; 1975, Gartia, 1978; Anonymous, 1980) impractical and uneconomical. The low cost kiln dryers could also not be used due to inferior and non-uniformly dried copra obtained from them.

The indirect type of small dryer, with provision to control the drying air temperature and using low cost easily available agricultural waste as fuel, was designed and developed by the author at the Central Plantation Crops Research Institute, Kasaragod.

Description of the Dryer: The dryer was fabricated from M.S. angle, Asbestos Cement sheets, G.I. sheets and asbestos rope as raw materials. The cost of the materials required is given in Table 1.

Table 1. Materials required for the fabrication of the dryer

Material	Size	Quantity
M S Angle	38mm 38mm 3mm	20 m
M S Flat	38mm 3mm	22 m
M S Flat	25mm 6mm	5 m
G I sheet (corrugated)	22 gauge	1.5 m^2
G I sheet	22 gauge	1.5 m^2
Asbestos sheet	4mm	6 m^2
Asbestos rope	12.5 mm	10 m
G I bolts and washers	—	2 pkts.
Hinges	5 cm	6 nos.

The dryer as shown in Figures 1a and b has the following components.

Drying chamber: It is made of asbestos cement sheets on the sides and wire mesh tray at the bottom, supported on an M.S. angle frame. The volume of the chamber is 0.34 m^3.

Plenum chamber: It is an inverted prism-shaped chamber. It is made of asbestos cement sheets supported on M.S. angle frame. The volume of the chamber is 0.68m^3. At the bottom of the chamber an adjustable opening is provided to regulate the entry of the fresh air for drying. The burning cum heat exchanging unit is also located in the centre of the plenum chamber.

Burning-cum-heat exchanging unit: It is a 30 cm diameter cylinder made of 22 gauge galvanised iron sheet. Bottom half is made of plain GI sheet whereas upper half is made of corrugated GI sheet to get more surface area for heat transfer. The volume of the chamber is 0.085 m^3 and the surface area is 1.15 m^2. The length of the chamber is equal to the length of the plenum chamber. One end of the chamber is covered by asbestos cement sheet lined with GI sheet damper containing holes for the entry of air required for combustion. The other end is connected to a 10cm diameter chimney

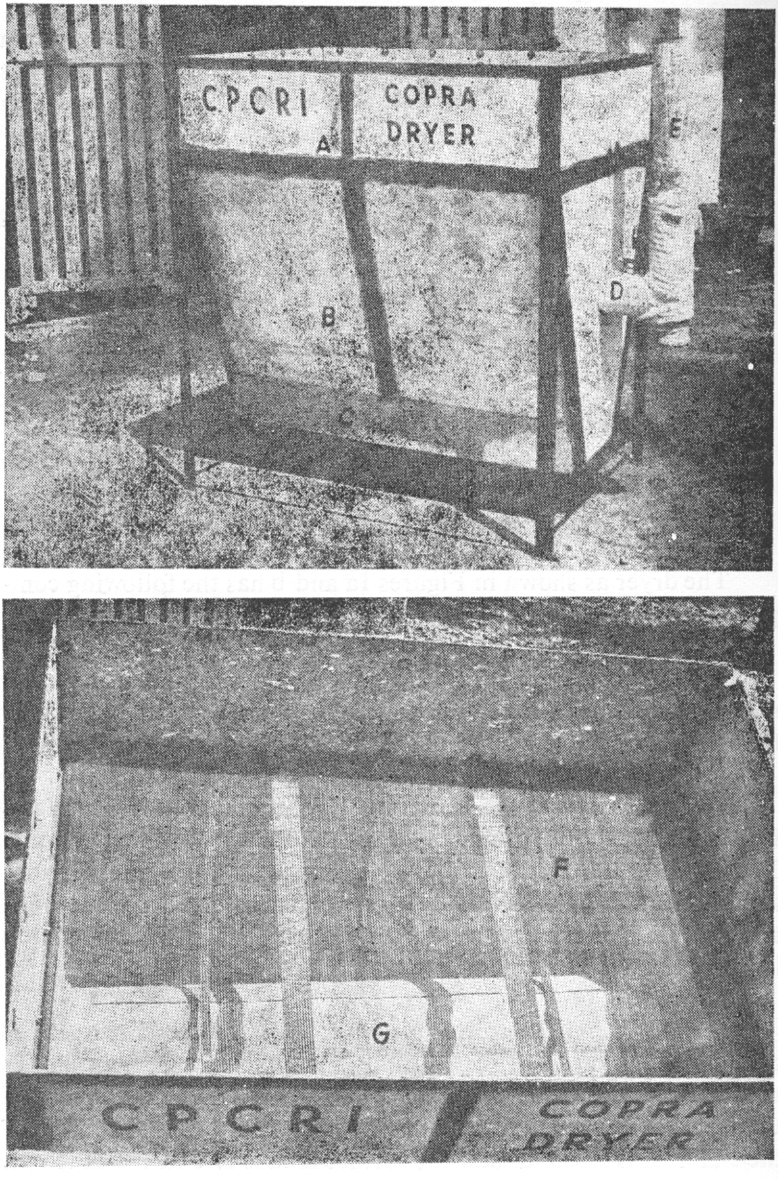

Fig. 1. a & b.

A—Drying Chamber B—Plenum Chamber C—Fresh air inlet
D—Butter-fly valves E—Chimney F—Drying Platform
G—Burning-heat exchanging unit

which lets out the flue gases after combustion. The cylinder is placed at an inclination of 3° for the smooth flow of gases. The fuel is burnt in that chamber in a welded wire mesh tray of 30cm × 15cm × 15cm.

In the chimney, two butterly valves are provided to regulate the escape of flue gases. This in turn regulates the entry of air for combustion and thus controls the drying air temperature. The chimney is covered by asbestos rope with plastering by plaster of Paris to avoid the danger of scalding during handling.

Principle of Operation: When the fuel is burnt in the burning chamber, due to higher temperature of flue-gas the GI sheet is heated up. The heat from GI sheet is transferred by radiation to the surrounding fresh air entering from the bottom. The hot air being light comes in contact with the wet material in the drying chamber. The hot air laden with moisture escapes in to the atmosphere from the top of the drying chamber. This phenomenon also helps the natural convection of the air through the drying bed. The dial thermometer was fixed just below the drying platform to measure the temperature of the incoming hot air to the drying chamber.

Operation of the Dryer: The nuts were cut into two halves after dehusking and nut water was drained off. The nuts were kept in inverted position for 15 min to remove the adhering moisture. Then the cups are loaded in the drying chamber, the first two bottom layers with the cups facing up and the rest of the cups being kept face down until full capacity is reached in brick fashion. The fuel is then kept in the welded wire-mesh tray and fired. The tray is kept in the centre of the cylinder (burning chamber) and fuel is fed as and when required to keep the fire burning. The temperature in the dryer is recorded on the dial thermometer, and if found more, the valve positions are adjusted to maintain the required temperature.

Materials and Methods

The dryer was tested for drying time required at 70°C for 150, 250 and 400 coconuts per batch capacity. The first two layers were stacked facing up and the remaining cups were arranged in the inverted position in brick fashion. Drying was carried out from 07.00 to 17.00 hours each day, On the second day, the shells were removed when possible. The cups found difficult for shell removal were placed at the bottom facing up. The bottom two layers were occupied by the cups with kernels inverted above them. The shells from the bottom layer were removed at the end of second day. The drying was continued till the moisture content of copra reached 6 per cent. The copra cups were raked after every two hours during drying.

The fuel used was husk, shell and a mixture of husk, shell, petiole and spathe. The temperature of drying air for drying time test was kept at 70°C for all three capacities of 150, 250 and 400 nuts. The moisture content of the composite sample was determined at 105±2°C for 8 hours by standard oven drying method. The temperature of hot air just below the drying platform was measured by bimetallic dial thermometer. The temperature of air leaving the drying chamber, flue gas, and ambient air was measured by mercury thermometer.

A detailed study of all the drying parameters was done only at 400 nuts per batch capacity. The relative humidity of the air leaving the material and ambient air was measured by the Assmans' psychrometer. The moisture content of the sample was recorded at every 4 hour interval. Two tests at 400 nuts per batch capacity were also conducted for two stage drying, namely, initial temperature at 80°C and later at 75°C.

The efficiency of the drying was calculated by using the following equation No. 1.

$$\eta t = \frac{Q\lambda(Mo - Mf)}{WC\ (100\text{-}Mo)}$$

Where,

ηt=thermal efficiency of the dryer in per cent.
Mo=initial moisture content per cent, wet basis.
Mf=final moisture content percent, wet basis.
Q=quantity of dried copra at Mf moisture content in Kg
λ =latent heat of vapourization in KCal/Kg.
W=quantity of fuel required in Kg.
C=calorific value of fuel required in Kcal/Kg.

Results and Discussion

The initial moisture content of all the samples was found to be 46 per cent on an average (wet basis). The drying time, fuel required, and efficiency of drying are given in Table 2. The time required was (28 hours) minimum at 150 nuts per batch capacity whereas maximum time required was for 400 nuts per catch capacity i.e. 37.5 hours. The thermal efficiency of the dryer was maximum at 400 nuts capacity (20.67 per cent) and least at 150 nuts capacity (11.9 per cent). Even at 400 nuts capacity the efficiency varied with the kind of fuel used. The highest efficiency was observed when fuel used was shells (21.7 per cent). The type of drying also had an effect on the drying efficiency. With shells as fuel the drying efficiency increased by 13.1 per cent due to double stage drying. The reason for getting a higher thermal efficiency in case of shells as fuel may be due to its higher calorific value compared to husk and mixed fuel (4800 Kcal/Kg, 4400 Kcal/Kg and 4500 Kcal/Kg for shells, husk and mixed fuel respectively). The fuel required, on an average, was about 30 Kg (29.7 Kg) i.e. about 250 shells or 100 husks at maximum capacity. The average quantity of copra obtained per batch (400 nuts) was 64.5 Kg.

Table 2. Drying test results

Capacity nuts/batch	Quantity of copra (Kg)	Quantity of fuel (Kg)	Type of fuel	Time of drying (hr)	Thermal efficiency %	Calorific value Kcal/Kg
150	25.20	21	mixed	28.00	11.90	4500
250	42.25	25	mixed	35.00	16.44	4500
400	63.60	33	husk	40.00	18.60	4400
400	66.00*	26**	shells	36.50	23.52	4800
400	64.00	30	shells	36.00	19.82	4800

*average of two tests
**two stage drying

In the two-stage drying, the air temperature was kept at 80°C till the temperature leaving the material reached 65°C. It was found that upto 20 hours of actual drying the difference between the two temperatures was reduced from 35° to 80°C. When the cooling effect due to evaporation of moisture was reduced to nil, the material temperature also might have reached the same as drying air

TEMPERATURE AND RH VARIATION OF THE AIR DURING DRYING

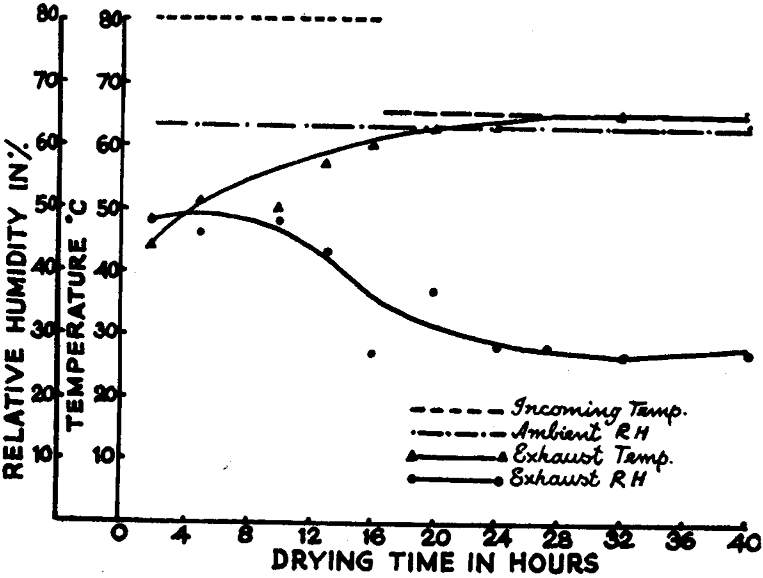

Fig. 2

DRYING CURVE FOR COPRA IN AGRIL. WASTE FUELED DRYER

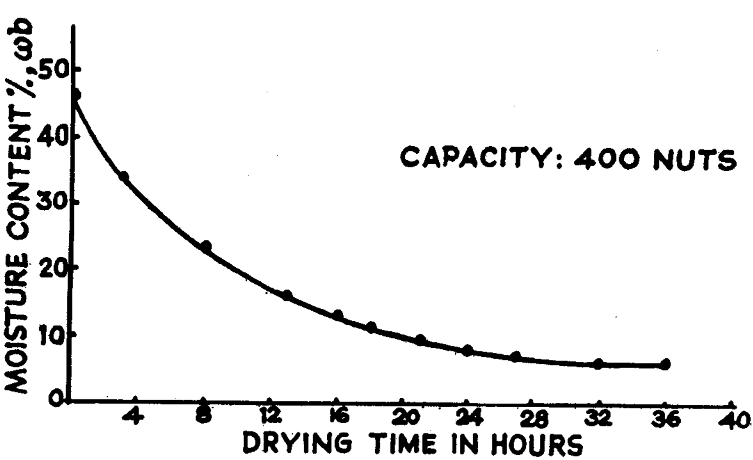

Fig. 3

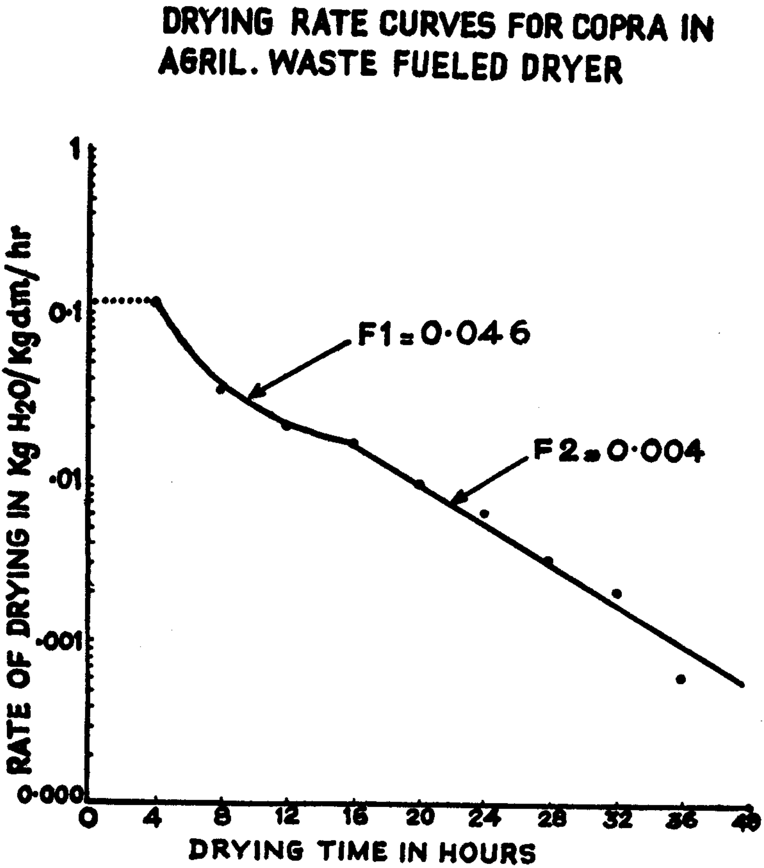
DRYING RATE CURVES FOR COPRA IN
AGRIL. WASTE FUELED DRYER
F1 = 0·046
F2 = 0·004
RATE OF DRYING IN Kg H2O/Kg dm/hr
1
0·1
·01
·001
0·000
0
4
8
12
16
20
24
28
32
36
40
DRYING TIME IN HOURS

Fig. 4

temperature. Since charring has been reported due to the higher temperature of material (Rajshekharan *et al.*, 1961) from 16 hours onwards when the material temperature was approaching 65°C, the hot air temperature was further maintained at 65°C, till the end of the drying. The variation in moisture content of copra with drying time is shown in Fig. 2, and the variation in temperature and relative of humidity of ambient air and air leaving the dryer during drying is shown in Fig. 3.

To get a clear picture of the drying process in this dryer, the drying curve was further analysed. The drying rate was calculated by the equation No. 2.

$$R = \frac{(Mo - Mi) \times 100}{(100 - Mo)(100 - Mi)(to - ti)}$$

Where,

R=rate of drying in Kg H_2O/Kgdm/hr

Mo=moisture content per cent, wet basis at *to*

Mi=moisture content wet basis at *ti*

and *to* and *ti* are respective drying times.

The graph of drying rate versus drying time (Fig. 4) on the semi-log paper showed that the rate of drying was faster in the beginning for first four hours. The rate was more or less constant at 0.105 Kg H_2O/Kgdm/hr, and may be due to availability of free moisture. The rate was further reduced to average 0.046 Kg H_2O/Kgdm/hr from 4 to 16 hours. It may be due to the moisture migration by capillary action and at later stage at 0.004 Kg H_2O/Kg dm/hr (second falling rate period) may be due to moisture migration by diffusion. The average rate of drying was found to be 0.052 Kg of H_2O/Kg dm/hr.

Economic Analysis of the Dryer:

The construction cost of the dryer was estimated at about Rs. 1000/- and expected life of the dryer was at least 10 years. The use of the dryer for copra and other crops can be at minimum of 200 days per year. The straight line method of depreciation was adopted to calculate annual depreciation. The interest rate was assumed at 12 per cent per annum for the half initial cost as capital every year. The cost of low quality dry agricultural waste was considered at Rs. 0.10 per Kg of fuel. With all these assumptions and considerations the cost analysis was done as shown in Table 3. The cost of the drying came to only Rs. 0.35 per Kg of copra when household labour was used for firing. The cost of open drying has been reported to be about Rs. 0.20/Kg of copra (Anon, 1981), which shows that the drying cost was only Rs. 0.15 more per kg of copra compared to open drying.

Table 3 Economic analysis of the dryer

Coast of the dryer: Rs. 1000.00	
Expected life of the dryer: 10 years	
Use of the dryer in a year: 200 days	
Time required for drying in days per batch: 4 days	
FIXED COST:	
Depreciation: Rs. 100.00	
Interest @ Rs 12 per annum: Rs. 60.00	
Maintenance: Rs. 10.00	
Total fixed cost: Rs. 170.00	
VARIABLE COST:	
Dehusking charges @ Rs. 20.00/1000 nuts:	Rs. 8.00
Splitting and deshelling charges:	Rs. 8.00
Cost of low cost fuel:	Rs. 3.00
Total cost of operation per batch: Rs. 22.40	
Cost of drying per Kg of dried copra: Rs. 0.35	

Special Features of the Dryer:

(1) It needs only about $2m^2$ for housing. Temporary shade could serve as a cover during rainy season.

(2) Two to three persons can lift and transfer the dryer to short distances.

(3) Temperature control ensures uniform and perfect drying and yielded good white copra.

(4) Controlled combustion ensures economical use of fuel

(5) Any low quality but dry fuel could be used.

(6) It is easy and very safe to operate.

(7) It could be successfully be used for drying other plantation crops also.

(8) Cheap but strong materials are used for fabrication; hence it is durable.

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DEVELOPING AN IMPROVED PALM CLIMBING DEVICE*

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ABSTRACT

An attempt was made to develop an improved device for climbing of palms. The device comprises three major parts, namely, (1) Upper clutch around the trunk with handle and with independent clutching mechanism, (2) Lower clutch with platforms for footrest having arrangement for clutching with the trunk and (3) the body with collapsible lever mechanism connecting the top and bottom ring. The device will work on the principle of alternate clutching of upper and lower clutches and lifting of the device with the help of collapsible lever mechanism. The design of the device is described in this paper.

INTRODUCTION

Climbing palms like coconut and arecanut is necessary for harvesting nuts and carrying out hybridization and plant protection measures. By and large, it is done by professional climbers who get trained from their younger days. Since it is a strenous and risky job, and with the changed socio-cultural outlook, fewer young men are taking it up and this has caused a scarcity of palm climbers. Also the wages demanded for climbing is about Re. 1/- per palm at present.

The need for developing an efficient palm climbing device has been long felt. The research workers are also looking for a reliable device enabling them to reach the crown of the palm (Davis 1961). A few gadgets have been devised for this purpose during the past three decades; but none of them could satisfy all essential requirements. In this paper, a brief account of the gadgets developed so far and the design features of an improved palm climbing device are discussed.

*CPCRI, Kasaragod Publication No. : 260

Earlier Work: Many attempts have been made for devising gadgets for climbing coconut palms. Wickramasuriya (1953) developed a crane type ladder for harvesting coconuts in Sri Lanka. T. A. Davis (1963, 1964, 1968, 1977) developed a palm bicycle which works on the principle of moving a pair of friction rollers pressed to the trunk by the weight of the climber (Cantilever principle). Swamy and Patil (1975) developed a much simpler device which consists of moveable supports for legs and hands, and lifted alternately while the other one is gripped for climbing.

In Jamaica, a Swiss equipment used in forestry for climbing, known as the Baumvelo (tree bicycle), was tried with some modifications for coconuts (Anon. 1976) but problems were faced when leaving the device near the crown of the tree. Sliding aluminium ladders are being used in Jamaica now. A farmer from Kerala, M.J. Joseph (Anon. 1982) had developed a coconut tree climbing device which is similar to the 'Baumvelo' tree bicycle. This device works on the principle of gripping the device through rings by self weight with the legs providing the motive power. At TNAU, Coimbatore also attempts were made towards developing a similar model (Anon. 1981). Dwivedi (1977) has also designed a palm climbing device.

Improvised oval rings have been used for scaling tall forest trees in Czechoslovakia, Poland, Soviet Union and Germany (Davis, 1977). Oil palm in West Africa is climbed by using a waist ring. In Ivory Coast, (Anon. 1963, 1966) for climbing oil palms, spiked boots, and flexible steel cable around the body of the climber and tree, are used.

For climbing palmyrah palms (Anon.1967) a ladder type device was developed. Later a device with wire rope or cable running over a pulley fixed at the crown with a dead weight connected to one end, was developed for scaling palmyrah palms with ease.

The Present Device: An attempt has been made recently at the Technology Section, CPCRI, Kasaragod to develop an improved palm climbing device.

Design Considerations: The following factors were considered while designing the device.

1. The device should ensure sufficient safety to the climber
2. It shall need low physical effort by the climber.
3. Scientists and growers alike should be able to use it to climb the palm easily with little training.
4. It should be possible to easily and quickly dismantle and carry it from one palm to another by one man.
5. It should be simple and fabricated locally.
6. The cost of the device shall not exceed Rs. 1,000/-.

Concept of Design: The device is expected to perform the following basic operations.

(*i*) Aid in climbing up the palm.

(*ii*) Hold on to the trunk when left free after reaching the crown.

(*iii*) Aid in climbing down.

1. Climbing mechanism: The climbing mechanism shall consist of (*i*) clutching/gripping arrangement (*ii*) lifting and lowering arrangement. For the gripping arrangements, there are several possible mechanisms and a few are illustrated in Fig. 1. The wire rope mechanism (Fig. 1A) grips the trunk by tightening of the wire rope around the trunk when pressure is applied on foot rest by body weight of the climber whose hands are free at the time. This mechanism shall work only when the palms are erect. This principle was used in Baumvelo (tree bycycle) in Jamaica and in Joseph's model later in Kerala.

The roller-mechanism (Fig. 1B) ensures the firm gripping of the device to the trunk by a pair of rollers which are held on to the trunk by the weight of the person, on the canti-lever principle. This principle has been tried by T. A. Davis.

The third mechanism (Fig. 1C) provides independent gripping by hands and legs by a spring-loaded lever mechanism. This mechanism has been made use of in the present gadget.

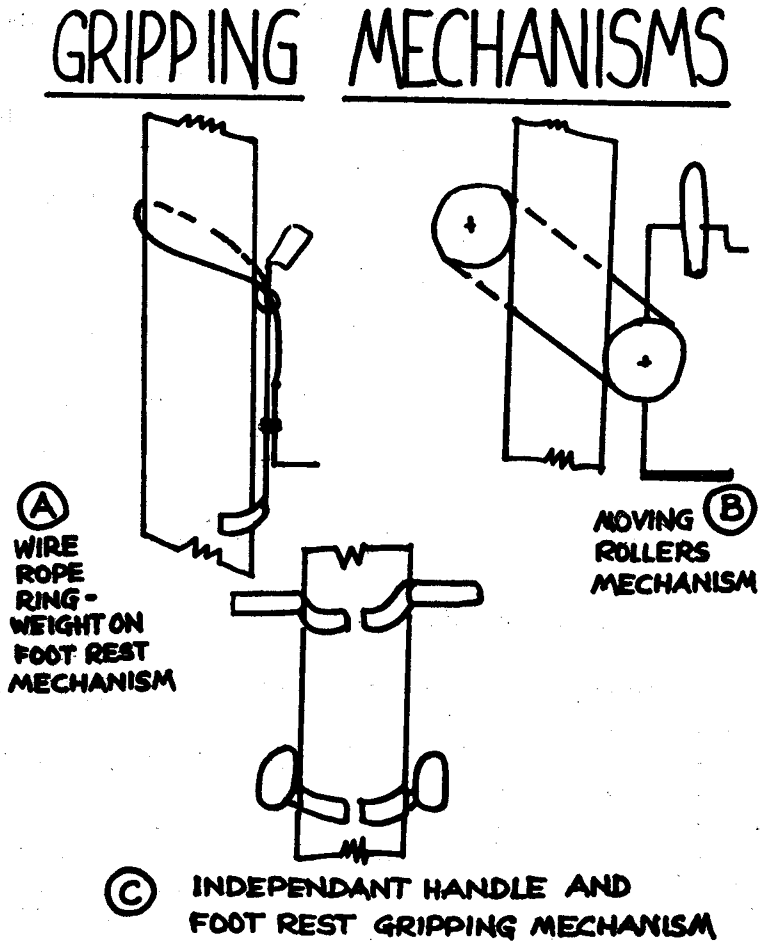

FIGURE 1.

Independent Gripping Mechanism: The gripping mechanism of the device consists of two independent parts, namely upper clutch and lower clutch (Fig. 2). The upper clutch consists of a guide ring with handles to which a pair of curved arms (sector of a ring) fitted with old rubber tyres are hinged with operating levers. The arms are spring-loaded to facilitate quick recoil action. The upper clutch unit can be gripped to the trunk or released from the trunk by pressing or releasing the levers at the handles.

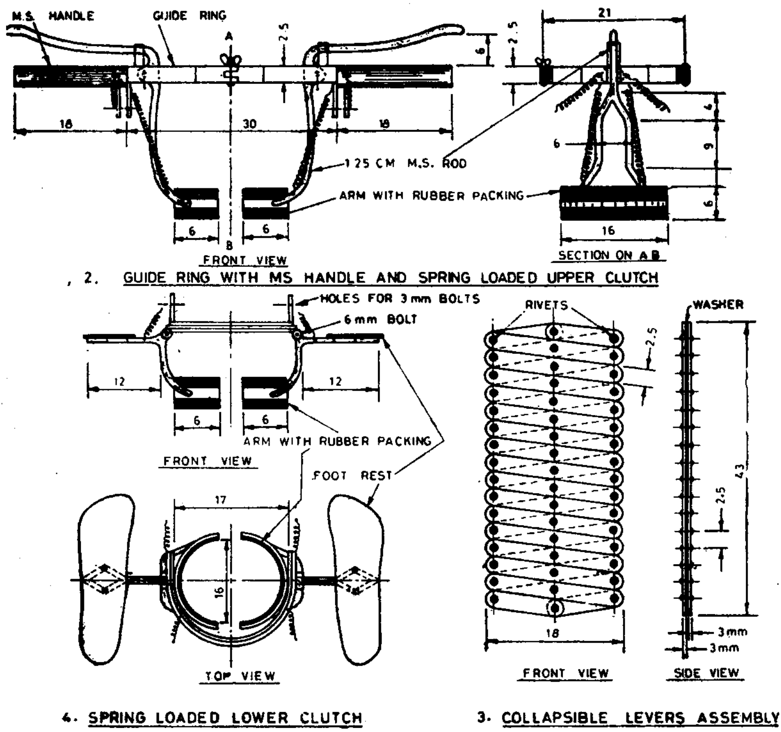

FIG. 2

The lower clutch also similarly consists of a pair of curved arms fitted with rubber tyres. The arms are hinged through spring-loaded levers to foot rests. The weight of the person applies pressure on the foot-rests when the levers get actuated and the arms are gripped to the trunk tightly. The arms are loosened of their grip by releasing the pressure on the foot rests from body weight due to the recoil action of the spring loaded levers. A guide plate connecting the two arms are provided. The upper and lower clutches are to be operated alternately.

Lifting and Lowering Arrangement: Both the arms are connected by a pair of collapsible levers made of aluminium and the collapsible levers aid in lifting the device as well as providing a safety arrangement to the climber.

Safety Arrangement: A safety chain tethered round the waist of the climber and conected to the device and trunk is provided. Apart from this, the collapsible levers also provide safety to some extent.

Operating the Device: The device has to be operated in the following four steps:

(1) *Mounting the device on the palm*: The device is mounted on the palm by opening the guide plate of upper clutch and closing it by bolt and nut. The device is positioned in such a way that the collapsible levers are on opposite sides of the palm.

(2) *Gripping the lower clutch*: The climber mounts on the device by standing on the foot rests and holding the handle of upper clutch. The foot rests are firmly pressed so that the lower arms are tightly gripped to the trunk.

(3) *Raising the upper arm*: Then the upper clutch is loosened and can be raised with ease because of the collapsible levers to a convenient height above the head level. This will provide enough moment or leverage to the climber while lifting himself up. The levers at the handles are pressed to grip the upper arms. Now the climber holds the handles with levers firmly gripping the trunk.

(4) *Releasing the lower clutch grip and lifting up*: The pressure on the foot rest is released by slight loosening and simultaneously the climber gives a slight lift to his body with the help of the leverage at handles. The collapsible levers close up by this action and the climber and the lower clutch get lifted up. The height of lift may vary from 30-70 cm. in each lap depending upon the effort put forth by the climber.

After lifting himself and the lower clutch to a convenient height, the foot rests are pressed again for gripping the lower clutch to the trunk. This completes one lap or one cycle of climbing.

This operation is repeated and the climber can reach the crown of the palm wiih little effort. The operation has to be reversed while climbing down. Locking arrangement is provided to enable the fixing of the device at any position on the palm trunk without automatically slipping down.

Prototype Development: The above principles and mechanism

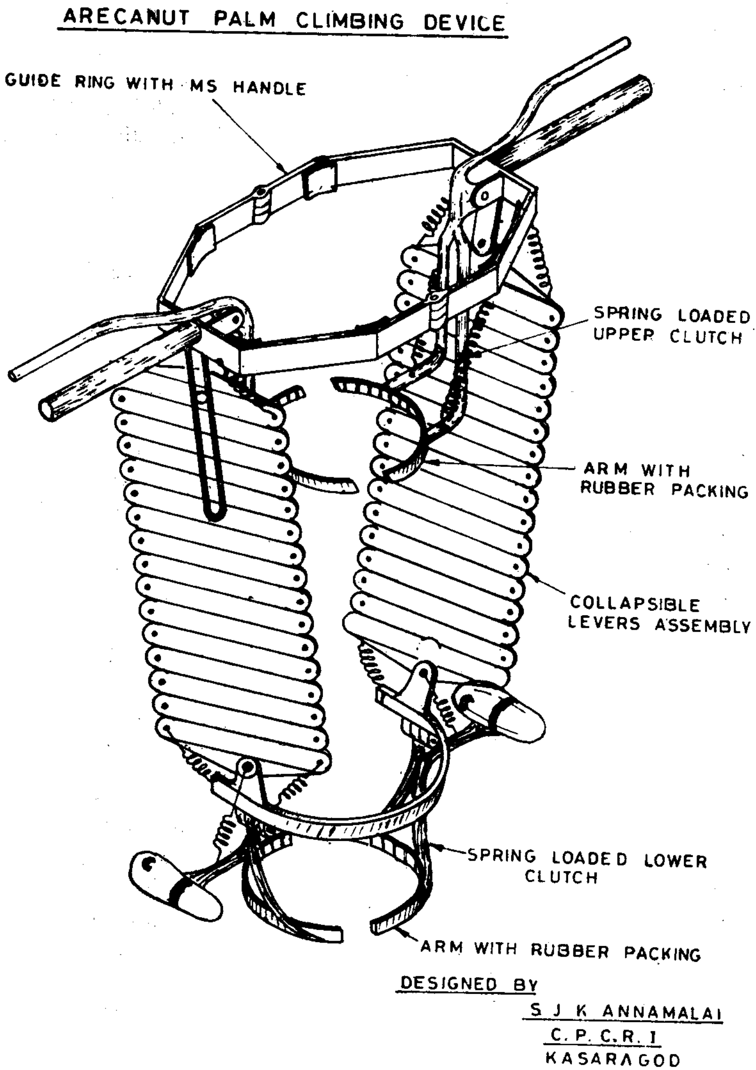

FIG. 3

have been employed in fabricating a climbing device suitable for arecanut palms (Fig. 3). The performance of the device was found to be satisfactory in the preliminary trials.

ACKNOWLEDGEMENT

I thank the Director, Central Plantation Crops Research Institute, Kasaragod for providing the facilities for this study, and Shri EV Nelliat, Head, Division of Agronomy for his guidance and for critically going through the manuscript. I place on record the excellent help rendered by Shri MV Krishnan, Welder-cum-Fitter in fabricating the prototype and suggesting necessary modifications to overcome hurdles at the time of fabrication.

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SESSION V

Agronomy & Soils

Chairman : **Shri V. Ranganathan**

Rapporteurs : **Shri W. Krishnamurthy Rao**

Shri K. Sivaraman

IMPACT OF SOIL SCIENCE RESEARCH ON FERTILIZER RECOMMENDATIONS AND CULTURAL PRACTICES IN SOUTH INDIAN TEA

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ABSTRACT

A review of basic studies on soils and their influence on genesis and development of fertilizer recommendations and cultural practices, is presented. Some notable contributions concern: (i) organic matter flux in tea soils in relation to maintaining the fertility of soils, (ii) ephemeral nature of K in soils which helped to evolve recommendations on the finer aspects of manuring, (iii) fixation of P, (iv) soil and root CEC systems, interaction on availability of nutrients, and compatibility of shade trees, (v) physical properties which led to avoidance of unnecessary soil disturbance, and (vi) ammonium chloride retentivity of soils which helped to increase the efficiency of urea-N uptake. Further investigations on: (i) non-exchangeable forms of reserve nitrogen in soil, (ii) thermodynamic and kinetic aspects of cation flux in soils, and (iii) transport and uptake mechanisms in soils including the role of aluminium and calcium on Viet's effect in tea culture, are suggested as some of the important lines of future work.

INTRODUCTION

A critical review of work done in the past, is required periodically to assess the current state of knowledge, to identify gaps, and to decide the priorities for future work. It also acts as a stock-taking exercise on how many research findings have been converted into commercial practices and how many of them require further attention for transfer to field.

LOCATION AND CLIMATE

Tea is grown in the humid belt of Western Ghats which run in a NW-SE direction parallel and close to the west coast of peninsular India, at latitudes between 8° and 13°N and altitudes ranging between 300 and 2500m above MSL. The annual rainfall varies between 90 and 750 cm. The rainfall pattern, within a planting district, varies from the western zone with predominant SW monsoon rains to the eastern zone with predominant NE monsoon rains, through the middle transition zone at altitudes 1060 to 1676m above MSL where both the monsoons are active. The drought period varies between 3 and 5 months and it shows an increase northwards with the latitude. The climatic conditions can be classified as, tropcial/sub-tropical at low/mid elevations, and sub-tropical/temperate at mid/high elevations depending on the latitude with distinctly dry winter followed by one or two months of hot weather before monsoon breaks in.

Geology and Taxonomy

The soils are mainly derived from granite and gneissic rocks and occasionally from basalts and schists containing good amounts of mica. The area is dominated by a mature topography which had witnessed a number of geomorphic cycles punctuated with uplifts, followed by prolonged periods of erosion and subsidence. Lateritization is extensive and the soils are derived from varied geological formations of different ages from Early Eocene to Recent and on almost every rock type from the Archaean gneisses to the Recent sedimentaries (Babu, 1981). Lateritization is also observed at different altitudes over the flat to gently sloping erosion surfaces seen on the mountain tops, terrace-like land forms on the intermediate slopes of the valleys, and pavements in lower slopes. Under the impact of monsoon with alternate wet and dry conditions, the lateritization process continues to be active to the present day. It has also influenced the soil formation to the extent that illuvial zone containing precipitate sesquioxide occurs over the eluvial zone.

Soils are generally classified as laterite and lateritic (Latosols), and they may come mostly under great groups of oxisols, ultisols and inceptisols in the USDA classification, 7th approximation (Anon., 1978).

Physical and Chemical Properties

The physical and chemical properties of soils of different tea districts are well documented (de Jong, 1952; Jayaraman, 1961; Ranganathan, 1973b, 1976c and 1977a). Soils have undergone considerable weathering as shown by low clacium content and are strongly leached as shown by low CEC. All the soils are distinctly acidic. Texture and organic matter content are found to be the functions of latitude, altitude and rainfall of the area. The soils of Central and South Travancore, High Ranges and Anamallais are open in texture and coarse with fine sand fractions comprising between 62 and 67 per cent. Those of Nilgiris and Wynad are of clay loam to clay types. The disadvantages of high clay content in some pockets of Nilgiris are offset by the high organic matter content. Fragipan formation at 30 to 90 cm depth, in areas at the centre of high plateaus surrounded by high mountain ranges, due to overburden and consequent low percolation of water to substrata leading to secondary consolidation, are encountered in certain pockets of Anamallais (Ranganathan, 1968 and 1976c). Opening of contour trenches and filling them with organic debris are recommended to increase percolation of water to the substrata; long-term effect of such operations in breaking the pans and preventing consolidation is being studied.

Chemically the soils are poor with abundant sesquioxides and low bases. Nevertheless, they respond to good management, cultural and manurial practices, thus making them amenable for raising plantations on commercial scale.

Organic Matter Flux

As the soils lack in inoiganic structure-building substances, organic matter plays a vital role in maintaining their tilth and ferti lity, and confers buffering capacity for sustaining optimum aeration, temperature and moisture for prolonged periods. This provides favourable conditions for water and nutrient uptake to as much of the root system as possible and for as long a period as possible. Hence, the success of soil and fertilizer management in exploiting the yield potential of tea fields rests entirely on the maintenance of organic matter status of the soils. Critical examination of all aspects of organic matter flux on tea soils such as, the rates of decomposition at different altitudes, additions by way of retention of shade tree loppings and tea prunings, the impact of recommendation on conservation measures made in 1970, adequacy of conservation measures at mid/high elevation in the maintenance of its status in soils, its inadequacy at lower elevations, and nutrients added through recycling materials has been made (Ranganathan, 1973a, 1973b and 1974; Ganesan and Ranganathan, 1978; Ranganathan, Ganesan and Natesan, 1980). The classification of soils with respect to N-availability was based on the 'N' released by the decomposing organic matter at different altitudes. At mid-elevations eventhough 40 to 60 kg N/ha is released from every 1 per cent organic matter in the soil, the maximum amount utilized by tea out of that was found to be only 30 kg N/ha (Ranganathan, 1968). Liming, at the recommended rates, has no adverse effect on soil organic matter flux; on the other hand, it has shown a marginal beneficial effect (Ranganathan and Swaminathan, 1973; Ganesan and Ranganathan, 1978).

Ephemeral Nature of K in Soils

The basic similarity of South Indian tea soils, from Koppa-Kadur in the North to Kanyakumari in the South, has been established from studies on adsorption isotherms, fixation, fractionation and leaching of potassium. It was also shown that the soils are predominantly kaolinitic and lack in fixation sites (Ranganathan and Narayanan, 1974; Ranganathan, 1976b). The leaching losses of K, also increases with acidity. The average release of K from weathering of soils, estimated to be equivalent to 10 ppm per month (Ranganathan, 1975), is not adequate to meet the crop requirement during rush periods.

Therefore, K is as ephemeral as N in tea soils of South India and it has to be applied in as many splits as possible to maintain availability at the optimum levels for the efficient uptake by tea roots and it is enough to broadcast them. The results from field trials have substantiated the theoretical deductions on the finer aspects of K manuring (Ranganathan and Ganesan, 1975; Ranganathan, Ganesan and Natesan, 1978).

Soil Phosphorus

All forms of P are theoretically expected to be equally effective in acidic soil abundant in sesquioxides as they are fixed and made available through solubility product mechanisms. The results from field trials have confirmed the above conclusions (Ranganathan, 1971). The laboratory experiments have shown that the soluble 'P' compounds can effect considerable breakdown of kaolin by phosphatalysis leading to lowering of CEC values (Ganesan and Ranganathan, unpublished) and this is one of the reasons for discouraging the use of soluble phosphates in tea soils where the CEC is already very low.

As the fixation and ageing effects on availability of P in soils with rock phosphate additions are negligible, the requirements of 2 to 4 years can be applied at a time; but its fluoride content limits the quantity that can be applied at a time to 80-100 kg P_2O_5 ha^{-1} which will support availability for 2 years (Ranganathan and Ganesan, 1976). The field trials have also substantiated the above findings. Moreover, in the path analysis, it was shown that the subsoil P contributes more towards yield than the surface soil P (Ranganathan 1968, 1971). This is also shown by the significant superiority of placement treatments in the field trials (Ranganathan and Ganesan, 1976; Ranganathan, Ganesan and Natesan, 1978).

With the above background, and considering the fact that placement is a costly operation, phosphorus is now recommended to be applied by placement method as a straight fertilizer once in two years at the rate of 80 to 100 kg P_2O_5 ha^{-1} (Ranganathan and Ganesan, 1976). In the national interest, the low grade ores are recommended for straight P applications, as the high grade ores can profitably be used for phosphoric acid and superphosphate manufacture (Ranganathan, 1976a). As soil phosphorus is utilized efficiently by tea roots, the uptake is probably aided by contact exchange and mycorrhizal association (Ranganathan, 1971). The studies on mycorrhizae have already been initiated (Venkata Ram and Chandra Mouli, 1979). There is wide scope for recycling the native and residual phosphorus reverves in the soil(Ranganathan, 1976a). Certain phosphate dissolving fungi have been isolated in the laboratory (Venkata Ram and Chandra Mouli, 1980), and are under study for field exploitation.

Cation Exchange Studies

The CEC of soils is low and 50 per cent of it is derived from the organic matter content (Ranganathan and Narayanan, 1974).

Detailed investigations on the various CEC systems in tea soils (Ranganathan and Narayanan, 1975) showed that the valence effect of Donnan distribution will dominate in the competition for mono valent and divalent ions by the root surfaces and the soil colloidal surface because of the base deficiency created by low CEC of soils, absence of fixation and decreased binding energies due to acidity. Because of the higher CEC of tea roots (16 to 25 meq in mature tea fields) than that of kaolinite clay colloids (8-10 meq per cent per 100g clay), large amounts of divalent to monovalent ions will be distributed near the root surfaces compared to that on the clay colloidal surfaces. This means more calcium than potassium will be distributed on the tea root surfaces while the requirement of tea for optimum and vigorous growth is just the reverse (Ranganathan, 1978b). To break the Donnan effect and to make more K available near the tea root surfaces, the potassium acitvity in soil solution should be increased by applying it in large quantities. This is shown by the higher K requirement of tea than in other crops. In good tea fields, the degree of potassium saturation (dKS) required for maintaining adequate supply of K to meet the demand of the plants is about 7 per cent while it is about 2 per cent in most other crops (Ranganathan and Swaminathan, 1968).

Tea roots face severe competition for monovalent ions from clay colloids and hydrous oxide colloids having very low CEC values (8 to 10 and 2 to 4 meq per cent respectively) and for divalent ions from humic acid colloids having very high CEC values (180-270 meq per cent). The effect of dilution and concentration of soil solution on Donnan distribution during monsoon and dry months demands respectively, more divalent ions around humic acid colloids and more monovalent ions near silicate colloids compared to that found near the tea roots. This means that the probability of expectance of deficiency of divalent and monovalent ions is high in the wet and dry months respectively. This supports the occurrence of Mg deficiency seasonally during or immediately after the wet months, in soils with low/medium availability which fade out as the dry season advances with the severity of potassium deficiency symptoms during drought months. Similarly, the roots of grasses and dadaps with their low root CEC (7 to 15 meq per cent) rob most of the potassium and they are to be avoided in tea fields. *Grevilleas* have a higher root CEC (30 to 35 meq per cent) than tea roots and hence do not compete unduly for potassium in the soil. Most of the dicot weeds have their root CEC in the same range (15 to 30 meq per cent) as that of tea roots and hence they do not pose any problem in the competition for cations within the soil.

Soil Physical Properties

Based on the heavy nature of soils of Wynad and some pockets of Nilgiris, deep cultivation in the form of turn-over forking or taking trenches and filling them with organic matter was recommended to improve drainage and percolation of water. The soils contain non-expanding kaolinite and hydrous-oxide colloids and their permeability is also good. These soils, of course, turn hard on drying, but they get wetted easily with the first rains and do not impede percolation of water even though they look puddled (Ranganathan, 1973b). The permeability of lateritic clays determined in the laboratory is less than the *in situ* measurements indicating that they permit high seepage (Sahasrabudhe and Vaidyanath, 1981). Their consolidation coefficients are, also, very high and as such, compaction due to frequent treading by pluckers in the field does not occur to any appreciable extent. Based on these findings, the recommendations on deep forking is now, withdrawn even for heavy soils and the accent given on minimum cultivation practices in tea culture.

The retentivity of moisture of the kaolinite and hydrous-oxide colloids is comparatively lower than that of montmorillonite clays. But the availability of water seems to be good as tea plants are able to survive through long periods of drought better in heavy soils of Wynad and Karnataka than in the light soils of other Districts (Ranganathan, 1973b and 1977a). Information on the wilting coefficient in relation to crop species and the nature of colloids, and also the soil physical properties in relation to their ability to reduce drought effects on plants are lacking, and studies on these aspects will be useful especially to rear the plants through drought during the initial years of establishment.

Ammonium Chloride Retentivity

Kaolinite and halloysite retain large quantities of ammonium chloride (220mM$(100g)^{-1}$ clay) while the comparative figures for 2:1 and 2:2 clay minerals are negligible (Koji Wada, 1963). Koji

Wada (1965) has postulated a definite interlayer salt complex formation of mono-molecular layers of ammonium chloride between kaolin layers which are held by Van der Waal's forces, as shown by the polymorphic effect of its release mechanism. Ammonium chloride retentivity of tea soils varies between 15 and 52 mM $(100\ g)^{-1}$ soil equivalent to 0.21 to 0.73 per cent N (Ranganathan, 1976c and 1977a). The substantial increase in efficiency of urea at 1:1 NK ratio compared to that at 2:1 is achieved by the retentivity of ammonium chloride (formed by the interaction of ammonium carbonate, the hydrolysis product of urea, and muriate of potash) whose probability of formation is increased by increasing the content of muriate of potash in the NK mixture (Ranganathan, 1981). Further studies on the role of retentivity of ammonium chloride in inorganic N-fixation will certainly help improve the efficiency of nitrogen manuring.

Miscellaneous Studies

While replanting the lightning attacked patches, the accumulation of nitrite in the soils poses problems; the plants start dying even before the monsoon stops. The mortality during drought is also increased. Critical examination of the problem with reference to clonal, manurial and other factors was carried out (Ranganathan, 1979) and certain tentative remedial measures suggested such as: (*i*) taking planting pits larger than usual and also well in advance (*ii*) adding redox catalysts like copper compounds to the soil, and (*iii*) avoidance of N manuring in the first year of establishment, and these are reported to be useful (Ranganathan, 1980). Certain nitrite utilizing fungi have been isolated, and are under study for field exploitation (Venkata Ram, 1975). The usefulness of rubber latex mulch for soil, and water conservation measures was also studied (Ranganathan, 1977b, 1978a and 1979). Heat treatment of the soils for nematode control is a routine practice. The chemical changes mainly that of nitrite flux, and available Fe and Mn fractions that occur in soils following heat treatment were examined in detail, and based on these, the optimum conditions for heat treatment were worked out, striking a balance between that required for nematode control and that for keeping the adverse effect of such changes at the minimum extent possible (Ganesan, Ramanathan and Ranganathan, 1978). There is no accumulation of SO_4^{-2} in tea soils even after continuous use of ammonium sulphate over several years indicating a need for its annual application; that means ammonium sulphate should be continued to be applied at least at a minimum level to satisfy sulphur requirements of tea (Subrahmanya Bhat and Ranganathan, 1980; Venkata Ram and Ranganathan, 1980).

Transfer of Technology

A survey carried out in 1977 by UPASI has shown that the transfer of technology for commercial exploitation was quite efficient and fast in tea industry and within a period of 2 to 6 years, the recommendations were implemented in 68 to 100 per cent of the area (Anon., 1976; Ranganathan, Ganesan and Venkata Ram, 1978). Some of them are: (*i*) a separate manuıial schedule for the pruned year was recommended in 1969/70 and it was implemented in 100 per cent of the area by 1976; (*ii*) the organic matter conservation measures recommended in 1970 has spread to 82 per cent of the area by 1976 and 99 per cent of the area by 1982; (*iii*) the replacement of straight N with NK applications and a need for minimum 4 splits of fertilizer application were recommended first in 1974 and they have already become routine practices in 99 per cent of the area; (*iv*) the straight P application once in two years was recommended first in 1976 and it was followed in 68 per cent of the area within a year (by 1977) and almost in 90 per cent of the area by 1982; (*v*) the tentative remedial measurss to counteract nitrite toxicity for establishing tea in lightning attacked patches are accepted and followed in full; (*vi*) dadaps are almost extinct in tea fields; and (*vii*) the minimum cultivation concept is followed in about 90 per cent of the area. Some of the findings which await field exploitation are on (1) mycorrhizae (2) 'P' solubilizing fungi, (3) the nitrite utilizing fungi, and (4) the intensive manuring schedules required in high yielding fields to get over the limitations imposed by ion-transport processes within the soil.

Future Lines of Work

The soil organic matter is, generally, considered as the only source of N reserves. Recently, the other forms of non-exchangeable ammonium compounds which aıe not associated with organic matter such as aluminium ammonium phosphate, magnesium ammonium phosphate (Hauck, 1973) and intercalate complexes such as kaolin-ammonium chloride (Ranganathan, 1976c, 1977a) are reported to contribute substantially to the N reserves in the soil, up to 10 per cent of the total N in the surface soil and 50 per cent in the sub-soil. In tea culture, both the high aluminium content of soils and the high fertilizer usage as well as the pH ranges, are conducive for formation of aluminium ammonium phosphate (Tarakanite). Moreover, in some areas like Anamallais, the annual Mg release in soils by weathering is considerable, and if the released Mg could be fixed as magnesium ammonium phosphates, it will serve the double purpose of retaining both Mg and N in the soil. The formation of double phosphates with other polyvalent ions, notably Fe and Zn, are not ruled out. Detailed investigations on inorganic N fixation and mode of its release in soils will be useful to enhance the efficiency of use of nitrogenous fertilizers. The priming and catalytic effects of inorganic N and kaolin respectively on the breakdown of proteins, and decomposition of organic matter, need closer examination to evolve suitable measures to slow down the rate of decomposition of organic matter at low/mid altitudes.

The role of calcium and other polyvalent ions in the outer soil solution in reducing efflux of K from the roots is known as Viet's effect and, recently, it has been suggested that aluminium ions may have such a role in acidic soils (Mengel and Kirkby, 1978). The minimum concentration of Ca in nutrient solution for net positive uptake of K is 10^{-3}M and in tea area a concentration of Ca above the minimum required, normally exists in soils with a pH above 4.5. In soils with a pH below 4.5, the role of other polyvalent ions and aluminium, in particular, in preventing efflux of K by modifying the root permeability is worth studying.

In high yielding fields, the demand for K per unit time is high and the transport processes within the soil appear to limit the availability of K in the vicinity of roots. As such, a higher rate of K in relation to yield has been found necessary for maintaining yield levels above 3500 kg made tea ha^{-1}. Detailed studies on the thermodynamics and kinetic aspects of ion transport in the soils and the uptake characteristics of tea roots will be useful to plan improved cultural practices for the efficient use of fertilizers.

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AGRONOMIC AND CULTURAL FACTORS INTERACTING WITH POTASSIUM MANURING IN TEA

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ABSTRACT

The broadcasting method of potassium fertilizer application was found to be marginally superior to the placement method. The efficiency of K increased with increasing number of split application in a year: 4 applications gave 10 and 6 per cent more crop than one or two applications, and 6 to 8 applications gave 6 to 12 and 10 to 18 per cent more crop than 4 and 2 applications, respectively. The efficacy of split applications was more pronounced in 'dome' than in 'flat' plucking surface, thus, indicating a probable positive correlation with the area of plucking surface and hence the number of plucking points. Application of K at higher levels up to 200 kg K_2O ha^{-1} in the pruned year increased yields significantly in the following years. Beyond this level, the above beneficial effect was delayed to 3rd and 4th year of the cycle, probably because the development and thickening of frames continued for a longer time up to 2nd or 3rd year of the cycle, with no adverse effect on yield. A significant third order interaction between K level, N level and plucking interval, indicates a need for optimization of these factors in relation to each other for increasing the productivity of tea. Highest productivity was achieved in the experiment with the highest N and K levels and with extended plucking interval.

INTRODUCTION

In an intensive cultivation which is progressive and dynamic like the tea culture in South India, the use of fertilizers at increasing rates is inevitable. As the intensity and extent of their use increases, interactions of manuring with agronomic, cultural and nutritional practices are encountered as successive limiting factors in maintaining the productivity trends. Nutritional interactions with potassium manuring in tea in South India are recognized since late forties and reported time and again (de Jong, 1950; Jayaraman and de Jong, 1955; Ranganathan, 1970, 1971, 1982; Ranganathan, Natesan and Subrahmanya Bhat, 1982). The importance of agronomic, cultural and varietal factors in enhancing their interaction with potassium manuring on productivity has been recognized in recent times (Loue, 1978). Nevertheless, they have been recognized since early sixties in South India, with increasing accent on balanced manuring for achieving productivity breakthrough following introduction of economic control measures for blister blight and mites as routine practices on commercial scale in early and mid-sixties respectively (Venkata Ram, 1964; Rao, 1970). The results of investigations on the interaction of certain agronomic and cultural practices with potassium manuring, and their practical utility in tea culture are discussed in this paper.

MATERIAL AND METHODS

Details of field experiments carried out to study the interaction of agronomic and cultural practices with potassium manuring are as follows:

1. The influence of the method of application of K on yield was studied in 1972 in a fourth year field of clone C-194, planted in 1961 and last pruned in April, 1968, with twelve replications. Two methods of application, broadcasting and placement, were tried. The quantities of N and K_2O were respectively 200 and 120kg ha^{-1} applied in 4 splits, 2 NK and 2 straight N applications.

2(*a*). The interaction of K levels with frequency of application was studied in 9 randomized blocks in a multi-clonal plot planted in 1970 at a spacing of $120 \times 75 \times 60$ cm and skiffed in 1974 in Mount Stuart Estate, Anamallais from May, 1976 to October, 1977. The treatments tried were:

(*i*) K levels—50, 75 and 100 per cent of the N level (300 kg ha^{-1}) and

(*ii*) Number of splits—4, 6 and 8.

The results were analysed by co-variance technique taking pre-treatment yield as concomitant variant.

(*b*) The effect of split applications of K was also studied during 1974–77 at the Research Institute, Cinchona in a clonal area (C-194), planted in 1961 and last pruned in April, 1973. The number of splits tried were 1 and 4, 2 and 4, and 2 and 6 in the 2nd, 3rd and 4th year of the pruning cycle respectively. There were twelve replications in the experiment.

(*c*) In the above experiment, the interaction between split applications of K and type of plucking surface, dome and flat, was also studied during the period 1976-77.

3(*a*). The influence of 3 levels of K_2O (80, 140 and 200 kg ha^{-1}) applied in the pruned year on the efficiency of fertilizer use over the entire pruning cycle was studied during 1971–75 in young tea (UPASI-10 (B/6/62)) planted in 1964 and last pruned in 1971. There were six replications in the experiment and four levels of Nitrogen (0, 60, 120 and 240 kg N ha^{-1}) from 2nd year onwards to get information on the efficiency of fertilizer use as affected by manuring levels in the pruned year.

(*b*) Another experiment was carried out in seedling area at Etear Division, Kallyar Estate, Anamallais for two cycles during the period 1973–82. In the first cycle, three levels of K_2O (150, 200 and 250 kg ha^{-1}) were applied in the pruned year and their influence on yield under normal practices of manuring in the subsequent years was studied. In the second cycle, the effect of interaction of two levels of K_2O in the pruned year and three levels of K_2O with N at recommended levels in subsequent years was investigated. There were 14 replications in the first cycle and 7 in the second cycle.

4. The interaction of K_2O level (50 and 60 per cent of N levels), N level (180, 240 and 360 kg N ha^{-1}), and plucking interval (x and x+2 days) on tea yield, was studied during the period 1975/78 in a clonal area (ATK-1), planted in May, 1968, and last pruned in April, 1974 at Caroline Estate, Wynad, in a 3×2×2 confounded design with 2 replications. The 'x' was equal to 7 to 9 days during the rush periods (May to June and September to December) and 11 to 13 days in the lean periods (January to April and July to August) as per Department's recommendation.

The plot size varied between 40 and 196 bushes (40 in experiments 1, 2a, 2b, 2c and 3a, 100 in experiment 3b and 196 in experiment 4. The results of the experiments were statistically analysed by variance method (Panse and Sukhatme, 1954).

Results and Discussion

(1) **Methods of application of potassium:** The intrinsic studies on soils from 1968 onwards have clearly shown the lack of fixation and hence the high mobility of K in tea soils of South India, thus indicating that it is enough to broadcast them if timed properly (Ranganathan, 1970; Ranganathan and Narayanan, 1974). The field evaluation of different methods of application of N/NK fertilizers had shown that broadcast and dibbling in was marginally superior to broadcast method, the difference between them varying between –4 to +5 per cent with an average of +3 per cent for the cycle (Ranganathan, Ganesan and Natesan, 1978). A direct comparison of methods of application of K fertilizer alone was, therefore, tried and the results are given in Table 1.

Table 1. Methods of application of K on tea yield (C-194, January to December, 1972)

Treatment	Yield of made tea kg ha^{-1}	Per cent yield
Broadcasting	2358	102.6
Placement	2299	100.0
CD at $P=0.05$	68	3.0

The broadcasting method of application of K fertilizer is marginally superior to placement method giving 2.6 per cent more crop which had just fallen short of significance at 5 per cent probability level. Potassium fertilizers are usually applied broadcast and only in soils with low level of available K or with high K fixation capacity, banded application is recommended (Mengel and Kirkby, 1978). In tea soils of South India which are predominantly kaolinitic and lack in fixation, potassium fertilizers applied broadcast on the surface move down freely to the root zone with the percolating rain water whereas the sub-soil placed fertilizer moves down below the root zone, thereby, not being readily available during the rush months, until they are brought again to root zone by evaporating water as the dry weather sets in. Hence, the broadcasting of K fertilizer is as good as, or, marginally superior to placement method of application in tea culture in South India.

(2) **Frequency of application:** Theoretically, in South Indian tea soils, the application of K in as many splits as possible is

warranted to exploit the short growing periods by maintaining optimum NK ratio throughout the year for the efficient utilization of nitrogen and also to get maximum benefit out of K fertilizers (Ranganathan and Ganesan, 1975). The potassium dynamics studies on Indian laterite soils, have also shown the need for maintaining a higher concentration of K ions to overcome their poor mobility arising from their light texture and poor moisture retentivity of the soils (Panda, 1978). Further limitations are imposed by low CEC of soils and the high rainfall in the areas where tea is grown. It was also shown in earlier experiments that 2 and 4 applications of potassium fertilizer will give 4 and 10 to 13 per cent more crop respectively than a single application (Ranganathan and Ganesan, 1975). The results obtained from the present trials are given in Table 2.

Table 2. Effect of split application of K on tea yield (Clone: C-194, 1974–77)

2nd year field (April to March)		3rd year field (April to March)		4th year field (April to March)	
Split No.	Made tea kg ha^{-1}	Split No.	Made tea kg ha^{-1}	Split No.	Made tea kg ha^{-1}
1	3664 (100)	2	2831 (100)	2	3609 (100)
4	4034 (110)	4	3009 (106)	6	3975 (110)
C.D. at P=0.05	225 (6)	C.D. at P=0.05	85 (3)	C.D. at P=0.05	85 (2)

$N:P_2O_5:K_2O$ kg ha^{-1} applied are 220:45:120, 240:45:130 and 320:50:160 in the 2nd, 3rd and 4th year, respectively. Figures in parentheses denote percentage.

It could be seen that a significant 10 per cent more crop could be obtained with 6 applications compared to 2; and with 4 applications, compared to 1; and 6 per cent more crop with 4 applications as compared to 2. It, also, appears as though the response to K increases with the number of split applications which is further substantiated by the results obtained in young tea (Table 3).

During the first five months of the experiment, there was no response to either the level or the frequency of application of potassium fertilizer. However, in subsequent periods, there was no

Table 3. Number of splits × level of K interaction on tea yield as percent yield (Mount Stuart Estate, 1976–77)

Split No.	105 kg K_2O ha^{-1}			225 kg K_2O ha^{-1}			300 kg K_2O ha^{-1}			Average		
	a	b	c	a	b	c	a	b	c	a	b	c
4	100.0 (793)	100.0 (1113)	100.0 (1523)	100.0 (769)	100.0 (1140)	100.0 (1576)	100.0 (734)	100.0 (1195)	100.0 (1662)	100.0 (767)	100.0 (1140)	100.0 (1587)
6	91.7	112.7	105.9	91.9	116.8	111.0	102.3	107.1	102.4	95.4	112.4	106.4
8	89.3	118.8	116.7	90.5	121.8	110.5	95.4	114.0	105.8	91.5	118.5	110.9
C.D. at P: 0.05	NS	NS	5.9	NS	NS	5.7	NS	NS	5.4	NS	NS	3.2
C.D. at P: 0.10	NS	9.0	—	NS	8.8	—	NS	8.4	—	NS	5.2	—

Figures in parentheses denote base yield kg ha^{-1}

a: May to August, 1976; b: September 1976 to May 1977; c: June to December, 1977.

N—300 kg ha^{-1}; P_2O_5—45 kg ha^{-1}.

response to level of K_2O application beyond 225 kg ha^{-1}. Nonetheless, the response to split applications was more pronounced and was seen at all levels of K_2O application. It was reported earlier that irrespective of N levels, 4 split applications of K gave almost the same increased response compared to 1 or 2 applications (Ranganathan and Ganesan, 1975). On an average, 12.4 and 18.5 per cent more crop was obtained with 6 and 8 applications respectively than that with 4 applications during September 1976 to May 1977, and 6.4 and 10.9 per cent during June to December 1977. Moreover, after the initial period, there was a transition period where the response was significant at 10 per cent before ultimately stabilizing at 5 per cent probability level. It fits in with the general observation that the effect of fertilizers including potassium on continual use stabilizes after a year or sometimes two, during which it helps in the development and formation of sound and healthy frames. The split applications are, therefore, found to be useful in tea culture in South India to overcome the limitation imposed in maintaining the available K status by soil and climatic factors. The responses obtained to split applications in 'dome' and 'flat' plucking surfaces are given in Table 4.

Table 4. Interaction of plucking surface and split application of K on yield (Clone: C-194, April 1976 to March 1977, 4th year field)

Split No.	Yield of made tea kg ha^{-1}		Per cent yield	
	Dome	Flat	Dome	Flat
2	3413	3805	90	100
6	3828	4122	101	108
C.D. at P: 0.05	120	120	3.2	3.2

N: P_2O_5: K_2O applied kg ha^{-1}: 320:50:160

Because of difficulties in controlling blister blight effectively, the yield in 'dome' plucking surface was considerably reduced compared to that in 'flat' plucking surface. Nevertheless, the application of K in 6 splits had considerably reduced the crop loss in 'dome' plucking surface compared to that in 2 splits. This is because of the greater response to split application in 'dome' plucking surface than in 'flat' plucking surface. The increased response in 'dome' shaped plucking surface may be due to its greater surface area and hence, the greater number of growing points than in the flat plucking surface. This is in conformity with the general observation that the response to split applications of K is more in 3rd and 4th year fields than in first and second year fields and also, there is an increase in response to both the level and frequency of K application with N levels. It is well known that N influences significantly the density of growing points and K enhances the effect of N as reported elsewhere in this paper. Also, all the physiological processes relating to yield and dry matter production increase the uptake by roots, the transport and also, the requirement of K (Mengel, 1976). In the above study, the processes involved are, the maintenance of larger plucking surface area and number of plucking points in 'dome' shaped plucking surface compared to 'flat' shaped one.

(3) **Effect of K levels applied in the pruned year:** In the pruned year, within a short period the bushes mobilize large quantities of nutrients for the formation of sound and healthy frames and sufficient foliage to start the cycle for yield exploitation in the years to follow (Ranganathan, 1973). Since potassium is a limiting nutrient in South Indian tea soils, the application of large quantities of this nutrient is required in the pruned year for the formation of sound and healthy frames which will support high yields in the subsequent years. The effect of K levels in the pruned year on the yield obtained in the subsequent years of the cycle is shown in Table 5. The bushes were pruned at 35 to 40 cm height and tipped at 75 cm height from the ground level.

With the increasing K levels applied in the pruned year, there was a significant crop increase for the same level of fertilizer use in the subsequent years of the cycle. Over the cycle, 12 and 6 per cent more crop was obtained by applying 200 and 140 kg K_2O ha^{-1} in the pruned year compared to 80 kg K_2O ha^{-1}. The made tea/nitrogen ratio was also considerably increased with the increase in K application in the pruned year from 11.08 at 80 kg K_2O ha^{-1} level to 12.45 at 200 kg K_2O ha^{-1} level. Similar results were obtained in the seedling tea also (Table 6). The pruning height was 50 to 60 cm and the tipping height 75 cm from ground level.

Although, there was an increase in crop due to the pruned year K levels in all the years of the cycle, it attained the level of

Table 5. Effect of K levels applied in the pruned year on yield (UPASI-10 (B/6/62) 1971/75—Pruned in August 1971, 35-40 cm clean prune and tipped in December, 1971, 75 cm+GL)

K_2O level in the pruned year kg ha^{-1}	Yield made tea kg ha^{-1}					Made tea: N ratio
	Pruned year (Aug. to July)	2nd year (Aug. to July)	3rd year (Aug. to July)	4th year* (Aug. to April)	Total for the cycle	
80	904 (100)	2597 (100)	3169 (100)	2634 (100)	9304 (100)	11.08
140	1056 (117)	2800 (108)	3349 (106)	2687 (102)	9892 (106)	11.78
200	1184 (131)	3020 (116)	3535 (112)	2718 (103)	10457 (112)	12.45
C.D. at P=0.05	94 (10.4)	201 (7.7)	333 (10.5)	NS (–)	391 (4.2)	—
N applied kg ha^{-1}	120	240	240	240	840	—

*Pruned in April, 1975

Figures in parentheses denote percentage.

P_2O_5: 80 kg ha^{-1} in the pruned year and 30 kg ha^{-1} in the subsequent years

K_2O: 50% N level in the subsequent years.

Table 6. Effect of K levels applied in the pruned year on yield (Seedling tea, Etear, 1973/78—pruned in April, 1973 at 50 to 60 cm and tipped in July, 1973 at 75 cm+GL)

K_2O level in the pruned year kg ha^{-1}	Yield of made tea kg ha^{-1}						
	Pruned year April to March	2nd year April to March	3rd year April to March	4th year April to March	5th year April to March	Total for the cycle	Made tea: N ratio
150	682 (100)	2698 (100)	2767 (100)	3364 (100)	3810 (100)	13321 (100)	10.61
200	692 (102)	2839 (105)	2771 (100)	3457 (103)	3917 (103)	13676 (103)	10.90
250	719 (105)	2809 (104)	2822 (102)	3493 (104)	3924 (103)	13767 (103)	10.97
C.D. at P: 0.05	NS	NS	NS	92 (2.7)	41 (1.1)	236 (1.8)	—
N applied kg ha^{-1}	135	240	260	320	300	1255	—

P_2O_5: 90 kg ha^{-1} in the pruned year and 45 kg ha^{-1} in the subsequent years.

K_2O;: 67% of N level in the subsequent years.

Figures in parentheses denote percentage.

Table 7. K_2O level in the pruned year × N:K_2O ratio (K_2O level) in other years on yield of made tea kg ha^{-1} (Seedling tea, Etear Division, Kallyar estate, Anamallais (1978/82)—cut across in April, 1978 at 65-70 cm and tipped in July, 1978; +2 leaves)

N:K_2O ratio in other years	Pruned year April-March		2nd year April-March		3rd year April-March		4th year April-March		Full cycle 1978–82	
	A	B	A	B	A	B	A	B	A	B
2:1 (180)*	1409	1409	2841	2866	3794	3598	3252	3059	11296	10932
4:3 (270)*	1413	1399	2912	2800	3753	3673	3153	3014	11231	10886
1:1 (360)*	1401	1445	2897	2970	3803	3921	3308	3352	11409	11688
Average	1403	1418	2883	2879	3783	3731	3238	3142	11312	11169
CD at P: 0.05										
A,B × level	NS		98		182		152		246	

*values in parentheses denote level of K_2O (kg/ha/year) applied in other years.
A and B correspond to 200 and 300 kg K_2O ha^{-1} applied in the pruned year, 160 kg N ha^{-1} in the pruned year and 360 kg N ha^{-1} in the subsequent years.

significance only from 4th year onwards. However, the increase for the cycle as a whole was significant and the application at rates beyond 200 kg ha^{-1} did not bring out any further increase. The made tea/nitrogen ratio, also, did not show any appreciable increase after 200 kg K_2O ha^{-1} level.

The interaction between K level in the pruned year and NK ratio in the subsequent years on yield is shown in Table 7.

As in the experiments discussed earlier, there was no significant difference in yield in all the years between the treatments 200 and 300 kg K_2O ha^{-1} in the pruned year. However, at the highest NK ratio of 1:1 in the years following the prune, the differences between treatments involving K levels in the pruned year became progressively more marked as the cycle advanced; probably the lower NK ratios of 2:1 and 4:3 were not adequate for the yield levels to get the full benefit out of manuring. This also confirms the Department's recommendation on the use of NK ratio of 1:1 and 10:8 for yields above 3500 and 3000 kg made tea ha^{-1} respectively. The response to increasing NK ratios was seen in all the years only in treatments which received 300 kg K_2O ha^{-1} in the pruned year. It indicates that by developing good frames in the pruned year by applying large quantities of K in that year, a higher N:K ratio can be used in the following years to exploit the yield potential of *the bushes to a greater extent. The formation of sound and healthy* frames in the pruned year for supporting high yields is a physiological process relating to the yield formation in tea and, as already stated elsewhere, it is obvious that K requirement is very high during that year.

(4) **Interaction of plucking interval $\times$K level$\times$N level:** In this experiment, the interactions involving years were not significant indicating that the trend of effects of treatments was the same in all the years. The third and second order interactions involving K level, N level and plucking interval were significant indicating the need for optimization of these factors in relation to each other to achieve highest productivity. The results are given in Table 8. A combination of low NK ratio and extended round had a detri mental effect on yield. On the other hand, the high NK ratio and extended round had shown a positive effect on yield. Highest pro-

Table 8. Interaction of K level, N level and plucking interval on yield (Clone: ATK-1, 1975/78, Caroline Estate—pruned in April, 1974 at 45-50 cm and tipped in August, 1974 at 75 cm+GL)

Treatment	Yield of made tea kg ha^{-1}							
	1st year (Nov. 75-Oct. 76)		2nd year (Nov. 76-Oct. 77)		3rd year (Nov. 77-May 78)*		Total	
	K_1	K_2	K_1	K_2	K_1	K_2	K_1	K_2
A. **Short rounds** (x days)								
N_1	2657	2657	3341	3305	1930	1800	7927	7762
N_2	2858	2779	3600	3614	2326	2268	8784	8662
N_3	2894	2909	3614	3809	2239	2419	8748	9137
Average	2803	2782	3518	3576	2165	2162	8486	8520
B. **Extended rounds** (x+2 days)								
N_1	2671	2599	3290	2916	1951	1656	7913	7171
N_2	2794	3067	3384	3722	1966	2520	8143	9310
N_3	2902	3232	3384	4111	2124	2736	8410	10080
Average	2789	2966	3352	3583	2014	2304	8155	8854

CD at P: 0.05 N×K×Plucking interval 626

*Pruned in end May, 1978.

N_1, N_2 and N_3 are 180, 240 and 360 kg N ha^{-1} respectively.

K_1, K_2 are NK ratio 10:5 and 10:6 respectively.

Table 9. Interaction of K level, N level and plucking interval on growth characters (weighted mean for different seasons)

Treatment	Plucking density* (Weighted average for the year)		Pluck size (Average for the year) cm		Mean weight of plucking (g/pluck)						Moisture content of plucks (Weighted average for the rush periods) %	
					Rush period		Lean period		Weighted average for the year			
	K_1	K_2	K_1	K_2	K_1	K_2	K_1	K_2	K_1	K_2	K_1	K_2
A. Short rounds (x days)												
N_1	17.0	16.6	6.9	6.8	0.44	0.44	0.45	0.43	0.44	0.44	78.7	78.6
N_2	17.2	17.0	6.9	7.0	0.45	0.46	0.46	0.48	0.45	0.47	77.5	78.9
N_3	17.1	17.3	6.8	7.1	0.47	0.46	0.50	0.47	0.48	0.47	77.3	78.9
Average	17.1	17.0	6.9	7.0	0.45	0.45	0.47	0.46	0.46	0.46	77.8	78.8
B. Extended rounds (x+2 days)												
N_1	14.8	14.6	7.0	7.1	0.46	0.45	0.44	0.44	0.46	0.45	78.2	77.2
N_2	16.1	16.3	7.0	6.9	0.47	0.48	0.47	0.47	0.47	0.48	77.0	78.6
N_3	15.6	16.7	7.0	7.0	0.49	0.48	0.50	0.48	0.50	0.48	77.0	79.1
Average	15.5	15.9	7.0	7.0	0.47	0.47	0.47	0.46	0.48	0.47	77.4	78.3

*in 0.1 m^2

ductivity was achieved with highest N and NK ratio, and extended round. The effect of treatments on certain morphological characters of plucks was studied to find out the possible ways by which they had influenced the yield. The results are given in Table 9.

Increasing N and decreasing the plucking interval increased the plucking density. K had a beneficial effect on plucking density only at high N levels and this was more marked in extended plucking rounds than in short plucking rounds.

Extending the plucking interval increased the pluck weight; this was more pronounced in the rush periods than in the lean periods. K had no influence on pluck weight while N had a marked positive effect on pluck weight in both the rush and the lean periods.

Nitrogen increased the moisture content at high K level and decreased it at low K level. At low K level extending the plucking interval had a negative effect on moisture content indicating hardening of shoots, but at high K level, the negative effect was nullified with increasing N levels, and at the highest N level, a positive effect was seen.

Generally, applied N is only fully utilized for crop production when K supply is adequate (Mengel and Kirkby, 1978) and tea nutrition is no exception to this. Due to soil factors, nutritional interactions on yield in tea in South India are marked and pronounced (Ranganathan, Natesan and Subrahmanya Bhat, 1982). The interaction with plucking interval arises from the kinetic factor, namely the time required for utilizing the increased uptake of N and K optimally and converting them into yield.

Thus, optimization of the three factors, (*i*) NK ratio in relation to yield and N level for maintenance of vegetative growth for prolonged period, (*ii*) N level in relation to yield and plucking interval for maintaining reasonably high density of plucking points and pluck weight, and (*iii*) appropriate plucking interval for getting maximum benefit out of N and NK ratios on pluck weight, is required for increasing tea productivity and to sustain it over the years.

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Discussion

J. BENNETT (Madras Fertilizers): I would like to know whether Nitrogen was also split into 8 applications along with Potassium?

S. NATESAN: Yes. N should be applied along with Potassium.

N. A., AWATRAMANI (Consolidated Coffee): Is there any objection to foliar application in tea? If not, why N and K cannot be applied through foliar sprays?

S. NATESAN: We have no objection to foliar application of nutrients in tea. Unfortunately, foliar application of nutrients in tea was found to be ineffective expecially for N, P and K and therefore, we have no recommendation for this. However, we have recommended foliar application of Zinc but this has no relevance to this paper.

E. V. NELLIAT (CPCRI): (1) What is the economics of 8 split applications for tea?

(2) Does K application influence the quality of made tea?

S. NATESAN: (1) The cost incurred in 8 split applications in high yielding tea gardens is more than compensated by the increase in yield obtained. Economics have been worked out, although it was not presented in this paper.

(2) Results obtained in our Institute and other institutes in various countries have shown that there is no influence of K on the quality of made tea.

DISTRIBUTION OF MANGANESE IN SOILS CROPPED TO COFFEE 1. STATUS OF KOPPA ZONE

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ABSTRACT

Soils of Koppa zone, cropped to coffee, were analysed for available (water soluble + exchangeable) and easily reducible manganese and pH. Available manganese ranged between 0.5 and 60 ppm, while active (available + easily reducible) manganese varied from 40 to 1260 ppm. Of the samples analysed, 95.83 per cent had a high content of active manganese and had the potential to cause toxicity. The negative correlation between pH and available manganese was found to be statistically significant.

INTRODUCTION

In a preliminary survey of Chikmagalur and Coorg Districts (Karnataka), Wynad (Kerala), and Anamallais (Tamil Nadu) through soil analysis for different forms of manganese, Iyengar (1972) noted that the soils from Giris and some parts of Kalasa and Balehonnur in Chikmagalur District contained high amounts of both total and available forms of manganese. Interveinal chlorosis was discernible and high soil manganese could be one factor. Therefore, the need to demarcate zones of deficiency and toxicity was felt as a prerequisite. Data pertaining to manganese status of Koppa zone are reported in this article.

MATERIAL AND METHODS

Two hundred and sixteen surface soil samples collected by Mobile Soil Testing Unit, representing Koppa, a primarily *robusta* coffee zone, were utilized. The soils chosen ranged from clay loams to sandy loams in texture with organic carbon content varying between 1.5 and 3.7 per cent. Soil pH was determined in 1:2.5 soil: distilled water suspension.

Water soluble, exchangeable and easily reducible manganese were determined as described by Black (1965) using the colorimetric method developed by Willard and Greathouse (1917).

Results and Discussion

The exchangeable manganese ranged between 0.5 and 60 ppm, while easily reducible manganese varied from 40 to 1260 ppm with a mean of 11.4 and 436.6 ppm respectively.

Sherman and Harmer (1943) had suggested 3 ppm available (exchangeable+water soluble) manganese as the critical limit below which deficiency conditions might prevail. Toth (1951) prescribed 5 ppm available manganese as the critical limit. According to Bondroff (1956), the deficiency was observed in 95 per cent cases with available manganese lying between 0 and 0.5 ppm. The frequency distribution of the available manganese in soils is given in Table 1.

Table 1. Frequency distribution of available manganese (exchangeable+water soluble)

Range ppm	Samples %
0 – 1	12.04
1 – 2	11.11
2 – 3	8.33
3 – 4	3.71
4 – 5	5.55
5 – 10	19.44
above 10	39.82

About 31 per cent of the soils had less than 3 ppm available manganese while 40 per cent had available manganese content less than 5 ppm. Iyengar (1972) reported that the exchangeable manganese content in most of the surface soils was well above 5 ppm and soils from Giri, Balehonnur and Kalasa areas contained still higher quantities.

The distribution of active manganese is projected in Table 2.

Kanwar and Randhawa (1967) fixed a critical range of active Mn at 15 to 100 ppm, classifying soils containing less than 15 ppm as deficient and greater than 100 ppm being rated high. Accordingly, 95.8 per cent of the samples analysed had a high active manganese content and had the potential to cause toxicity. Iyengar (1972)

Table 2. Distribution of active manganese (exchangeable+water soluble+easily reducible)

Range ppm	Samples %
0 – 15	0.00
15 – 100	4.17
above 100	95.83

also reported a high active manganese content (44 to 1355 ppm) in most coffee soils excepting those from Wynad and Anamallais.

The pH of soil samples ranged from 4.7 to 7.2 and its correlation with available manganese was significant ($r = -0.32$). Iyengar (1972) observed a significant correlation between pH and available manganese content at 5 per cent level.

The results reported in this paper indicate that most of the soils cropped to coffee from Koppa zone were opulently supplied with high active form of manganese, which could become toxic under conditions of low pH, poor drainage and increased use of acid forming fertilizers. Rao *et al.* (1978) reported a decrease in leaf manganese status with liming. In an incubation study, it was observed that liming at different rates brought about a decrease in exchangeable manganese. Liming accordingly appeared to be a practical solution in alleviating Mn toxicity. However, soils on which coffee is cultivated are generally high in organic matter status. High manganese content is more than offset by this, which probably explains the reasons for not having encountered manganese toxicity frequently though the indications are otherwise.

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Discussion

V. S. SHARMA (UPASI): What are the Mn toxicity symptoms in coffee?

H. K. DHRUVAKUMAR: Manganese toxicity symptoms are akin to interveinal chlorosis as those seen under deficiency of iron. Young leaves turn pale green, with the midrib and lateral veins remaining greenish. Cupping of leaves is also noticed.

C. C. BIDDAPPA (CPCRI): Since these soils are lateritic in nature and rich in iron, would you expect Mn toxicity at this concentration when Fe content is high?

H. K. DHRUVAKUMAR: Excessive quantities of manganese may be taken up by the coffee trees particularly under conditions of high acidity in very acid soils where uptake of iron is reduced followed by chlorisis and leaf fall.

FERTILIZER MANAGEMENT FOR COCONUT PALMS GROWN UNDER NEGLECT+

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ABSTRACT

An experiment was conducted from 1973 to 1980 in a 20-year old coconut garden near CPCRI, Kasaragod to work out the fertilizer schedule for the quick revival of West Coast Tall palms grown under neglected condition. The study revealed that application of double the recommended annual dose of fertilizers in the first one or two years, followed by the recommended dose of 500 g N + 320 g P_2O_5 + 1200 g K_2O/palm/year in subsequent years, resulted in the earlier response and higher cumulative yield of nuts than the application of one-third, half or recommended dose in the first year followed by the recommended dose in later years. It gave also, an additional return of Rs. 21,754/ha over the farmer's practice and Rs. 8354/ha over the standard dose from the beginning.

INTRODUCTION

Differential fertilizer recommendations are not presently available for adult coconut palms grown under poor, average or good management. The Coconut Research Institute of Sri Lanka had recommended the application of one and a half times the standard dose during the first two years to palms which were not properly cared for (De Silva, 1967). In India, in the fertilizer demonstration trials conducted in farmers' fields during the fifties, a higher dose of fertilizers was applied during the first three years, before reverting to the standard dose (John and Jacob, 1959). Although application of a higher initial dose may result in earlier manifestation of response, there may also be an under utilization

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of applied nutrients since these palms may not be able to utilize them due to their poorly developed root system and leaves. On the contrary, starting with a lower dose may result in more efficient utilization of applied nutrients, thus enabling the palm subsequently to utilize larger quantities, but this may result in delayed response. However, there is no experimental evidence to substantiate the above premise. An experiment was, therefore, carried out to elicit information on the economic and efficient application of fertilizers to palms grown under neglect for their revival.

Material and Methods

The experiment was conducted at Kottikulam, about 10 km south of Kasaragod, in a private garden during 1973–1980, on 20-year old WCT palms grown under neglect in shallow laterite soil. They were spaced 7.5 m apart in the square system. The overall mean yield of the experimental palms was 8.3 nuts/year. The experiment was laid out in RBD with four replications. Each plot had about 20-25 palms, of which six central palms formed the net plot. The fertilizer treatments are given in Table 1.

Table 1. Fertilizer schedule under different treatments

Treatment No.	1973–74	1974–75	1975–76 and onwards
T_1*	Nil	Nil	Nil
T_2	1/3F	2/3F	F
T_3	1/2F	F	F
T_4	F	F	F
T_5	2F	F	F
T_6	2F	2F	F

*Farmer's practice

F denotes the recommended dose of 500 g N, 320 g P_2O_5 and 1200 g K_2O/palm/year

The fertilizers were applied in two splits i.e. one-third during April-May, applied on the surface and forked in, and two-thirds in September in the basins of 1.8m radius and 20 cm deep, along with 50 kg of green leaf. To start with, the first dose of fertilizer was applied in September, 1973.

Data on the number of leaves on the crown, leaf production and yield of nuts were recorded. The ripe nut samples were collected during April 1978 and nut characters determined. Soil samples at two depths (0-25 cm and 25-50 cm) were collected at a distance of about 1.0m from the trunk of the palms at the end of the experiment (May, 1980) and analysed for pH and available N, P and K. Tissue samples were also collected from the standard leaf during May 1980, and N, P, K, Ca and Mg contents determined.

The data were analysed adopting the standard procedure for RBD. Covariance analysis, using the yield data for the year 1973–74 as the ancillary variate, was employed for analysing the yield of nuts per palm.

RESULTS AND DISCUSSION

A. Growth characters

1. Leaf production: Leaf production during the first eight months of the experiment (Nov. '73–June '74) showed significant differences due to the application of graded dose of fertilizers (Table 2). Palms which received double the recommended dose recorded higher rate of leaf production. This clearly showed that application of higher quantity of NPK served as a better starter dose.

Table 2. Effect of fertilizer application on leaf production (no. / palm)

Treatment	11/73-6/74	6/74-7/75	7/75-6/76	7/76-6/77	11/73-6/79
T_1	7.4	8.8	9.5	9.9	56.1
T_2	7.2	9.0	9.7	10.3	57.5
T_3	7.9	9.4	9.8	10.3	57.9
T_4	7.5	9.7	9.9	10.2	57.5
T_5	8.2	9.0	9.9	9.9	58.7
T_6	8.3	9.3	9.8	10.7	60.1
SE/plot	0.40	0.90	0.93	0.89	1.85
CV (%)	5.21	9.81	9.57	8.71	3.19
CD (P=0.05)	0.61	NS	NS	NS	NS

2. Number of leaves on the crown: The control palms, (farmer's practice and 'no fertilizer') had fewer number of leaves on the crown during all the years from 1974 (Table 3). However,

Table 3. Effect of fertilizer application on number of functional leaves on the crown

Treatment	1973	1974	1975	1976	1977	1978	1979
T_1	24.3	24.8	24.6	26.2	27.9	24.4	22.2
T_2	25.0	26.7	26.7	27.2	28.9	26.2	23.8
T_3	23.8	27.6	27.4	27.5	29.7	26.0	24.0
T_4	24.6	27.4	27.5	27.9	29.7	25.7	23.1
T_5	24.9	28.6	28.2	28.3	29.9	25.0	24.6
T_6	25.3	30.1	28.3	28.1	30.1	27.0	23.3
SE/plot	1.81	1.76	1.27	1.07	1.13	1.24	2.30
CV (%)	7.34	6.40	4.67	3.88	3.85	4.84	9.77
CD (P=0.05)	NS	2.65	0.90	NS	NS	NS	NS

the differences were statistically significant only during 1974 and 1975. This was mainly because during those years, the palms which received double dose of fertilizer in the initial years recorded higher number of functional leaves than the palms receiving the other treatments. These palms also showed a higher rate of leaf production during 1973–74.

B. Yield of nuts

The adjusted yield data of the palms presented in Table 4, illustrate the beneficial effect of application of double the recommended dose of fertilizers in the first one or two years on palms

Table 4. Effect of fertilizer application on yield (nuts/palm)*

Treatment	1974–75	1975–76	1976–77	1977–78	1978–79	Total
T_1	13.1	18.6	17.3	25.0	26.8	100.8
T_2	11.7	32.5	43.5	43.3	47.9	178.9
T_3	32.4	48.5	50.3	45.5	53.5	230.1
T_4	33.2	42.9	48.8	40.5	55.5	220.9
T_5	36.0	62.9	52.2	56.4	57.8	265.3
T_6	38.9	57.3	53.3	53.6	56.3	259.4
SE/plot	11.0	10.8	10.1	9.6	7.9	—
CV (%)	39.7	24.7	22.8	21.8	15.8	—
CD (P=0.05)	17.8	17.6	16.3	15.6	12.8	—

*Yield adjusted by covariance analysis taking 1973–74 yield as the concomitant variable.

grown under neglect. These palms have recorded the highest yield of nuts during the years of study. By the end of third year (1975–76), the palms receiving double the dose in the first year (T_5) gave a cumulative yield of 98.9 nuts which was 67.2 nuts more than the yield of control palms and 22.7 nuts more than the yield from palms receiving standard dose from the beginning of fertilizer application. Response to the application of NPK fertilizers for coconut under rainfed condition had been recorded already by John and Jacob (1959) and Muliyar and Nelliat (1971). The palms receiving half the recommended dose in the first year (T_3), also, gave significantly higher yield during 1975–76 than T_1 and T_2. However, application of the recommended dose in the first year (T_4) did not confer any additional advantage over application of half the recommended dose.

The palms receiving double the dose in the first one or two years attained their highest yields in 1975–76. In the other fertilizer treatments, the increasing trend continued for one more year, even though the highest yields were recorded only during 1978–79. This clearly showed that application of a higher dose initially served to boost up such palms to attain their peak yields earlier. The data also show that even in the control plot there was an increase in yield over the years. This increase is attributable to the better care and management practices like tillage and green leaf application which the farmer had adopted after noticing the marked improvement in yield and stand of palms in the other plots.

The cumulative yield of nuts/palm for the five year period (1974–75 to 1978–79) showed a marked increase due to the application of double the recommended dose of fertilizers in the first one or two years and the standard dose of 500 g N, 320 g P_2O_5 and 1200 g K_2O/palm/year in subsequent years. Palms which received double dose of fertilizers in the first year gave the highest cumulative yield of 265 nuts/palm which was 165 nuts more than that under farmer's practice (T_1) and 44 nuts more than the application of standard dose from the first year of the experiment (T_4).

C. Economics

The additional cost and returns for the treatment schedules (Table 5) clearly shows the advantage of manuring coconut palms.

Table 5. Additional costs and returns for the different manurial schedules

Treatments	Cumulative yield of nuts/palm (1974–75 to 1978–79)	Increase in yield over T_1 (nuts/palm)	Value of increased yield/palm	Cost of fertiliser application per palm (1973–74 to 1978–79)	Additional Returns per palm	Additional Returns per ha
	No.	No.	Rs.	Rs.	Rs.	Rs.
T_1	100.8	—	—	—	—	—
T_2	178.9	78.1	97.63	65.80	31.83	5570
T_3	230.1	129.3	161.63	69.68	91.95	16091
T_4	220.9	120.1	150.13	73.56	76.57	13400
T_5	265.3	164.5	205.63	81.32	124.31	21754
T_6	259.4	158.6	198.25	89.08	109.17	19104

Note: (i) Prevailing price of ccconut=Rs. 1.25/nut

(ii) Cost of fertilizer per kg of nutrient, N:Rs. 5.11 (urea), P_2O_5:Rs. 5.87 (Superphosphate), K_2O: Rs. 2.77 (muriate of potash), green leaf: Rs. 2.00/50 kg.

(iii) Application charges Rs. 2.50/palm/year.

Among the different manurial schedules, application of double dose in the first year and standard dose in the subsequent years gave the highest net return of Rs. 124.3 per palm over a period of five years, followed by the application of double dose in the first two years and the standard dose in subsequent years (Rs. 109.2). By the end of third year (1975–76) palms receiving the treatment T_5 had given the highest cumulative net return of Rs. 7906/ha followed by T_3 (Rs. 5005/ha). The net returns per hectare was Rs. 21,754/ha during the five year period, when double dose was given in the first year compared to Rs. 13,400/ha when the standard dose was applied from the beginning and Rs. 16,091/ha when half the recommended dose was given in the first year and standard dose in subsequent years. The cost:benefit ratio was also most favourable under the former treatment. For every rupee invested on manuring the total return was Rs. 2.53 (T_5). It ranged from 1.48 to 2.32 in the other treatments.

D. Nut characters

The nut characters, namely, volume and weight of the husked and unhusked nuts, and the copra content per nut, were not influenced significantly by any of the treatments. However, the palms under farmer's practice (T_1) recorded lower values for all the characters; whereas the palms which initially received double the recommended dose for two years recorded the highest values. Increase in the copra content due to fertilizer application had been reported by Markose and Nelliat (1975) also. The copra content of nuts of control palms was only 130 g/nut while it was 198 g/nut in T_6 and ranged from 143-165 g in other treatments.

E. Nutrient content of leaf

The N and P contents in the standard leaf (14th leaf) did not show any significant difference among the treatments (Table 6). The nitrogen content of the standard leaf (1.65 — to 1.79 per cent) is quite satisfactory compared to the accepted critical level of 1.8-2.0 per cent. The P content was also very close to the critical level of 0.12 per cent. The K content of the standard leaf of the palm in the control plot (1.04 per cent) was within the range of sufficiency (0.8-1.0 per cent). However, the K content showed a marked increase in the fertilized plots (1.45-1.72 per cent) which to some extent reflected on the yield of nuts. This observation is at variance from that of earlier workers (Kanapathy, 1972) and hence suggests the need for a reexamination of the critical values fixed for K. Under oui conditions, the Mg content showed a significant reduction in the manured plots. Hence, there is a need for adequate Mg nutrition, especially when high levels of potash are applied (Nelliat, 1973).

Table 6. Effect of fertilizer application on nutrient composition of the standard leaf (May 1980) and copra content

Treatment	N	P	K	Mg	Copra
		Percentage			(g/nut)
T_1	1.75	0.12	1.04	0.41	130
T_2	1.76	0.12	1.45	0.33	143
T_3	1.79	0.13	1.61	0.33	160
T_4	1.65	0.13	1.50	0.31	165
T_5	1.75	0.11	1.72	0.30	146
T_6	1.65	0.12	1.56	0.32	198
SE/plot	0.12	0.01	0.17	0.03	27.0
CV (%)	6.76	8.90	11.59	8.24	
CD (P=0.05)	NS	NS	0.26	0.04	NS

F. Soil pH and nutrient status

The soil pH and available nitrogen at 0-25 cm and 25-50 cm depths were not influenced by the fertilizer treatments (Table 7).

Table 7. Effect of fertilizer application on soil chemical properties (May 1980)

Treatment	Available N (ppm)		Available P (ppm)		Available K (ppm)	
	0-25cm	25-50cm	0-25cm	25-50cm	0-25cm	25-50cm
T_1	110	109	3.9	0.4	56	31
T_2	107	104	26.1	2.4	218	181
T_3	107	106	18.0	1.2	216	190
T_4	111	108	18.5	1.4	224	150
T_5	112	107	30.3	1.1	227	155
T_6	101	102	33.8	1.5	168	127
SE/plot	13.1	8.5	8.7	0.50	82.2	75.4
CV (%)	12.10	8.06	39.93	37.73	43.37	54.30
CD (P=0.05)	NS	NS	13.09	0.75	123.8	NS

The pH of soil at 25-50 cm depth was 5.0 while it was 5.4 in the upper (0-25 cm) layer. There was a marked build up of available phosphorus in 0-25 cm layer and available K in the 0-25 and 25-50 cm depths. In the control plot, available P content in 0-25 cm depth of soil was only 3.9 ppm and it was raised to 18.0 to 33.8 ppm in the fertilized plots. The available P in the 25-50 cm was very low, in all treatments, although there was a slight increase in P status of the fertilized plots, the actual increase being 0.7 to 2.0 ppm. The available K content in the control plot was 56 ppm in the 0-25 cm depth and 31 ppm in 25-50 cm depth. It increased 3-4 times in the surface layer (168-227 ppm) and 4-6 times in the 25-50 cm depth (127-190 ppm) due to fertilizer application.

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Discussion

K. SHAMA BHAT (CPCRI): Can we now conclude that to get a response to fertilizers applied we need not wait for 3 years, in the case of coconuts?

P. GOPALASUNDARAM: The fertilizers in the experiment were first applied in 1973. One of the beneficial effects of K, is the improving of setting percentage. The increase in yield obtained in 1974–75 is mainly due to this. The full response to the fertilizers applied from 1973–74 is manifested only from 1975–76; which is the 3rd year (which is as expected).

C. S. SRINIVASAN (Coffee Research Sub-Station, Chethalli): The root growth may be poor under neglected conditions, in which case, applying the full or higher dose of nutrients may not give immediate response. How do you explain this reasoning in the light of twice the recommended dose of fertilizer giving better response in your study ?

P. GOPALASUNDRAM: There are three points to be considered:

(1) Soil is very much depleted because coconut had been growing for 20 years without any addition of nutrients.

(2) The annual dose of fertilizers are applied in two splits.

(3) The concentration of the applied nutrients in the soil solution would not have been sufficiently high to result in too much of a loss, because of the depleted condition. Hence, the palms would have been able to absorb more nutrients over a longer period and exhibit their response earlier.

RAINFALL AND COCONUT YIELD IN THE PILICODE REGION, NORTH KERALA

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ABSTRACT

The onset of effective monsoon and dry spells during the monsoon season have been worked out using the daily rainfall data from 1942 to 1981 of the Regional Agricultural Research Station, Pilicode. An attempt has been made to study the relationship between the annual coconut yields and rainfall trends using 20 years' moving average. The study indicates that both high rainfall during the months of June, July and August, as well as the absence of post-and pre-monsoon showers adversely affect the subsequent years' yields.

INTRODUCTION

Coconut production unlike in other crops is greatly influenced by annual variations of climatic factors such as temperature, rainfall, humidity, wind speed and sunshine. Of these, studies indicate that only rainfall influences coconut yields significantly. Patel (1938) pointed out that coconut yield in any particular year is influenced by the January to April rains for two years prior to harvest, together with the rains received in January to April of the year of harvest. Further, the influence of weather on the yield is a cumulative function of seasonal conditions prevailing in the period of 44 months after spadix primordia initiation (Bhaskaran and Leela, 1977).

Though the annual rainfall of the Pilicode region (North Kerala) is abundant, crop yields are low due to its uneven distribution and high intensity during the monsoon. This region, also, experiences soil moisture deficit from October to May due to lack of rains, which inhibits crop growth and production. An attempt has been made in this paper to understand the relation between the distribution of rainfall and coconut yields under rainfed conditions.

Material and Methods

The unit yields of West Coast Tall and the annual rainfall received at the Regional Agricultural Station, Pilicode for the period 1942 to 1981 have been used for the present study. The onset of effective monsoon was determined on the basis of Raman's (1978) criteria, which stipulate that the first day's rain in a period of 7 days should be atleast 5 mm with the total rain of 35 mm with 4 rainy days in that period. The number of dry spells, 7 days without rain, in the rainy seasons were also recorded during the study period. The 20 years-moving averages of the annual rainfall and coconut yields were used to analyse the relationship between them.

For a better understanding of the utilization of soil moisture in the years of high and low coconut production, the annual water balances were worked out using Thornthwaite and Mather's (1957) book-keeping procedure. The optimum rainfall for coconut palm under rainfed conditions of this region was worked out and represented graphically using Azzi's (1956) method. The optimum rainfall for coconut palm was obtained by the method of approximations drawing a series of optimum precipitation lines in a graph between years on X-axis and rainfall on Y-axis, and indicating excellent yield as in a particular year by a dot over that line and poor yield on a circle below the line. The line that gives approximately equal number of dots and circles below and above it was taken as the optimum precipitation line for the coconut palm.

Results and Discussion

Figure 1a shows the onset of effective monsoon over the Pilicode region. It can be seen that the early and the late onset of effective monsoon was on 12 May in 1960 and 13 June in 1979 respectively. The percentage number of dry spells in rainy season during the period 1942 to 1982, was 0 per cent in June, 2.5 per cent in July and 12.5 per cent in August. The number of dry spells in the rainy seasons was low and appeared to have no effect on coconut yield.

Figures 1b and 1c show the 20 years-moving average between the annual rainfall and coconut yields respectively.

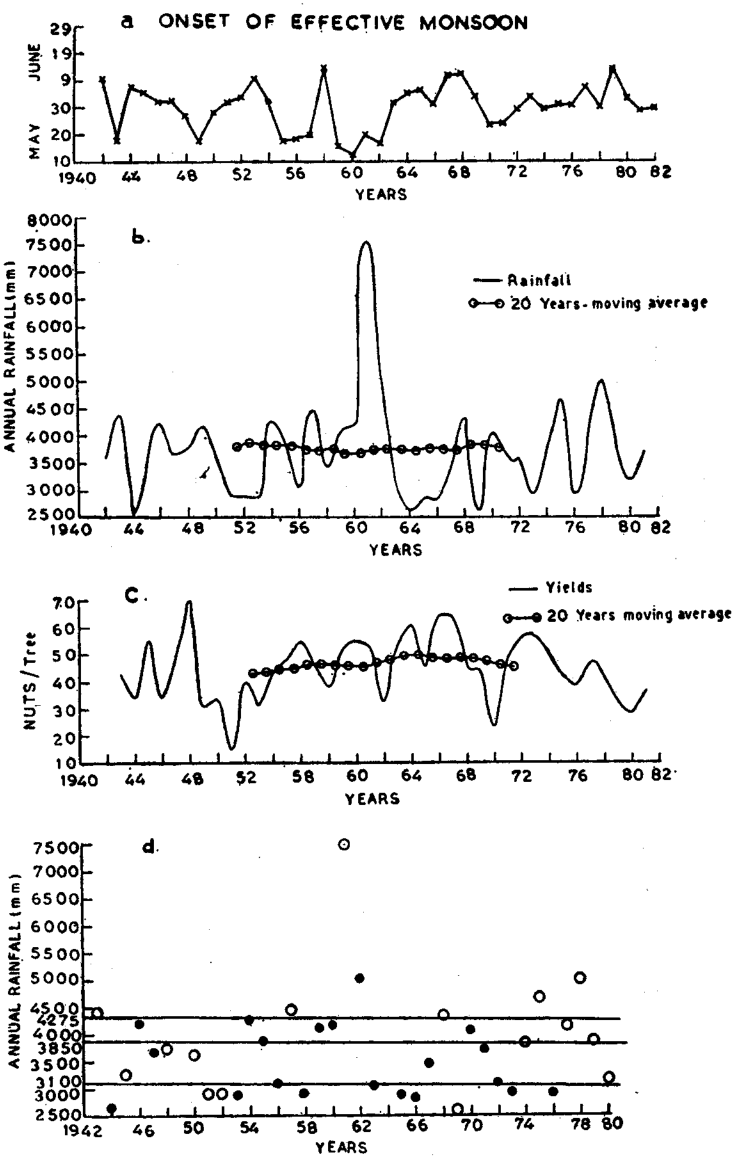

Fig. 1. Rainfall and coconut yield over the period 1942–1981.

Table 1. Water Balance Parameters (mm)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1946													
P	0	0	16	87	48	1281	1034	1027	171	190 •	218	133	4205
PE*	139	142	170	154	139	99	93	102	111	113	115	128	1505
AE	107	62	54	97	58	99	93	102	111	113	115	128	1139
WD	32	80	116	57	81	0	0	0	0	0	0	0	366
WS	0	0	0	0	0	955	941	925	60	77	103	5	3066
1947													
P	0	14	57	179	60	755	1027	698	633	190	37	18	3668
PE*	139	142	170	154	139	99	93	102	111	113	115	128	1505
AE	107	72	88	154	82	99	93	102	111	113	105	83	1209
WD	32	70	82	0	57	0	0	0	0	0	10	45	296
WS	0	0	0	0	0	463	934	596	522	77	00	0	2592
1949													
P	0	0	0	32	497	970	1286	720	452	190	6	0	4153
PE*	139	142	170	154	139	99	93	102	111	113	115	128	1505
AE	80	46	26	44	139	99	93	102	111	113	95	65	1016
WD	59	96	141	110	0	0	0	0	0	0	20	63	489
WS	0	0	0	0	126	871	1193	618	341	77	0	0	3226
1950													
P	0	0	0	2	222	904	1374	436	537	86	75	0	3636
PE*	139	142	170	154	139	99	93	102	111	113	115	128	1505
AE	42	23	16	9	139	99	93	102	111	113	112	86	945
WD	97	119	154	145	0	0	0	0	0	0	0	42	560
WS	0	0	0	0	0	646	1281	334	426	27	0	0	2714

P—Precipitation, PE—Potential evapo-transpiration, AE—Actual evapo-transpiration, WD—Water deficit, WS—Water surplus.

PE*—The same values are used for all the years and PE values are taken from I.M.D. Scientific Repot No. 136.

To understand the soil moisture utilization, the water balances are worked out and presented in Table 1. The water deficit (WD) was not seen in 1946 during November and December and it was also low (184 mm) in 1947 during January to April, which were responsible for the high yield obtained in 1948. Also, the water surplus (WS) in July during 1946 (941 mm) and 1947 (934 mm) was comparatively low. On the other hand, the high water deficit (598 mm) from November 1949 to April 1950 and the high water surplus in July 1949 (1193mm) and 1950 (1281 mm) were responsible for the low yield in 1951. From this analysis, it appears that the continuous dry spell for six months with high moisture deficit and high surplus during July decreased the coconut yields in the subsequent years considerably.

The rainfall lines with distribution of high and poor annual yields presented in Figure 1d, show that the yield in a particular year is *above normal* if the previous year's annual rainfall was above 3100 mm, and *below normal* if it was above 4275 mm. The distribution of high and poor at the rainfall line of 3850 mm was almost equal and taken as the optimum rainfall for coconut palms.

ACKNOWLEDGEMENT

The author is grateful to the Director of Research, Kerala Agricultural University and the Associate Director, R.A.R.S., Pilicode for providing facilities.

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Discussion

R. C. MANDAL (CPCRI): Absence of pre-and post-monsoon showers may, affect yield adversely but not high rainfall combined with absence of the pre- and post-monsoon showers.

G.S.L.H.V. PRASAD RAO: Under the Pilicode climatic conditions, absence of post-monsoon, pre-monsoon, and high water suplus will certainly affect the subsequent years' yields. Moreover, this is the reason why coconut yields are poorer in North Kerala than in South.

SHADE RESPONSE OF SOME COMMON RAINFED INTERCROPS

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ABSTRACT

An attempt is made to develop a field method with artificial shade to evolve parameters for classifying crops according to their shade requirements. In shade sensitive crops like sweet potato, all growth parameters namely, leaf area index, total dry weight per plant, net assimilation rate, yield and harvest index, showed an exponentially decreasing trend with increase in shade intensity. In shade tolerant crops, the growth parameters showed either a linear decreasing trend with shade, as in *Coleus* or an initial passiveness with a sharp decline after 50 per cent shade intensity as in *Colocasia*. In shade loving crops such as ginger and turmeric, the growth parameters showed a positive beneficial effect upto 25 per cent and 50 per cent shade respectively with a sharp decline thereafter. The results will be useful to assess the suitablity of the crops to be raised as intercrops in agrosystems such as coconut or arecanut culture.

INTRODUCTION

A factor that decides the compatibility of crop combinations in a cropping system such as coconut culture is the ability of associated crops to come up under shade. This ability has been reported to vary widely between species of plants, there being varying degrees of yield decline in most of the common 'sun plants'. Yet, many crops like ginger (Singh, 1967; Aclan and Quisumbing, 1976) and coffee (Silveira and Maestri, 1973) are reported to be performing better under shade. The present study was conducted to evaluate the shade response of fivec ommon rainfed intercrops of coconut namely, colocasia (*Colocasia esculenta* (L) Schott), coleus (*Coleus parviflorus* Benth), sweet Potato (*Ipomoea batatas* L.) turmeric (*Curcuma domestica* Val.) and ginger (*Zingiber officinale* Rosc).

MATERIAL AND METHODS

This field experiment was conducted at the College of Horticulture, Vellanikkara, Trichur, Kerala during 1980-81.

The experiment was laid out in RBD with five replications. The treatments consisted of four intensities of shade as given below:

S_0— 0.0% shade (no shade)

S_1—25.0% shade (low shade)

S_2—50.0% shade (medium shade)

S_8—75.0% shade (high shade)

Artificial shading to the desired level was obtained by fixing unplaited coconut leaves on erected 'pandals' 11.0×6.0×3.0 m supported on wooden reapers and posts with 3m space between them. Each 'pandal' was covered on all the sides with unplaited coconut leaves except for 60 cm from the ground level to avoid the the direct entry of sun's rays from sides. The sizes of the raised beds were 4.0×1.2m for sweet potato, 4.0×3.0m for *Colocasia* and 4.0×1.0m beds for *Coleus*, turmeric and ginger. The light intensity in the plots was checked frequently with an Aplah luxmeter to maintain the shade intensity at the desired levels.

Local varieties of sweet potato, *Coleus* and *Colocasia* varieties, Kasturi Tanuka of turmeric and Juggijan of ginger were used. They were harvested at 110, 125, 140, 270 and 275 days after planting or sprouting as the case may be.

Observations on plant height, leaf area index (LAI), net assimilation rate (NAR), and dry matter accumulation were recorded at monthly/bimonthly intervals, and those on harvest index and tuber/rhizome yield at the time of harvest. For recording observations on height, ten plants were marked in each plot, and for dry weight, LAI and NAR, three plants were harvested each time at periodical intervals.

RESULTS AND DISCUSSION

Observations recorded on plant height, leaf area index, net assimilation rate, dry matter yield and harvest index are given in Tables 1 to 5. Based on the effect of shade intensity on the growth parameters, the crops are classified according to their reaction to shade.

(a) Shade Sensitive crops: In sweet potato, all growth parameters except height of plants which showed etiolation effect showed exponential decrease with the intensity of shade (Table 1). The regression equation for the effect of shade (x) on yield (y) is as follows:

Log $(y+1)=0.2089-0.1589x+0.0289x^2$ ($R^2=0.995$) The exponential decrease of both total dry matter and harvest index indicate that not only the photosynthetic efficiency is reduced but also the partitioning of assimilates into tubers.

(b) Shade tolerant crop: (*i*) In *Coleus*, all growth parameters except the plant height which showed a slight etiolation effect showed linear decrease with shade (Table 2). The regression equation of shade (x) on yield (y) is given below:

$$y=22.66-3.95\times \quad (R^2=0.9913)$$

The decline in total dry matter with shade was much slower than that in harvest index, and, also, the leaf area index showed an increasing trend with shade at 95 days and after. All these indicate that the photosynthetic efficiency factors are more involved in increasing reduction in yield with shade than the partitioning, factors.

(*ii*) In *Colocasia*, the growth parameters except the height of plants showed marginal variations upto 50 per cent shade intensity and then started manifesting a sharp declining trend (Table 3). The regression equation of shade (x) on yield (y) is given below:

$$\text{Log } y:1.2311-0.0584x-0.0198x^2 \quad (R^2=0.9103)$$

Similarity of the patterns of response on tuber yield and dry matter accumulation, and the marginal effect on the harvest index indicate that the efficiency of photosynthesis as affected by shade may be the cause for the drop in yield after 50 per cent shade. *Colocasia* appears to have high flexibility with respect to shade requirements and it is amenable for cultivation both as a monocrop or as an intercrop in other agro-systems offering interspace with shade upto 50 per cent intensity.

Table 1. Effect of shade on growth and yield of sweet potato

Shade intensity %	Plant height at 90d (cm)	Leaf area index at				Total dry weight at 110d g/plant	Net assimilation rate g/m²/d		Tuber yield (fresh weight) t/ha	Harvest Index
		30d	60d	90d	110d		Between 30 & 60d	Between 60 & 90d		
0 (No shade)	276.2	2.72	8.01	7.55	11.09	149.6	3.48	2.68	7.65 (0.938)	0.26 (0.101)
25 (Low shade)	356.3	1.58	4.84	6.37	6.74	73.0	2.79	2.25	1.63 (0.420)	0.09 (0.039)
50 (Medium shade)	391.7	1.20	2.68	4.58	6.60	66.8	1.84	1.78	0.14 (0.056)	0.01 (0.005)
75 (High shade)	400.2	1.18	2.45	3.03	2.74	18.7	1.24	1.25	0.00 (0.000)	0.00 (0.000)
SEm	17.8	0.32	0.69	0.59	0.90	11.4	0.26	0.82	0.17	0.032
CD (0.05)	54.8	0.97	2.11	1.81	2.78	35.0	0.81	NS	0.53	0.097

NS=Not significant

Figures in parentheses represent log (y + 1) transformed values.

Tab'e 2. Effect of shade on growth and yield of *Coleus*

Shade intensity %	Plant height 125d (cm)	Leaf area index at 35 d	65 d	95 d	125 d	Total dry weight at 125d g/plant	Net assimilation rate ($g/m^2/day$) Between 35 & 65 days	Between 65 & 95 days	Tuber intensity no. per plant	Tuber yield (Fresh weight) t/ha	Harvest Index
0 (No shade)	76.3	3.11	9.46	8.15	3.32	43.9	3.30	1.08	27.1	34.10	0.61
25 (Low shade)	81.1	2.41	7.92	10.61	4.58	32.0	3.34	2.26	37.5	26.56	0.60
50 (Medium shade)	80.0	2.55	8.52	10.38	3.09	23.6	2.14	1.36	33.0	20.04	0.54
75 (High shade)	77.1	1.65	6.42	5.59	3.82	17.2	1.99	0.15	39.8	9.92	0.49
SEm	3.3	0.42	1.42	1.80	1.05	5.1	0.35	0.58	3.9	2.11	0.03
CD (0.05)	NS	NS	NS	NS	NS	15.6	1.06	NS	12.1	6.50	0.07

Table 3. Effect of shade on growth and yield of *Colocasia*

Shade intensity %	Plant height at 150d (cm)	Leaf area index at 30 d	60 d	90 d	120 d	150 d	Total dry weight at 180d g/plant	Tuber yield fresh weight Total tuber	Side tuber	Harvest Index
0 (No shade)	45.6	0.67	1.43	0.83	0.83	0.41	131.4	17.51	12.54	0.95
25 (Low shade)	52.0	0.71	1.13	1.07	0.74	0.55	112.5	16.71	11.06	0.95
50 (Medium shade)	51.2	0.76	0.55	0.67	0.80	0.54	109.2	15.77	9.75	0.92
75 (High shade)	51.9	0.68	0.57	0.55	0.31	0.48	61.0	7.29	3.47	0.87
SEm	3.2	0.10	0.30	0.13	0.09	0.07	12.9	1.81	1.34	0.01
CD (0.05)	NS	NS	NS	NS	0.29	NS	39.7	5.58	4.12	0.04

Table 4. Effect of shade on growth and yield of turmeric and ginger.

Shade intensity %	Plant Height at 180d (cm)	Leaf area index at 60 d	Leaf area index at 120 d	Leaf area index at 180 d	Total dry weight at 220d g/plant	Net assimilation rate ($g/m^2/day$) Between 60–120 days	Net assimilation rate ($g/m^2/day$) Between 120–180 days	Rhizome yield (fresh weight) t/ha	Harvest Index
Turmeric:									
0 (No shade)	115.5	4.05	9.57	15.77	10.85	1.40	1.66	48.91	0.59
25 (Low shade)	126.0	2.89	10.57	11.97	10.41	1.60	1.63	48.84	0.66
50 (Medium shade)	144.0	2.89	11.46	13.44	12.05	1.58	1.54	53.26	0.58
75 (High shade)	133.9	2.21	8.91	9.61	7.89	1.36	1.49	28.89	0.64
SEm	3.5	0.27	1.18	2.00	0.76	0.18	0.41	3.31	0.03
CD (0.05)	10.8	0.82	NS	NS	2.33	NS	NS	10.19	NS
Ginger:									
0 (No shade)	46.6	0.75	3.45	6.21	54.6	2.44	2.39	21.05	0.64
25 (Low shade)	58.6	0.50	3.11	6.56	60.9	2.77	2.26	22.22	0.57
50 (Medium shade)	63.9	0.55	2.13	7.18	49.6	1.89	2.82	19.54	0.52
75 (High shade)	66.5	0.60	2.24	5.48	47.8	1.96	1.96	14.03	0.50
SEm	2.4	0.11	0.48	0.67	5.5	0.24	0.41	1.40	0.03
CD (0.05)	7.5	NS	NS	NS	NS	NS	NS	4.32	0.09

Note: days are counted after sprouting

(c) Shade loving crop: In turmeric, the growth parameters except harvest index which showed marginal variation, exhibited a quadratic trend with shade, with the maximum value lying between 25 and 50 per cent. In ginger, the growth parameters except the height of plant which increased with shade, exhibited a quadratic trend with a maximum at 25 to 50 per cent shade. The regression equations of shade (x) on yield (y) are given below:

Turmeric: $\text{Log } y = 1.7234 + 0.0267x - 0.0115x^2 - 0.0072x^3$ $(R^2 = 0.9998)$

Ginger: $\text{Log } y = 1.3295 - 0.0292x - 0.0105x^2$ $(R^2 = 0.9998)$

Considering the total dry weight and rhizome yield, the optimum shade appears to be 25 and 50 per cent for ginger and turmeric respectively. Aclan and Quisumbing (1976) also observed that the ginger yields are high at 25 to 50 per cent shade. Similar trends have also, been reported in other shade loving crops like tomato (Edmond *et al.*, 1964), tea (Joseph, 1979) and green panic (Wong and Wilson, 1980). Hardy (1958) opined that there may be a threshold illumination intensity for optimum performance of photosynthesis beyond which the stomata tend to close in shade loving plants. In ginger, the harvest index decreased with shade indicating that the partitioning factors are involved in reducing yield beyond the optimum shade. In turmeric, the similarity of the trends in dry matter and yield responses to shade indicate that the photosynthetic factors might play a dominant role in deciding the response of turmeric to shade.

A classification of plants according to their shade requirement, thus, appears to be possible from a study of response of crop to shade with respect to certain growth parameters such as height of plants, LAI, NAR, dry matter, yield and harvest index.

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The authors wish to place on record their sincere thanks to Dr. P. C. Sivaraman Nair, Director of Research, Kerala Agricultural University (Former Associate Dean, College of Horticulture), and Dr. P. K. Gopalakrishnan, Associate Dean, College of Horticulture for providing facilities for conducting this work. The financial assistance in the form of Junior Fellowship to the senior author, by the Indian Council of Agricultural Research is also duly acknowledged.

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DISCUSSION

P. S. SREENIVASAN (Agrometeorologist, Palghat): The curve fitted to turmeric does not appear to be a mathematical one for the simple reason that it is not a smooth one.

VIKRAMAN NAIR: It is a mathematical regression model—a polynomial (cubic) fitted to the logarithm of yield. It is smooth enough for the regression model.

T. RAMANATHAN (Coconut Research Station, Veppankulam):

(1) What was the method adopted to regulate the light intensity in this, experiment?

(2) Whether the light entensity was regulated throughout the crop period of intercrops?

VIKRAMAN NAIR: (1) It was regulated using measurements with a luxmeter.

(2) Yes.

STUDIES ON INTERCROPPING COCONUT WITH DIFFERENT FIELD CROPS IN MAIDAN TRACT OF KARNATAKA

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ABSTRACT

Intercropping trails taken up with eleven crops in coconut plantations showed that the maximum net income/ha was obtained with Chilli (Rs.8784 followed by Ragi (Rs. 6473), Potato (Rs. 6181) and Bengalgram (Rs. 6116). In the six double cropping sequence systems, the maximum net income/per ha was obtained with Potato-Wheat (Rs.12801), followed by French Beans-Wheat (Rs. 12,750), and Ragi-Wheat (Rs. 9,208) systems. There was no deleterious effect on coconut crop due to intercropping. The employment opportunities also increased on an average by 204 days in single intercropping and by 479 days in double cropping sequence systems.

INTRODUCTION

Growing inter-crops in coconut gardens is an age-old practice in the maidan tract of Karnataka. Nair (1979) described possibilities for increasing agricultural production from areas planted with coconuts by intensive cropping practices. Also, promising practices, particularly suitable to small farmers such as, growing seasonal, annual and or perennial crops in the interspace of coconut was reported by many workers (Liyanage, 1974; Bavappa, 1976; Santhirasegaram, 1967; Varghese *et al.*, 1979). Investigations were undertaken on growing field crops in the interspaces of coconut so as to determine a suitable combination of intercrops specific to the maidan tract of Karnataka.

MATERIAL AND METHODS

The field experiments were conducted for four years from 1977 to 1981 under the All India Co-ordinated Coconut and Arecanut Improvement Project at Agricultural Research Station, Arsikere, Karnataka. The soil type is medium black clay with a pH of 8.2. The intercrops were raised in the existing bulk plantations having 14 year old palms. The plot size consisted of a single palm planted at 9×9m. Six crops were tried at a time with a check plot of 'coconut alone' in 3 randomized blocks. Intercrops were grown in a 65 m^2 area around each palm leaving a 2m space around the base to facilitate fertilizer application to the main crop. The fertilizers were applied as per the recommended package of practices.

RESULTS AND DISCUSSION

The results show that the yield of coconut has generally increased due to intercropping irrespective of the crops tried and the number of intercrops taken in a year. However, among eleven crops tried, French Beans, Cowpea, Chillies and Ragi were found to be superior in increasing yield of nuts. Among the various intercrops tried, the cost-benefit ratio of Ragi (1.15), Chillies (1.43) and Bengal-gram (1.21) were the best among the single crops.

Among the six double intercropping sequences tried, the cost-benefit ratios of French Bean-Wheat (2.58); Chillies-Wheat (1.47); Potato-Wheat (1.38), and Ragi-Wheat (1.22) proved to be most profitable. In this study, it is evident that by adopting such cropping practices the labour employment can be increased on an average by 204 days in single intercrop systems and 479 days in double cropping sequence systems.

ACKNOWLEDGEMENT

The authors are thankful to Dr. K. Krishnamurthy, Director of Research, University of Agricultural Sciences, Bangalore for providing facilities and to the Indian Council of Agricultural Research for financial assistacne.

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DISCUSSION

K.V.A. BAVAPPA: (CPCRI): Comment: The advantage to coconut in a mixed cropping system comes from the inputs of nutrients which are given for each crop, the weed control and favourable microbial changes that take place in the soil, for which there are evidences. Thus there is a system advantage.

PERFORMANCE OF DWARF X TALL HYBRID COCONUT IN ROOT (WILT) AFFECTED AREAS OF KERALA UNDER DIFFERENT FERTILIZER LEVELS

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Abstract

A field experiment was conducted to study the performance of Dwarf × Tall hybrid coconut palms under different fertilizer levels in the root (wilt) disease affected area. With the lowest level of fertilizer application, an average yield of 120 nuts/palm/year was obtained. 500 g N, 300 g P_2O_5 1000 g K_2O with 500 g Mg O could be taken as the ideal dose of fertilizer application in the early bearing periods under rainfed conditions. About 22 per cent of the total palms had contracted root (wilt) disease at the end of ninth year from planting.

Introduction

The beneficial characters of Dwarf × Tall hybrid coconut palms such as early bearing and high production of nuts with high copra content have been reported by Satyabalan (1956). Based on the results of the survey on the performance of D × T hybrids in the root (wilt) disease affected areas of Kerala, Pillai and Rawther (1972) have recommended the large-scale propagation of the hybrids in these areas as they show considerable tolerance against root (wilt) disease. The influence of fertilizer management on growth, yield and incidence of root (wilt) disease, in Chowghat Dwarf Orange × West Coast Tall hybrid palms (D × T) up to ninth year of planting are presented in this paper.

Material and Methods

The experimental field representing endemic root (wilt) affected area has sandy loam soil with low fertility status. The soil is acidic

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(pH 5.5) and mechanically analysed 86 per cent sand, 7.8 per cent clay and 2 per cent silt. The nutrient status was poor with 4 and 28 ppm of available N and K. The soil was rich in available P (18 ppm). One year old D$\times$T hybrid coconut seedlings were planted in July 1972 in a randomized block design with three levels of NPK, at L_1 = g 500, 300 and 1000 g N, P_2O_5 and K_2O/adult palm/year respectively; L_2-twice the dose of L_1; L_3—thrice the dose of L_1; two levels of Ca (0 and 12.5 kg $Ca(OH)_2$/palm/year) and three levels of Mg (0.500 and 1000 g Mg0/palm/ year) in a 3$\times$2$\times$3 factorial design with three replications. The seedlings were planted at a spacing of 7.5$\times$7.5 m. Each plot consisted of 6 palms in a 3$\times$2 rectangular shape.

Fertilizers were applied to the seedlings at the rate of 1/10th the adult dose after three months of planting, 1/3rd after one year, 2/3rd after two years and full dose from third year onwards using urea and ammophos for N and P, muriate of potash for K, slaked lime for Ca and magnesium sulphate (hydrated) for Mg. Fertilizers were applied in two splits namely, 1/3 of the annual dose in April-May (pre-monsoon), and 2/3 in August-September (post-monsoon). NPK and Mg fertilizers were applied in basins around the palms, whereas lime was broadcast over the entire plot including the basins, and ploughed/forked in. A basal application of 50 kg of cattle manure per palm was given during July-August every year since 1974. The palms were grown under rainfed conditions.

Height, girth at collar and total number of leaves were recorded at the time of planting, and observations on leaf production, flowering and incidence of disease were taken, periodically in addition to the yield of nuts.

Results and Discussion

The interaction of NPK$\times$Ca$\times$Mg was significant on the production of leaves in 1973 and till December, 1978 (Table 1). The first level of NPK, Ca_1 Mg_1 combination and the second and third levels of NPK, Ca_1, Mg_2 combinations gave the highest leaf production. In 1974, the effect of NPK became significant on frond production (Table 2). Maximum number of leaves were produced under the highest level of NPK namely, 1500g N, 900g P_2O_5 and 3000g

K_2O. The main effect of Mg on frond production was significant only in 1978 (Table 2). Although the effect of Mg was positive on the height of the palms, it was not significant.

Table 1. Interaction of NPK×Ca×Mg on leaf production till 1978 (mean)

	$N_1P_1K_1$		$N_2P_2K_2$		$N_3P_3K_3$		
	Ca_0	Ca_1	Ca_0	Ca_1	Ca_0	Ca_1	Mean
Mg_0	71.37	70.97	71.97	72.27	76.53	75.10	73.03
Mg_1	70.63	76.67	73.53	71.07	74.00	74.60	73.41
Mg_2	75.10	68.47	74.53	75.10	72.70	77.17	73.84
Mean	72.36	72.03	73.34	72.81	74.41	75.62	73.42

C.D. (0.05): 5.11

Table 2. Effect of NPK and Mg on leaf production

Treatment	Leaves produced in 1974	Leaves produced till December 1978	Treatment	Leaves produced in 1978
$(NPK)_1$	9.28	72.2	Mg_0	16.61
$(NPK)_2$	9.12	73.1	Mg_1	16.73
$(NPK)_3$	9.93	75.0	Mg_2	17.24
CD (0.05)	0.66	2.1	CD (0.05)	0.47

The effect of NPK and Mg, and the NPK×Mg and Ca×Mg interactions on the percentage of palms flowering upto December 1976 was significant (Table 3). The highest percentage of palms

Table 3. Effect of NPK, Ca and Mg on the percentage of palms that flowered upto December, 1976

Treatment	Mg_0	Mg_1	Mg_2	Mean
$(NPK)_1$	8.3	44.4	38.9	30.6
$(NPK)_2$	25.0	38.9	58.8	40.9
$(NPK)_3$	52.8	50.0	50.0	50.9
Mean	28.7	44.4	49.2	40.7
Ca_0	29.6	38.9	50.0	39.5
Ca_1	27.8	50.0	48.1	42.0

CD (0.05)=NPK level: 10.1, Mg level: 10.1
NPK×Mg: 17.5 and Mg×Ca: 14.5

flowered in $(NPK)_2$ Mg_2 treatment. An interaction between Ca and Mg levels was also noticed in the percentage of palms flowering.

The effect of treatments on the yield of nuts harvested in 1981 is summarized in Table 4. The yield was highest under the treatment $(NPK)_1$. Application of Mg also increased the yield.

Table 4. Yield of D×T (nuts/palm/year) at the 9th year (1981) under varying fertility levels.

	Ca_0	Ca_1	Mg_0	Mg_1	Mg_2	Mean
$(NPK)_1$	115.3	109.8	98.5	125.3	113.8	112.5
$(NPK)_2$	111.5	109.0	97.4	110.5	122.8	110.2
$(NPK)_3$	90.3	94.3	95.6	93.7	87.6	92.3
Mean	105.7	104.4	97.2	109.8	108.1	105.0

C.D. (0.05) for NPK=14.2

Yellowing of leaves in the outer whorls characteristic of Mg-deficiency was noticed on palms which did not receive Mg. Root (wilt) disease incidence during the period of investigation showed an increase from 1.8-22.2 per cent in D×T as compared to 2.2-35.5 per cent in WCT. (Table 5).

Table 5. Comparative performance of D×T and WCT palms with respect to disease and yield upto 9th year of planting

Years after planting	Disease incidence (%)		Average yield (nuts/palm/year)	
	D×T	WCT	D×T	WCT
4	1.8	2.2	—	—
5	3.5	4.3	55.9	—
6	5.0	8.8	100.9	—
7	5.0	22.5	75.9	16.8
8	8.8	29.3	91.1	39.6
9	22.2	35.5	104.8	49.4

From the results presented it would be seen that the young D×T hybrid palms respond to higher levels of fertilizer with respect to growth and early flowering and the lowest dose with 500g MgO gave an average yield of 125 nuts per palm in the 9th year. Hence, 500g N, 300g P_2O_5, 1000g K_2O, along with 500g MgO could be taken as the ideal dose for this variety under rainfed condition. Application of Mg at the rate of 500g MgO, gave a significant response, on growth, flowering and initial yield. Robert Cecil *et al.* (1978) reported response to magnesium application in WCT palms also in a similar fertilizer experiment. Fertilizer experiments on coconut hybrids by I.R.H.O. in the Ivory Coast on coastal soils with low fertility status, have stressed the need for N, K and Mg application from young stages (Coomans, 1977). Experimental results from Sri Lanka also show that palms which received NPK+ Mg gave 46 nuts compared to 20 nuts only with NPK alone and that Magnesium deficiency could be one of the limiting factors in establishing new plantations (Anon., 1964).,

In this study, application of NPK, Ca and Mg was not found to be effective in preventing incidence of root (wilt) disease in D×T hybrid palms. The results of nutritional survey conducted in healthy and root (wilt) disease affected area of Kerala, (Pillai *et al.*, 1975) indicated that the contents of major nutrients in the soil and in the leaf were not related to the incidence of root (wilt) disease (Robert Cecil *et al.*, 1978). However, the incidence of disease was low in D×T hybrids in the present investigation when compared to that of WCT palms of the same age at CPCRI farm at Kayangulam (Table 6).

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ADSORPTION, DESORPTION AND SELECTIVE DISTRIBUTION OF PHOSPHORUS AND POTASSIUM IN RELATION TO SOIL FERTILITY POTENTIAL IN MAJOR COCONUT GROWING SOILS OF INDIA

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ABSTRACT

Sixteen major coconut growing soils of India representing laterite, red sandy loam, river alluvium and coastal sand were evaluated for adsorption, desorption and selective distribution properties with special reference to Neubauer seedling test. The adsorption of P and K obeyed the Freundlich Adsorption Isotherm (FAI): $x/m = KC^{1}/n$ where x/m is the amount (μg) of P or K adsorbed per g of soil; C, the equilibrium concentration of P or K in $\mu g/cm^3$; and K and 1/n are constants. The magnitude of the constants, K and 1/n, are related to the differences in the P and K adsorption characteristics of different soils. Generally, the desorption of P is slow, whereas about 90 per cent of applied K is extracted in the first two extractions. Selective dissolution studies showed that the reductant soluble P and the HNO_3-extractable K are the dominant P and K fractions respectively in these soils. The biologically extractable P and K (Neubauer seedling test), a a measure of the fertility potential of the soils, were in the range of 0.013 1.181 mg P/100 g soil, and 0.85 to 3.45 mg K/100 g soil respectively. Association between the FAI constants, the selective distribution of and the biologically extractable P and K, are discussed based on the simple correlation coefficients among them.

INTRODUCTION

In view of the economic desirability of having single phosphorus application to provide long-term P supply to coconut, the P retention/release characteristics of soils are considered to be most important. From the point of view of K nutrition which forms a key element for coconut production, it has been experienced that soil testing for K using 1N neutral ammonium acetate more often gives overestimates in soils having low K supplying power, and under-estimates in soils having high K supplying power (Padmaja, 1977). In the present investigation on the adsorption-desorption characteristics and on the selective distribution of applied P and K in sixteen coconut growing soils representing four soil groups, an attempt has been made to judge the fate of applied P and K in these soils.

MATERIAL AND METHODS

Sixteen soils sampled from different coconut growing areas were used in this study.

Adsorption studies: The P adsorption was studied by batch equilibration method using 0, 25, 50 and 100ppm P, and equilibrating for 72 h (Fitter and Sutton, 1975). The unadsorbed P was estimated colorimetrically whereas the adsorbed P was computed.

Similarly, the adsorption of K was studied using 0, 50, 100 and 200 ppm K and equilibrating for 48 h. The unadsorbed K was estimated flame-photometrically.

The data were fitted in Langmuir and Freundlich Adsorption Isotherms. However, of the two, the Freundlich Adsorption Isotherm (described below) was found to be better; and hence its constants were employed in the correlation studies. The FAI is

$$x/m = KC^{1/n}$$

where

x/m is the amount of solute (P or K) adsorbed per unit amount of adsorbent (soil), given in μg/g.

C is the equilibrium concentration of solute in $\mu g/cm^3$;

K and n are empirical constants, which can be related to adsorption phenomena.

Desorption studies: The soils saturated with 100 ppm P and 200 ppm K were subjected to successive desorption using Bray-1 and neutral 1N ammonium acetate solutions respectively.

Selective distribution studies: The soils saturated with 0 and 100 ppm P; and 0 and 200 ppm K were fractionated after removing the unadsorbed P and K. P was fractionated following the procedure outlined by Hesse (1971). The selective distribution of K was studied by sequential extraction using water, 0.01M $CaCl_2$, 1N NH_4OAc, and boiling 1N HNO_3.

Neubauer seedling test: A short term biologically extractable P and K were studied by employing Neubauer seedling test (Neubauer and Schneider, 1923) using ragi (*Eleusine coracana* (L.) Gaertn.) as a test crop.

Correlation coefficients were worked out between biologically extractable P and K, and the different fractions of chemically extractable P and K in the soils.

Results and Discussion

The physico-chemical properties of the four groups of soils employed in this study are given in Table 1. The P and K adsorption data did not fit well in the Langmuir Adsorption Isotherm. However, they followed FAI better within the limits of concentration employed. FAI of P and K for the different coconut growing soils are depicted in Figs. 1 and 2 respectively. The adsorption of P and K were almost linear upto the maximum concentration employed. The laterites adsorbed maximum of applied P and the other soils also showed considerably high P adsorption. Among the soil

Table 1. Physico-chemical properties of soils

Character	Group			
	Laterite	Red sandy loam	River alluvium	Coastal sand
pH	5.8–6.7	5.6–6.2	5.9–8.2	5.4–8.0
Bray 1-P (ppm)	2–4	25–610	14–654	3–52
Avail. K (ppm)	63–125	59–80	57–125	23–200
Organic carbon (%)	0.2–2.7	0.2–1.5	0.6–1.0	0.1–0.3
Texture	Sicl to c	sl	Sic to c	S to ls

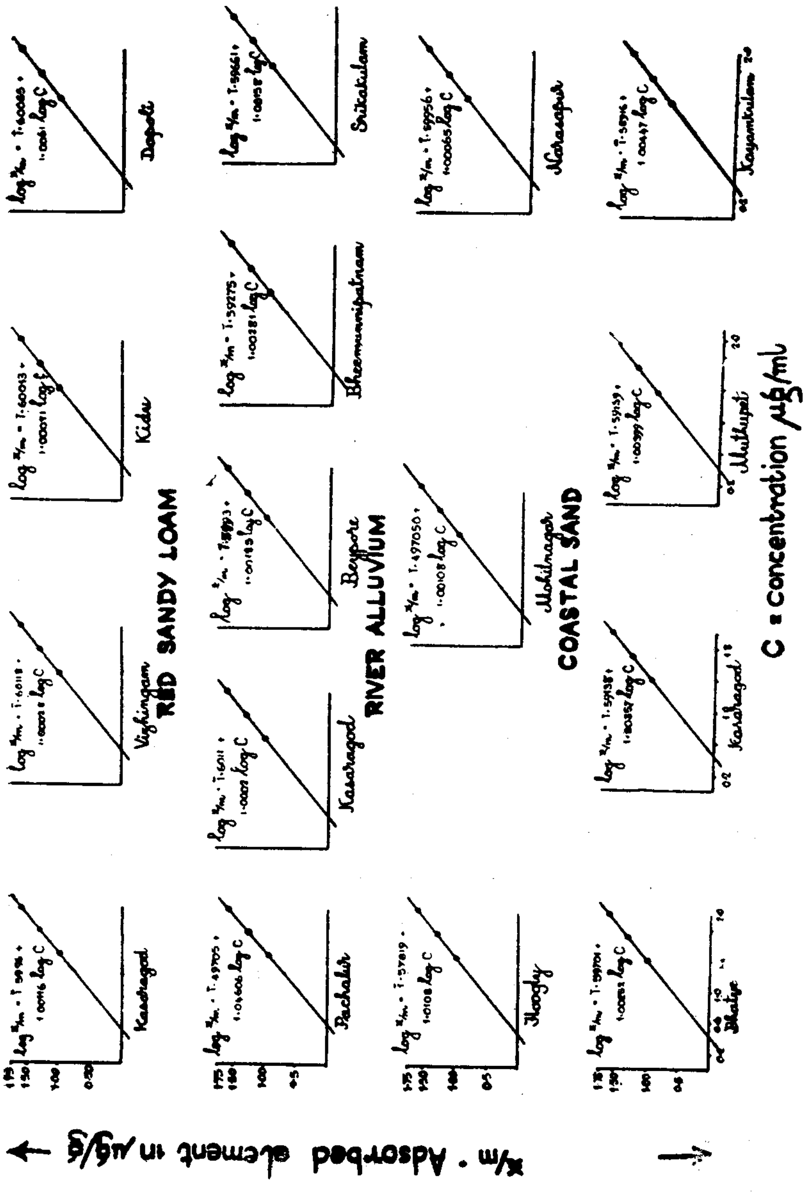

Fig. 1 Adsorption of Phosphorus by coconut growing soils

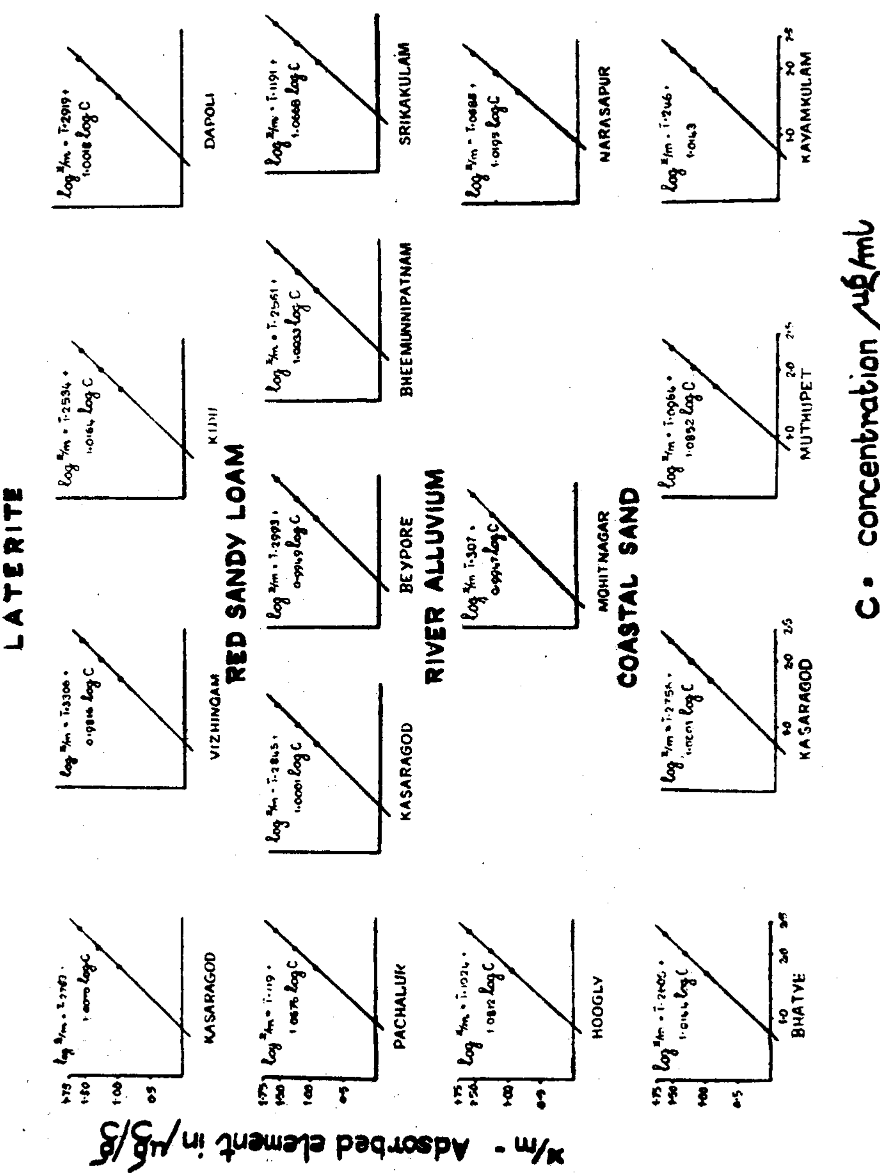

Fig. 2. Adsorption of Potassium coconut growing soils

groups, only Pachalur soil in red sandy loam showed much deviation from other soils in the magnitude of adsorption.

The K adsorption was also found to be comparatively more in laterites than in red sandy loam, river alluvium or coastal sands. The soils of laterite group showed a more uniform K adsorption pattern than the rest of the soils studied. The magnitude of the constants, K and 1/n, varied for the different soils, thus explaining the differences in their P and K adsorption characteristics. The differences in the values of these FAI constants may arise from the differences in the content of oxides and hydroxides of Fe and Al in the soils for P adsorption (Tamhane *et al.*, 1964; Nad *et al.*, 1975) and the content and nature of clay minerals in the soils for Kadsorption (Ramanathan and Krishnamoorthy, 1976).

The results of P and K desorption are presented in Figs. 3 and 4 respectively. The desorption of P indicated that in the laterite soils, the release of adsorbed P progressively decreased with the number of extractions. It appears that the adsorption of P by laterites is much stronger and the adsorbed P maintains a gradual release of available P in the soil. Thus, P adsorbed by laterites might act as long-term P reserves in soil (Larsen, 1973). On the contrary, in other soils in general, a sudden drop in the P release was noticed. In the sandy loam, river alluvium and coastal sands, a constant low release of P was observed even after the fourth extraction. It is interesting to observe that the first two extractions desorbed approximately 40 to 87 per cent of the total extracted P except in the coastal sand of Bhatye (Ratnagiri) which released only 28 per cent.

Desorption of K also showed a constant release after third/fourth extractions irrespective of the soil group (Fig. 4). Even after the eighth extraction, and average release of 1.5 to 2.5 ppm K was observed. Howbever, on an average 90 per cent of the total extractable K was removed in the first two extractions. The fast depletion of K from the soils can be explained on the basis of the nature of clay mineral present in these soils. Kansal and Sekhon (1976) have reported that the nature and content of clays and fine silt, influence the exchangeable K in soils. The soils under the

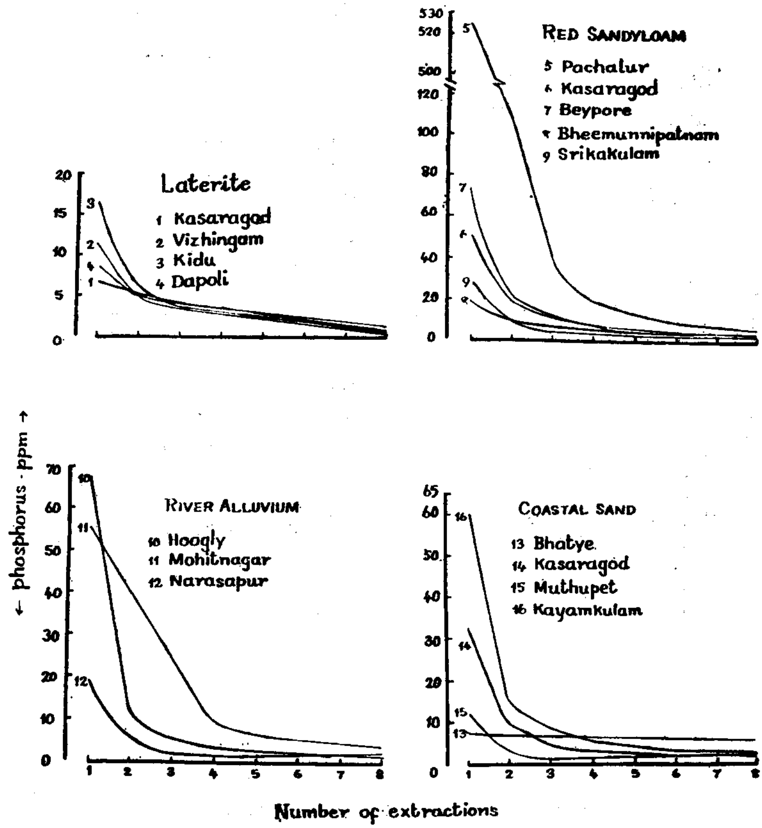

Fig. 3. Phosphorus desorption patterns

present study are dominated by kaolinite clay minerals which have no interlattice binding sites for K, and hence these cannot hold any non-exchangeable K (Patil *et al.*, 1976). This behaviour of K indicates that K applied to these coconut growing soils may be lost from the feeding zone more easily and therefore, there is a need for evolving a more suitable way of K fertilizer management.

The data on selective distribution of P (Table 2) revealed that the reductant soluble P formed the dominant fraction in all the soils followed by Fe-P and Al-P. The Ca-P was very low and its contribution to plant may not be significant in these acid soils. Although,

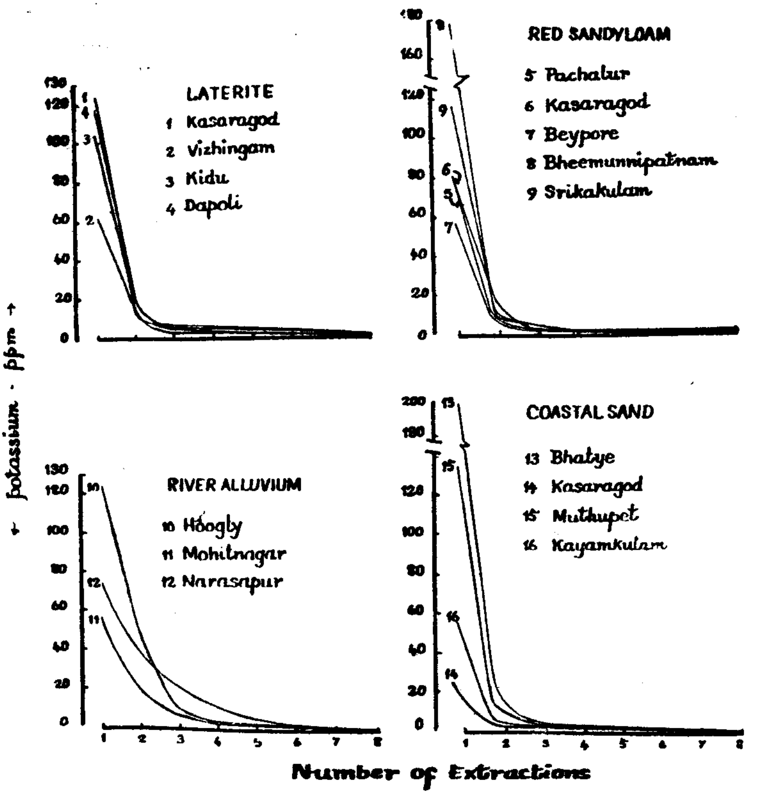

Fig. 4. Potassium Desorption Patterns

200 μg P/g soil was added to all the soils, there seems to be no significant contribution of added P towards saloid P. The distribution of added P clearly indicates the dominance of chemi-sorption than adsorption. A rapid reversion of soluble P to form Al and Fe-P has been suggested (Juo and Ellis, 1968). Kar and Chakravarthy (1969) also observed an appreciable increase in Al-P,Fe-P, reductant soluble-P and occluded-P fractions in acid soils following P application.

The selective distribution of K (Table 3) revealed that the dominant fraction of applied K was extracted with HNO_3 (difficultly exchangeable K) followed by NH_4OAc (exchangeable K). The variations observed in water soluble K in the different soil groups

Table 2. Selective distribution of P (ppm) in different inorganic fractions

Location	Saloid-P	Al-P	Fe-P	Reductant soluble-P	Occluded-P	Calcium-P
Laterite						
Kasaragod	Trace	14	42	74	14	7
Vizhingam	1	9	36	74	7	5
Kidu	1	15	27	56	11	4
Dapoli	Trace	15	67	148	38	15
Red sandy-loam						
Pachalur	55	576	37	111	8	7
Kasaragod	4	43	44	93	4	4
Beypore	5	71	68	111	7	6
Bheemunnipatnam	14	25	51	93	6	7
Srikakulam	9	70	36	111	5	10
River alluvium						
Hooghly	25	93	371	333	12	133
Mohitnagar	1	75	21	37	2	7
Narasapur	12	34	209	148	12	56
Coastal sand						
Bhatye	2	21	156	241	59	41
Kasaragod	16	27	26	56	4	8
Muthupet	2	16	22	74	5	4
Kayamkulam	13	54	47	37	4	4

may be accounted for the initial available K in the soils, prior to saturation with K for this study. A more or less uniform distribution of 0.01M $CaCl_2$-extractable K was observed among the different soil groups. This distribution of K in different forms shows that a certain amount of applied K is removed from the solution to form difficultly exchangeable fraction. The above observations, and the earlier K desorption results showing the loss of approximately 90 per cent applied K in the first two extractions, suggest that the equilibrium between the difficultly exchangeable K and labile K is maintained relatively faster in these soils.

Table 3. Selective distribution of K (ppm) in different inorganic fractions

Location	Water soluble	0.01M $CaCl_2$	1N NH_4OAc	Boiling HNO_3
Laterite				
Kasaragod	23	61	68	50
Vizhingam	26	39	26	285
Kidu	26	58	51	135
Dapoli	11	34	76	112
Red sandy-loam				
Pachalur	75	48	26	25
Kasaragod	37	43	32	70
Beypore	31	41	26	46
Bheemunnipatnam	64	79	73	250
Srikakulam	67	56	43	120
River alluvium				
Hooghly	20	33	118	238
Mohitnagar	14	20	43	95
Narasapur	55	55	155	127
Coastal sand				
Bhatye	18	56	125	100
Kasaragod	61	22	7	20
Muthupet	31	61	59	120
Kayamkulam	62	39	19	25

The short term biologically extractable P and K have been correlated with the different fractions of P and K; and FAI constants. The P supplying power, as evaluated by Neubauer technique, ranged between 0.013 (Kayamkulam, coastal sand) and 1.181 mg (Pachalur, red sandy loam), while that of K ranged from 0.85 (Kasaragod, coastal sand) to 3.45 mg (Hooghly, river alluvium), per 100 g of soil.

The correlation studies between biologically extractable P and the FAI constants (Table 4) revealed that 1/n gave a significant positive correlation with plant P (0.51*). The P uptake by plant also showed a positive significant correlation with available P extracted by Bray-1 (0.68**) and Olsen's extractant (0.54*). Also, the plant

Table 4. Relationship (simple correlation coefficient) among P uptake, FAI constants, available P, and P fractions

	Plant-P	Log K	1/n	Bray 1-P	Olsen's-P	Saloid-P	Al-P	Fe-P	Reductant Sol.-P	Occluded P	Ca-P
Plant P	—	–0.04	0.51*	0.68**	0.54*	0.17	0.55*	0.59*	0.60*	0.06	0.39
Log K		—	–0.21	–0.11	0.21	–0.90**	–0.33	0.12	0.21	0.13	0.69**
1/n			—	0.76**	0.98**	0.27	0.95	0.22	0.01	–0.06	–0.02
Bray 1-P				—	0.70**	0.39	0.68**	0.71**	0.39	–0.08	0.04
Olsen's-P					—	0.26	0.98**	0.18	0.06	–0.08	0.09
Saloid-P						—	0.38	0.22	0.01	–0.02	0.28
Al-P							—	0.17	0.10	–0.12	–0.04
Fe-P								—	0.59*	0.29	0.82**
Reductant Sol.-P									—	0.06	0.47
Occluded-P										—	0.10
Ca-P											—

*Significent at 5% level
**Significant at 1% level

Table 5. Relationship (simple correlation coefficient) among K uptake, FAI constants and K fractions

	Plant K	Log K	1/n	Water soluble K	0.01M $CaCl_2$-K	1N $NH_4$0Ac-K	Boiling $HN0_3$-K
Plant K	—	–0.37	0.37	0.52*	0.41	0.44	0.73**
Log K		—	–0.99**	–0.85**	–0.50*	–0.33	–0.16
1/n			—	0.81**	0.46	0.33	0.17
Water Soluble-K				—	0.75**	0.47	0.33
0.01M $CaCl_2$-K					—	0.82**	0.35
1N $NH_4$0Ac-K						—	0.35
Boiling $HN0_3$-K							—

P showed a significant association with Al-P (0.55*), Fe-P (0.59*) and reductant soluble-P (0.60*) fractions. The relationship between log K and saloid-P showed a significant negative relationship (–0.90**). The Bray-1 P (0.76**), Olsen's P (0.98**) and Al-P (0.95**) showed a definite relationship with 1/n.

In the case of potassium, the FAI constants, log K and 1/n, showed negative and positive correlations respectively with plant K (Table 5). However, they were not significant. The water soluble K (0.52*) and boiling HNO_3 extractable K (0.73**) fractions revealed a significant correlation with plant K confirming the earlier results. Ramanathan (1978) observed that the HNO_3 fractions of K correlated well with the plant K, in their study on red soils of southern states. The relationship worked out among different K availability parameters indicated that log K was negatively correlated with water soluble (–0.85**), and 0.01 M $CaCl_2$(0.50*) K fractions, while 1/n was positively correlated to water soluble K (0.89**).

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DISCUSSION

C. S. KRISHNAPPA NAIK (Coffee Research Station): Can you consider HNO_3 extractable K as available K?

H. H. KHAN: No. Boiling HNO_3-extractable K cannot be considered as available K in the normal terminology used. In the discussion it was only indicated as difficulty exchangeable K.

R. C. MANDAL (CPCRI): (1) Coconut belt in coastal areas are subjected to salinity; Whether absorption and desorption of P and K interaction have not been brought to light?

(2) Since there is a great constrast in laterite and red-sandy loam soils of P and K, Potassium absorption and K exchange capacity in relation to root growth needs attention.

H. H. KHAN: This aspect has not been studied in this attempt. It is worthwhile to take up such studies in specific areas if needed.

STANDARDIZATION OF FOLIAR DIAGNOSIS OF NITROGEN, PHOSPHORUS AND POTASSIUM IN PEPPER

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ABSTRACT

Of the leaves analysed from different positions of the fruit bearing lateral, the recently matured leaf provided the best index for foliar diagnosis in pepper for nitrogen, phosphorus and potassium. The values for phosphorus and potassium in this leaf were found to be significantly correlated with yield of pepper.

INTRODUCTION

Tissue analysis is an useful tool for assessing fertilizer requirements of crops since it provides a measure of the nutrient levels in the plant. Standardization of tissue for assessing the nutrient status of the crop, and the determination of critical values of nutrients in pepper have been carried out by DeWaard (1969) in Sarawak. This study was undertaken to standardize the tissue which will best reflect the status of N, P and K of pepper in relation to yield, under the agroclimatic conditions of Kerala State.

MATERIAL AND METHODS

Tissue samples were drawn from a NPK fertilizer trial on pepper (variety, Panniyur-1) commenced in 1975 as a 3^3 factorial experiment with two replications. The levels of N, P_2O_5 and K_2O applied were each at 50, 100 and 150 g/vine/year.

The following types of tissue (Chandy and Pillay, 1980) were examined for assessing the nutrient status of the plant;

1. Stem portions of fruit-bearing laterals (plageotropes), hanging shoots (geotropes), running shoots and top shoots (orthotropes).
2. The leaves of fruit-bearing laterals were numbered from top to bottom taking the recently matured leaf as Number 1.

Results and Discussion

Standardization of leaf position for foliar diagnosis:

Increased application of nitrogen, phosphorus and potassium always resulted in increased content of these nutrients in plant tissue (Table 1). The nitrogen content decreased significantly with increasing age of the leaf. However, there was no significant correlation between N content of leaf and mean yield irrespective of the leaf positions. The first mature leaf gave a better indication of the variation in the levels of application of nitrogen to the vine.

Table 1. Nitrogen, phosphorus and potassium contents of leaf in relation to leaf positions

Treatment	Leaf position 1	2	3	4	Mean yield for 1976 kg/ha
		Nitrogen %			
N_0	3.55	3.07	2.90	2.50	1042
N_1	3.28	3.22	3.13	2.40	884
N_2	3.70	3.69	3.61	3.16	871
Mean	3.51	3.33	3.21	2.69	932
P_0	0.137	0.126	0.107	0.111	809
P_1	0.146	0.143	0.114	0.118	1040
P_2	0.151	0.134	0.126	0.119	947
Mean	0.145	0.135	0.116	0.116	932
		Potassium %			
K_0	1.72	1.51	1.17	1.16	804
K_1	1.78	1.56	1.44	1.41	979
K_2	2.01	1.81	1.46	1.46	1013
Mean	1.84	1.63	1.36	1.35	932
C.D. (0.05) for comparing levels of N, P and K		N 0.293	P 0.004	K 0.106	—
C.D. (0.5) for comparing positions		0.338	0.006	0.120	—

The pattern of variation in the phosphorus content of leaf in relation to leaf position was similar to that of nitrogen. The phosphorus content of the first mature leaf established significant positive correlation with yield of pepper (r=0.462**).

Similar to nitrogen and phosphorus, the highest level of potassium (1.84 per cent) was observed in the first mature leaf which then decreased with increasing age of the leaf. The potassium in leaf increased with increasing levels of application irrespective of leaf positions. The potassium content of the first mature leaf established significant correlation with yield of pepper ($r=0.523^{**}$).

These observations indicate that, the first mature leaf is superior to other leaves as an index for foliar diagnosis in pepper for N, P and K status of the plant.

Distribution of N, P and K in different types of shoots

Data on the distribution of nitrogen, phosphorus and potassium in different kinds of shoots are presented in table 2.

Table 2. The distribution of N, P and K in different types of shoots

Types of shoot	N %	P %	K %
Runner shoot	3.14	0.32	1.39
Top shoot	2.17	0.27	1.41
Hanging shoot	3.60	0.27	1.25
Fruit bearing lateral	2.98	0.19	2.78
CD (0.05) for comparising type of shoots	0.10	0.08	0.26

The hanging shoots of the upper canopy recorded the highest nitrogen content (3.60 per cent) and the top shoot the least (2.17 per cent). The differences in nitrogen content between different types of shoots were statistically significant.

The different types of shoots in general, shared relatively higher content of phosphorus as compared to that in leaf. The runner shoot contained the highest percentage of phosphorus (0.32 per cent) and the fruit bearing lateral the least (0.19 per cent).

Fruit bearing lateral recorded the highest content of potassium (2.78 per cent) while the top shoot, runner shoot and hanging shoot registered only low values. The N, P and K contents of the shoots did not show any correlation with yield.

Acknowledgement

The authors are grateful to Dr. P. C. Sivaraman Nair, Director of Research, Kerala Agricultural University, and Dr. P. K. Gopalakrishnan, Associate Dean, College of Horticulture, Vellanikkara, for providing necessary facilities and encouragement during the course of this study.

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EFFECT OF BIOFERTILIZER ON CARDAMOM

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ABSTRACT

Application of carrier-based cultures of *Azotobacter* and *Azospirillum* as well as culture filtrate sprays resulted in higher number of tillers, more number of panicles, high plant vigour and yield of caramom. The effect of CF and GA was comparatively less marked. The results are discussed with reference to the nitrogen-fixing capacity of the bacteria, and the effect of hormones produced by them.

INTRODUCTION

Application of the non-symbiotic nitrogen fixer *Azotobacter* sp., has resulted in better plant vigour and higher yield in several crop plants (Mishustin *et al.*, 1963; Brown *et al.*, 1964; Mehrotra & Lehri, 1971; Rangaswami, 1975; Oblisami *et al.*, 1977; Singalani, 1980; Jayaraman, 1980). The effect of 'Azoviggor' a carrier–based culture of *A. chroococcum*, and *Azospirillum* culture has been studied on cardamom, and the results are presented in this paper.

MATERIAL AND METHODS

The carrier based culture of *A. chroococcum* (Azoviggor) was used as a soil inoculant and culture sprays. The final concentration of cells was $2 \times 10^{10} g^{-1}$. The same concentration of *Azospirillum braziliense* (cultures obtained from IARI, New Delhi) was used. The culture, culture filtrate (CF), and CF+GA (gibberellic acid) were also sprayed to study the metabolite effect. The final concentration of CF employed was 0.4 per cent and of GA 20 ppm per plant. The experiment was carried out at the Indian Cardamom Research Institute, Myladumpara, Kerala. Another trial was conducted with *Azotobacter* spraying in a private estate at Injipudippu, Kerala.

Results and Discussion

The application of cultures of *Azotobacter* to cardamom seeds resulted in a favourable response. More than 90 per cent of treated seeds resulted in good germination into vigorous seedlings compared to only 70 per cent germination of the untreated seeds.

The application of *Azotobacter* and *Azospirillum* cultures either in the soil or as a spray resulted in marked stimulation of tillering (Table 1). The height of tillers also increased following the application of *Azotobacter* and *Azospirillum*. It is of interest to mention here that the CF and GA sprays were more effective in increasing the height and the growth of tillers than the soil applications. A significant increase in number of leaves over control was observed in all the treatments. The yield was highest in plants receiving soil application of *Azotobacter* closely followed by those that received

Table 1. Effect of Biofertilizers on Cardamom (5-6 year old plants)

Treatment	Increase in tiller no. (Mean of 9 plants)		Increase in height of tillers (m) (Mean of 6 plants)		Increase in girth of tillers (Mean of 6 plants)	Increase in leaves (Mean of 3 plants)	Capsule wt. (Mean of 27 plants)
	A	B	A	B	cm	no.	g/plant
Control	2.7	3.3	1.84	4.15	0.30	3.2	33.7
Azotobacter soil application	8.3[b]	14.8[a]	2.75	5.94	0.38	6.0[a]	168.3[a]
Azospirillum Soil application	3.3[b]	9.39	2.09	4.51	0.93	5.5[a]	103.0[a]
Culture spray	3.8[b]	10.2[a]	2.15[d]	5.15	1.14	6.0[a]	44.0[e]
Culture filtrate spray	5.9[b]	15.4[a]	2.38[d]	6.54	1.65	7.4[a]	66.3[a]
Culture filtrate+ GA spray	3.1[b]	8.2[a]	2.51	6.09	1.35	5.2[e]	84.0[a]

a=Significant at t=0.995 c=Significant at t=0.975
b=Significant at t=0.990 d=Significant at t=0.950
e=Significant at t=0.900

A & B refers to after first and second application of cultures.

Azospirillum. Although the culture spray, CF, and CF+GA spray, resulted in higher yields than control, they were considerably inferior to *Azotobacter* and *Azospirillum* soil application.

In another trial conducted in an infertile area with *Azotobacter* culture sprays, similar results were obtained. The culture spray increased the number of tillers and panicles each by 2 per bush in 4 months over control (Table 2). The yield increase for three pickings

Table 2. Effect of spraying *Azotobacter* culture on cardamom (mean of 27 plants)

Date	Parameter	Control	Treated
13-9-1979			
(Pre-treatment)	Tiller no. clump^{-1}	18.1	12.6
	Panicle no. clump^{-1}	4.4	6.7
22-1-1980			
(Post-treatment)	Tiller no. clump^{-1}	29.7	26.3
	Panicle no. clump^{-1}	7.6	1.8
Increase in 4 months	Tiller no. clump^{-1}	11.6	13.6
	Panicle no. clump^{-1}	3.2	5.1
10-10-1979			
(1st picking)	Dry wt g clump^{-1}	20.3	38.9
28-12-1979			
(2nd picking)	Dry wt g clump^{-1}	14.8	24.1
2-2-1980			
(3rd picking)	Dry wt g clump^{-1}	5.6	24.1
Total yield	Dry wt g clump^{-1}	40.7	87.1

was 90.2 kg dry weight per hectare. The application of *Azotobacter* cultures at the rate of 6-8 kg per acre (Azoviggor) may supplement N to the available pool in the soil. In addition, these cultures are known to produce growth substances such as IAA, GA and kinins which may result in higher plant gfowth and vigour as reflected in increase in number of tillers, early initiation of tillers, retention of more number of flowers and capsules, and size of the capsule.

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DISCUSSION

SETHURAJ (RRII): *Azotobactor* has increased the growth, yield, number of panicles and tillers. Besides its effect on nitrogen fixation, what other physiological effects were responsible for the superior peiformance? Can we simulate some of these effects by synthetic phytohormones?

LAKSHMANAN: It has to be a combined effect of nitrogen and hormones. If hormones alone would do, culture filtrate should have given the same response. If is probably the continuous slow release of both fixed nitrogen and homones which is involved in this phenomenon and hence is difficult to simulate by the application of chemicals one or more times.

W. KRISHNAMURTHY RAO (CCRI): Is it clarified that products tried for the past few years had not resulted in increased population of bacteria, soil available-N or yield?

LAKSHMANAN: Variations in strains, soil factors, method and quantity applied would determine the results of such trials.

K. D. PATIL (CPCRI): Normally, when you apply the fertilizers, there is an increase in number or quantity but not in the size of grain. In this case, it is the size of capsule and also the size of seed (grain) which has increased due to the application of biofertilizers. Would you like to comment on this?

LAKSHMANAN: It is well known that GA treatment would increase the size of fruits. It is probable that the fruit size increase is a GA effect. This is a different kind of fertilizer which lives and multiplies in the soil.

K. RAMAN (UPASI Tea Research Institute Cinchona): How did you determine the levels of PGRS? If it is by TLC and bioassay, it is better you mention they are GA-like, IAA-like and Kinetin-like materials.

LAKSHMANAN: By column-chromatography it has been proved to be IAA and GA and they were further isolated and characterized. There is no need to call them IAA-like or GA-like.

V. RAJAGOPAL (CPCRI): Does the *Azotobacter* application influence the *de novo* synthesis of hormones?

LAKSHMANAN: Yes. *Azotobacter* synthesizes hormones *de novo*.

J. BENNETT (Madras Fertilizers Ltd.): I am apprehensive of the statement that *Azotobacter* can replace chemical nitrogen for cardamom when it is not clearly understood whether the yield component is the result of nitrogen fixation or due to hormonal effect. Moreover, in the treatments different forms of nitrogen are not included to compare it with *Azotobactor* and also there is no mention about P and K application.

LAKSHMANAN: Only the control (treatment) received NPK at the normal recommended dose for cardamom. All other treatments were fertilized as mentioned without any NPK addition. It has been known for several years that the response of cardamom to added chemical fertilizers is poor or inconsistent. Such a treatment cannot serve for comparative experiments.

N. A. AWATRAMANI (C.C. Ltd.): The trend of discussion indicates certain doubts regarding the results of Dr. Lakshmanan's experiments. These may hence be repeated by various other institutes and valid conclusions drawn. The Project Coordinator, IARI, has said that Indian culture of *Azotobacter* is the best. Trials have indicated that the bacterial culture contributes to an increase in available N in soil and further work is in progress there.

S. NATESAN (UPASI, TRI): (1) How could a green weight of 51.8 kg/acre (increase in cardamom yield) give a dry weight of 37.8 kg/acre?.
(2) If GA_3 and IAA influence the growth of cardamom, how did they induce the shedding of capsules? How can you justify that the Azoviggor produces optimum level of GA_3 and IAA in the soil?

LAKSHMANAN: (1) This may be due to an increase in oil content. We have, however, not carried out any analysis for oil content.
(2) In experiment involving hormones it is difficult to simulate concentrations and balances of different types of auxins that are produced under natural conditions by micro-organisms. Some understanding can be obtained by varying their concentrations under axenic culture conditions. GA + IAA + NAA increased shedding of fruits; IAA alone gave some protection.

METHODOLOGY FOR CONDUCTING MANURIAL TRIALS IN CARDAMOM (*ELETTARIA CARDAMOMUM* MATON)

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ABSTRACT

The fertilizer trials conducted over the past decade were reviewed to identify the causes for the inconsistent response to major nutrients observed in cardamom. The major causes for the inconsistency in results were, lack of uniformity in shade and high genotypic variation. By controlling these two main sources of inconsistency by providing uniform shade and monoclonal materials, a considerable improvement was obtained in the control of errors in a recent experiment. Significant response was seen with respect to sucker production in the initial years which might lead to increase in yield in the subsequent years.

INTRODUCTION

Results of the fertilizer trials in cardamom conducted in India and elsewhere are seen to be inconsistent. Based on a critical analysis of the fertilizer trials carried out since 1968 at the Regional Research Station, Mudigere a methodology for studying fertilizer responses has been evolved in order to identify the causes for such inconsistency.

MATERIAL AND METHODS

Details of the three experiments considered in the present study are given below:

(*a*) In 1968, 2^3 factorial NPK trial with 4 replications was laid out in a seedling population spaced at 1.8×1.8 m, under a mixed and non-uniform shade. The levels of NPK were 37.5 and 62.5 kg/ha for N; 27.5 and 75.0 kg P_2O_5/ha and 50.0 and 70.0 kg K_2O/ha applied in two equal doses, one in May and the other in September. The plot size was 10 plants, surrounded by a single guard row.

(*b*) In 1974, another 3^3 factorial NPK trial with 2 replications was laid out in a seedling population raised from progenies of known parents spaced at 1.8×1.8 m, under a mixed shade. The genotypic variations were kept at minimum by distributing the plants from a particular plant to a block and confounding the treatments. The nutrient levels were 0.60 and 120 kg N/ha, 0.15 and 30 kg P_2O_5/ha, and 0, 120 and 240 kg K_2O/ha. The plot size was 10 plants with one guard row on all sides.

(*c*) In 1978, the third 2^3 NPK trials with 3 replications was laid out in a monoclonal area spaced at 1.8×1.8 m under a uniform artificial shade with coir mat. The levels of NPK were 0 and 100 kg N/ha; 0 and 75 kg P_2O_5/ha and 0 and 150 kg K_2O per ha. The yield data were statistically analysed.

Results and Discussion

The statistical analysis of yield data for 8 years from 1971–72 to 1978–79 of the first trial started in 1968 showed no significant response to N, P and K or their interactions in any of the years; aslo the trends in yield due to levels of NPK and their interactions were inconsistent over the years. The inconsistent and non-significant results obtained may arise from (*a*) lack of uniformity in shade due to mixed tree species and to their evergreen or deciduous nature, (*b*) heterogeneity created by the differential leaf fall from the mixed tree species, and (*v*) the heterogeneity of the plant population.

The variations due to the heterogeneity of the plant population in the second experiment, started in 1974, were controlled to a large extent by raising plants from known parents for each block and confounding the treatments to eliminate interaction effects. Yet, the treatment effect or their interactions did not attain significant levels in any of the five years of study from 1977–78 to 1981–82.

In the third experiment, uniform artificial shade with coir mat and the monoclonal planting material were used. Even in the first year, there was a significant effect of fertilizers on number of suckers, number of leaves and height of suckers (Table 1). It is expected that this trial will give some useful information on the response of cardamom to NPK in the years to come.

Table 1. Effect of NPK on the growth of Cardamom* (2^3 NPK level, 1979)

Treatment	Av. No. of suckers/ clump	Av. No. of leaves/ clump	Av. height of suckers (cm)
$N_0P_0K_0$	12.31	62.00	50.51
$N_1P_0K_0$	17.51	72.96	53.75
$N_0P_1K_0$	18.12	94.83	61.77
$N_0P_0K_1$	18.09	89.08	60.30
$N_1P_1K_0$	23.74	110.62	54.08
$N_0P_1K_1$	22.31	116.66	65.53
$N_1P_0K_1$	19.22	92.16	52.08
$N_1P_1K_1$	31.84	171.20	64.46
C.D. at 5%	4.95	29.90	9.76
C.D. at 1%	6.67	40.33	NS

*Observations recorded 11 months after planting.

By proper control of sources of inconsistencies, it is thus possible to improve the efficiency of field experiments to get the best out of them.

DISCUSSION

EAPEN GEORGE (A. V. Thomas & Co. Ltd.,): Please include data on No. of capsules/kg green capsules to draw conclusions, along with total yield.

H. V. PATTANSHETTI: Number of capsules was also taken into consideration but there was no consistency in the data, and also there was no significant difference between the various treatments in the experiments conducted under natural shade with seedling progenies.

POSTER PRESENTATIONS

EFFECT OF AGRONOMIC INPUTS ON THE GROWTH AND YIELD OF COCONUT

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ABSTRACT

Results of a study carried out to investigate the effect of agronomic inputs, manuring, irrigation and cultural operation, on the morphological characters and yield of coconut in alluvial soils in Cauvery delta of Peninsular India are reported. The treatment effects on combinations were additive on morphological characters and synergistic on yield. There are indications to show that the selection of seedlings alone for planting is not effective.

INTRODUCTION

Though coconut is an important perennial oilseed crop in Tamil Nadu, very little attention has been paid to crop management, particularly manuring and irrigation. In this paper, the results of an experiment carried out at Regional Coconut Research Station, Veppankulam, Thanjavur District, Tamil Nadu to investigate the effect of manuring, irrigation and cultural operation on the growth and yield of coconut are discussed.

MATERIAL AND METHODS

The experiment was laid out in 1966 with newly planted seedlings, in a split-plot design, with either main (combinations of presence and absence of fertilizers, cultural and irrigation treatments), and two sub treatments (selected and unselected seedlings) replicated thrice in four-tree plots. During initial stages of growth, the seedlings received graded doses of fertilizers, full dose (N560g: P_2O_5 320g: K_2O 1200g) being reached at the 9th year. The fertilizers were applied in semicircular trenches, once in a year during August-September. In plots receiving cultural operations, two ploughings were given in the interspaces, one in July-August and the other in December-January. Pot watering twice weekly upto the third year, and basin irrigation once a week during fourth and fifth year, and thereafter once in ten days, formed the irrigation treatment.

Observations were recorded on morphological characters such as height, girth at base, number of functional leaves, length of leaf, yield of nuts (1977–81) and nut characters. All the data were statistically analysed.

RESULTS AND DISCUSSION

Analysis of data has shown that differences in morphological characters and yield between selected and unselected seedlings were not significant (Table 1). The interaction between main-plot treatments was also not significant. Data on morphological characters, yield and nut characters, as affected by main treatments are also shown in Table 1. The significance or otherwise of individual effects of fertilizers, cultural operations and irrigation and their interaction on different characters studied are given in Table 2.

Manurial and irrigational effects were significant in all the morphological characters and yield of nuts. The effect of cultural operation was significant only in the case of girth at base and number of functional leaves. The height, girth, functional leaves, and length of leaf were significantly higher in individual treatments and their combinations than in control. The interactions of treatments on morphological characters were not significant, except for $M \times I$ interaction on height and $M \times C \times I$ interaction on functional leaves. This shows that the effect of treatments are independent of each other and are additive on combinations. All the treatments showed beneficial additive effect on combination, so that in combination treatment, the beneficial effect was almost equal to or marginally less, or more than the sum of beneficial effects of individual treatments. For example, the increase in height due to manurial, irrigation, and cultural treatments were, 2.58, 0.66 and 1.41m respectively, while in $M \times C + I$ treatment, the increase was 3.5m, which was slightly higher than the total of increases due to individual treatments.

Table 1. Morphological characters and yield as affected by treatments

Treatment	Height m	Girth m	Functional leaves no.	Length of leaf m	Yield of nuts/palm no.	Kernel weight g	Copra weight/nut g	Copra yield/palm kg
Main Plot:								
1. $M_0I_0C_0$	1.76	1.14	17.0	4.04	0.5	212	104	0.05
2. $M_1I_0C_0$	4.34	1.31	29.3	4.81	26.0	317	130	3.10
3. $M_0I_1C_0$	2.42	1.33	21.1	4.55	1.3	327	116	0.16
4. $M_0I_0C_1$	2.17	1.27	22.6	4.01	1.3	227	126	0.20
5. $M_0I_1C_1$	3.17	1.47	26.3	4.89	4.0	236	118	0.59
6. $M_1I_0C_1$	4.08	1.51	29.0	4.75	32.3	252	132	3.32
7. $M_1I_1C_0$	5.29	1.42	29.9	5.23	44.5	257	134	6.14
8. $M_1I_1C_1$	5.34	1.47	32.5	5.16	53.0	262	138	7.89
C.D. at P=0.05	0.79	0.16	5.89	0.33	17.5	—	—	—
Sub-plots:								
S_0	3.57	1.37	26.01	4.67	20.03	Not recorded		
S_1	3.57	1.35	25.89	4.69	20.68	Not recorded		

(M_0: No manuring, and M_1: Manuring as per treatment; I_0: No irrigation, and I_1: irrigation as per treatment; C_0: No cultural operation and C_1: Cultural operation as per treatment, S_0: unselected seedlings, S_1: selected seedlings)

Table 2. Statistical significance of data on morphological characters and yield

Character	C	I	M	C×I	C×M	M×I	M×CXI
Height	NS	S	S	NS	NS	S	NS
Girth base	S	S	S	NS	NS	NS	NS
Functional leaves	S	S	S	NS	NS	NS	S
Length of leaf	NS	S	S	NS	NS	NS	NS
Yield of nuts/palm	NS	S	S	NS	NS	S	S

S=Significant at P=0.05
NS=Not significant

In the case of yield, M×I and M×C×I interactions were significant indicating the inter-dependence of individual treatments. Manuring and irrigation effects were significant whereas that of cultural operations was not significant. However, when the treatments were combined, the increase in yield was more than the sum of individual increases and a synergistic effect was noticed in combinations involving manuring. The order of dominance of effects was manurial, irrigational and cultural; but the interactions produced synergistic effect on yield, so that the increase in yield in combination treatments was more than the sum of increases due to individual treatments, and this was even more pronounced in combinations involving 'manuring'. The treatments benefited the nut characters also. The effect of treatments on copra weight per nut and the copra yield per palm was similar to that observed with yield of nuts discussed above.

The response of coconut to agronomical inputs, particularly to the application of complete fertilizers has been brought out by earlier workers (Aiyadurai, 1965, Varisai Muhammed *et al.*, 1974). At eight years after planting, manuring and irrigation, together promoted early and uniform flowering and increased the number of flowers, length of stem and yield (Henry Louis and Chandrasekar, 1983). Manuring as a means of increasing the yield of coconut was stressed by Manciot *et al.*, (1981). The results in the present experiment also indicate the importance of manuring and irrigation. The highest yield was achieved in the combination of manuring, irrigation and cultural treatments.

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EFFECT OF SPACING AND FERTILIZER ON GROWTH AND YIELD OF ARSIKERE TALL COCONUT CULTIVAR IN MAIDAN TRACT OF KARNATAKA

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ABSTRACT

In the maidan tract of Karnataka, closer spacing (7.3×7.3 m) gave significantly higher yield of nuts per hectare over wider spacing (9.7×9.7 m) after 3 and 4 years in black and red soils respectively. The five year average showed that the yield increase per hectare due to closer planting was 28 per cent in red soil and 3 per cent in black soil. The application of fertilizers did not increase the yield significantly in red soil, whereas it increased the yield significantly in black soil in 4 out of 5 years. Generally, closer planting and fertilizer application increased the yield of Arsikere tall coconut.

INTRODUCTION

Plant population and soil fertility are the two important factors influencing the growth and yield of a crop. Different planting distances advocated for coconut were discussed in some early publications. (Sampson, 1923; Patel, 1938). Whitehead and Smith (1968) and Kannan *et al.*, (1978) studied the influence of the planting distance ranging from 6 to 10m on yield of coconut. The planting density not exceeding 160 plams per hectare in poor soils and 138 palms per hectare in good soils was recommended in Sri Lanka (Child, 1964). Results of spacing experiments in Jamaica were in favour of adopting a higher rate of planting density in pure stands (6.7 to 7.6m).

John and Jacob (1959) reported differential response to fertilizer application in different soils. The series of fertilizer experiments conducted at CPCRI, Kasaragod indicated that it was possible to increase the yield from 17 to 57 nuts/palm/year in the course of 5 years by the application of a balanced NPK mixture (Nelliat *et al.*, 1976). Differential response to fertilizer depending on yield groups was reported in India (Marar, 1962). Adopting a spacing of 9 to 11m without any application of fertilizeis to coconut palms was the general practice prevailing in maidan tract of Karnataka. Since experimental findings were not available on the important aspects of spacing and manuring, for the maidan tract of Karnataka, investigations were undertaken on this aspect at Agricultural Research Station, Arsikere (Karnataka) under the All India Co-ordinated Coconut and Arecanut Improvement Project.

MATERIAL AND METHODS

Experiments were conducted on Arsikere Tall coconut cultivar, planted in 1964, in red and medium black soils, at two spacings (S_1=9.7×9.7m, and S_2=7.3×7.3m), The initial nutrient status of red and black soils were; N=8.6 and 6.6 kg/ha; P_2O_5=4.0 and 2.7 kg/ha; and K_2O=240 and 349 kg/ha respectively. Th pH of red and black soils were 7.5 and 8.0. In addition to the spacings, the treatment consisted of three levels of graded dose of NPK (F_0: no fertilizer; F_1=340, 227 and 453g of N, P_2O_5 and K_2O respectively per palm per year; and F_2=680, 454 and 906 g of N, P_2O_5 and K_2O respectively per palm per year). The sources of N, P_2O_5 and K_2O were ammonium sulphate, superphosphate and muriate of potash respectively. The experimental plot size consisted of 10 palms, planted in a RBD with three replicates.

Fertilizer application was started only 6 months after planting, 1/3rd of annual dose being applied in June-July and the 2/3rd in September-October. Fertilizers were applied by making furrow rings of 20 cm depth at 1.5 m away from the bole. During the first three years from planting, 1/3 dose of fertilizers were applied, followed by 2/3 dose, in the next two years and then the full dose of fertilizers. The annual yield of nuts per palm was recorded.

RESULTS AND DISCUSSION

The rainfal data for all the five years (Table 1) showed that it was low and ill-distributed, and there was a continuous dry period from December to March. The trends in total rainfall, its distribution and the number of rainy days from year to year were irregular and unpredictable. The yield of nuts follow the rainfall patterns

Table 1. Rainfall (mm) and number of rainy days (in parentheses)

Years	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1977	—	9	17	21	174	53	38	82	126	272	109	—	901
	—	(1)	(1)	(2)	(10)	(7)	(4)	(7)	(8)	(16)	(6)	—	(62)
1978	—	91	—	38	171	22	44	79	117	150	69	48	829
	—	(1)	—	(2)	(8)	(3)	(8)	(4)	(6)	(12)	(7)	(2)	(53)
1979	—	10	23	31	40	106	30	32	143	160	76	—	651
	—	(2)	(1)	(2)	(3)	(4)	(5)	(3)	(7)	(14)	(5)	—	(35)
1980	—	—	—	83	122	63	66	28	175	82	75	5	699
	—	—	—	(8)	(5)	(4)	(6)	(3)	(8)	(7)	(7)	(1)	(49)
1981	—	—	—	49	158	3	54	65	151	125	20	28	653
	—	—	—	(4)	(7)	(1)	(5)	(5)	(13)	(6)	(2)	(1)	(44)

of the previous year as well as of the year of harvest. Thus rainfall in general, was inadequate for proper growth and production of nuts.

The yield data of coconut grown in red and medium black soils are given in Tables 2 and 3 respectively.

Table 2. Effect of spacing and fertilizer on yield (nuts/ha. and nuts/palm in parentheses) of Arsikere Tall cultivar in red soil

Treatment	1977	1978	1979	1980	1981	Average
S_1	4275 (40)	4888 (46)	7640 (72)	8526 (80)	7574 (70)	6580 (61)
S_2	6867 (36)	6726 (36)	10027 (53)	10385 (55)	8127 (44)	8444 (45)
F_0	4672 (32)	5377 (39)	7657 (54)	9036 (43)	5727 (38)	6943 (44)
F_1	6006 (41)	5541 (39)	9003 (64)	9291 (44)	8227 (55)	7114 (45)
F_2	6290 (43)	6501 (45)	9840 (68)	10039 (48)	8760 (56)	8222 (52)
S_1F_0	3922 (37)	4982 (44)	6801 (64)	8360 (79)	7738 (73)	6360 (58)
S_1F_1	4452 (42)	4628 (47)	8041 (76)	8112 (76)	7704 (71)	6587 (62)
S_1F_2	4452 (42)	4982 (47)	8073 (76)	9104 (85)	7162 (66)	6754 (63)
S_2F_0	4914 (26)	5702 (30)	8514 (45)	9712 (51)	7137 (37)	6311 (38)
S_2F_1	7560 (40)	6454 (35)	9964 (52)	10469 (55)	8680 (45)	8625 (45)
S_2F_2	8127 (43)	8021 (48)	11604 (61)	10973 (57)	8873 (46)	9519 (51)
CD at P=0.05						
Spacing	1131	1533	2163	858	NS	
Manuring	NS	NS	NS	NS	NS	
Spacing× Manuring	1959	NS	NS	NS	NS	

Table 3. Effect of spacing and fertilizer on yield (nuts/ha, and nuts/palm in parentheses) of Arsikere Tall cultivar in medium black soil

Treatment	1977	1978	1979	1980	1981	Average
S_1	4417 (42)	3898 (37)	6636 (62)	8030 (75)	6814 (63)	5959 (56)
S_2	6132 (32)	5628 (30)	8325 (44)	10007 (53)	9626 (50)	6144 (42)
F_0	3879 (28)	3550 (27)	6066 (44)	6585 (51)	6330 (42)	5282 (38)
F_1	5957 (41)	4773 (32)	7930 (55)	9798 (67)	8952 (59)	7482 (51)
F_2	5987 (42)	5967 (40)	8446 (60)	10672 (74)	10203 (68)	8246 (57)
S_1F_0	3851 (36)	3887 (33)	5951 (56)	7297 (75)	5534 (51)	5304 (50)
S_1F_1	4477 (42)	3498 (37)	6589 (62)	7935 (68)	6294 (58)	5746 (53)
S_1F_2	4982 (47)	4311 (41)	7368 (69)	8856 (83)	8681 (80)	6839 (64)
S_2F_0	3906 (21)	3213 (27)	6180 (33)	5234 (27)	6366 (33)	4980 (28)
S_2A_1	6804 (36)	6048 (32)	9271 (49)	12298 (66)	11767 (61)	8149 (48)
S_2F_2	6993 (37)	7623 (40)	9523 (50)	12487 (67)	10802 (56)	9485 (50)
CD at P=0.05						
Spacing	1266	1196	NS	NS	2759	
Manuring	1551	1465	NS	2825	3379	
Spacing× Manuring	NS	2075	NS	3996	NS	

Effect of spacing: The yield of nuts was found to be significant in four years in red soil, and in three years in black soil. The closer spacing (7.3×7.3 m) generally gave higher yield irrespective of soil types. Overall for the five years, the increase in yield per hectare due to closer spacing was 28 per cent in red soil and 3 per cent in black soil.

Effect of fertilizer: In red soil, the effect of fertilizers on annual yield of nuts was not significant in all the five years, but in black soil, it was significant in 4 out of 5 years. In red soil, though the results obtained were not significant, the increase in yield of nuts due to fertilizer was consistent, and the overall increases in yield due to F_1 and F_2 levels of fertilizer were 2.5 and 18 per cent respectively over control. However, the response to fertilizers was high in black soil; at F_1 and F_2 levels, the increase in 5-year average yield of nuts per hectare was 42 and 56 per cent respectively.

Spacing $\times$ Fertilizer effect: Interaction effect was found to be significant for yield of nuts during 1977 in red soil, and 1978 and 1980 in black soil. The closer spacing with the highest level of fertilizer application was found to be the best among the six treatment combinations tried in both the soil groups.

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INTERCROPPING IN COCONUT

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ABSTRACT

Results of intercropping experiments carried out in coconut under the soil and climatic conditions prevailing at the Coconut Research Station, Veppankulam in the east coast of Tamil Nadu, are discussed. Cocoa and pineapple are unlikely to be economical as intercrops, whereas banana grows well and is suitable if the market demand is good. All varieties of banana, culinary and table ones, behave similarly, and the choice of variety should be based on local market demands, and its resistance to damage by cyclone which is of common occurrence during monsoon months.

INRODUCTION

Majority of coconut growers in Tamil Nadu are small and marginal farmers who cannot afford to rely on coconut alone for their livelihood. There is hence a need to raise some annual, biannual or perennial intercrops to supplement their income and also to provide employment throughout the year. The area of coconut gardens under intercrop in Tamil Nadu was estimated at 65 per cent, the popular ones being rice, sugarcane, sorghum, tapioca and vegetables (Krishna Marar, 1964). Intercroping is defined as growing of annuals or perennials in the interspace of a well laid-out coconut garden at definite and recommended spacings. In Tamil Nadu, the mixed orchards of mango, jack and citrus with coconut are also grown.

The compatibility and economics of cocoa, banana and pincapple in coconut gardens were tested in experiments started in 1969 at the Coconut Research Station, Veppankulam, Tamil Nadu, and the results obtained are discussed in this paper.

MATERIAL AND METHODS

Experiment 1.: Cocoa variety 'criolo' was planted in 1969 in interspaces of 20 year old coconut garden in a plot of 0.40 ha having 30 palms. Out of the 36 cocoa trees planted, only 24 survived till the bearing stage. In 1974, two rows of pineapple variety 'Coconut Ken' was planted at a spacing of 90 cm between rows and 60 cm between plants, in beds on either side of cocoa trees. There were 640 pineapples in the plot. An adjoining plot of 0.40 ha with 36 palms served as control. The cocoa received 10 kg farmyard manure, 220g urea, 250g superphosphate, and 200g muriate of potash per plant/annum. The coconut palms received 50kg farmyard manure, 1.3kg urea, 2.0kg superphosphate and 2kg of muriate of potash per tree/annum. Irrigation was given once in 10 days for coconut and once in 7 days for intercrops.

Experiment 2: The second experiment was started in April 1980 in a 20 year old garden planted at a spacing of 7.5×7.5m. The plot size was 0.10 ha with 19 palms. The intercrops tried were cocoa (Forastero), and banana (two culinary varieties-Kanchi and Mondhan; and 4 table varieties-Poovan, Rastali, Karpuravalli and Jurmony), at a spacing of 2.4×2.4m. The intercropping treatments were:

(A) **Raising intercrop in alternate interspace**

(1) Cocoa (23 nos.)

(2) Rastali (23 nos.)

(B) **Raising intercrop in every interspace**

(3) Cocoa (46 nos.)

(4) Poovan (46 nos.)

(5) Cocoa+Mondhan (each 22 nos.) in alternate rows

(6) Cocoa+Karpuravalli (each 26 nos.) in alternate rows

(7) Cocoa+Kanchi (each 26 nos.) in alternate rows

(8) Kanchi+Rastali (each 26 nos.) in alternate rows

(9) (Jurmony 22 nos.)+(Karpuravalli 14 nos.+Rastali 7 nos.+Poovan 7 nos.), in alternate rows.

The manurial schedules were (*i*) 6kg farmyard manure+156g urea+180 g superphosphate+165 g muriate of potash per tree/annum for Cocoa; (*ii*) 10kg farmyard manure+240 g urea+225 g superphosphate+550 g muriate of potash per tree/annum in 2 splits at 3rd and 5th month after planting for banana. Manuring of coconut, and irrigation schedule for coconut and intercrops are as in experiment No. 1.

Results and Discussion

The criteria to be considered for assessing the suitability/compatibility of intercrops in coconut ecosystem in a particular region are (*i*) there should be no adverse effect on the growth and yield of the main crop, *viz*., coconut, and (*ii*) the yield and the profitability of the intercrops should justify the extra investment on their cultivation and man power employment. In both the experiments, the main crop of coconut was benefited by the intercropping.

The coconut yield was increased by 32 per cent in the first experiment and 5.3 per cent in the first two years of the second experiment (Table 1). The yield increase might be due to the additional inputs and irrigation given to intercrops and also due to the addition of soil organic matter through the intercrops.

Table 1. Effect of intercropping on coconut yield

Experiment No.	Year	Intercrops	Mean yield nuts/palm/year		Increase %
			Control	Intercrop	
1	1976—81	Cacao and pineapple	46.2	62.0	32.0
2	1976—79 (pre-expt.)	Cacao and banana	89.0	75.0	—
	1980—81 (post-expt.)		95.0	100.0	5.3

The performance of intercrops in a coconut ecosystem under east coast conditions is discussed cropwise below:

Cocoa: In experiment 1, cocoa started flowering in 1974, but the recordable yield occurred only from 1977 onwards i.e., 8 years after planting. The main problems encountered were: (1) the long gestation period to get economic yields, (2) malformation and premature dropping of beans, (3) large scale occurrence of fruit-rot, reducing the proportion of good beans by 16 per cent, (4) difficulties in controlling fruit-rot with bordeaux mixture spraying, (5) occurrence of mealy bugs, (6) lack of marketing facilities after the cessation of procurement by M/s. Cadbury & Co., in 1980–81, (7) lack of adequate irrigation due to shortage of power and water and (8) high cost of plant protection measures against fruit-rot and mealy bugs.

The cost of cultivation of cocoa was Rs. 1212/ha/annum while the income from cocoa even at 5 years after planting was Rs. 519/ha (Table 2). The yield was low with a mean of 17.3 kg of dried beans for the period 1978–81.

Table 2. Overall economics of cocoa and pineapple as intercrops (Experiment 1)

Particulars	Coconut + intercrop	Coconut alone
Receipts (Rs./ha)		
(*a*) Coconut	10987	8321
(*b*) Cocoa	519	—
(*c*) Pineapple	208	—
Total	11714	8321
Expenditure (cost of cultivation, Rs./ha)		
(*a*) Coconut	3300	3300
(*b*) Cocoa	1212	—
(*c*) Pineapple	2232	—
Total	6742	3300
Net profit (Rs./ha)	4972	5021

The cocoa in Experiment 2 has not commenced bearing till 1982 and hence no information could be given on the performance of the variety 'Forastero'.

Pineapple: The pineapple yield was 81 kg/ha in 1978, 175 kg in 1979, and 69.0 kg in 1980. A replanting was also done in 1981 as the yield declined in 1980. The cost of cultivation was Rs. 2232/ha while the income was only Rs. 208/ha. The overall economics (Table 2) was not in favour of cocoa and pineapple as intercrops in the sandyloam soils of Thanjavur district, even after due allowance was given to the increase in coconut yield.

Table 3. Economics of banana as intercrop (Experiment 2)

Treatment	Yield (kg/ha)*		Receipts (Rs./ha)			Cost of cultivation (Rs/ha)			Net profit (Rs/ha)
	Main crop	Intercrop	Main crop	Intercrop	Total	Main crop	Intercrop	Total	
Coconut	18050	—	18050	—	18050	3300	—	—	14750
Coconut + banana	19000	3000	20000	2250	22250	3300	2000	5300	16050
Coconut + Cocoa**	17670	—	17670	—	17670	3300	1540	4840	12830

*190 palms only, 500 bananas/ha; economics based on prices prevailing in 1981—82

**Cocoa had not yet come to bearing

Banana: Details of the yield and economics of banana intercrop are given in Table 3. The average yield of banana intercrop was 3000 kg/ha with an income of Rs. 2250/ha. The cost of cultivation of banana intercrop in one ha of coconut garden was around Rs. 2000/-. The growth and yield of intercroped banana was satisfactory and comparable to the pure crop. The net profit due to banana was low, (only Rs. 250/ha), compared to the increase in net profit of main crop to the tune of Rs. 1950/ha due to banana intercrop. Banana can be grown as intercrop when there is a market demand for it. All varieties tested, culinary and table ones, performed well and the choice should, therefore, be based on local market demand and resistance to damage by cyclone which is of common occurrence in the east coast.

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SHADE AND MOISTURE REQUIREMENT OF CACAO SEEDLINGS

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Abstract

Results of investigations to study the response of young cacao to shade and moisture are presented in the paper. In general, the growth of young cocoa plants was good at 50 to 55 per cent shade and irrigation at 25 per cent soil moisture depletion. Interaction between shade and moisture on growth of young cacao was absent, indicating that the extent of soil moisture depletion that the plants could withstand without any effect on growth remained the same at all shade levels.

Introduction

Earlier reports suggest that cocoa plants respond more favourably to shade during the establishment period (1-3 years) (Holland, 1931; Goodall, 1955; Hardy, 1958; Wood, 1975) than the established cocoa, where productivity is often reported to improve with increasing illumination (Murray, 1954; Cunningham and Lamb, 1959). Experiments conducted in Ghana indicated that while excessive soil moisture was harmful for cocoa plants, the soil could be allowed to dry out to 60 per cent available moisture by regulating shade (Anon., 1972). As no such data is available pertaining to our conditions, this study was undertaken to evaluate the response of very young cocoa plants up to the 5th month to different shade and soil moisture levels.

Material and Methods

The expeiiment was conducted at the College of Horticulture, Vellanikara, in Kerala State. The treatments numbering 12, included four levels of shade (0, 25-30, 50-55) and 70-75 per cent of full light) and three levels of available moisture (25, 50 and 75 per cent depletion). It was laid out in completely randomized design with 4 replications. Shade variations were provided using selected types of mosquito net, cotton cloth and loose gunny mat respectively for the low, medium and high shade levels, respectively. The selected shade materials were then stretched and tied tightly over wooden frames of size 10 × 3m. The shade materials covered the top and all sides except for a clearance of 60cm from the ground level to facilitate ventilation. Fortnightly shade measurements were recorded with an 'Aplab' lux meter to adjust the shade as per treatment requirements.

Seedlings were raised in polythene bags of 30 × 20cm filled with 4 kg of sieved (through 5 mm metallic sieves) fertile top soil. The soil moisture was maintained at 25, 50 and 75 per cent available water by weighing the sample pots daily along with the plants and noting the loss in weight, and making up by watering if and when required.

In all the treatments, a sample of three test plants each was harvested at monthly intervals for recording observations on height, girth, number of leaves, leaf area, total dry weight and NAR. In addition, meteorological data, solar intensity, canopy temperature and soil temperature at two depths of 5 and 10cm were recorded once every week at hourly intervals.

Results and Discussion

In general, with increase in shade from 25-30 per cent to the intermediate level of 50-55 per cent all growth characters exhibited improvement though there were indications of higher shade intensity being better during the earlier months (Table 1). Those shaded to 25-30 per cent were inferior to both medium and heavily shaded plants with few exceptions. Plants in the open sunlight were always inferior to all shade levels, and they could not thrive beyond the third month. The mean dry weight and leaf production remained nearly static from first to third month in these plants and the leaf area by the second month was about 60 per cent less than that of the first month. By the third month, all the leaves abscised, though plants remained alive. The effect of shade on NAR was not significant throughout the experiment except between the third and fourth month when the lowest shade level was significantly inferior to the other two levels. NAR showed a slight increase with advancing age.

Table 1. Effect of shade and moisture on height, girth, number of leaves, leaf area, dry weight and NAR of cocoa seedlings

Treatment	Height (cm)		Girth (cm)		No. of leaves		Leaf area (cm^2)		Dry weight g/seedling		NAR ($mg/dm^2/day$)		
	1st month	5th month	1st month	5th month	1st month	5th month	1st month	5th month	1st month	5th month	1st & 2nd month	3rd & 4th month	4th & 5th month
Shade level (%)													
0	16.77	**	0.37	**	5.5	**	77	**	0.41	**	4.42	**	**
25–30	18.41	31.57	0.42	0.74	8.3	17.3	218	622	1.31	6.35	6.08	7.22	12.13
50–55	19.32	43.32	0.42	0.86	8.1	26.6	251	1302	1.39	11.86	7.03	16.39	9.44
70–75	18.73	39.68	0.42	0.83	7.7	25.6	245	1380	1.46	10.55	7.34	16.21	10.14
CD at 5%	0.80	3.92	0.02	0.05	0.8	3.5	21	237	0.11	1.61	NS	5.65	NS
Available moisture (%)													
75	18.51	45.82	0.42	0.91	8.0	26.7	223	1484	1.26	12.60	6.01	16.36	8.54
50	17.85	35.99	0.40	0.79	7.3	22.5	188	1103	1.14	8.66	6.65	13.43	10.45
25	18.56	32.77	0.41	0.73	7.0	20.5	183	717	1.04	6.72	5.99	10.03	12.72
CD at 5%	NS	3.92	NS	0.05	NS	3.5	18	237	0.09	1.61	NS	5.65	NS

**Plants did not survive beyond 3rd month

NS: Not significant

Like in the case of shade, irrigation significantly influenced the growth of cocoa seedlings. Maintaining the soil moisture at 75 per cent (25 per cent depletion) showed better performance over the others in majority of the characters studied. The interaction between shade and moisture levels was not significant in any character at the different months.

In general, the height and girth of seedlings was better under the medium shade of 50-55 per cent. The number of leaves produced as well as their expansion were also optimal under this shade regime. These results are in agreement with those reported earlier (Gourley, 1920; Holland, 1931; Goodall, 1955; Hardy, 1958; Wood, 1975). Hardy (1958) speculated that under higher illumination some sort of hormonal inhibition of leaf production and growth is operative in this species, as he observed the stomata remaining open even at full light intensity. Eventhough, we did not investigate on these aspects, in our study we observed the minimum number of leaves and their least expansion in the first month under zero shade. Furthermore, the plants succumbed by fourth month under full sunlight. Eventhough the dry weight per seedling was maximum at the medium shade, the dry matter accumulation by unit leaf area (NAR) was inconsistent, and the treatment differences were not significant, except by the 3rd and 4th month. From this, it is apparent that the rates of photosynthesis did not vary at the various shade levels employed in this study.

As can be expected, the growth was maximum at 75 per cent of available moisture. At higher levels of depleted conditions, all the growth parameters monitored registered a negative influence. The effect of levels of moisture was independent of shade levels, and the treatment maintained at the highest moisture level was the best at all shade levels. The absence of a significant interaction between shade and moisture level may thus indicate, that the extent of soil moisture depletion that the cocoa plants would withstand without affecting growth, remained the same at all shade levels.

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INFLUENCE OF COCONUT SHADE ON MULBERRY AND SILKWORM REARING

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ABSTRACT

Results of an investigation on the effect of coconut shade on mulberry as a whole and its influence in turn on cocoon yield in particular are reported. The coconut shade affected not only the morphology of the mulberry plants but also the quality of leaves, which in turn influenced the weight of the larvae as well as cocoons. The morphological changes include increase in internodal length, increase in number of leaves per Kg, and differences in size and colour of leaves. The changes in life cycle of silkworm included, increase in duration of moulting and difference in weight of the larvae.

INTRODUCTION

The mulberry (*Morus alba L.*) is grown in many parts of the world under varied environmental conditions. The plant shows variations in morphology and structure according to soil type, fertility and climatic conditions Tazima, 1972). In Arsikere taluk, mulberry is grown as a mixed crop in coconut gardens. In the present study, the effect of coconut shade on the yield and quality of mulberry leaves in general and its influence on cocoon yield in particular were investigated. Observations were also made on the yield and health of the coconut palms.

MATERIAL AND METHODS

The experiment was conducted on an 18 year-old private coconut garden near Arsikere with the following treatments:

(*a*) Mulberry grown under coconut shade

(*b*) Mulberry grown as mono–crop in open

(*c*) Coconut as mono–crop.

Coconut and mulberry were grown singly or in combination on homogeneous soil in adjacent plots as per the treatments given above. The first two treatments were given the same quantities of nutrients and irrigation. The third treatment received the usual local cultivation practices.

Mulberry was grown by pit system of planting (60×60 cm), 90 cm away from the bole of coconut palms in both the treatments, and all agricultural practices were followed as described by Ullal and Narasimhanan (1978). One hundred disease-free layings of cross breed (MYS×NB 18) silkworms (*Bombyx mori*) were used for each rearing experiment.

RESULTS AND DISCUSSION

The data on the morphology of mulberry plants and weight of the larvae as well as cocoons are presented in Tables 1 to 4.

I. Influence of coconut shade on mulberry plant: The biometric observations recorded during the growth of the mulberry are as follows: (Table 1).

(*a*) Slender and succulent plants with long internodes in shade compared to open, (*b*) thin, broad and pale green leaves weighing little less than that of open field plants, and (*c*) quick and luxuriant growth of plants under shade compared to open field.

II. Effect on silkworm and cocoons: The life cycle of *Bombyx mori* was increased to 24-28 hours when fed with mulberry leaves grown under coconut shade. Larvae fed with open field leaves and their cocoons weighed slightly more than those fed with leaves grown under shade (Tables 2, 3).

III. Effect on coconut yield: The nut yield of coconut was more when mulberry was grown as intercrop compared to a pure stand of coconut (Table 4). There was an increase of 9 nuts/palm/year on an average over a period of three years.

IV. Pests and diseases on mulberry: The growth of powdery mildew fungus (*Phyllactinia corylea*) was more when mulberry

Table 1. Effect of coconut shade on mulberry (mean of 10 plants)

Habitat	Branches no./tree	Leaves no./tree	Internodal length*(cm)			Height of plants (cm)	Size of leaves**		Colour of leaves	Leaves per Kg no.
			B	M	T		L	B		
Mulberry grown in open	5 to 8	18 to 26	3.1	6.0	5.6	100 to 138	19	14	green	546
Mulberry grown under coconut shade	4 to 7	16 to 23	3.5	6.5	5.9	125 to 155	19	16	pale green	592

*B, M and T refer to Bottom, Middle and Top respectively

**L and B refer to length and breadth respectively.

Table 2. Effect of coconut shade on the quality of mulberry leaves—duration of different instars and moulting periods

Instars and Moults	Leaves from trees in open field		Leaves from trees under shade	
	Duration	Quantity of leaf fed (kg)	Duration	Quantity of leaf fed (kg)
I Instar	3.5 d	2.5	3.5 d	2.5
I Moult	22 h	—	24 h	—
II Instar	2.5 d	6.0	3.0 d	6.0
II Moult	24 h	28.0	26 h	28.0
III Instar	4.0 d	28.0	4.5 d	28.0
III Moult	24 h	82.0	28 h	82.0
IV Instar	5.0 d	82.0	6.0 d	82.0
IV Moult	26 h	—	24 h	—
V Instar	8 d	624.0	7-8 d	624.0
Total	27d	742.5	28.25-29.25	742.5

Feeding Hours: 6,10,14,18 and 22 h IST d—days h—hours
Rearing conditions: Room temperature 27°C to 29.5°C and relative humidity 75 to 83 per cent.

Table 3. Effect of coconut shade on mulberry leaves–rearing observations

Particulars	Leaves from trees in open field	Leaves from trees under shade
Number of layings reared	100 DFLS (C.B.)	100 DFLS (C.B.)
Average weight of 10 larvae at 5th stage	31.10 g	30.23 g
Average weight of 10 cocoons after a day of spinning	11.84 g	11.32 g
Number of days taken from hatching to cocoon formation	27d	28.3 to 29.3 d
Total quantity of leaves fed upto the date of spinning	742.5 kg	742.5 kg
Yield	43.4 kg	41.5 kg

Table 4. Effect of mulberry intercropping on coconut yield (Mean of 40 palms) Average for 3 years (1980–82)

Treatment	Yiled of coconut nuts/palm/year
Coconut + mulberry	85
Coconut alone	76

plants were grown under shade. On such plants, larvae and adults of *Illis cincta* (Coccinellidae) were found to feed on the fungus and helped in suppressing the spread of the fungus to a certain extent.

Scutillarid bug *Chrysocoris stolli* (Scrutillaridae) was found feeding on the central surface of the top leaves in groups. Sucking of the plant sap resulted in outward curling of the mulberry leaves. Three to five bugs were recorded on a single leaf on the mulberry grown under shade. Such bugs were rarely found on the mulberry grown in an open field. These bugs did not appear to cause any economic damage to the mulberry.

DISCUSSION

The morphological changes in mulberry, such as increase in the internodal length, size of the leaves and paleness of leaves may be attributed to the shade effect of coconut palsm. The appearance of such characters is reported to be common in plants grown in shade and marshy habitat (Daubenmire, 1974).

The differences in weight of the larvae, cocoons and life cycle could be attributed to the difference in nutrient contents of the leaves grown in two treatments. The difference in weight of the cocoon was negligible (Table 3).

The increase in the yield of coconuts could be due to the better availability of nutrients and water in the plots where mulberry was grown. Such an increase in the yield of coconut was recorded when cacao was grown as an intercrop with coconut (Nair, 1979).

The increase in fungal growth on mulberry leaves under shade may be due to higher humidity. Similar observations in coconut gardens were made by Alexopoulos (1972).

The market price of both coconut and silkworm cocoons fluctuated widely. Based on the prices which prevailed between September and October 1982, the gross income from the coconut-mulberry mixed planting was estimated at Rs. 29,520/- per annum per ha compared to Rs. 13,500/- from a pure plantation of coconut (Table 5). The present investigation opens up the possibility of growing

Table 5. Effect of coconut shade on mulberry—economics of intercropping

Particulars	Coconut + mulberry			Coconut alone
	Coconut	Mulberry (cocoons)	Total	
Fruits/Cocoons harvested per year/ha	8000 no.	420 kg	—	7500
Estimated value of produce Rs./ha/year,	14400	15120	29520	13500

Note: (*a*) 100 coconut trees/ha (*b*) average productivity of 80 coconuts/tree/year in case of mixed garden and 75 in case of pure plantation (*c*) coconut at Rs. 1800/ thousand nuts (*d*) cocoons at Rs. 36/kg (*e*) average weight of cocoons at 42 kg/100 DFLS and only four crops reared in a year.

mulberry profitably in coconut gardens. The quality of mulberry leaves was not affected when grown under coconut shade, and the yield of cocoons was not affected appreciably when fed with these leaves.

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NOTE ON THE INTER-CROPPING OF MULBERRY IN COCONUT PLANTATION

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ABSTRACT

An observational trial to study the feasibility of growing mulberry crop in coconut plantation was laid out for three years from 1978. The results indicate that growing mulberry as a mixed crop in coconut has no adverse effect on the growth and productivity of the coconut crop. Silk worm rearing and cocoon production using the leaves of mulberry, grown as a mixed crop in an area of 0.4 hectare, increased the net return from Rs. 4811/- (coconut alone) to Rs. 16,182/- (coconut + mulberry) The employment opportunities were also more than doubled compared to monocropping practice.

INTRODUCTION

Growth habit of the coconut palm and the pattern of its utilization of soil nutritents, and solar energy permits other crops to grow in compatible combinations (Kushwaha *et al.*, 1973; Nelliat *et al.*, 1974; Nair and Balakrishnan, 1976). The wider spacing of 9×9m generally adopted in maidan tract of Karnataka unlike the 7.5×7.5m spacing in coastal areas, increases further the available interspace for other crops. Therefore, growing of mulberry as an inter-crop with coconut was explored in a trial under the All India Co-ordinated Coconut and Arecanut Improvement Project at the Agricultural Research Station, Arsikere.

MATERIAL AND METHODS

Two plots consisting of 8 palms (650m^2) were selected, one for control and the other for raising intercrop. Mulberry crop was planted leaving a space of 2 meters around the base of the palm. Recommended package of practices were followed as for pure crops (Krishnaswamy, 1978; Anon., 1979). Rearing trials were carried out using mulberry leaves harvested from plants grown as intercrop under coconut shade, and also those obtained from plants grown in open area.

Results and Discussion

The observations are presented in Tables 1 and 2. The results showed that mulberry as an intercrop in coconut gardens has no

Table 1. Economics of intercropping mulberry in coconut gardens

Treatment	Economics of cultivation/ha/year					
	Yield of coconut (No.)	Cocoon yield* (Kg)	Gross income (Rs.)	Cost of Cultivation (Rs.)	Net return (Rs.)	Man–days
Coconut + mulberry	5125	375*	18818	3981	16182	265
Coconut alone	4925	—	6881	2070	4811	127

*100 layings, 4 crops a year.

Table 2. Effect of coconut shade on the rearing qualities of mulberry leaves (mean of rearing 50 silkworms)

Character	Leaves from mulberry inter-crop	Leaves from mulberry pure stand
Weight of leaves fed (kg)	1840.00	1759.00
Weight of worms (g) (before spinning)	200.00	203.00
Length of cocoon (cm)	3.52	3.30
Girth of cocoon (cm)	6.40	6.43
Weight of cocoon (g)	1.41	1.56

adverse effect on the main crop. The cocoons produced from larvae fed with leaves from plants grown under shade and open area showed very little difference in their silk yield properties. The net return obtained in 1981 from a hectare was Rs. 26,248 by growing mulberry crop with coconut, with an employment potential of 273 man–days as compared to Rs. 7800 in the monoculture with an employment potential of 128 man–days. The present trial opens up the possibility of growing mulberry as an inter-crop in the wider spaced coconut gardens in the maidan tract of Karnataka.

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STANDARDIZATION OF LEAF POSITION FOR FOLIAR DIAGNOSIS OF NITROGEN IN COCONUT

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ABSTRACT

Results of a study to standardize the leaf position for foliar diagnosis in coconut with particular reference to N are presented in the paper. Samples of leaf lamina and mid-vein (of leaflets) from all the leaves (fronds) were drawn and analysed separately. The N content of leaf increased with increasing age of the leaf till leaf No. 6 or 7 (the leaves were numbered from top to bottom taking the last fully open leaf as leaf No. 1) and thereafter declined, the lowest values being observed for the last few leaves. The average yield of the palms was significantly correlated with the N content in leaves sampled from different positions.

INTRODUCTION

Fremond *et al.*, (1966) of IRHO, Ivory Coast have standardized leaf tissue for foliar diagnosis and proposed critical levels of nutrients in coconut. While Romney (1965) suggested higher critical levels for nitrogen and potassium in the case of Malayan dwarfs grown in Jamaica, Nethesinghe (1966) in Sri Lanka, and Kanapathy (1971) in Malaysia have suggested different values based on their work. The present investigation was undertaken to standardize the foliar diagnosis in coconut for nitrogen under the agroclimatic conditions prevailing in the west coast region of Kerala.

MATERIAL AND METHODS

The NPK experiment laid out in 3^3 factorial design in 1964 with West Coast Tall palms spaced at 7.5×7.5m at the Coconut Station, Balaramapuram, Trivandrum was utilized for the study. The fertilizer levels were 0, 340 and 680 g N/palm/year; 0, 225 and 450g P_2O_5/palm/year; and 0, 450 and 900g K_2O/palm/year. The plot size was four palms, and the treatments were imposed from seedling stage. Ammonium sulphate, super phosphate and muriate of potash were used as sources of N, P and K respectively. The soil of the experimental area was deep, non-saline (EC=0.36 mmhos/cm) moderately acidic (pH 6.03), and well drained, lateritic, red loam with 0.46 per cent organic carbon. The soil analysed 6.8 ppm of available P (Bray No. 1) and 62 ppm of available K (Neutral 1N ammonium acetate). The crop was under rainfed conditions and the annual rainfall ranged from 135 to 210 cm.

Leaf samples were collected from all the experimental palms and from all the available leaves of each palm separately. The youngest fully open leaf in the crown was referred to as the first leaf and other leaves were numbered in the order of their increasing age. Leaf sampling was done by cutting two leaflects from the middle portion of the leaf, from either side of the rachis, with the help of a hooked knife. The laminae were separated from the leaflets. The marginal threads of the laminae were removed and 10 to 20 cm strips from the middle region were cut, dried and ground. The mean yield (nuts/palm/year) obtained for four years during 1976 to 1979 (which represented the 12th to 15th year after planting of the palms) was used for correlation studies.

Results and Discussion

Results revealed that the application of nitrogen did not increase the number of leaves (Table 1). The N_0, N_1 and N_2 treatments influenced to produce 21.9, 19.8 and 21.0 leaves per palm respectively. However, palms receiving no nitrogen were poorer in nitrogen content and yield of nuts.

The level of N application significantly influenced the yield of the palms, mean yield of nuts being 3.0, 8.3 and 12.3/palm/year at N_0, N_1 and N_2 levels respectively. The N content in leaf lamina and mid-vein of leaflet increased with advancing age of the leaf upto leaf number six or seven (Table 2) and thereafter gradually decreased. The content of N in the mid-vein of leaflet was much lower than that in the leaf lamina.

The relationship between the N per cent in leaf lamina and mid-vein of leaflet at different leaf positions, and yield was studied (Table 3). The partial correlations indicated that N per cent of leaf lamina at positions 2,3,4,8,10 and 26 were significantly related

Table 1. The mean annual yield (1976–79), of nuts/palm and number of leaves at the time of sampling

Treatment	Leaves No./Palm				Mean yield of nuts No./Palm			
	K_0	K_1	K_2	Mean	K_0	K_1	K_2	Mean
N_0P_0	19.8	23.0	24.3	22.4	0.5	4.0	2.9	2.5
N_0P_1	14.3	27.0	24.0	21.8	0.0	10.0	0.6	3.5
N_0P_2	13.0	24.8	27.0	21.6	0.0	0.2	9.0	3.1
N_1P_0	10.3	25.0	20.0	18.4	0.0	6.4	4.8	3.7
N_1P_1	9.5	25.8	28.5	21.3	0.1	17.9	22.3	13.4
N_1P_2	10.3	23.8	25.0	19.7	0.0	6.5	17.3	7.9
N_2P_0	11.5	28.0	26.3	21.9	0.3	8.8	8.7	5.9
N_2P_1	7.3	22.3	29.3	19.6	0.3	16.3	24.6	13.7
N_2P_2	8.3	27.3	29.3	21.6	0.3	25.9	25.7	17.3

to yield. The K_0 plots were omitted as the yields were very much influenced by this element while working out partial correlation coefficients; and only those treatments in which K alone was not a limiting factor, were used. However, the highest value of 0.78 was registered for leaf position 10 followed by 0.70 for leaf position 2. The yield was significantly correlated with N per cent of mid-rib leaflet at positions 6, 14 and 18 at 1 per cent level of significance. The highest value of 0.68 was recorded for leaf position 14 followed by 0.64 for leaf position 6. The correlation between yield and N per cent of leaf lamina was more pronounced than that between yield and N per cent of mid-rib leaflet.

In the present study, the leaf position 10 appeared to be the best, based on the highest coefficient of partial correlation with yield. Ziller and Prevot (1961) recommended the 14th leaf as the best reflect for foliar diagnosis of major and secondary nutrients. They indicated that 14th leaf has reached physiological maturity but not entered the phase of senescence.

The 14th leaf suggested by Ziller and Prevot (1961) represents the middle whorl whereas the 14th leaf of most of the palms under the present study will be a leaf in its early stage of senescence. The average leaf number on the palms in the present study was only 20.92 with a range between 5 and 32. Perhaps, leaf number 10 in

Table 2. Nitrogen in coconut leaf lamina and mid-vein

Leaf position	N % (mean of 9 treatment combinations)					
	Leaf lamina			Mid-vein of leaflet		
	N_0	N_1	N_2	N_0	N_1	N_2
1	1.20	1.99	1.98	0.20	0.19	0.23
2	1.56	1.94	2.01	0.20	0.20	0.24
3	1.54	1.99	2.05	0.19	0.20	0.24
4	1.68	2.19	2.28	0.19	0.20	0.24
5	1.86	2.21	2.11	0.20	0.20	0.25
6	1.93	2.37	2.22	0.19	0.20	0.25
7	1.79	2.22	2.42	0.20	0.21	0.25
8	1.84	2.19	2.67	0.19	0.21	0.25
9	1.79	2.08	2.24	0.19	0.21	0.24
10	1.91	2.15	2.12	0.19	0.21	0.24
11	1.88	2.19	2.05	0.18	0.21	0.24
12	1.77	2.13	1.86	0.18	0.21	0.23
13	1.96	2.19	2.12	0.19	0.20	0.23
14	1.48	2.04	1.98	0.19	0.19	0.24
15	1.51	2.03	1.94	0.18	0.20	0.23
16	1.51	2.19	2.08	0.19	0.18	0.21
17	1.68	2.10	1.96	0.19	0.20	0.22
18	1.68	1.96	2.10	0.19	0.18	0.22
19	1.76	1.96	1.94	0.19	0.17	0.22
20	1.58	1.94	1.89	0.19	0.17	0.23
21	1.56	1.82	1.89	0.20	0.17	0.22
22	1.32	1.84	1.77	0.20	0.19	0.22
23	1.40	1.82	1.80	0.19	0.17	0.22
24	1.44	1.73	1.77	0.18	0.16	0.22
25	1.20	1.59	1.89	0.19	0.17	0.22
26	1.22	1.61	1.80	0.18	0.16	0.20
27	1.18	1.70	1.66	0.17	0.16	0.20
28	1.23	1.51	1.71	—	—	—
29	1.40	1.49	1.60	—	—	—
30	1.26	1.33	1.96	—	—	—

Table 3. Partial correlation coefficient of leaf lamina and mid-vein of leaflet N on yield (N—2=17)

Leaf position	Leaf lamina	Mid-vein of leaflet
1	0.47	0.27
2	0.70**	0.23
3	0.65**	0.42
4	0.64**	0.35
5	0.30	0.43
6	0.28	0.64**
7	0.50*	0.45
8	0.64**	0.32
9	0.39	0.21
10	0.78**	0.51*
11	0.50*	0.57*
12	0.60*	0.52*
13	0.18	–0.13
14	0.60*	0.68**
15	0.59*	0.60*
16	0.34	0.32
17	0.24	0.43
18	0.45	0.61**
19	0.58*	0.60*
20	0.22	0.46
21	0.23	0.38
22	0.25	0.55*
23	0.36	0.37
24	0.42	0.41
25	0.49*	0.40
26	0.62**	0.35

**Significant at 1% level
*Significant at 5% level

the experimental palms of the present study represents the middle whorl which has reached physiological maturity but not yet entered the phase of senescence.

The relationship between N content of lamina of leaf position 10 and yield was represented by the simple linear regression, Y= 38.49 N per cent—56.21. This reveals that a unit increase in the N per cent at leaf position 10 will result in an increase in yield to the tune of 38.49 nuts/palm/year, and for the very expression of yield the minimum N content will be 1.46 per cent. This investigation, therefore, tends to recommend the lamina of leaf number 10 which represents the middle whorl of the crown as the most suitable tissue for foliar diagnosis of N for yield prediction and fertilizer management.

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EFFECT OF MAJOR NUTRIENTS ON THE INCIDENCE OF ROOT (WILT) DISEASE IN COCONUT

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ABSTRACT

Studies on the effect of application of N,P,K, Ca and Mg, from the time of planting in the main field at Kayangulam, on the incidence and severity of root (wilt) disease in West Coast Tall palms indicated that, young palms are more susceptible to the disease at the onset of bearing. When young palms under good management contracted the disease before flowering, the onset of bearing was delayed by about 12 months. The frond production rate and the number of functioning leaves on the crown are considerably reduced in diseased palms. Among the nutrients, Mg significantly increased the expression of both these characters thereby preventing the reduction in growth due to the disease. The disease caused about 60 per cent reduction in yield in the early bearing period. The mean yields of healthy and diseased palms at the 10th year of planting were 58.8 and 23.8 nuts/palm respectively. The disease caused about 12 per cent reduction in copra weight per nut while the reduction in oil content was not significant.

INTRODUCTION

In the etiology of coconut root (wilt) disease, the involvement of biotic factors such as fungus (Thomas Joseph, 1978), virus (Solomon and Sasikala, 1980) and bacterium (Mathew George *et al.*, 1976) have been implicated but the precise cause of the disease needs to be established.

Studies on soil and tissue samples of palms in diseased area indicated a lower status of Ca and Mg and a higher N, P and K contents in the tissue. (Verghese *et al.*, 1959; Cecil, 1975; Pillai *et al.*, 1975). The possibilities of nutritional imbalance with regard to

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major nutrients was indicated by Verghese *et al.* (1959), Pandalai (1959), Cecil (1975) and Pillai *et al.* (1975). The application of Ca and Mg salts along with N.P.K. fertilizers showed improvement in the condition of root (wilt) affected palms and their yields (Nair and Radha, 1959; Davis, 1964).

With a view to studying the effect of Ca and Mg in combination with N, P and K from the time of planting of coconut in the main field, an experiment was started in 1970 at CPCRI Regional Station, Kayangulam and the results obtained are reported in this paper.

MATERIAL AND METHODS

Split plot design with main plot treatments as combinations of 3 levels of N, P and K in a 3^3 confounded factorial arrangement confounding N P^2K^2, and sub-plot treatments as factorial combinations of 2 levels of Ca and Mg with a single replication, was adopted for the study. The main plot size was 24 palms and the sub-plot 6 palms.

Nutrient levels (Adult dose/palm/year)

N_1—500 g N	P_1—300g P_2O_5	K_1—1000g K_2O
N_2—750 ,,	P_2—450 ,,	K_2—1500 ,,
N_3—1000 ,,	P_3—600 ,,	K_3—1200 ,,

Ca_0—No calcium
Ca_1—Lime requirement to raise the soil pH to 6.5
Mg_0—No magnesium
Mg_1—500 g Mg0
50 kg cattle manure (from 1973 onwards)

One-year-old WCT seedlings were planted in October, 1970 at a spacing of 7.5m in the square system of planting.

Nutrients were given in the form of ammophos (16:20)+urea for N and P, muriate of potash for K, slaked lime for Ca and magnesium sulphate (hydrated) for Mg. The young palms were fertilized at the rate of 1/3 adult palm dose in the first year after planting, 2/3 in the second year, and the full dose from third year onwards. The fertilizers were applied by broadcasting in circular basins of the palms in two splits, 1/3 in April–May, and 2/3 in August–September every year.

The dose of Ca was fixed as the lime requirement (Shoemaker *et al.*, 1961) for raising the pH of the 0-50 cm layer soil to 6.5. The quantity required for a sub-plot of 6 palms, (75 kg slaked lime) was broadcast uniformly over the entire sub-plot area including the palm basins during June every year and ploughed in.

Results and Discussion

The total number of palms under the experiment was 648. The progressive incidence of disease upto December, 1981 (Table 1) showed that the maximum number of palms contracted the disease at the 7th year.

Table 1. The progressive incidence of root (wilt) disease in the experimental palms

Progression from year of planting (1970)	No. of palms affected	Cumulative percentage
1973	2	0.3
1974	16	2.8
1975	10	4.3
1976	29	8.8
1977	89	22.5
1978	44	29.3
1979	40	35.5
1980	47	42.7
1981	51	50.6

The distribution of disease under different treatments from 1977 to 1981 was analysed separately. From 1980–81, the data (Table 3), also indicates that none of the main effects had any significant influence on the incidence of disease which suggests that the disease incidence is not related to the major element nutrition of the palm.

The effect of root (wilt) disease on the onset of bearing was studied on 43 such palms in different treatments that exhibited visible symptoms before the emergence of the first inflorescence.

Irrespective of the treatments, the mean pre-bearing age of these affected palms was 84.8 months and that of all other healthy palms was 73.1 months. Eventhough the time lapse between the appearance of visible symptoms and the onset of bearing varied in different palms, an overall assessment based on the above consideration showed that, under good management, the onset of bearing in WCT palms was delayed by about 12 months when the young palms contracted the disease before flowering.

The total number of palms affected by the disease till Dec. 1979 was 230 and the number of palms that contracted the disease during 1980 was 47. Observations recorded in 1980 relating to the 230 palms that had already contracted the disease before 1980, and those relating to the palms remaining healthy upto December, 1980 were separately considered for studying the influence of disease on frond production rate, functioning leaves on the crown, nut yield and yield attributes. Since the number of healthy and diseased palms under different treatments was small and their distribution uneven, the effects of nutrients on the various parameters under healthy and diseased conditions might not be very realistic. Further, the disease had occurred at irregular intervals since its first appearance in 1973 and the intensity of disease had also been different in different palms. Nevertheless, an overall assessment on the differences between healthy and root (wilt) affected palms for the various characters observed was found to be very useful for estimating the damage caused by the disease in the early bearing period.

The effects of nutrients on the number of functioning leaves on the crown and frond production rate are given in Table 2. The beneficial influence of Mg was more and of Ca less on disease. The frond production rate was reduced by 3.4 per cent and the number of functioning leaves by 15.1 per cent.

Higher levels of N, P and K had no significant influence on yield and yield attributes of healthy as well as diseased palms (Table 3). In contrast to healthy palms, the yield and yield attributes of root (wilt) affected palms were slightly depressed at the third level of N P and K application. Sahasranaman *et al.* (1964) also opined that heavier doses of NPK fertilizers aggravated the disease condition and reduced the yield of root (wilt) affected palms, whereas lower

Table 2. Effect of nutrients on functioning leaves, frond production, copra and oil contents of healthy and root (wilt) affected WCT palms, and on disease incidence

Main effects	No. of functioning leaves in Dec. 1980		No. of fronds produced from Jan. to Dec. 1980		Weight of copra per nut (g)		Oil content (%)		% palms affected by disease (1981)
	H	D	H	D	H	D	H	D	D
N_1	28.8	24.4	14.4	14.1	195.7	171.7	68.5	67.3	46.7
N_2	29.6	24.4	14.6	14.0	195.7	165.3	68.1	66.1	51.9
N_3	28.8	25.3	14.7	14.3	186.2	170.5	68.5	68.7	53.3
P_1	28.9	25.8	14.5	14.3	193.0	167.5	69.0	68.3	52.3
P_2	29.6	24.1	14.9	14.1	193.8	167.3	66.8*	65.7	48.6
P_3	28.7	24.2	14.3	14.0	190.8	172.8	69.3	68.2	50.9
K_1	28.5	25.2	14.3	14.3	193.4	168.8	68.3	68.0	51.5
K_2	29.9	24.8	14.7	14.2	196.9	169.3	68.7	66.1	51.4
K_3	28.8	24.1	14.8	13.9	187.3	169.5	68.1	68.1	49.1
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	2.0	NS	NS
Ca_0	27.8	24.1	14.4	14.0	191.1	171.2	69.2	67.6	50.7
Ca_1	30.3**	25.3	14.4*	14.3	193.9	167.2	67.5*	67.2	50.6
Mg_0	27.5	23.0	14.3	13.5	194.6	169.4	69.0	68.1	48.2
Mg_1	30.6**	24.4**	14.9**	14.8**	190.4	169.0	67.8	66.7	53.1
C.D. (P=0.05)	1.1	2.1	0.4	0.7	NS	NS	1.6	NS	NS
General mean	29.1	24.1	14.6	14.1	192.5	169.2	68.4	67.4	50.7

*Significant at 5% level
**Significant at 1% level
NS—Not significant

H—Healthy palms
D—Diseased palms

Table 3. Effects of nutrients on yield and yield attributes of healthy and root (wilt) affected WCT palms at the 10th year of planting (1980)

Main effects	No. of bunches/palm		No. of female flowers/bunch		No. of nuts/bunch		Nut set (%)		No. of nuts/palm	
	H	D	H	D	H	D	H	D	H	D
N_1	10.2	6.5	20.8	22.2	5.3	3.2	27.3	14.7	56.5	24.3
N_2	10.7	6.3	23.2	18.5	5.6	3.0	26.7	15.3	62.2	23.0
N_3	10.5	7.1	21.9	17.7	5.3	3.1	27.2	16.8	57.6	24.0
P_1	10.6	6.4	20.8	18.5	5.3	3.2	27.0	16.5	57.8	23.9
P_2	10.8	6.9	21.9	21.7	5.5	3.4	27.4	16.4	62.1	25.3
P_3	10.1	6.6	23.2	18.1	5.4	2.6	26.7	13.8	56.4	22.1
K_1	10.2	6.7	19.3	20.2	5.4	3.5	29.3	16.8	56.5	24.2
K_2	11.1	6.9	23.8	20.9	5.2	3.2	24.9	15.8	59.0	24.6
K_3	10.2	6.3	22.7	17.4	5.7	2.6	26.9	14.2	60.8	22.5
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Ca_0	9.9	6.4	20.8	18.2	5.0	3.1	26.2	16.2	52.1	22.8
Ca_1	11.1**	6.9	23.1	20.8	5.8*	3.1	27.9	15.1	65.5**	24.8
Mg_0	9.5	5.5	20.5	18.3	5.0	2.8	27.5	14.4	49.6	18.3
Mg_1	11.6**	7.8**	23.4	20.7	5.8	3.4	26.6	16.9	67.9**	29.2**
C.D. (P=0.05)	1.0	1.4	NS	NS	0.6	NS	NS	NS	9.5	7.9
General mean	10.5	6.6	21.9	19.5	5.4	3.1	27.0	15.6	58.8	23.8

*Significant at 5% level

**Significant at 1% level

NS—Not significant

levels helped to maintain an economic yield. The beneficial effects of Ca on yield and yield attributes were more in healthy palms, and of Mg in diseased palms. When the increase in yield of nuts by Mg treatment in healthy palms was 37 per cent the corresponding increase in diseased palms was 60 per cent. Similar responses of Mg on healthy and diseased palms were reported by Varkey *et al.* (1979) and Davis (1964).

The mean yield of nuts per palm at the 10th year was 58.8 in healthy and 23.8 in diseased palms, and the reduction in yield of nuts over healthy ones was about 60 per cent. Radha *et al.* (1962) reported that palms affected by leaf-rot disease yielded, on an average, 70 per cent less whereas root (wilt) affected palms yielded 43 to 82 per cent less than healthy palms depending on the stage of the disease. The reduction in yield observed in the present study was mainly due to the production of lesser number of bunches (10.6 and 6.6) and a very low percentage nut set (27.0 and 15.6) in healthy and diseased palms respectively.

The copra and oil contents of healthy and diesased palms are given in Table 1. It is interesting that while the addition of Mg had been very effective in promoting growth and increasing yield and yield attributes, it had no effect on the weight of copra per nut. This is in agreement with the observation made by Manciot *et al.* (1979). The mean weights of copra per nut of healthy and diseased palms were 192.5 g and 169.2 g respectively, and the reduction in copra weight due to disease was 12.1 per cent. Based on the mean values of nut yield and copra content, the copra yield of healthy and diseased palms at the 10th year of planting was 11.3 and 4.0 kg/palm respectively, and the loss in yield of copra due to the disease was 64.4 per cent. The reduction in oil content (68.4 per cent in healthy and 67.4 per cent in diseased) due to the disease was not considerable in the initial periods.

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INTERACTION OF SOIL GROUPS ON THE NUTRIENT EXHAUST BY COCONUT

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ABSTRACT

Results of investigation carried out to study the effect of soil groups on the nutrient content of various components of coconut fruit are reported in this paper. Potash was found to be removed most, followed by nitrogen, calcium, magnesium and phosphorus. Soil types were found to influence the nutrient exhaust by nuts. On comparison, palms growing on coastal alluvium removed 70 kg K_2O ha^{-1} whereas the average value for red sandy loam and laterite was 53 kg K_2O ha^{-1}.

INTRODUCTION

Cooke (1950) reported that from one hectare of coconut garden (148 palms) with a mean productivity of 25 nuts per tree, 29.1, 9.0, 26.9, 14.6 and 22.4 kg of N, P_2O_5, K_2O, CaO and MgO respectively were exhausted annually. Pillai and Davis (1963), computed the annual exhaust from one hectare of 173 palms in sandy loam soil at 65.6, 29.7, 84.5, 47.4 and 20.3 kg of N, P_2O_5, CaO and MgO respectively taking into account the nuts, fallen leaves spathes, and the annual stem growth.

In India, coconut is grown on almost all types of soils ranging from pure littoral sand, red sandy loam, laterite, alluvial clays to peaty dark 'kari' soils.

The present study was envisaged to understand the influence of soil groups on the nutrient exhaust by coconut, mainly in the form of nuts.

MATERIAL AND METHODS

Two West Coast Tall palms, each from the low yield group (30 nuts and below per tree per year) and high yield group above 30 nuts/tree/year), were selected at random from the coastal sand, red sandy loam and lateritic soils at C.P.C.R.I. Kasaragod. Two mature nuts from each tree harvested in the summer (January to May), and monsoon (June to August) seasons, were taken at random for this study. Physical characters, such as weight and volume of the unhusked nut, volume of nut water, and weight of copra, were recorded for calculating the total nutrient removal. The experiment was carried out for 2 years (1969 and 1970).

The different components of the nuts such as coconut water copra, shell and husk were analysed for N,P,K,Ca and Mg, according to Piper (1966). The oil content in copra was estimated by soxhlet extraction.

RESULTS AND DISCUSSION

The removal of N, P_2O_5, K_2O, CaO and MgO by the different components of the nuts from the coastal sand, red sandy loam and laterite soils are given in Table 1, The average yield of the palms,

Table 1. Nutrient removal by coconut (Kg ha^{-1})

Soil group	Part	N	P_2O_5	K_2O	CaO	MgO
Coastal sand (alluvium)	Coconut water	0.34	0.19	2.28	0.36	0.13
	Copra (Meat)	12.48	4.11	8.14	1.45	1.56
	Husk	7.66	3.20	57.12	10.62	4.33
	Shell	1.30	0.75	3.18	2.34	0.71
	Total	21.78	8.25	70.72	14.77	6.73
Red sandy loam	Coconut water	0.33	0.10	1.97	0.44	0.07
	Copra (Meat)	13.14	2.23	5.71	2.53	0.50
	Husk	6.46	2.96	43.73	3.59	2.68
	Shell	1.16	0.42	3.71	0.93	0.53
	Total	21.09	5.71	55.12	7.49	3.78
Laterite	Coconut water	0.26	0.06	2.44	0.24	0.08
	Copra (Meat)	11.62	3.96	12.35	2.47	3.49
	Husk	4.10	1.62	34.71	2.59	2.23
	Shell	1.18	0.38	2.71	1.44	0.48
	Total	17.16	6.02	52.21	6.74	6.28

from coastal sand, red sandy loam and laterite soil groups at C.P.C.R.I. farm was 38.0, 50.2 and 36.7 respectively.

Potash was found to be the dominant nutrient removed, followed by nitrogen. The nitrogen removal (in the nuts) from the coastal sand and red sandy loam is 21.78 and 21.09 kg/ha respectively. Pillai and Davis (1963) reported the annual removal for sandy soil as 24.0 kgN/ha. However, the nitrogen removed in the nuts in the laterite soil was only 17.16 kg/ha which was lower than that in other two soil groups.

The removal of P_2O_5, K_2O, CaO and MgO was the highest by the palms growing on coastal sand, being 8.28, 70.72, 14.77 and 6.73 kg/ha respectively, followed by red sandy loam. The removal of K_2O and CaO was lowest in the laterite soil (52.21 and 6.77 kg/ha respectively).

Though the coastal sand is deficient in almost all the nutrients, the nutrient removal is highest by the palms growing in these soils. This may be due to the readily available forms of nutrients with easy access for plant roots. Moreover, absorption of nutrients from the underground seepage water (Menon and Pandalai, 1960) by the foraging coconut roots was also reported. The study has indicated the effect of soil groups on the nutrient removal pattern in coconut.

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INTERCROPPING IN TURMERIC

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ABSTRACT

A comparative field trial was carried out for two years on intercropping in turmeric with pulses like greengram, blackgram and redgram; vegetables like bhendi and onion; cereals like ragi (finger millet) and maize; green manure crop like sunnhemp. Intercrops like bhendi, onion, greengram (*Phaseolus aureus* L.) and blackgram (*Phaseolus mungo* L.) increased the yield of turmeric and the income. Maize and ragi as intercrops reduced the yield of turmeric and the income.

INTRODUCTION

Turmeric (*Curcuma domestica* Val.) is one of the important cash crops raised under irrigated conditions in wetlands and gardenlands of Tamil Nadu covering an area of 15,260 ha. It is raised as a pure crop as well as in combination with a number of pulses, millets and vegetables. Intercropping with castor reduced the yields of turmeric by 30 to 50 per cent at Coimbatore (Anon., 1924) as compared to pure crop. Aiyadurai (1966) reported that the shade crops of *arhar* and sunnhemp did not affect turmeric yield. Sundararaja and Thulasidas (1976) indicated that turmeric comes up well under partial shade conditions but high intensity of shade affects the yield adversely. The possibility of raising turmeric with chillies, colocasia, onion, brinjal and cereals like maize and ragi has also been suggested earlier (Sundararaja and Thulasidas, 1976; Rao, 1979). The present study was undertaken to investigate the effect of intercropping on turmeric yield, in order to select suitable and profitable intercrops.

MATERIAL AND METHODS

The experiment was laid out in the wetlands of Tamil Nadu Agricultural University, Coimbatore in three randomized blocks.

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The soil texture was clay loam where the availability of N and P_2O_5 was medium and K_2O high.

There were eight treatments comprising of a pure crop of turmeric and its combinations with greengram, blackgram, ragi, maize, onion, bhendi and sunnhemp in the first year. In the second year, redgram was included in addition to the above treatments. The turmeric crop was raised at a specing of 45.0×22.5 cm in ridges and furrows. The intercrops were sown on the other side of the ridges. Along the ridges spacing between the plants was 22.5 cm for maize and bhendi, and 10.0 cm for other crops. The crop was uniformly manured with N, P_2O_5 and K_2O at 120, 60 and 60 kg/ha respectively. The nitrogen was applied in 3 splits i.e., 1/3 at planting, 1/3 at 60th day and 1/3 at 120th day. The sowings were done on 29th June in first year and 15th May in second year along with turmeric. Turmeric was harvested in April 1975 and March 1976. The intercrops like bhendi, greengram, sunnhemp, blackgram, onion, maize and ragi were harvested from 73 to 99 days after sowing depending on maturity of the respective crop(s).

Results and Discussion

The results of first and second year are presented in Tables 1 and 2, respectively. The growth of turmeric crop was affected much when ragi and maize were raised as intercrops. The turmeric crop was pale and weak, and lodged when the intercrops of maize and ragi were harvested. The maximum height of turmeric was observed under sunnhemp intercrop which was almost on par with pure crop during the first year. However, during the second year, the pure crop showed the best growth followed by that having redgram as intercrop. Reduction in the number of leaves was more apparent with ragi and maize as intercrops. Due to quick growth of these cereals the turmeric was affected by their shading and smothering effect.

The highest rhizome weight of 402 g/plant was recorded in 'turmeric+bhendi' combination which was on par with 'turmeric+ sunnhemp' combination during the first year. In the second year, 'turmeric+greengram' recorded the highest rhizome weight

Table 1. Growth and yield of turmeric, and economics of intercropping (First year)

Treatments	Plant Height (cm.)	No. of Leaves/ plant	Rhizome weight (g/plant)	Value of turmeric Rs/ ha @Re 1/kg	Yield of intercrop (Kg/ha)	Value of intercrop (Rs.)	Gross income (Rs.)	Additional income over pure crop (Rs.)
T_1:Turmeric	64.0	13.2	321	11412	—	—	11412	—
T_2:T_1+Greengram	62.5	13.1	360	12338	550	1100	13438	2026
T_3:T_1+Blackgram	60.4	13.7	301	10308	800	1600	11908	496
T_4:T_1+Ragi	40.5	7.2	204	4978	1360	2040	7008	—
T_5:T_1+Maize	45.2	8.2	285	6907	1950	4720	11627	215
T_6:T_1+Bhendi	54.5	11.6	402	13102	16000	6400	19502	8090
T_7:T_1+Onion	63.3	11.6	320	10926	4000	2000	12925	1513
T_8:T_1+Sunnhemp	65.8	12.9	375	12375	7500	750	13126	1713
SE	2.9	0.98	8.9	794				
CD P:0.05	9.1	2.15	27.0	240.7				

Table 2. Growth and yield of turmeric, and economics of intercropping (Second year)

Treatments	Plant Height (cm.)	No. of Leaves/ plant	Rhizome weight (g/plant)	Value of turmeric Rs/ ha@ Re 1/kg	Yield of inter crop (Kg/ha)	Value of inter crop (Rs.)	Gross income (Rs.)	Additional income over pure crop (Rs.)
T_1:Turmeric	76.0	6.5	420	15894	—	—	15894	—
T_2:T:+ Greengram	61.9	6.2	468	15995	660	1320	17315	1421
T_3:T:+ Blackgram	61.8	6.1	440	15366	650	1300	16666	772
T_4:T:+ Ragi	50.8	5.0	340	13011	1780	2670	15681	—
T_5:T:+ Maize	49.0	4.3	395	13321	2500	5000	18321	2427
T_6:T:+ Bhendi	62.1	5.7	443	17542	15000	6000	23542	7648
T_7:T:+ Onion	64.9	5.9	460	20149	2130	1065	21214	5320
T_8:T:+ Sunnhemp	62.2	5.7	413	15869	10000	1000	16869	975
T_9:T:+ Redgram	70.9	5.3	448	13984	450	1350	15334	—
SE	0.54	0.24	10.1	38.9				
CD P:0.05	1.62	0.72	21.3	116.7				

which was on par with onion and redgram. In both the years, the rhizome weight was the lowest with ragi followed by maize as intercrops.

The rhizome yield of 13,102 kg/ha obtained in turmeric+bhendi (basides 16,000 kg/ha of bhendi) was on par with sunnhemp and greengram. The crop of turmeric yielded 11,412 kg/ha during first year. During the second year, turmeric+onion gave the highest turmeric yield of 20,149 kg/ha followed by 17,542 kg/ha with turmeric+bhendi besides the yield of 2,130 and 15,000 kg/ha of onion and bhendi, respectively. Turmeric yield was lower when ragi and maize were raised as intercrops. This might be due to the shade effect caused by maize and ragi crops during the critical early growth phase of turmeric. The initial setback caused by these intercrops affected the turmeric yield considerably. On the other hand, the leguminous intercrops because of shorter duration and their ability to fix atmospheric N, have helped the main crop.

Besides turmeric yield, the yields of intercrops were also considerably high. The highest total income of Rs. 19,502 and Rs. 23,542/ha was obtained with bhendi as intercrop during the first and second years, respectively. The additional income due to the various intercrops except ragi ranged from Rs. 215 to 8090 during the first year and from Rs. 772 to 7648 during the second year. These intercrops did not receive any additional dose of fertilizers nor any other cultural operation except sowing and harvesting. By growing these intercrops, not only the yield and the income had increased, but also the weed growth was reduced. This also affords the maximum utilization of the unit area in unit time. The gross income from the treatment, turmeric+ragi was the lowest during both the years. Though turmeric yields were low with maize, the income was more than the pure crop due to the higher yield and price obtained for maize. From this study, it is evident that turmeric can, profitably, be grown with intercrops like bhendi, onion, greengram and blackgram, whereas the cereals like ragi and maize as intercrops adversely affect the turmeric yields to a considerable extent.

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NUTRIENT REMOVAL BY THE SECONDARY NURSERY IN CARDAMOM

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ABSTRACT

Chemical analysis of normally grown cardamom seedlings, collected from five nurseries of Cardamom Board in Kerala region have shown nutrient contents of 1.22g N, 0.08g P, 2.36g K, 0.32g Mg and 0.51g Ca per seedling. The fertility status of nursery soils did not show any influence either on total nutrient uptake or on dry matter production.

INTRODUCTION

In cardamom, the plants remain in secondary nursery beds for more than a year. The health and vigour of plants at the time of going to the field depends on the fertility of the soil and on the management practices at the secondary nursery stage. To study the influence of soil factors of the secondary nursery bed on the growth, dry matter production and nutrient uptake by the plants, the present experiment was carried out, the results of which are presented in this paper.

MATERIAL AND METHODS

The cardamom nursery maintained by the Cardamom Board at Vandiperiyar, Pampadumpara, Udumbanchola, Santhanpara and Kallar (all in Idukki District of Kerala), were chosen for this study. The nursery beds of secondary nursery cardamom plants that are ready for transplanting in the field were grouped into three classes: best, medium and poor, depending upon the vigour of seedlings. Three beds were selected at random from each group and the number of tillers of ten plants from the middle of each bed were counted. One plant which represented the bed for number of tiller and vigour, was removed from each of the three beds to get a representative sample. The lower portions of the plants were washed to remove dirt and the plants were separated into leaf, shoot, rhizome and root. The samples were dried at 60–65°C, powdered and analysed for N,P, K,Ca and Mg by adopting standard methods (Jackson, 1967; Piper, 1966).

Also, the composite soil samples collected from the beds were air dried and analysed for available nutrient content by rapid soil test methods.

RESULTS AND DISCUSSION

The data on the growth characteristics of plants collected from different categories of bed at various locations are given in Table 1. The best and medium size plants sampled for the study had 5 to 9 tillers with a height of 12 to 120 cms producing 33 to 74 leaves and the dry weight of individual seedlings varied from 31 to 149 g. Of the total dry weight, 36 to 41% is contributed by the leaves, 31 to 44% by shoots, 8 to 14% by rhizome and 6 to 15% by the roots.

Table 1. Growth characteristics of Cardamom seedlings

Location and classification* of bed		Height of tillers Range (cm)	Number per clump			Dry matter** (g plant^{-1})
			Tiller	Leaf	Root	
Vandiperiyar	B	64–120	9	74	96	149
	M	23–66	9	59	69	58
	P	22–48	5	28	24	12
Pampadumpara	B	26–83	7	58	81	76
	M	42–62	6	40	69	50
	P	12–66	2	13	22	9
Kallar	B	35–86	6	43	63	53
	M	12–66	6	40	61	33
	P	12–32	1	11	19	4
Udumbanchola	B	32–81	5	33	36	34
Santhanpara	B	22–82	5	34	50	31

*classification based on vigour and health of plants;
B, M and P denote Best, Medium and Poor

**Average for 3 plants.

All the sites selected for the present study were being used for raising nursery cardamom for the last 4 to 5 years. They were originally grasslands without practically any other vegetation. The management practices adopted were, application of organic manure or forest litter at the time of preparation of beds, mulching with potha grass (*Granotia stricta*), irrigation, and periodic weeding. The variation in soil nutrient status as revealed by the soil test results (Table 2) has not been reflected in the dry matter production.

The chemical composition of different plant parts is presented in Table 3. The contents of nutrient elements in different plant parts differed greatly. The nutrient uptake by the seedlings was

Table 2. Results of soil analysis and dry matter production in cardamom

Location and classification* of bed		Organic Carbon %	P mg %	K mg %	Mg mg %	Ca mg %	pH	Dry matter** (g $plant^{-1}$)
Vandiperiyar	B	2.6	0.4	18	15	94	4.7	149
	M	2.7	0.7	19	15	164	4.3	58
	P	3.1	0.9	23	15	236	4.9	12
Pampadumpara	B	2.5	0.6	10	10	48	4.4	76
	M	2.4	1.2	11	5	94	3.9	50
	P	2.6	2.7	15	15	128	3.8	9
Kallar	B	4.2	2.8	5	5	26	3.9	53
	M	3.7	2.7	8	5	30	4.1	33
	P	3.5	4.2	10	5	16	4.1	4
Udumbanchola	B	3.0	2.0	20	18	94	4.6	34
Santhanpara	B	3.3	0.2	14	15	108	5.1	31

**See Footnotes under Table 1

Table 3. Chemical composition of healthy cardamom seedling (air dry basis)*

Plant organ	N %	P %	K %	Mg %	Ca %
Leaf	3.17	0.16	2.90	0.51	1.41
Shoot	1.34	0.10	4.89	0.50	0.60
Rhizome	1.67	0.11	4.18	0.87	0.47
Root	1.13	0.11	3.80	0.34	0.33

*average of 24 plants from 8 locations.

Table 4. Nutrient removal by Cardamom seedlings (g/plant)

Plant organ	Dry weight	N	P	K	Mg	Ca
Leaf	22.80	0.72	0.04	0.66	0.12	0.32
Shoot	23.90	0.32	0.02	0.17	0.12	0.14
Rhizome	7.18	0.11	0.01	0.30	0.06	0.03
Root	6.07	0.07	0.01	0.23	0.02	0.02
Total	59.95	1.22	0.08	2.36	0.32	0.51

computed from the dry weight and elemental composition of different plant parts (Table 4). In a ha of nursery with 45,000 to 55,000 seedlings, the nutrient removal was about 60 kg N, 4 kg P, 120 kg K, 15 kg Mg and 25 kg Ca.

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EFFECT OF SOWING DATES AND MULCHING MATERIALS ON THE YIELD OF TURMERIC

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ABSTRACT

The results of a trial conducted for 3 years to assess the effect of five sowing dates beginning from 23rd May at 15-day intervals and three mulching materials, namely, shisham leaves, mango leaves and paddy straw on the yield and net return from turmeric (*Curcuma domestica* Val.) are reported. Early sowing after the pre-monsoon showers, and mulching increased the productivity of turmeric. The turmeric sown on 23rd May and mulched with shisham (*Dalbergia sissoo* Roxb.) leaves produced significantly higher yield of fresh rhizomes in unirrigated calcareous soils of North Bihar and also gave the highest return.

INTRODUCTION

Turmeric is grown as a rainfed crop in North Bihar, and is planted from early June with the onset of premonsoon showers upto late July. Though mulching is essential for obtaining higher yield, it is not generally practised by the growers. The results of investigations carried out to get information on the influence of planting time and mulching on the productivity of turmeric in calcareous soils of North Bihar, are discussed in this paper.

MATERIAL AND METHODS

The studies were conducted at the Department of Agronomy, Rajendra Agricultural University, Pusa during the years 1979–82. The trial was laid out in split plot design with three replications with a local variety of turmeric. The main treatments were, five sowing dates namely, 23rd May (T_1); 7th June (T_2); 23rd June (T_3); 7th July (T_4) and 23rd July (T_5), and the sub-treatments were three mulch materials, shisham leaves (M_1); mango leaves (M_2) and paddy straw (M_3). Also, there was a control (M_0) sub-treatment without the addition of mulch. Seed-rhizomes with 3 buds were planted at 30×30 cm spacing between and within the rows. The sub-plot size was 9 m^2. The mulching materials were applied @ 15 t/ha just after sowing. All cultural practices were adopted as per recommended package of practices and the fertilizers applied at the rate of 120:50:120 kg $N:P_2O_5:K_2O$/ha. Harvesting was carried out 8 months after planting and fresh rhizome yield recorded.

Results and Discussion

The data on the average yield of turmeric (fresh rhizomes) are presented in Table 1. The turmeric sown on 23rd and mulched with shisham leaves produced significantly higher yield (323 q/ha) of fresh rhizomes over rest of the treatments. The crop shown on 23rd July without mulching produced the lowest yield of 35 q/ha fresh rhizomes. The yield decreased progressively as the sowing delayed after 23rd May. It is possible that early sowings gave an early start to the crop, resulting in higher yields as has been reported by Randhawa and Mishra (1974). Aiyadurai (1966) reported that the growth of late sown crop was poor due to continuous rain immediately after sowing. Similar findings were reported from the work done in Kerala (Anon., 1978).

Table 1. Sowing dates×mulching materials-(mean yield of 3 years)

Treatment	Mean yield (q ha^{-1})					
	T_1	T_2	T_3	T_4	T_5	Mean
M_0	186	126	114	62	35	105
M_1	323	219	180	114	71	181
M_2	291	205	149	96	56	159
M_3	262	160	136	85	52	139
Mean	266	178	145	89	54	146

	Date of sowing	**Mulching**	**Date of sowing× mulching**
S.Em.	15	13	30
C.D. (P: 0.05)	41	37	82

Mulching generally increased the productivity over the control. The mulching with shisham leaves proved superior to mango leaves, paddy straw and no mulching. Shisham leaves when applied as mulching material decomposed more readily than mango leaves and paddy straw, which might have helped to maintain the soil tilth resulting in enhanced yield. Rao (1979), and Aiyadurai (1966) reported that yield of turmeric increased appreciably when the crop is mulched with tree leaves because mulching makes the soil tilth congenial for plant and rhizome growth). (Anon. 1978 McCalla and Army (1961) have reported increased yield of corn due to stable mulching.

The economics of the treatments are shown in Tables 2 and 3.

Table 2. Sowing dates×mulching materials—net profit (mean of three years)

Treatment	Net profit Rs./ha				
	M_0	M_1	M_2	M_3	Mean
T_1	4076	9705	8526	6332	7160
T_2	1847	5510	4965	2336	3665
T_3	1137	4068	2579	1250	2259
T_4	–1038	1059	289	–862	–138
T_5	–2150	–768	–471	–2316	–1426
Mean	775	3915	3178	1348	2304

Table 3. Sowing dates×mulching materials—net return per rupee investment (mean of three years)

Treatment	Net return per rupee investment (Rs.)				
	T_1	T_2	T_3	T_4	T_5
M_0	1.00	0.51	0.31	(–)0.29	(–)0.00
M_1	2.46	1.46	1.07	0.28	(–)0.20
M_2	2.12	1.29	0.67	0.07	(–)0.40
M_3	1.37	0.52	0.27	(–)0.19	(–)0.51

The maximum net profit of Rs. 9705/ha was obtained when the crop was sown 23rd May and mulched with shisham leaves, while crop sown on 23rd July mulched with paddy straw gave the maximum loss of Rs. 2316/ha. Actually the total loss was more in the treatment than in control due to cost of paddy straw. The net return per rupee investment was maximum (Rs. 2.46/–) from the crop sown on 23rd May and mulched with shisham leaves. The maximum loss of Rs. 0.51 per rupee investment was from the crop sown on 23rd July and muclched with paddy straw.

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EFFECT OF POPULATION DENSITY AND SEED-RHIZOME SIZE ON THE YIELD AND PROFIT POTENTIAL OF TURMERIC

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ABSTRACT

Results of a trial to investigate the influence of population density and seed rhizome size on productivity in turmeric (Curcuma domestiea Val.) are reported. The productivity and seed requirement/ha are directly related to population density. The bulking effcacy is inversely related to population density. The profit potential attains a maximum at the population density of 1,11,000/ha. Similarly, profit potential is maximum when whole daughter rhizomes weighing around 25g are used as seed material followed by whole mother rhizomes weighing around 30g, and daughter rhizomes with 3 buds weighing around 20g.

INTRODUCTION

Heavy seed rate which increases the cost of cultivation is a limiting factor in turmeric cultivation. Investigation was, therefore, undertaken to determine the economical seed rhizome size and optimum plant population/ha for economizing on seed rate without affecting the productivity and profit.

MATERIAL AND METHODS

The present trial was laid out at the Department of Horticulture, Rajendra Agricultural University, Dholi, Bihar, in three randomized blocks with 20 treatments, during 1980–82. Details of the treatments are given below:

Treatments: 20–Population density (4) $\times$ seed rhizome size(5).

(A) Population density:

Treatment	Plants/ha	Spacing
P_1	3,33,000	20×15 cm
P_2	1,66,500	30×20 cm

P_3	1,11,000	30×30 cm
P_4	83,250	40×30 cm

(B) Seed–rhizome size:

SR_1 : Mother rhizomes (bulbs) average weight 30g
SR_2 : Whole daughter rhizomes (fingers) average weight 25g
SR_3 : Daughter rhizomes with 3 buds, average weight 15g
SR_4 : Daughter rhizomes with buds, average weight 15g
SR_5 : Daughter rhizome with one bud, average weight 15g

The experiment was carried out in a sandy loam soil with pH of 8.5; and available N, P_2O_5 and K_2O of 0.031%, 22 kg/ha and 225 kg/ha respectively. A local cultivar, *Meenapur*, was sown in the last week of May, in both the years. The fertilizers were applied at the rate of 100 kg N, 60kg P_2O_5 and 60 kg K_2O/ha, in addition to 10 tonnes of farm-yard manure. Other field operations were done as per recommended package of practices for turmeric. Harvesting was done in the last week of January in both the years, after 240 days from sowing. The fresh rhizome yield was recorded. The bulking efficiency of seed-rhizomes was calculated as per the following equation:

$$\text{Bulking efficiency (BE)}\% = \frac{\text{HRY}-\text{SRP}}{\text{SRP}} \times 100$$

Where HRY =Harvested rhizomes yield (kg/ha)
SRP =Weight of seed rhizomes planted (kg/ha)

Results and Discussion

The data on the average yield of fresh rhizomes and average weight of seed rhizomes planted per hectare are presented in Tables 1 and 2 respectively.

The effects of population density and seed rhizome material are independent as the interaction effect is non-significant. The whole daughter seed rhizomes with an average weight of 25 g significantly increased the yield of turmeric (277 q/ha) over rest of the seed rhizome sizes. The lowest mean yield of 143 q/ha was recorded where daughter rhizomes with only one bud were planted. The higher yield with whole daughter rhizomes used as seed

Table 1. Population density × seed-rhizome size on yield of turmeric (mean of 2 years)

Treatment	Yield (q ha^{-1})					Mean
	SR_1	SR_2	SR_3	SR_4	RS_5	
P_1	226	290	195	179	148	207
P_2	224	287	190	170	155	205
P_3	219	276	175	162	146	196
P_4	187	254	167	134	121	173
Mean	214	277	182	161	143	195

Effect	SE (m)	C.D. at (P=0.05)
SR	1.8 q/ha	5 q/ha
P	1.5 q/ha	4 q/ha
SR×P	3.6 q/ha	N.S.

Table 2. Population density × seed rhizome size-requirements of seed-rhizomes (q/ha)

Treatment	Seed rhizomes (q ha^{-1})					Mean
	SR_1	SR_2	SR_3	SR_4	SR_5	
P_1	100	83	67	50	33	67
P_2	50	42	33	25	17	33
P_3	33	28	22	17	11	22
P_4	25	21	17	13	8	17
Mean	52	44	35	26	17	35

may be due to its early germination giving a better start to the crop as compared to mother rhizomes and other treatments.

Large-sized seed rhizomes giving higher yield has also been reported by Hussain and Said (1965), and Randhawa and Mishra (1974). Mohte (1963) recorded higher yield from mother rhizomes as compared to daughter rhizomes. It appears that the weight of seed rhizome is related to yield of turmeric and the minimum weight needed may be 25 g. There is a sharp decline in yield when daughter rhizomes weighing 20g and less are used as seed material. However, it is difficult to say from this investigation whether the weight or the number of buds of daughter rhizomes is important in selecting the seed material.

The higher plant population (3,33,000 plants/ha) increased the mean yield (207 q/ha) significantly over lower plant populations. The yield is linearly related to the density of population. The weights of seed materials treatment-wise are given in Table 2. The bulking efficiency which gives the additional crop harvested over the seed material used and which decides the net returns are given in Table 3. There was a negative relationship between bulking efficiency of rhizomes and population density. Since the cost of seed material is a single major item which decides the profitability, the profit potential is calculated as the difference between gross income and cost of seed rhizome. The data on profit potential are given in Table 4. While fixing the optimum population density and the parameters for selecting seed material, the profit potential and the bulking efficiency are to be considered. The maximum gross income was Rs. 6070/– under the treatment with whole daughter rhizomes sown @ 1,11,000 plants/ha i.e., at the spacing

Table 3. Population density × seed rhizome size–bulking efficiency

Treatment	Bulking efficiency %					Mean
	SR_1	SR_2	SR_3	SR_4	SR_5	
P_1	126	249	193	257	344	234
P_2	349	590	170	581	830	564
P_3	560	895	689	872	1218	847
P_4	650	1120	903	976	1355	1001
Mean	421	714	564	672	937	662

Table 4. Population density × seed rhizome size–profit potential*

Treatment	Profit potential (Rs. ha^{-1})					Mean
	SR_1	SR_2	SR_3	SR_4	SR_5	
P_1	2642	4756	2874	2965	2700	3187
P_2	4103	5930	3744	3503	3370	4130
P_3	4495	6070	3714	3545	3326	4230
P_4	3934	5722	3675	2971	2777	3816
Mean	3794	5620	3502	3246	3043	3841

*Profit potential=Gross income—seed rhizome cost.

Note: Price of seed rhizome and fresn rhizomes at harvest taken at Rs. 30 and 25 per quintal respectively.

of 30 × 30 cm. Though the yield under this treatment was significantly lower than that of whole daughter rhizomes sown at the rate of 3,33,000 and 1,66,500 plants/ha, the profit potential was maximum due to high bulking efficiency and low requirement of seed rhizome/ha as seen in this treatment compared to the other treatments. On the same considerations, the next best treatments are, mother rhizomes weighing 30g and daughter rhizomes weighing 20g as seed materials at a population density of 1,11,000/ha.

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MODERN TRENDS IN IRRIGATION SYSTEMS

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ABSTRACT

This paper deals with the modern trends in irrigation techniques. classification of irrigation systems, conventional methods, and micro-irrigation systems are described in brief. An apparaisal of various techniques in micro-irrigation system for the successful field application especially in undulating and hilly terrain is attempted. The specific advantages and limitations of the different systems are discussed.

INTRODUCTION

The objective of water distribution system for irrigation is to provide suitable moisture environment to the crops to obtain optimum and sustained crop yields with maximum economy in the use of water as input.

Scientific water management practices encompass integrated development of water resources, efficient method of conveyance and distribution of water on the farm, judicious methods of water application, proper soil management practices and cropping patterns and scientific timing of irrigation according to the development rhythm of the plant. The entire system should be free from residual toxic effects and ecological imbalance.

About 55 per cent of the total extent of Kerala State is under agriculture and nearly 85 per cent of the net cultivable area is rainfed, the remaining area being irrigated. Irrigated area under plantation crops constitutes only about 1.4 per cent of the total irrigated area in Kerala. Even though Kerala falls in high rainfall zone of the country, the frequency, distribution and amount of rainfall are not uniform throughout the year. The continuous and prolonged dry period from January to June leads to severe moisture stress affecting adversely the growth and yield of plantation crops in this state. Only about 45 per cent of the total agricultural land can be covered under irrigation even if all the available water resource potentials are harnessed, because of topographic and ground-water limitations. The remaining 55 per cent of the agricultural area in the hills and foot hills cannot be provided with irrigation by conventional methods. If irrigation has to be extended to more areas under cultivation with limited water resource during lean season with less power, sophistication and time—specific systems with the essential characteristics of continuous and low volume application of water to the localized root zone, are to be developed.

Classification of water Distribution Systems for Irrigation

Water distribution system for irrigation at the field level may be broadly classified into two kinds namely, the systems which wet more or less uniformly all the soil in the field, and those which wet only a part of the soil. In both the systems, surface and underground application of water is done either by gravity or pressurized pipes.

Conventional Irrigation Methods

Conventional methods of surface irrigation are: 1) border-strip irrigation, 2) basin irrigation, and 3) furrow irrigation. In the border-strip irrigation method, solid ridges keep the water flowing down a strip of land. This system works well if the soil surface is level in the direction perpendicular to the water flow and the slope is gentle in the direction of water flow. Losses in the form of percolation and runoff will be about 20 to 45 per cent of applied water. In basin irrigation, water is held at the surface surrounded by soil ridges. This type of irrigation is successful in less permeable soils of flat terrain under tree crops like orchards and coconut. In furrow irrigation, water flows by gravity from a main ditch and through each furrow. The crop is ususally planted on top of these ridges before water is applied. The velocity of flow and volume of discharge through the furrow are controlled to reduce soil erosion and runoff losses.

Sprinkler irrigation is the overhead application of water to simulate rainfall (sprinkling) to irrigate both unlevelled and sandy lands which do not lend themselves to conventional methods and those of normal condition. Uniform application of water at the desired rate, less physical labour, elimination of ridges, application of fertilizer through water, increasing atmospheric humidity, and economy in water use, are its advantages while high cost and energy consumption and plugging of the nozzles are its major disadvantages.

New Developments in Irrigation System (Micro–Irrigation System)

Adoption of micro-irrigation system which causes wetting of only that part of the soil at the base of the plant (the plant root zone) is becoming popular in undulating terrain and also where the water economy is necessary. The concept of micro-irrigation system is not new; in Kerala the use of earthern pots with a small hole at its bottom to supply water continuously at a very limited rate to the base of young coconut and aracanut, especially in sandy and highly permeable soils was in vogue in the past. In England, it was first used in glass-houses in the late 1940's, and in Israel it was first used under field conditions in the 1950's. During the last two decades, extensive research has been carried out in various parts of the world and its commercial importance grew following the development work done in various countries, particularly Israel. India also developed the technique using indigenous and relatively cheap material and the system now possesses very good potential for successful application in the field for irrigating plantation crops in the hills and foot hills.

A schematic diagram of basic components of a micro-irrigation system is shown in Fig. 1. In this scheme, the source of water is either from a pump or overhead reservoir. Nutrient tank, filter unit and control valves are the important components of main line, which is divided into sub-main lines and laterals, followed by sub-lateral loops (if necessary), and distributors.

The various micro-irrigation systems that could be adapted for plantation crops are discussed below:

A. **Drip irrigation using earthern pots:** This is a very old and cheap irrigation method. In this method, mud pots of 20 litres capacity provided with a wick at the bottom are buried neck deep

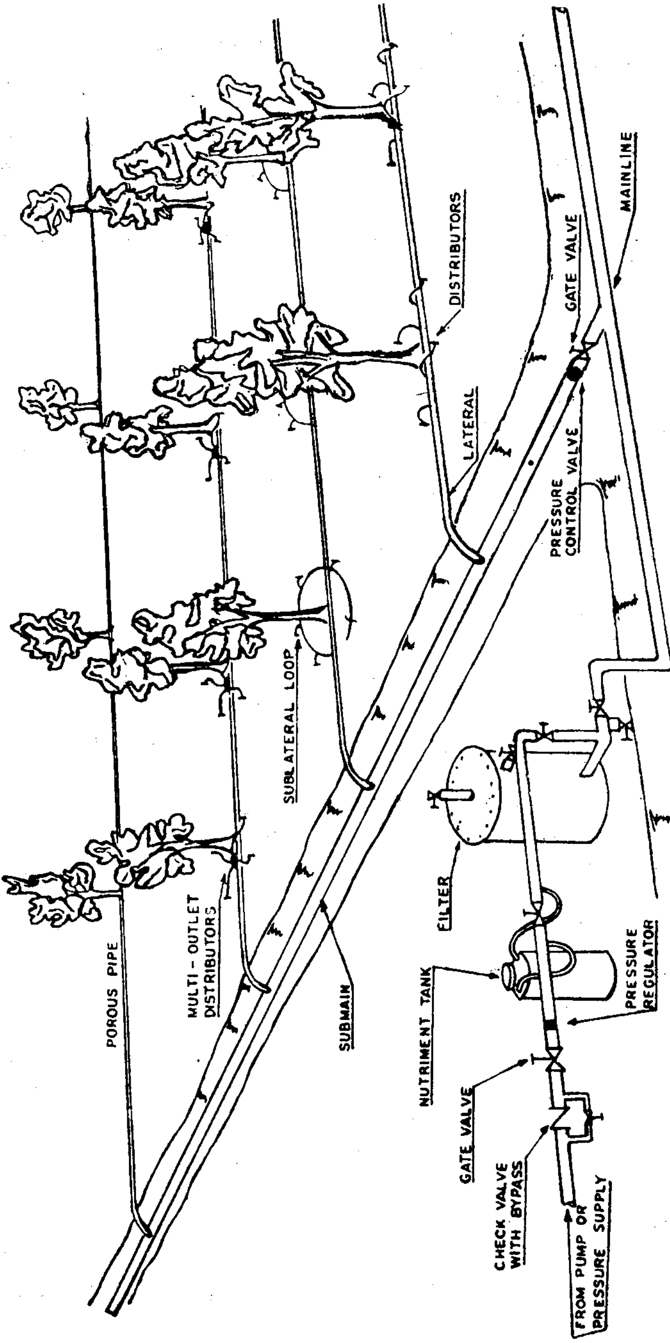

Fig. 1 Basic components of a localized irrigation system

in the basin of trees. Water is poured into the pots once in a week or once in 10 days, depending upon soil, climate and plant requirement, and the pot is covered with a lid. Water trickles or drips down slowly from the pot into the root zone of the plant. Evaporation of water is almost eliminated. Weed growth in basin receiving irrigation is considerably less. Fertilizer can also be added in small quantities to water in the pots. Substantial saving in water requirement is observed to be the most beneficial part of this irrigation system.

B. Drip irrigation using flexible pipes: Drip irrigation system for plantation crops in slopes can be successfully carried out using polyethylene pipes for conveyance and polypropylene nozzles for dripping water to the root zone of each tree. In this closed system, air relief valves at suitable points have to be fitted to ensure continuous flow and controlled dripping of water. The number and size of drippers can be designed according to the water requirement of crop, leaching factor and climate conditions.

C. Drip irrigation using bamboo: The split bamboos are used to carry water wherever they are available. Controlled dripping is achieved by drilling holes in the bamboos. Different stages are connected with bamboo pieces out into specific shape, as appropriate. The system is very good considering economy, simplicity and energy input. At CWRDM campus, a slight modification by introducing polyethylene microtubes to the desired depth through drilled holes at appropriate sections of running bamboo channels was experimented and the results were quite encouraging.

D. Suction irrigation: There is excellent scope for harvesting soil energy present in the form of soil water tension, to irrigate plantation crops in undulating terrain. In this system, soil water suction is utilized as the driving force for the flow of water through emitters to the root zones of plants, thereby eliminating booster pump and filtering unit. The emitter made up of locally available animal dung and clay suitably be designed to obtain the required emission of water and to irrigate the crop to the desired moisture level below the field capacity of any soil. The rate and interval of application of water is controlled automatically. Irrigation facility can be extended to additional areas through the maximum con-

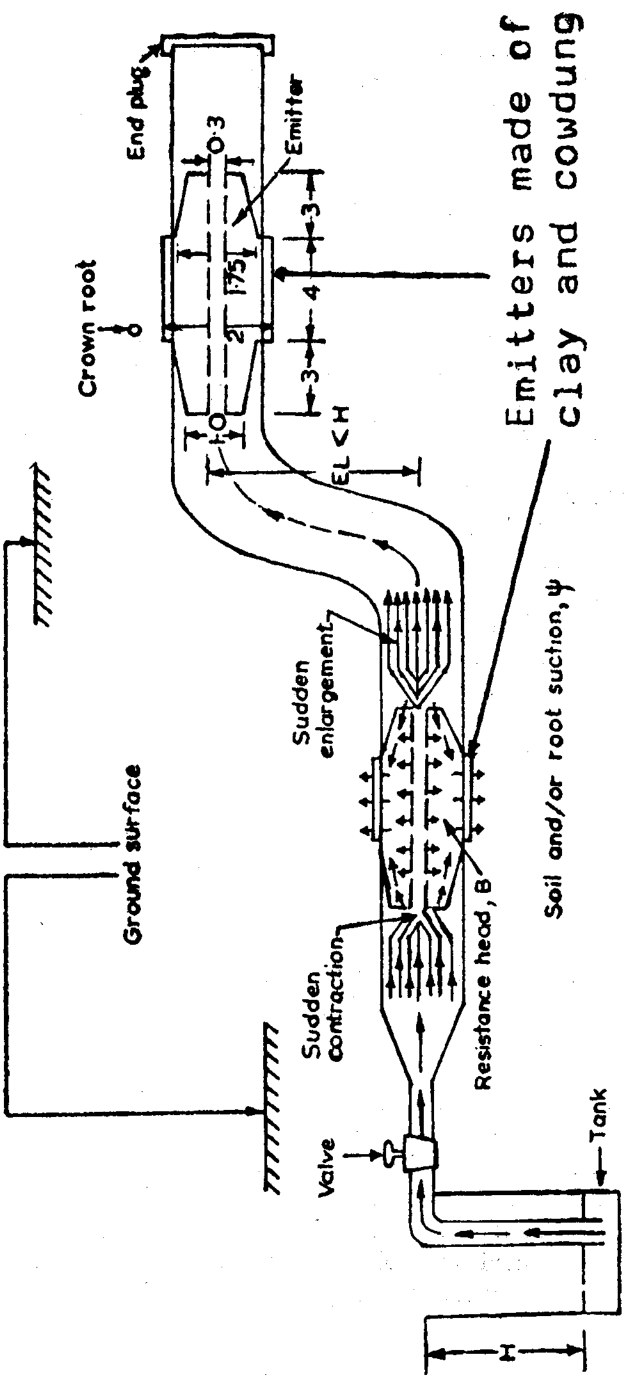

Fig. 2. Schematic diagram of indigenous emitters used in the suction irrigation

servancy of available water and it is less expensive due to less input of energy and use of locally available cheap materials. Details of the emitter embedded at the root zone are shown in Fig. 2.

E. Micro-irrigation using underground pipe system [subsoil irrigation]: This system of irrigation can be adopted and promoted on a family based developmental programme. In undulating and sloping terrains where residual gravity head is sufficient to cover the designed command area, underground pipe system with projecting nozzles can be advantageously adopted for irrigating the slopes as well as the adjacent low lying areas. Even though it is capital intensive, better control in the application of water and minimum losses are its specific merits over channel irrigation system.

Advantages and Problems of Micro-Irrigation System in Plantation Crops

The amount of water and nutrients and the frequency of application can be controlled and economically used in undulating terrains. There is a substantial reduction in labour and maintenance work compared to conventional method. The topographic, economic and other limitations restrict the successful application of conventional irrigation systems in plantation crops. There is less consumption of water, and because of this, low capacity water sources such as springs, shallow wells, and streams commonly found in hilly regions can successfully be utilized in this system and more areas could be brought under irrigation for a a given amount of water than that possible with conventional systems.

The main drawbacks noted in micro-irrigation systems are, clogging of pipes and nozzles, limited root development, and capital intensiveness.

The micro-irrigation system should not be regarded as a substitute for the long-established and proven methods of conventioal irrigation practices. It is a specific method to extend irrigation facilities to crops like coconut, rubber, arecanut, and pepper in undulating terrains. Topographic limitations, economic constraints, limited availability of water, and marginal individual land holdings, restrict the application of irrigation systems in plantation crops. Micro-irrigation systems discussed above offer excellent potential to overcome some of these constraints for a successful field application, especially wherever the water is scarce and its cost high.

ACKNOWLEDGEMENT

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SESSION VI

Plant Pathology

Chairman : **Prof. P. V. Rai**

Rapporteurs : **Dr. C. Rajendran**

Dr. Y. R. Sarma

AGGRAVATION OF COFFEE LEAF DISEASE BY SIMULTANEOUS OR CONSECUTIVE ACTION OF *HEMILEIA VASTATRIX* AND *CERCOSPORA COFFEICOLA*

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Abstract

Coffee leaf rust, the major disease of coffee, is controlled in India usually by Bordeaux mixture sprays. However, in spite of timely application of this fungicide, heavy defoliation of the rust infected leaves has often been observed. Our studies have revealed that among the leaves infected by rust in the field, a high percentage was secondarily infected by *Cercospora coffeicola*, another important pathogen of coffee. Inoculation studies conducted under controlled conditions in the glasshouse revealed that infection by *C. coffeicola* took place easily through the leaf rust pustules. Thus, a need to adopt effective control measures against incidence of *Cercospora* on coffee leaves in the field as well, is indicated.

Introduction

Coffee leaf rust disease caused by *Hemileia vastatrix* Berk. *et.* Br. is one of the main causes limiting production in most of the coffee growing countries. Almost all the largely cultivated varieties of *arabica* coffee in India are susceptible to this disease. In South India, coffee leaf rust disease occurs throughout the year and becomes severe, resulting in defoliation when the weather conditions are favourable, reaching a peak from August to December (Mayne, 1930).

Two cultivars of *arabica* coffee, viz., Kents and S-795, especially the former, grown in India are known for their susceptibility to coffee leaf rust disease. In spite of regular Bordeaux mixture sprays adopted for the control of coffee leaf rust disease, heavy defoliation in the field was often observed. The rust-infected leaves, especially those with mature rust pustules, showed well-developed necrotic spots. Such necrotic spots also revealed, the presence of another important fungal pathogen of coffee, namely, *Cercospora coffeicola* Berk. & Cke.

The present paper gives an account of detailed studies conducted on the pathogenicity of *C. coffeicola* on leaves of coffee through the rust pustules, and also the extent of damage due to leaf rust in association with *C. coffeicola*.

Material and Methods

Pathogenicity tests

About 25 apparently healthy 1½-year-old Kents *arabica* coffee plants were selected and kept in the glasshouse. On each plant, one branch was tagged and the third pair of leaves from the tip was inoculated at the rate of one spot per leaf, with rust uredospores collected from apparently uncontaminated uredopustules. All the inoculated plants were covered with polythene bags moistened with sterile water for 24 hours. When the inoculated points showed the development of rust pustules 35 days later, 18 plants with well developed rust pustules of 1–2 mm diameter were selected and arranged in 3 sets of 6 plants each. Using a 10-day old culture of *C. coffeicola*, isolated from necrotic spots on rust pustules, the rust pustules in one set of 6 plants were inoculated by placing bits of culture containing conidia. Similarly, the rust pustules in the other set of 6 plants were incoculated with conidial aggregates of *C. coffeicola* collected directly from the surface of necrotic spots developed on rust pustules in the field. Six plants with 12 pustules were kept as check. All the plants were then sprayed carefully with sterile water and covered with moist polythene bags to maintain sufficient humidity, and incubated.

Field assessments

Three plots, with 600 plants each at 3 locations of CCRI estate, were used for the study. The cultivars of coffee grown in plots I and II were Kents, whereas in Plot III it was S–795. All the plants were about 10 to 12 years old and received regular cultural operations including the pre-and post-monsoon Bordeaux mixture sprays. During October–November 1981 and 1982, which is the usual peak period for the leaf rust incidence in the field, 10 plants with medium to high incidence of leaf rust were selected at random in each plot, and one secondary branch in each plant was tagged. On each of these tagged branches, the total number of leaves infected with rust alone, those with rust and association of *C. coffeicola*, and healthy leaves were counted. Whenever necessary, the observations were made with the help of a hand lens to identify clearly the growth of *C. coffeicola* on the necrotic spots.

Results and Discussion

Pathogenicity tests

At all the points inoculated with *C. coffeicola* culture or *C. coffeicola* conidial aggregates collected from the field specimens, development of clear necrotic symtoms was observed one week after inoculation. Rust pustules not inoculated with *C. coffeicola* did not show any necrotic symptom. The necrotic spots developed by *C. coffeicola* on rust pustules in most of the cases were larger than those of the rust pustules kept as check (Table 1). There was no difference in size of the spots developed due to infection by *C. coffeicola* culture and *C. coffeicola* conidial aggregates collected from the field.

Table 1. Inoculation of *C. coffeicola* on leaf rust pustules—Length (L) and breadth(B) of infected spots in mm*

Check (infection by rust alone)		Infection by rust and *Cercospora* culture		Infection by rust and *Cercospora* spores from field	
L	B	L	B	L	B
2	2	11	7	defoliated	
5	4	11	7	10	9
4	2	13	12	10	10
3	2	10	8	9	6
3	3	5	4	14	11
3	2	5	4	15	9
4	3	13	9	7	4
4	2	7	6	6	4
5	3	7	5	9	7
5	5	14	7	12	8
2	2	14	7	16	13
2	2	10	7	13	9

Field assessment

Data on field incidence of leaf disease due to infection by rust alone, and rust and *C. coffeicola*, are presented in Table 2. The disease incidence in general, either due to infection by rust alone or rust association with *C. coffeicola*, was slightly higher during 1982. Most of the leaves recorded as healthy or infected by rust alone were comparatively young.

C. coffeicola is known to cause two important diseases of coffee, namely, brown-eye-spot of leaves and berry blotch. The former disease occurs mainly on young plants in the nurseries and new clearing from April to November, and the latter on mature berries in exposed patches from August to December—both becoming severe from October onwards (Swaminathan *et al.*, 1960; Sridhar and Subramanian, 1969). Since exposure to direct sun is the main predisposing factor, both these diseases are also controlled to a considerable extent by providing proper shade to the disease affected areas. Since brown-eye-spot disease occurs rarely on mature plants in the field, it is considered as unimportant in Indian plantations. However, it is reported to cause serious damage to coffee in some of the Latin American countries (Wellman, 1953; Echandi, 1959; Siddiqi, 1970).

The present findings on the high incidence of infection by *C. coffeicola* on the leaves of coffee through the leaf rust pustules indicate that *C. coffeicola* could also become highly pathogenic to leaves of coffee in the field. It is seen that during the peak period of the incidence of leaf rust disease in the field, almost 50 per cent of the leaves infected by rust were secondarily infected by *C. coffeicola* (Table 2). It is known that *C. coffeicola* also causes premature defoliation of infected leaves (Sridhar and Subramanian, 1969). It is also seen from Table 1 that the size of the spots developed due to infection by both rust and *C. coffeicola* in most cases is about 3 times larger than the spots developed due to infection by rust alone. This also shows that secondary infection by *C. coffeicola* can influence greatly the severity of leaf disease in the field.

Furthermore, it was noticed during the field observation that majority of the leaves infected by both rust and *C. coffeicola*

Table 2. Leaf disease incidence in *C. arabica* due to *H. vastatrix* and *C., coffeicola* in the field

Year	Cultivar and location	Total leaves	Healthy leaves	Leaves infected by: *H. vastatrix* alone	Leaves infected by: *H. vastatrix* and *C. coffeicola*
1981	Kents PI	1401	598 (43)	422 (30)	381 (27)
	Kents PII	607	280 (46)	179 (30)	148 (24)
	S.795 PIII	1013	602 (59)	261 (26)	150 (15)
1982	Kents PI	1403	367 (26)	412 (29)	624 (45)
	Kents PII	1877	686 (37)	588 (31)	603 (32)
	S.795 PIII	826	364 (44)	301 (36)	161 (20)

Figures in parentheses indicate percentage; P=Plot.

were older than those infected by rust alone, This means that leaves infected by rust alone could also become infected by *C. coffeicola* at a later stage resulting in early defoliation. Since the peak period of both leaf rust disease and *C. coffeicola* incidence occurs simultaneously from October onwards severe infection by *C. coffeicola* through the leaf rust pustules would be possible, because of the availability in plenty of inoculum of *C. coffeicola*, and high incidence of leaf rust disease in the field.

The results of the present study indicate the need for evolving an effective control measure against both *H. vartatrix* and *C. coffeicola* in the field. Bordeaux mixture spray is effective against both leaf rust and *C. coffeicola*. However, the concentration required against the latter would be 1 per cent as against 0.5 per cent generally adopted for controlling coffee leaf rust. Being a contact fungicide, Bordeaux mixture may not afford adequate control even at 1 per cent concentration when the infection due to leaf rust and *C. coffeicola* has already advanced. Plantvax 20 EC is effective against leaf rust of coffee (Muthappa, 1980) and is known to protect the sprayed leaves for 50 to 55 days. Normally the interval between the usual pre-and post-monsoon sprays is more than this period, thus paving the way for the fresh build-up of rust, and secondary infection by *Cercospora*. Bayleton 25 EC (triadimefon), a systemic fungicide was reported to be highly effective against coffee leaf rust (Anonymous, 1980; Muthappa, 1979). Prolonged protection from leaf rust afforded by Bayleton 25 EC in turn prevents attack by *C. coffeicola*. A suitable spray schedule using such an effective fungicide might give adequate protection against this complex leaf disease caused by both coffee leaf rust and *C. coffeicola* in the field.

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MANAGEMENT OF THANJAVUR WILT OF COCONUT

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ABSTRACT

From the experiments conducted at Coconut Research Station, Veppankulam, it was found that for containing the Thanjavur wilt disease the soil organic matter level should be increased by the application of organics such as farmyard manure, tank silt or neem cake. Neem cake applied to the soil at the rate of 5 kg/palm/year, was effective in keeping the disease under control to a great extent. Giving regular irrigation to the diseased palms during summer helped in maintaining the vigour of the palms.

Among the fungicides tried, soil drenching with 40 litres of 1% Bordeaux mixture combined with steam injection of aureofungin-sol was very effective in containing the disease. Palms given this treatment thrice at quarterly intervals gave economical yields for 3-4 years with lower disease intensity.

INTRODUCTION

Among the various diseases affecting coconut, Thanjavur wilt is the most devastating in several parts of Tamil Nadu, especially in coastal areas of Thanjavur district. Since the disease was first reported from Thanjavur district, it is known as Thanjavur wilt. The disease is now prevalent in almost all the districts of the state wherever coconut is grown. Maximum wilt incidence (4.9%) is noticed in Thanjavur district followed by 4.5% in Chingleput district. In Thanjavur district, Muthupet block has maximum intensity of the disease (8.4%) and in some of the severely affected gardens in this block the incidence is as high as 31.4%. With a view to containing the disease, trials were conducted using various organic and inorganic fertilizers and a variety of fungicides, the results of which are presented in this paper.

MATERIAL AND METHODS

To study the effect of fertilizers on wilt disease intensity the following levels of nitrogen, phosphorus and potash were used:

Nitrogen	: 0.35, 0.70 and 1.05 kg/palm/year
Phosphorus (P_2O_5)	: 0.25, 0.50 and 0.75 kg/palm/year
Potash (K_2O)	: 0.45, 0.90 and 1.35 kg/palm/year

The experiment was conducted with four replications per treatment. Fertilizer application was done once a year during September–October.

To study the effect of organic manures on wilt intensity, the following organic manures were used either alone or in combination with 40 litres of 1% Bordeaux mixture as soil drenching.

i.	Farmyard manure (FYM)	200 Kg per palm
ii.	Green manure	50 ,,
iii.	Tank silt	300 ,,
iv.	Neem cake	5 ,,

Organic manures were applied once in a year and Bordeaux mixture (BM) drenching once in three months during the first year only. Three were five replications in each treatment. Disease intensity in each treatment was assessed as per procedure described by Vijayan and Natarajan (1975). Annual nut yield in each treatment was recorded.

Both the above experiments were under rainfed conditions.

To assess the efficacy of different fungicides, the following fungicides were used:

i.	Aureofungin-sol	20g in 20 litres of water as soil drench
ii.	Benlate	,,
iii.	Bavistin	,,
vi.	Vitavax	,,
v.	FM Spray 600ml in 30 litres of water	
vi.	Bordeaux mixture 1% 40 litres soil drench	

vii. Bordeaux mixture soil drenching+2g aureofungin-sol and 1g copper sulphate in 100ml of water as stem injection.

viii. Control.

The treatments were given thrice at quarterly intervals. Disease intensity and annual nut yield in each treatment were recorded.

Results and Discussion

Effect of fertilizers on disease intensity: Disease intensity recorded every month is given in Table 1 as cumulative disease index. The results indicate that increasing the fertilizer dose above $N_1P_1K_1$ level significantly increased the disease intensity. Very high disease index was observed in $N_1P_1K_3$ followed by $N_3P_1K_1$ The disease index was low in $N_1P_1K_1$ and highest mean yield of 72 nuts per palm was recorded in this treatment as compared to 48 nuts in control (Table 1).

Table 1. Effect of fertilizers on Thanjavur wilt of coconut

Treatments	Cumulative disease index (1977–81)	Yield of nuts/palm/year				
		1978	1979	1980	1981	Mean
N_1 P_1 K_1	4.20	72	70	82	62	72
N_2 P_1 K_1	29.65	41	61	69	40	55
N_3 P_1 K_1	99.60	30	25	29	1	21
N_1 P_2 K_1	50.04	48	45	56	23	43
N_1 P_3 K_1	67.43	72	61	57	49	60
N_1 P_1 K_2	58.63	72	44	74	46	59
N_1 P_1 K_3	127.73	50	25	44	29	37
N_0 P_0 K_0	2.58	57	39	54	42	48
C.D. (P=0.05)	32.05	N.S.	N.S.	10	27	22

Effect of organic manures: The data on disease intensity following organic manure application, either alone or in combination with Bordeaux mixture drenching, revealed that neem cake +Bordeaux mixture treatments recorded low disease intensity when compared to control. These treatments also recorded significantly more yield than control (Table 2). Though farmyard manure, and FYM+BM treatments also recorded significantly more yield than control, the disease intensity was more in these treatments when compared to neem cake or neem cake+BM treatments.

Table 2. Effect of organic manures on Thanjavur wilt of coconut

Treatments	Cumulative disease index (1978–81)	Yield of nuts/palm/year 1978	1979	1980	1981	Mean
Tank silt (TS)	55.76	54	22	32	15	31
T.S. + B.M.	41.50	54	30	42	16	36
FYM	56.46	64	13	55	36	42
FYM + BM	61.92	64	49	48	19	45
Green leaves (GL)	114.14	60	12	6	0	20
GL+BM	35.24	42	20	42	29	33
Neem cake (NC)	12.30	50	26	44	36	39
NC+BM	11.42	56	31	69	42	50
BM	69.84	56	20	25	19	30
Control	117.72	41	24	8	1	19
C.D. (P=0.05)	38.71	N.S.	N.S.	21	14	7

Table 3. Efficacy of fungicides on disease intensity and yield of wilt affected palms

Treatments	Cumulative disease index (1976–81)	Yield of nuts/palm/year 1977	1978	1979	1980	Mean
Aureofungin-sol (AF)	59.94	20	15	22	82	35
Benlate	70.52	42	41	14	136	58
Bavistin	95.65	6	32	30	25	23
Vitavax	98.48	10	47	38	77	43
F.M. Spray	66.89	20	27	13	84	36
BM	40.64	12	27	34	50	31
AF+BM	16.91	46	77	53	143	80
Control	89.09	20	79	32	63	49
C.D. (P=0.05)		N.S.	N.S.	N.S.	49	N.S.

Effcacy of fungicides: Among the various fungicides tested, Aureofungin-sol+BM treatment recorded low disease intensity of 16.91 followed by 40.64 in BM treatment as against 89.09 in control (Table 3). Aureofungin-sol+BM treatment has also recorded significantly higher yield than control, three years after treatment. Eventhough the mean yield for four years is not statistically significant (Table 3), still there is marked improvement in yield in this treatment (80 nuts/palm/yr) than in control (49 nuts).

The above study thus clearly indicates that by judicious application of fertilizer and neem cake, the vigour of the wilt-affected palms can be maintained to produce economical yields. Application of Aureofungin-sol+BM thus helps in containing the disease to a great extent and at the same time increases the yield of the palms.

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DISCUSSIONS

P. RETHINAM (Project Coordinator, C & A): When was the survey made in which the disease incidence in Thanjavur was found to be only 4.9%?

T. RAMANATHAN: The survey was conducted in 1978.

P. R.: Inspite of the fact tnat a recommendation has been given for the discase, the incidence has increased to more than 20% in Kanyakumari district. So, is it possible to contain the disease by following your recommendation.

T. R.: It depends upon the actual inplementation of the recommendation in the farmer's field. Disease control calls for an integrated approach of crop as well as disease management. It is possible to contain the disease provided the recommendation is followed properly.

P. R.: When neemcake and Bordeaux mixture has only 11.4 as index, why do you recommend Aureofungin–sol+Bordeaux mixture which gives an index of 16.4?

T. R.: The mean yield in neemcake+Bordeaux Mixture was 50 nuts/palm as against 80 nuts/palm in Aureofungin+Bordeaux mixture treatment. Because of the significantly higher yield obtained in the latter treatment, this is recommended even though there is slight increase in the disease index.

P. R.: Please clarify whether recommended dose of fertilizers were applied to the palms in Experiment II?

T. R.: Excepting organic matter, no fertilizers were added.

P. R.: Reports say that application of Potassium helps to reduce disease incidence.

T. R.: In our experiment, higher dose of K has favoured disease, a result which is inexplicable.

P. R.: Are we right in recommending Aureofungin sol+Bordeaux mixture, for controlling the disease?

T. R.: Yes. These should be super imposed over a heavy dose of organic matter, supplemented with only the minimum of fertilizers, and irrigated properly.

P. R.: A combination effect of organic matter + neem cake + BM + Aureofungin–sol is not readily available now.

T. R.: The experiment to study the combination effect was started only this year (1982), and is in progress.

K.K.N. NAMBIAR (CPCRI): Don't you feel that you have used a high concentration (0.1%) of Aureofungin–sol as against the dose recommended by Hindustan Antibiotics, i.e. 20g in 120 litres of water? They recommended 6g of copper sulphate also to be used along with it. Have you used copper sulphate?

T. R.: For soil drenching, 20g of Aureofungin sol was used in 20 litres of water. For stem injection 2g of Aureogfunin+1 g of $CuSO_4$ in 100 ml of water was used. These two are separate treatments.

A SERIOUS DISEASE OF *ANACARDIUM OCCIDENTALE* L. CAUSED BY *CYLINDROCLADIUM CAMELLIAE* AND ITS POSSIBLE CONTROL

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ABSTRACT

A seedling disease of *Anacardium occidentale* L. caused by *Cylindrocla dium camelliae* Venkataramani & Venkata Ram and its teleomorph *Calonectria camelliae* Shipton, is reported for the first time in India. The disease is characterized by leaf blight, stem and root-rot in young seedlings in the nursery as well as in the plantation. High mortality (c. 70%) of 4-month-old seedlings due to multiple infection of leaf, stem and root was recorded in a nursery at Kunnathur, Thaliparamba Forest Range. Widespread infection of the leaf and shoots resulting in severe dieback was also observed in a nearby 6-month-old-cashew plantation. The disease initially affected the leaves of seedlings causing severe leaf blight. Later, the infection spread to stem causing stem rot which usually resulted in dieback of apical shoots. In severe cases, the pathogen caused root-rot thus killing the seedlings outright. *C. camelliae* was consistently isolated from the affected parts of the seedlings. During monsoon, masses of conidia and ascocarps of the fungus were produced on rotten parts of the stem and leaf petioles. In the pathogenicity trials with the isolate, conducted by employing 4-month-old container-grown seedlings, severe infection of leaf, shoot and root developed within a fortnight of inoculation. Bavistin was the only effective fungicide in laboratory screening done against *C. camelliae*.

INTRODUCTION

In recent years, cashew is being raised in forest plantations for afforestation either as a monocrop or mixed with *Eucalyptus* or other fast growing softwood species. In a mixed cashew and *Eucalyptus tereticornis* plantation at Kunnathur, Thaliparamba Forest Range, we recorded a serious disease of cashew seedlings caused by *Cylindrocladium camelliae* Venkataramani & Venkataram during July–August 1980. The disease was observed in the nursery as well as plantations in 4–6 month old seedlings. The disease appeared to be very severe as, c. 70% and c. 60% mortality occurred in the nursery and plantation respectively. Considering the seriousness of the disease, its symptomatology was studied under field conditions. Investigations pertaining to etiology, pathogenicity of the isolate and screening of various fungicides against the pathogen were initiated in the laboratory.

Materials And Methods

Etiology of the disease:

(i) *Isolation of the pathogen:* Affected tissues from the root and stem were surface-sterilized with 0.2% mercuric chloride for 3 min, rinsed with sterile water and plated on PDA. Infected leaf tissues were dipped in 0.2% mercuric chloride for 1 min., washed in sterile water and similarly plated on PDA. The plates were incubated at 25±2°C. The fungal growth originating from the diseased tissues was subcultured on PDA slants for further studies.

(ii) *Cultural characteristics and morphology of the pathogen:* For studying the cultural characteristics and morphology, the fungus was inoculated on PDA and malt extract agar (MEA) medium, incubated at 25±2°C and observations recorded after 7 days.

Pathogenicity test of the isolate

(i) *Root inoculation*: Ten-day old colonies of the fungus grown on PDA containing mycelium and condia from 4 plates were removed with a sterile scalpel and blended with 250 ml of sterile distilled water. Four-month old cashew seedlings raised in sterile soil and sand mixture (1:3), were uprooted carefully and their root systems washed thoroughly with sterile water. Roots of 10 test plants were dipped in the homogenate of fungal mycelium and conidia for 5 min and transplanted into polythene container (18×12 cm) filled with sterile soil and sand (1:3) mixture. Seedlings whose roots were treated with PDA suspension alone served as control. The seedlings were kept in a humid chamber for 24 hours. Later they were transferred to open air and observed daily for the development of the disease.

(ii) *Leaf inoculation*: The conidia of *C. camellia* harvested from 10–day old culture plates were suspended in sterile distilled water containing Tween–20 (1:2000). The density of the conidia was adjusted to approximately 5×10^5 per ml of suspension using a Neubauer haemocytometer. The conidial suspension was sprayed uniformly using an atomizer separately on adaxial and abaxial surface of the detached leaves which were earlier surface-sterilized with 0.05% sodium hypochlorite solution. The inoculated leaves were placed on sterile Whatman filter paper moistened with Benzimidazole solution (5 ppm) in Petriplates (15 cm dia), and incubated at 25±2°C for 7 days. Observations were recorded every day for the appearance of symptoms.

(iii) *Stem inoculation*: A small hole was made with a capillary tube in the tender part of the stem near the apical shoot. Small mycelial bits containing conidia, harvested from a 10-day old colony on PDA, were placed in the hole. The control plants were inoculated with only PDA medium. The inoculated seedlings were kept in a moist chamber and observations recorded for 10 days.

Evaluation of fungicides

Since *C. camelliae* is a soil-borne pathogen producing resting structures like microsclerotia in the soil, a 'soil method' described by Zentmyer (1955) was employed for evaluationg six fungicides, namely, Bavistin (Methyl IH–benzimidazole-2-yl carbamate), Benlate (Methyl I–(butylcarbamoyl)-2-benzimidazole carbamate), Bordeaux mixture, Difolatan (cis-N-(1, 1, 2, 2,–Tetrachloroethylthio)–4–Cyclohexene–1, 2–dicarboximide), Dithane M–45 (Maneb+Zinc ion), and Fytolan (3 $Cu(OH)_2$–Cu Cl_2), for their efficacy. Fungal disc (10 mm dia) cut from an actively growing 10-day-old culture of *C. camelliae* on PDA, was placed on 10g sterile soil (soil: sand, 1:3) in a sterile glass vial (2.5 dia+8 cm). The disc was covered with another 10g of sterile soil, over which 7 ml. of an appropriate concentration of fungicide solution to be evaluated was poured. Sterile distilled water was used for the control set. The glass vials were covered with sterile aluminium foil and incubated for 25h at 25±2°C. Each concentration of the fungicide, was replicated thrice. After incubation, the agar disc was removed, and washed thoroughly with water. The excess water was removed from the disc by placing it gently between two sterile filter papers. The disc was then plated on PDA incubated for 7 days at 22±2°C, and observations recorded.

Results and Discussion

Disease symptoms in the field

The pathogen initially attacked the young leaves of seedlings and produced extensive necrotic lesions, which later coalesced to form large necrotic areas causing leaf blight. In mature leaves, often the infection caused rotting of petiole and midrib leading to premature defoliation. Under high humid conditions, the infection also caused stem-rot resulting in dieback of apical shoots. Numerous orange coloured perithecia were produced on the decayed parts of the seedlings (Fig. 3 a, b). The pathogen infected the roots, causing extensive root rot. Initial symptoms of the affected seedlings were, flaccidity and yellowing of mature leaves followed by wilting of the seedlings, Infection spread from feeder roots to the tap root. The diseased seedlings showed scanty feeder roots which were discoloured and decayed (Fig. 1).

The pathogen

Isolation from diseased leaf, stem and root tissues yielded consistently a *Cylindrocladium* sp. identified as *C. camelliae* from cultural and microscopic characters (Fig. 7 a, b). A few isolates of the fungus have been deposited at C.M.I. Kew, Surrey, England (IMI Herb Nos. 232980, 232981, 232922). The cultural characteristics and morphology of *C. camelliae* are given below:

Colony on PDA fast growing, dull white becoming pale yellow; aerial mycelium very little with characteristic sectoring. Conidiophore hyaline penicillate, primary, secondary, and tertiary branches present, main axis of the conidiophore bears a sterile hypha 66–98μm long terminating in ellipsoidal to broadly spathulate vesicle 12.2–52.5×6.4–9.2 μm. Phialides hyaline, 114, wider at apex than at base, and taper more abruptly; conidia hyaline, cylindrical, straight, 8.36–15.4×1.5–2.86 μm, ends rounded 1–septate, borne singly, accumulating in palisade-like clusters held together in mucus. Chlamydospores abundant in old cultures, intercalary or terminal, globose to oval 8.2–10.1 × 6.6–10 μm, thick walled, yellow to yellowish orange. Sterile appendages numerous in fresh cultures, but a few in old subcultures. Teleomorphs fail to form in cultures.

Some cultural differences recorded in the colonies on PDA and MEA are included in Table 1.

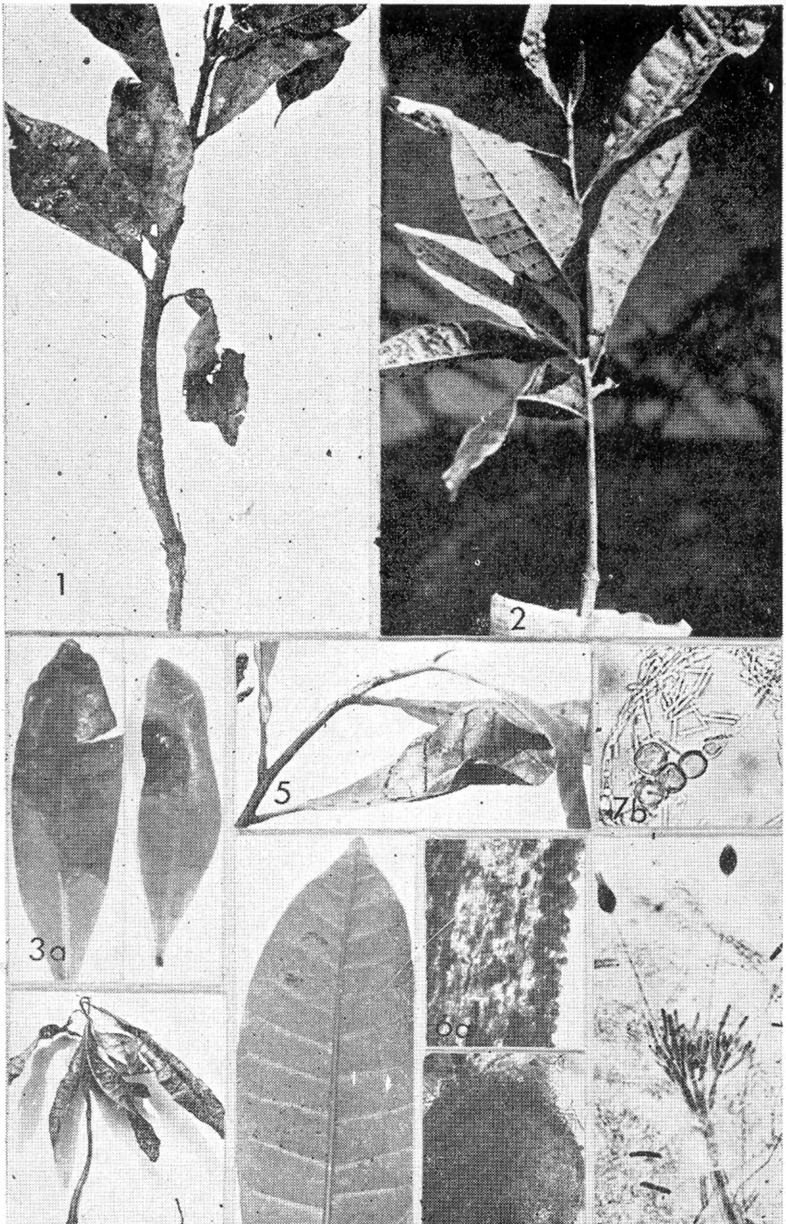
Table 1. Cultural characteristics and radial growth of *C. camelliae* on Malt-Extract-Agar and Potato-Dextrose-Agar

Cultural characteristics			
Malt Extract Agar		Potato Dextrose Agar	
Morphology	Colony diam. on 7th day	Morphology	Radial growth on 7th day
Colonies fast growing, white turning off-white with age; reverse initially light yellowish brown later changing to brownish yellow with the development of microsclerotia. Sporulation profuse. Sterile hyphae abundant, long ends in characteristic spear shaped vesicle.	7.5 cm	Colonies comparatively faster in growth, dull white, mycelium appressed with little white aerial mycelium. Reverse initially pale yellowish later turning to brownish yellow with some purple tinge at places, due to the production of abundant microsclerotia. Characteristic sectoring invariably seen in colonies. Sporulation less abundant. Sterile hyphae rare or absent in subcultured isolates.	8.35 cm

Perithecia produced on host tissues are globose or pyriform 200–345 × 150–290 μm, single or grouped together, yellowish orange at maturity, ostiole papillate, asci cylindrical becoming clavate at maturity, 52–68 × 2.9–6.7 μm, thin-walled, hyaline and stalked, paraphyses absent. Ascospores 8 in number, cylindrical, or fusiform with rounded to pointed ends 6.7–10.9 × 2.8–3.8 μm, 1-septate, hyaline, ascospores extruded from mature ascocarp as a pale yellowish mass.

Pathogenicity studies

Leaf: Greyish-black flecks appeared on the abaxial surface of the infected leaves 12 hr. after incubation. In juvenile leaves,


1
2
3a
5
7b
4
3b
6b
7a

the small flecks turned within two days into necrotic lesions, which coalesced to form large necrotic area covering more than half of leaf lamina (Fig. 3a). However, in mature leaves the spread of the necrotic lesion was slower and the spots become necrotic only after 7 days (Fig. 3b). Infection was more on the abaxial surface of the leaf than on adaxial.

Stem: The infection spread slowly on either side of the inoculated area. Within two weeks, the infection girdled the stem causing shoot dieback (Fig. 5). Later the infection spread to petioles causing defoliation.

Root: Flaccidity and yellowing of leaves and wilting of the inoculated seedlings occurred on the 5th day of incubation. Feeder roots of the inoculated seedlings were discoloured and completely decayed (Fig. 4). All the control seedlings remained healthy. *C. camelliae* was reisolated from all the diseased roots.

Discussion

High moratality of cashew seedlings due to infection by *C. camelliae* in both nursery and the field, in high rainfall atreas of north Kerala isindicative of the serious nature of the disease. The pathogen appealed to be gighly virulent causing severe root-rot of cashew and other hosts like tea (Venkataramani and Venkataram, 1961); *Wistaria sinensis* (Reddy, 1975), nutmeg (Rahman *et al.* 1981). The pathogen is also capable of attacking leaves, petiole and stem, thus causing severe damage to seedlings in nurseries and plantations. Sarma *et al.* (1979) had recorded *C. quinquiseptatum* causing leaf rot and mild to moderate defoliation in cashew.

Plate I. Cashew seedlings infected with *Cylindrocladium camelliae*

Fig. 1. Leaf infection and root rot in 4-month-old seedlings;

Fig. 2. Container seedlings (4-month-old) showing leaf infection;

Fig. 3a. Leaf necrosis in juvenile leaf (artificial inoculation on abaxial surface)

Fig. 3b. Leaf spot in mature leaf (artificial inoculation on abaxial surface);

Fig. 4. Wilt of seedlings due to root infection (artificial inoculation);

Fig. 5. Stem infection (artificial inoculation);

Fig. 6a, b. Perithecia on decayed host tissue;

Fig. 7a. *C. camelliae* conidiophore bearing conidia and steriie appendages;

Fig. 7b. Chlamydospores and conidia.

Table 2. Evaluation of fungicides against *C. camelliae* following soil method (Mean of 12 observations recorded from 3 plates)

Fungicides	Conc. (a.i.) in p.p.m.	Colony diam. of *C. camelliae* (in cm) on 7th day of incubation	
		Mean	SE
Bavistin	500	0.0	0.0
	1000	0.0	0.0
	2000	0.0	0.0
Benlate	500	7.6	0.021
	1000	7.4	0.040
	2000	7.17	0.085
Bordeaux mixture	500	7.43	0.025
	1000	7.39	0.035
	2000	7.50	0.040
Difolatan	500	7.71	0.045
	1000	7.73	0.077
	2000	7.63	0.022
Dithane M-45	500	7.54	0.033
	1000	7.76	0.028
	2000	7.72	0.029
Fytolan	500	7.8	0.024
	1000	7.6	0.023
	2000	7.6	0.027
Control*		7.616	0.018

*Mean of 24 observations from 6 petri-dishes

The teleomorph of *C. camelliae*, namely, *Calonectria camelliae* is produced in abundance on stem and petiole. However, in growth studies the fructifications did not develop. This is the first report of the occurrence of *Calonectria camelliae* from India. Earlier it has only been reported from Australia (Shipton, 1981) on fruits of unidentified rainforest trees. Recently Boeswinkel (1982) has suggested the transfer of *Calonectria camelliae* to *Nectria camelliae* on the basis of some taxonomical characters of the anamorphs.

None of the fungicides tested, except Bavistine, could inhibit the growth of the pathogen (including conidia, mycelium and microsclererotia) completely (Table 2). Prophylactic application of Bavistin just before the onset of monsoon, would possibly control the appearance of the disease. However, chemical control of this disease in plantations is not an economically viable preposition; the disease can be best managed following proper cultural practices. It would not be advisable to plant cashew in a mixed planting with *Eucalyptus* as the latter is equally susceptible to *C. camelliae* (Sharma and Mohanan, 1982). Among the two host species cashe v is highly susceptible to the pathogen, and hence, to the disease. This will result in a total failure of the cashew plantation as has been observed in 1980 at Thaliparamba. For this reason, cashew in high rainfall areas may be *as a phre crop or mixed crop, if necessary, with* some other complimentary species, other than *Eucalyptus*.

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CONTROL OF PANICLE ROT DISEASE OF CARDAMOM

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ABSTRACT

A large-scale trial-cum-demonstration experiment was conducted in a cardamom plantation at Santhanpara in Idukki District of Kerala, on the control of 'Azhukal' (Panicle rot) disease of cardamom, in 1975–76 crop season, when the disease incidence was very severe. It was found that Bordeaux mixture was more effective than Fytolan (Copper oxychloride) or Miltox (Copper oxychloride + Zinc ethylene bisdithiocarbamate) in controlling the disease.

INTRODUCTION

Panicle rot, commonly known as the *Azhukal* disease, is one of the most serious diseases of cardamom, *Elettaria cardamomum* (Maton) var. *minor*. The disease occurs with the onset of south-west monsoon, becomes severe during August-September and continues to prevail upto December. The severity of the disease is most pronounced during years of continuous and heavy rainfall. The disease is characterized by the rotting of capsules; the infection spreads from capsules to panicles and later to the base of the clumps and causes decay of affected pseudostems. Thus, apart from the crop loss due to rotting and shedding of capsules, whole plants rot and perish under extreme conditions. The etiology of the disease has been studied by Menon *et al.* (1972), Thankamma and Pillai (1973), Nambiar and Sarma (1976) and Nair and Menon (1982). Based on *in vivo* studies, (Menon *et al.*, 1973, Nambiar and Sarma 1974, Wilson *et al.*, 1974) prophylactic spraying with 1% Bordeaux mixture or 0.2% copper oxychloride (with a wetting agent) first in June and next in early August was recommended as control measure (Nambiar *et al.*, 1975). In this paper, the results obtained from adaptive trials conducted during

1975–77 season, based on the above recommendation are reported. Since the disease incidence was negligible during 1976–77 season, only the results obtained during 1975–76 season are discussed.

MATERIAL AND METHODS

The trial was conducted in a private plantation, in Santhanpara Village of Udumbanchola Taluk in Kerala, where the severity of the disease was quite high during the previous few years. A total area of about two hectares having more or less uniform plants of 5 to 7 years was selected in different blocks of the estate. No prophylactic measure was adopted by the planter prior to the experiment. The trial was laid out in a RBD with five replications and with a plot size of 40 plants. There were 8 fungicidal treatments and a control as detailed below:

Bordeaux mixture 1 % @ 1 litre per plant, Bordeaux mixture 1 % 0.5 litre per plant, Copper oxychloride (Fytolan) 0.2% 1 litre per plant, Fytolan 0.2% 0.5 litre per plant, Copper oxychloride containing zinc–ethylene bisdithio–carbamate (Miltox) 0.2% 1 litre per plant, Copper oxychloride containing Miltox 0.2% 0.5 litre per plant, Copper oxychloride containing Miltox 0.3% 1 litre per plant, Copper oxychloride containing (Miltox) 0.3% 0.5 litre per plant, and Control. Sandovit was used as wetting agent for Fytolan and Miltox.

The first round of spraying was done during the second week of July and the second round after 60 days, in September, using ordinary hand-compression sprayers. The panicles and the lower portions of the plants were thoroughly covered. Prior to the spraying operations, all the disease affected plants were marked, the number of total and affected panicles on each plant counted, and the affected panicles cut and removed. Similar observations were made at an interval of 30 days.

RESULTS AND DISCUSSION

The percentage of plants and panicles infected by the disease at different intervals are given in Table 1. The results clearly show that treatment No. 1 was very effective in checking the

Table 1. Percentage of plants and panicles affected by Azhukal disease, under various treatments (after angular transformation)

Treatment No.	On 30th day of 1st application		On 60th day of 1st application		On 30th day of 2nd application	
	Plants	Panicles	Plants	Panicles	Plants	Panicles
1	4.59	1.22	20.44	10.07	23.89	13.56
2	11.97	4.98	28.15	14.64	35.50	20.35
3	12.36	7.09	36.01	25.59	52.68	41.96
4	14.16	9.43	31.34	25.23	52.77	40.83
5	11.71	6.17	28.64	22.45	33.52	28.73
6	8.61	4.59	29.65	20.82	36.81	30.59
7	9.35	5.55	29.20	19.81	36.28	29.63
8	8.41	3.19	28.58	21.13	34.41	27.44
Control	20.32	11.46	36.05	29.40	53.79	46.70
F test:	NS	**	NS	**	*	**
C.V. %	61.49	71.99	37.04	40.72	32.19	37.53
C.D. (P=0.05)	—	5.50	—	10.96	16.47	14.94

*Significant at 5% level; **Significant at 1% level.

spread of the disease, followed by treatment No. 2. Copper oxychloride was found to be on par with control. Though the treatments were significantly better than the control, the disease incidence was relatively high under these treatments.

The maximum disease incidence occurred between the 30th and the 60th day following the first round of spraying. A second round of spraying within 30–35 days of the first one could have been very effective in further control of the disease. In the trial conducted, this could not be attempted due to the unfavourable climatic conditions.

Varietal differences in susceptibility to the disease: Earlier workers (Nambiar *et al.*, 1975) have reported that all the three cultivars of cardamom, 'Malabar', 'Vazhukka' and 'Mysore', are equally susceptible to the disease. In the trial plots all these cultivars were present, and the data obtained are compiled and presented in Table 2.

Table 2. Difference in the susceptibility of cardamom cultivars to Azhukal disease; % affected panicles (after angular transformation).[1]

Treatment No.	Malabar	Vazhukka	Mysore
1	11.83	14.00	8.82
2	8.26	43.80	15.87
3	28.83	54.50	23.44
4	47.70	26.40	17.08
5	23.56	32.00	17.96
6	31.63	10.70	14.20
7	22.96	15.00	13.80
8	30.20	44.50	13.74
Control	40.11	40.00	21.01
F. test	*	N.S.	N.S.
S.E.	13.27	15.44	8.76
C.D. (P=0.05)	19.64	—	—

[1] Between 30th and 60th day of 1st round of fungicide application

The results show that severity of the disease is relatively high in 'Malabar' and 'Vazhukka' cultures than in 'Mysore'. The panicles in the first two cultivars are prostrate and semierect respectively, and being more close to the ground than the erect panicles of Mysore cultivar, are more exposed to the inoculum.

Based on the results obtained, it is concluded that a timely and thorough spraying with 1% Bordeaux mixture is effective is checking the spread of Azhukal disease. Spraying has to be repeated after every 30–35 days if continuous rains prevail. The panicles and basal portions of the plant are to be sprayed at the rate of one litre of spray fluid per plant of 6–7 years age.

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SPORE RELEASE AND DISPERSAL IN GINGER LEAF SPOT PATHOGEN–*PHYLLOSTICIA ZINGIBERI*

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Abstract

Spore release from the pycnidium depends upon its contact with water drops. Pycnidiospores were released in the form of cirrus through ostioles. Rain spalsh has a vital role in the dispersal of spores. Multidirectional traps were used for collecting spores carried by rain splash. Though pycindiospores could be trapped at distances upto 120cm horizontally and upto 75cm vertically from the infection foci, the number of spores caught was higher at closer distance. Spores could also be collected from the dew-drops during morning hours. The importance of this phenomenon in disease incidence is discussed.

Introduction

Ejection of conidia occurs in various *Phyllosticta* spp. in an abundant gelatinous mass if sufficient moisture is supplied (Bilgrami, 1963) and this accounts for the spread of leaf spot disease in different plant species during July–August. The pathogen, *Phyllosticta zingiberi* Ramakr., causal agent of leaf spot of ginger, produces pycnidia on the lesions under wet conditions. The disease is generally noticed im the field during the South-West monsoon period and thereafter. However, no information is available on the spore release pattern and spore dispersal *vis-a-vis* disease incidence. Hence, to bridge the gap on these aspects, studies were initiated.

Material and Methods

To study the role of high humidity in spore release, 20 pycnidia were spread over a clean microscope slide and incubated *at 90, 95 and 100% relative humidity*. To another set, drops of water were added. Release of pycnidiospores was monitored periodically.

Multidirectional spore traps were used for collecting splashed spores. The traps were placed in the field at horizontal distances of 30, 60, 90, 120 and 150 cm and at different heights of 30, 60, 75 and 90 cm from the infected plants. The volume of water collected in the tube was reduced to 5 ml by evaporating under a ceiling fan. Spore content per ml of water was calculated with the help of haemocytometer. Dew drops were also collected during non-rainy days and presence of spores examined under a microscope.

The observations on disease intensities were recorded in the ginger field at the Institute farm from July to November at monthly intervals for 3 years, 1978, 1979 and 1980. Observations were recorded on 100 randomly selected seedlings. The scale of rating comprising 6 grades was prepared on the basis of number of spots. The disease intensity was calculated according to the formula developed by McKinney (1923).

The meteorological data recorded at the Institute were used for correlating with disease intensity.

To study the spore load, the lesion size was measured and the lesions were grouped into 6 categories ($\leq$2.5 mm^2, 2.5–5 mm^2, 5.0–7.5 mm^2, 7.5–10.0 mm^2, 10.0–12.5 mm^2, and 12.5 mm^2 and above). Number of pycnidia coming under different categories was recorded and number of spores computed.

RESULTS AND DISCUSSION

No spores were released at any of the different humidity levels tried, but when the pycnidia came in direct contact with water drops, spore release occurred. Spores oozed out of the pycnidium through the ostiole in the form of a cirrus. Dew drops collected in the morning hours contained a good number of mostly germinating spores. It is apparent that rain drop or dew alone and not merely humidity, can bring about spore release. For subsequent dispersal it has to depend upon splash mechanism. Gruenhagen (1945) observed a similar situation in *Hypoxylon pruinatum*, a causal agent of poplar canker, where a humid atmosphere alone did not influence discharge, but only wetting of stroma was effective. In *Mycosphaerella pyroides*, causing foot rot of peas, perithecia are formed on pea straw. The spore liberation in this pathogen depended on wetting, and this could be provided by dew alone (Carter, 1963).

Spore dispersal occurred efficiently when there was rain splash. Pycnidiospores trapped at different distances and heights from the focus of infection under different amounts of rainfall are shown in Tables 1 and 2. It was observed that the extent of dispersal,

Table 1. Horizontal splash dispersal of pycnidiospores

Date of observation	Rainfall (mm)	Distance (cm)	Spores trapped ('000/ml)
1-10-1980	6.4	30	20
		60	20
		90	10
		120	—
		150	—
2-10-1980	24.3	30	100
		60	50
		90	30
		120	10
		150	—
3-10-1980	15.2	30	80
		60	60
		90	30
		120	10
		150	—
11-10-1980	42.8	30	90
		60	60
		90	30
		120	20
		150	—
13-10-1980	5.2	30	20
		60	10
		90	—
		120	—
		150	—
23-10-1980	26.4	30	60
		60	30
		90	20
		120	10
		150	—

Table 2. Vertical splash dispersal of pycnidiospores

Date of observation	Rainfall (mm)	Height (cm)	No. of Spores trapped (000/ml)
25–10–1980	8.3	30	20
		60	10
		75	—
		90	—
17–11–1980	19.8	30	30
		60	20
		75	10
		90	—
19–11–1980	11.3	30	20
		60	10
		75	—
		90	—
20–11–1980	5.5	30	20
		60	10
		75	—
		90	—
21 -11–1980	12.4	30	20
		60	20
		75	—
		90	—

either horizontally or vertically, was dependent upon intensity of precipitation. Spore catch was higher at proximal points from the source and again was dependent upon intensity of precipitation. Higher intensity of rain accompanied by wind seems to exert greater impact on target leaf, so that rain drops are splashed to greater distances resulting in liberation of greater amounts of spores. Studying rain dispersal of uredospores of coffee rust, *Hemileia vastatrix*, Bock (1962) observed that abundant number of spores were deposited, that too only after heavy showers when daily rainfall exceeded 0.8 cm. In *Valsa leucostoma*, conidia were shown to be dispersed by wind-blown rain, and the distance of dispersal was correlated with the mean wind velocity during rain (Bertrand and English, 1976). Singh and Renfro (1971) could trap spores of *Sclerophthora rayssiae* var. *zeae*, horizontally upto 1.65m, and vertically upto 0.90m.

The number of pycnidia per lesion increased with increase in size of the lesion, and so also the number of spores (Table 3).

Table 3. Number of Pycinidia under different lesion sizes

Lesion area (mm^2)	No. of pycnidia	No. of Pycnidiospores (10^5)
⩽ 2.50	8.10	6.50
2.50— 5.00	9.93	8.00
5.00— 7.50	11.73	9.70
7.50—10.00	12.39	10.25
10.00—12.50	15.63	13.00
12.50 and above	17.04	14.10

The data on relationship between climatic factors, mainly humidity, temperature and rainfall, and disease incidence are presented in Table 4. The disease appeared in traces only towards the end of June, though the plants were at the most susceptible stage (3–4 leaf stage) and received high cumulative rainfall (1003.13 mm) for disease spread. During the first fortnight of the month, build up of inoculum was not sufficient with comparatively drier conditions when temperature varied between 23.4–29.6°C, and relative humidity was between 83.3–90.1%. This would have resulted in a lower level of disease incidence. Mandokhot and Basu Chowdhury (1980) found that the age of the crop, rainfall, humidity and temperature were important factors in the disease development of *Curvularia* leaf-spot of maize.

Table 4. Mean temperature, relative humidity, rainfall, and number of rainy days *vis-a-vis* leaf-spot disease incidence*

Months	Temperature °C		Humidity (%)		Rainfall (mm)	No. of Rainy days	% Disease incidence
	Max.	Min.	Forenoon	Afternoon			
June	29.6	23.4	90.1	83.3	1003.14	27.0	Traces
July	28.5	22.9	95.6	85.1	1084.30	29.9	10.05
August	28.5	23.1	94.3	84.3	763.20	28.3	19.00
September	29.2	22.6	93.0	77.0	239.00	17.3	22.55
October	31.3	23.2	95.0	70.3	99.10	10.3	21.72
November	31.9	22.1	91.3	64.0	115.15	9.0	18.99

July received the highest mean rainfall (1084.3mm) and had a mean 29.9 rainy days. This was accompanied by high humidity (85.0–95.6%) and lower temperatures (23.90–28.85°C) with a corresponding disease incidence of 10.05%. The temperature range of 23.0–28.0°C is found to be very favourable for the development of this disease (Brahma, unpublished). Very favourable weather conditions prevailed throughout August also, which encouraged further disease spread, and the disease incidence reached 19.10%, With intermittent rainfall and favourable temperature, disease incidence gradually increased in September to 22.55%. The severity of glume blight disease of rice caused by *Phyllosticta glumarum* (Ell. & Tr.) Miyake, was reported to be associated with heavy but intermittent precipitation four weeks prior to flowering (Singh *et al.*, 1978).

During October, the total rainfall was considerably reduced (99.10mm), so also the number of rainy days (10.3 days). The temperature also was higher (23.2–31.3°C), and as such there was no further fresh incidence. In fact, disease decreased gradually in October and November to 18.99%. The new leaves which were emerging in fewer numbers during this period were not affected by the disease because of uncongenial conditions. von Ramm and Lucas (1963) observed that a few rains in July helped in the development of a very low percentage of tobacco brown spot. A heavy rain at the beginning, and subsequent wet conditions throughout August helped in rapid disease development.

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VON RAMM, C. AND LUCAS, G. B. 1963. Epidemiology of tobacco brown spot caused by *Alternaria longipes*. *Phytopathology*, **53**: 450-455.

Discussion

C. RAJENDRAN (C.C.R.I.): What is the incubation period of *Phyllosticta zingiberi* on ginger?

R. N. BRAHMA: 48 hours.

A. H. RAJASAB (Gulbarga Univ.): Shri Brahma has used the drum-trap to study the horizontal dispersal of the pathogen. Instead, the susceptible host itself can be used for trapping spores. Similar observations are also reported by Hirst.

ROOT INFECTION AND POPULATION DENSITY OF VA MYCORRHIZAL FUNGI IN A COCONUT BASED MULTISTOREYED CROPPING SYSTEM*

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ABSTRACT

Spores of vesicular-arbuscular (VA) mycorrhizal fungi were found in all the soil samples collected from the root zones of plants forming a coconut-based multistoreyed cropping system, namely coconut, cacao, cinnamon and black pepper. Their numbers ranged widely from plant to plant (8-420 spores/100 g soil) and varied remarkably from sample to sample of the same crop. Of the eight species found, *Gigaspora gigantea, G. gilmorei, Glomus fasciculatus* (clusters), and *G. macrocarpa* were most common, *G. microcarpa* and a flat unidentified spore type were less frequent, whereas *Sclerocystis* sp. and a white unidentified spore type were rare. Usually more than two VA species occurred at the root zone of each crop. Root samples of all the hosts showed extensive infection (80-98%) with internal and external hyphae, and characteristic vesicles and arbuscules.

INTRODUCTION

Fungi of the family Endogonaceae, which form vesicular-arbuscular (VA) mycorrhizae, occur in most cultivated soils throughout the world (Gerdemann, 1968; Hayman, 1978). Their agricultural importance results mainly from their efficiency in nutrient mobilisation and stimulation of crop growth in poor soils. (Mosse, 1973; Tinker, 1975, 1982). Since their population varies greatly in size and species composition (Hayman 1978), ecological studies are fundamental to considerations on the possibilities of increasing the indigenous population or introducing more efficient species or strains (Mosse, 1973) into a field or plantation with a view to improving yield.

Many of the tropical agricultural systems are unique in that they involve plants growing together rather than in monocultures

*CPCRI Contribution No. 249.

which dominate temperate farming. A concept of high intensity cropping system in coconut stands has been conceived and the differences in multiple cropping practices in field and plantation crops with regard to maximum utilisation of solar energy and soil resources have been worked out (Nelliat, 1973; Nelliat *et. al.*, 1974; Bavappa and Jacob, 1982), The present study assesses the population of resting spores of VA fungi in relation to a coconut-based multistoreyed cropping system and to differences in the mycorrhizal infectivity of the crops involved.

Material and Methods

Soil samples, comprising several bulked subsamples were collected from the top 15 and 30 cm (coconut) and 15 cm (cacao, cinnamon and black pepper of soil in the root regions of coconut, cacao, cinnamon and black pepper) in a coconut based multistoreyed cropping system laid out at CPCRI, Kasaragod (Nelliat *et. al.*, 1974). For each crop, 10 bulked samples were collected during early summer with the help of a soil augur 1m away from the boll of the coconut palm and 15 cms away from the main stem of other plants. Coconut was planted in a square system 9.6 m apart, pepper was trained on coconut palm, while cacao and cinnamon were planted in single or double hedge (Nelliat *et al.*, 1974).

Recovery of spores: After thorough mixing, 100g of air-dried soil sample was wet sieved (Gerdemann and Nicolson, 1963) through 106 and 250mm sieves. The sievings were suspended in distilled water and recovered on filter paper discs following the procedure described by Sutton and Barron (1972). The filter paper discs were observed under a stereomicroscope and the spores were retrieved. The spore counts were calculated per 100 g of dry soil.

Root infection: To determine the extent of root infection in the host plants, root samples, bulked from 20 samples for each host plant were cut into 1cm bits, fixed in acetic alcohol (1:3), cleared in 10% KOH, and stained in 0.5% trypan blue in lactophenol. The extent of root infection was determined following the technique described by Ambler and Young (1977).

Identification of Endogonaceae species: The Endogonaceae spores recovered from the soils were identified using the keys for identification given by Gerdemann and Trappe (1974), and by several other authors (Becker and Hall, 1976; Nicolson and Schenk, 1979; Trappe 1977).

Results and Discussion

Table 1 shows the wide distribution of VA mycorrhizal fungi in different components of the multistoreyed cropping system. Spore numbers varied from crop to crop (8–420 spores/100g soil) and even for the same crop. In pepper, the unidentified flat spore type was found only in five samples out of the ten showing discontinuous occurrence for the same crop. In coconut, flat spore type was found only in two samples taken at 15 cm depth. Eight species of Endogonaceae were found, of which *Gigaspora gigantea*, *G. gilmorei*, *Glomus fasciculata* (clusters), and *G. macrocarpa* were the most common. *Glomus microcarpa* and the unidentified flat spore type occurred frequently, whereas *Sclerocystis* and the white unidentified type were rare. More than two species were associated with each host plant.

Root segments of all the crops analysed showed colonization by VA mycorrhizal fungi with characteristic arbuscules and vesicles. The extent of root infection ranged from 80–98% between crops. No difference in the extent of root infection was noticed within the crop. However, the number of arbuscules was very few or even absent in root samples of cacao.

The present study reveals the variability of the VA mycorrhizal population in the coconut based multistoreyed cropping system. Similar results have been reported in natural communities like rain forests, savannah lands and sand dunes (Crush, 1974, Hall, 1978; Powell, 1976; Koske, 1981). Population levels of dominant species such as *Gigaspora gilmorei*, *G. gigantea*, *Glomus fasciculata* and *G. macrocarpa* did not show any significant variation within the same crop. However, the difference in population levels between the crops may be due to the effect of the host on spore production (Crush, 1974). Colonization of the host root to the extent of 80–98% may be attributed to the perennial nature of the hosts, where the spores produced will have immediate access to fresh roots, and subsequent spread takes place. The knowledge of the

Table 1. VA mycorrhizal populations (mean values of 10 samples bulked for each host) associated with four hosts in a coconut-based multistoreyed cropping system

Crop	VA species [1] and spore No. [2]							
	GG	GGL	GMA	GMI	Flat	Wh	SR	GFS
Coconut	110 (98)*	204 (177)	380 (325)	23 (19)	14 (6)	—	—	57 (34)
Cacao	63.6	63	230	—	20	11	—	53
Cinnamon	66	60	165	—	—	—	17	54
Pepper	52	52	246	17	12	—	—	42

[1] *Gigaspora gigantea* (GG); *Gigaspora gilmorei* (GGL); *Glomus macrocarpa* (GMA), *Glomus microcarpa* (GMI); Flat unidentified; Wh, white unidentified; *Sclerocystis* (SR); *Glomus fasciculata* (GFS)

[2] Number of spores/100 g of dry soil

*Figures in parentheses denote spore no. at 15 cm depth.

species of the endophyte present may be valuable in view of the differences in efficiency reported among endophyte species (Mosse, 1973) and this could facilitate the choice of a VA inoculum. The spore population studies add further dimension to mycorrhizal ecophysiology wherein maximum productivity and stability of mixed communities are considered. The lack of general relation between the size of a spore population and the mycorrhizal infection of the host can be attributed to the presence of non-sporing endophytes (Powell, 1977) or the interaction between mycorrhizal species (Koske, 1981). Mycorrhizal fungi are hard to distinguish morphologically inside the root tissue, and hence it is difficult to estimate how many (if any) non-sporing strains are present in soil. Suggestions of interactions between different species of VA fungi occurring on the same species of host plants are found in the data of some investigators (Cooper, 1976; Hayman and Mosse, 1979; Krukelman, 1975; Mosse, 1975, 1977; Mosse and Hayman 1971; Powell 1977, 1979). Proportion of spore populations may differ with different hosts also. Hence, the present study would open up new areas for studies on interaction between VA fungi in such cropping systems where in the nutrient demands of two or more species growing together concurrently are usually considerably in excess of those of a single species and a competitive situation often occurs. Any theoretical treatment or experimental study of competition for limited soil nutrients must necessarily include mycorrhizal systems. Another consideration in multiple cropping is the mycorrhizal response to shading of one crop by another. Decreasing light intensity is known to reduce mycorrhizal development and mycorrhizal response with VA mycorrhizae.

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POSTER REPRESENTATIONS

PATHOPHYSIOLOGICAL DERANGEMENTS ASSOCIATED WITH YELLOW LEAF DISEASE OF ARECANUT

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ABSTRACT

In leaves of YLD affected arecanut palm, the activities of polyphenol oxidase and ascorbic acid oxidase had increased; on the other hand, peroxidase and catalase activities had declined. Ascorbic acid content was depleted in diseased palm. Extent of derangements in these factors was generally comparable with severity of yellow leaf disease.

INTRODUCTION

Arecanut (*Areca catechu* L.) is extensively cultivated in Kerala and Karnataka states of India. Yellow leaf diseasse (YLD) is the most serious and devastating disease of arecanut. The etiology of the disease is not known conclusively. In several plant diseases, alterations in the activities of key oxidative enzymes have been reported and the deranged enzyme activity correlated with the expression of disease syndromes (Fric, 1976). The results of a comprehensive study on derangements in the arecanut YLD with reference to oxidative enzymes, are reported in this paper.

MATERIALS AND METHODS

In YLD affected arecanut, the foliar yellowing usually appears in basal frond of crown at an early stage of the disease. The symptom later appears in younger leaves as the disease advances. Healthy and YLD affected palms in early and advanced stages of the disease were selected for the study. Leaf samples collected from healthy palms served as controls. Six leaf samples (1 gm each) were collected from each treatment and subjected to analysis of the activities of the oxidative enzymes, polyphenol oxidase, peroxidae, catalase and ascorbic acid oxidase. The content of ascorbic acid was also assessed.

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Polyphenol oxidase (PPO) was determined by the method of Matta and Dimond (1963). The difference in activity of reaction mixture was determined at 0 and 30 sec at 495 nm in a spectrophotometer. The enzyme activity was expressed in units, one unit representing a change of 0.001 optical density (OD) per 30 secs.

Peroxidase was estimated by the method of Mudd *et al.* (1959). The OD of reaction mixture of 0 and 30 secs interval was measureed at 430nm.

Catalase activity was measured by the perborate method of Feinstein (1949). The enzyme activity was arrived at by appropriate calculations as described in the method and expressed per g of leaf tissue.

Ascorbic acid oxidase and ascorbic acid: The method of Oberbacher and Vines (1963) was followed to estimate the activity of ascorbic acid oxidase. The absorption of reaction mixtures was measured in a spectrophotometer at 265nm and the change in absorbance read at 0, 2 and 3 min after mixing. Activity of the enzyme was expressed by taking a difference of 0.001 OD as one unit. The ascorbic acid content was estimated by the modified method of Roe and Kuether (1943). The OD was measured in a Klett-Summerson photoelectric colorimeter using 540nm filter. The quantity of ascorbic acid was calculated.

Results and Discussion

The activities of oxidative enzymes in healthy and YLD affected areca palms are presented in Table 1. When the activities of polyphenol oxidase and ascorbic acid oxidase were increased in diseased palm, the peroxidase and catalase activities declined. The content of ascorbic acid was less in diseased palm than in healthy.

Polyphenol oxidase (PPO): In early and advanced stages of YLD, the activity of PPO increased to 23.08 and 46.15 per cent respectively, over healthy, indicating on enhancement of enzyme activity as the disease advanced. An increase of PPO activity in host tissue is characterstic of a large number of plant diseases (Farkas and Kiraly, 1962; Kosuge, 1969). In arecanut leaves, the

Table 1. Activity of oxidative enzymes in leaves of healthy and yellow leaf diseased areca palms*

Nature of sample	Activity level of enzymes (units)**				Ascorbic acid (mg/g) (AA)	Diseased/Healthy (%)				
	Polyphenol oxidase (PPO)	Peroxidase (Po)	Catalase (Ca)	Ascorbic acid oxidase (AAO)		PPO	Po	Ca	AAO	AA
Healthy	13	194	41	648	2.51					
YLD-Early syndrome	16	150	2	683	1.83	123.08	77.32	5.43	105.42	72.91
YLD-Advanced syndrome	19	147	3	706	1.64	146.15	75.77	6.17	108.95	65.34

*Mean of 6 samples/treatment, **0.001 optical density=1 unit.

phenolics have been found to increase depending upon the severity of YLD (Srinivasan, unpubl.) The feeding of increased PPO activity, accompanied by accumulation of phenolics in YLD affected plants is in conformity with the results reported in several plant diseases. The accumulation of phenolic substances or activation of its enzyme in diseased plants is a non-specific consequence of tissue injury, rather than the cause of injury.

Peroxidase: The peroxidase activity declined in YLD-affected arecanut and the reduction in enzyme activity was negatively correlated with severity. In plant disease, changes in the activity of peroxidase occur non-specifically in plant cell, under the influence of various exogenous and endogenous factors (Wood and Barbara, 1971; Fric, 1976). A number of investigations show that increased peroxidase activity in the host enhances plant resistance to diseases (Lovrekovich *et al.*, 1968; Loon and Geelen, 1971). Thus, the present finding on YLD of arecanut is in line with those of previous workers on other plant diseases.

Catalase: In YLD affected arecanut, the catalase activity was reduced drastically to 5.43—6.17 per cent over that of healthy palm. Reduced catalase activity is usually observed in chlorotic leaves (Dekock *et al.*, 1960). Dabeck (1974) found a significantly, lower catalase activity in leaves of coconut affected with lethal yellowing disease (CLY). Dabek and Hunt (1976) ascribed the reduced catalase activity in CLY to disturbed protein metabolism upon the onset of leaf chlorosis. Such derangements may occur YLD-affected arecanut. Owing to significant decline of catalase in YLD affected areca, H_2O_2 may accumulate in cells resulting in toxicity to cells.

Ascorbic acid and ascorbic acid oxidase: In diseased arecanut palm, the ascorbic acid content declined by 65.34 to 72.91 per cent with a slight increase in the activity of ascorbic acid oxidase. Enhanced activity of ascorbic acid oxidase and decline in ascorbic acid have been reported in several plant diseases (Kiraly and Farkas, 1957; Tonzing and Marre, 1961). The ascorbic acid oxidase is partly responsible for decline of ascorbic acid by oxidation process. Ascorbic acid is essential for the normal physiologcial functioning of plants and hence its depletion would retard this function.

The present results have shown that changes occur in the activity of oxidative enzymes in arecanut palms affected by YLD. The enzyme activity was altered according to the intensity of the disease. The changes in activity of enzymes, may be the result of callular injury by an yet unknown agent or cause. Further understanding would provide a base for better knowledge on the patho-physiological syndromes of arecanut YLD.

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MULTIPLE DEFICIENCY OF ZINC, BORON AND COPPER IN CARDAMOM

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ABSTRACT

A malady reported from certain plantations in Idikki District especially in Santhanpara-Chinnakkanal area has been found to be a case of multiple deficiency of zinc, boron and copper. The symptoms of the malady are, conspicuous white streaks on the foliage of cardamom, and high brittleness of the stem. The plants affected by this malady were found to be very weak. It was found that plants could be rejuvenated by the application of 500 ppm zinc, 200 ppm boron and 100 ppm copper.

INTRODUCTION

A new disease in cardamom (*Elettaria cardamomum* (L.) Maton) showing symptoms very much akin to those of *katte* disease as noticed in 1977 in a few plantations in Santhanpara and Chinnakkanal areas of Idikki District. The affected plants were found to deteriorate rapidly and the spread of the malady was very fast. The symptoms appeared on the leaves as conspicuous white streaks. The pseudostems of the affected plants were highly brittle. This study was undertaken to suggest a suitable control measure.

MATERIAL AND METHODS

Three affected clumps from Muthucaud estate, Chinnakkanal were transplanted to a new area away from the affected estate, and the performance of the plants was observed.

The following treatments were given by foliar application, to the affected plants in the above estate, where the malady was noticed first:

1. Zinc 500 ppm
2. Boron 200 ppm

3. Copper 100 ppm
4. Zinc 500 ppm+Boron 200 ppm
5. Zinc 500 ppm+Copper 500 ppm
6. Boron 200 ppm+Copper 200 ppm
7. Zinc 500 ppm+Boron 200 ppm+Copper 200 ppm

Each treatment was replicated thrice, and observations recorded after one month.

Results and Discussion

The recovery of affected plants after being transplanted in a new area suggests that it was not a pathogenic disease. It was hence presumed to be a case of nutritional disorder. There is very little chance for the deficiency of macronutrients occurring in cardamom plantations. Deficiency of micronutrients like iron and manganese also cannot be suspected. Plants sprayed with a combination of Zn, B, and Cu, put forth fresh leaves which were free of disease symptoms. The revival of affected plants following the foliar application of zinc, boron and copper would indicate that the plants had suffered due to deficiency of these elements. Hence foliar application of zinc (500 ppm), boron (200 ppm) and copper (100 ppm) is suggested for revival of such affected plsnts.

Acknowledgements

The author is thankful to the owner of the Muthucaud Estate, Chinnakana, where the experiment was conducted. He is also thankful to Sri. K. V. Georgel Director, Cardamom Board for the facilities provided for the study.

MANAGEMENT OF 'KATTE' DISEASE OF SMALL CARDAMOM

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ABSTRACT

Influence of periodical roguing of 'Katte' affected clumps on disease spread was studied for three years in four different plantations with various levels of initial inoculum. Roguing of affected clumps at monthly interval has resulted in reduction of the disease to a manageable level of less than one percent incidence, within three years irrespective of initial level of inoculum in the plantation. However, higher the initial inoculum more is the number of clumps to be rogued and replanted with healthy plants during the first year. Comparison of data on expenditure incurred on roguing of affected clumps one one hand, and production during different years on the other, revealed that roguing was economical. Roguing of diseased clumps at shorter intervals (weekly) only for 3 months, which is an average disease incubation period in host, appeared to be more advantageous in reducing the chance of secondary spread before its elimination. Large-scale implementation of 'Katte' eradication programme in growers' plantations revealed that it was possible to extend such programmes whereby the growers pay for technical assistance in tracing and roguing of affected clumps.

INTRODUCTION

'Katte' or 'Mosaic' is a serious disease of cardamom caused by the systemic infection of a non-persistent virus transmitted by the banana aphid *Pentalonia nigronervosa* f. *caladii* (Verma and Capoor, 1958; Rao and Naidu, 1973). Diseased plants can be easily recognized by their stunted growth and by the presence of characteristic mosaic symptoms in young leaves (Verma and Capoor, 1958). Infected plants rarely die but remain as a continued source of inoculum. The spread of the disease within the plantation is mainly internal and the rate of spread is slow (Deshpande *et al.*, 1972). Recent studies conducted on distribution of the

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disease revealed that it is prevalent in all the major cardamom growing tracts with varying intensity (Venugopal and Naidu, 1981).

Roguing of affected plants has been successful in reducing losses or preventing the spread of disease in perennial crops where the disease spread is slow and infection source is mainly internal, e.g. Plum Pox Virus in England (Adam, 1978), Citrus Tristeza Virus in Israel (Bar-Joseph *et al.*, 1974), and Cacao Swollen Shoot Virus in South Africa (Posnette, 1980). The results of investigations carried out on the influence of roguing 'Katte' affected clumps on the spread of disease and its role in disease management in well established plantations are reported here.

Material and Methods

Field experiments were conducted by selecting four different plantations in an area of 15 ha with different levels of initial inoculum under various situations such as (a) old plantation (18–20 years) situated between two infected plantations, (b) old plantation (20 years) with moderate inoculum (11%) confined to the two ends, (c) old plantation (25 years) with a well established high initial inoculum (23%), and (d) young plantation (2 years) with low level of inoculum (<1%). During January 1980, all the clumps in the 4 experimental plots were individually examined and 'Katte' affected plants marked on the basis of visual leaf symptoms. Affected clumps were sprayed with a systemic insecticide (10.05% dimethoate) and destroyed on the following day (Deshpande *et al.*, 1972). Spraying of affected clumps with the insecticide was not done from the 2nd year onwards based on the experimental evidence obtained by the authors that insecticidal application may enhance the spread of the disease. Subsequent surveys were carried out at monthly intervals over a period of three years and affected plants were rogued. Replanting of existing gaps due to roguing was taken up with healthy plants during the planting season. Data on the number of clumps rogued in various plantations during different years, expenditure incurred on roguing and yield of dry cardamom in different years were recorded.

During 1981, another experiment was conducted to study the effect of removal of affected clumps at weekly intervals on disease incidence, in an area of 3 ha consisting of 8205 clumps. The first survey was taken up in September during which vector population was less and immediately all the affected clumps were rogued without spraying with insecticide. Totally, 13 weekly surveys were carried out, and continued later at monthly intervals. The data on number of affected clumps rogued during different surveys in various blocks were recorded.

In order to test the feasibility of the 'Katte' eradication programme and the response of growers, extension work was initiated on 14th April, 1982, under the name 'Katte Clinic Programme' with the help of trained mazdoors under the supervision of a Junior Technical Assistant, . The growers paid the wages to the labourers involved in survey and roguing of the affected clumps at the rate of Rs. 12/– per mazdoor per day. The latest findings on 'Katte' disease management and the availability of 'Katte' clinic facilities were made known to the growers through lecture demonstrations and training programmes organized in their locality. Soon after receiving the request from a grower, a survey team was sent for tracing and roguing of affected clumps The data on extent of area covered, disease incidence and cost involved in tracing, were recorded.

Results and Discussion

Percentages of affected clumps rogued during different periods in various plantations are shown in Fig. 1. The number of affected clumps rogued during the first three months in all the four plantations were high. This was mainly due to cumulative infection over a number of years. During the first year, 0.66 to 42.18% clumps were rogued and replaced with healthy clumps in the four plantations (Table 1). This clearly suggests that higher the initial inoculum, more the number of clumps to be rogued during the first year. The mean percent of affected clumps rogued in different plantations in the subsequent years decreased considerably from 15.6% during 1980, to 0.88% in 1982 (Table 1). There were 7–and 18–fold reductions in the number of clumps removed by the end of 24 and 36 months respectively. The disease incidence in Plantation (a) could be kept at a manageable level by periodical roguing, although it was situated in between

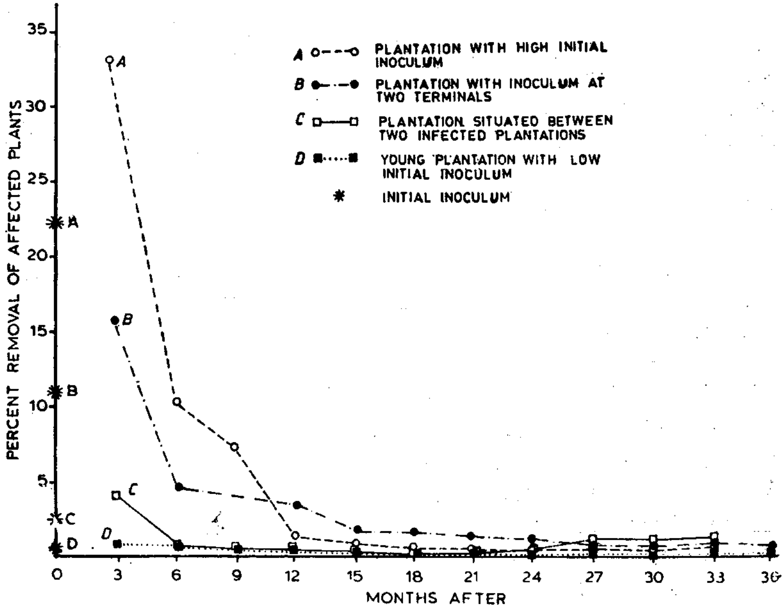

Fig. 1. **Effect of roguing of 'katte' affected clumps on disease incidence**

two affected plantations. This shows that, even if eradication of 'Katte' affected clumps is not practised in the neighbouring plantations this may not be a bottleneck in the management of disease in contiguous plantations. Varma (1962) studied the role of roguing of affected clumps with a view to eradicating the disease in severely affected plantations after complete removal and replanting with healthy clumps over a period of 7 years. The disease could not be eradicated completely. However, the disaease incidence could be kept below 1% by periodical roguing of affected clumps as against 80–90% in plantations where no roguing was done. In the present study, only affected plants were rogued and the results are in conformity with the findings of Varma (1962). There was yield reduction in plantations (b) and (c) during 1980 due to roguing of more number of affected plants (Table 1), whereas in the subsequent years, an increase in yield was observed. The expenditure involved in tracing and roguing of plants has been compensated for by the additional production realized during 1981 itself (Table 1). Thus, timely roguing and replacement with healthy seedlings resulted in checking the

Table 1. Number of affected clumps rogued during different years and production in different plantations

Plantation No. and description	Area (ha)	Total No. of Clumps	Initial inoculum		Clumps rogued						Yield of dry cardamom in Kg			
			No.	%	1980		1981		1982		1979	1980	1981	1982*
					No.	%	No.	%	No.	%				
(*a*) Old Plantation situated between two infected ones	0.5	1120	27	2.67	52	5.14	16	1.43	27	2.25	NR	NR	NR	NR
(*b*) Old plantation with inoculum at extreme ends	3.5	9510	942	11.23	1428	17.02	558	5.97	116	1.62	792	750	806	900
(*c*) Old plantation with high initial inoculum	5.0	15317	2331	23.64	4159	42.18	437	2.21	152	0.94	245	217	317	400
(*d*) Young plantation with less initial inoculum	6.5	17742	21	0.12	118	0.66	40	0.23	40	0.22	NC	242	1440	2000
Total	15.5	43689	3321	7.61	5757	15.56	1051	2.44	205	0.88				

NR=Not recorded
NC=No crop; 2nd year of planting
*=1982 Estimated yield

further spread of the disease, thus maintaining the production at a stable level and increasing the economic life of the plantation.

Effect of roguing at shorter intervals on disease incidence: The results presented in Table 2 show that the number of new outbreaks was very much less if the roguing is carried out at shorter intervals. The percent infection had reduced from 2.15 to 0.12 by the end of fourth month. Thus, it is advantageous to have a few surveys at shorter intervals for a period of 3 months which is the average disease incubation period in the host and most of the diseased clumps could be eliminated before they could serve as a source of inoculum for secondary spread. The results show, however, that total eradication of the disease is not possible because plants at symptomless stage or latent infections cannot be detected except through serological methods.

'Katte' Clinic Programme: There was encouraging response from the growers to this and in a period of 8 months, 60 plantations extending to 393 ha area distributed in 30 villages in Coorg District were covered. The salient findings of the 'Katte' clinic campaign are: (1) Disease is present in 88% of the plantations surveyed with different degrees of infection. (2) Isolated plantations remain free from the disease though these were planted 15–20 years ago. (3) disease incidence is very low (1%) in 70 per cent of the plantations and could ne economically managed by roguing the affected plants. (4) Disease is introduced in many isolated young plantations through the infected planting material due to lack of knowledge about the disease. (5) Nurseries raised adjacent to the affected plantation and also those raised through self-sown seedlings collected from diseased plantations were the sources of inoculum for the disease spread to disease-free areas. (6) Area covered by a mazdoor is 0.75–1.50 ha per day depending upon topography and age of the plantation, and the cost of tracing the affected plants is Rs. 12–18/ha.

The above study indicates that the 'Katte' eradication programme could be successfully implemented by charging the growers for the technical assistance rendered in tracing and roguing of affected plants. A 'Katte' clinic unit consisting of one Junior Technical Assistant and 3–4 trained mazdoors may be

Table 2. No of 'Katte' affected clumps eradicated in different blocks at CPCRI Res. Centre, Appangala.

Block No.	Total No. of Clumps	1981*														1982										
		Sept.	Oct.				Nov.					Dec.				Jan.	Feb.	Mar.	Apr.	May	June	Jul.	Aug.	Sep.	Oct.	Nov.
1.	1275	108	5	1	3	1	0	1	2	4	4	2	1	0	1	2	0	0	0	0	1	0	2	0	1	1
2.	750	19	1	2	2	1	1	0	2	2	2	0	0	0	0	0	0	0	1	1	0	2	1	1	1	0
3.	810	3	1	0	2	1	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.	682	15	2	2	2	0	0	0	3	1	2	1	1	0	0	1	0	1	0	0	1	0	0	0	0	0
5.	1948	3	7	3	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
6.	385	10	3	2	0	0	0	1	2	0	1	0	0	0	1	0	0	0	0	0	1	0	0	0	2	2
7.	790	10	0	0	1	3	4	0	0	0	0	0	0	1	1	4	2	0	1	0	1	0	1	0	0	0
8.	746	11	0	0	0	2	0	0	0	0	0	0	0	0	0	1	0	2	2	0	0	0	0	0	3	2
9.	809	—	—	—	—	—	—	—	—	—	—	—	0	0	0	0	0	0	1	1	0	2	2	0	1	3
Total	8205	176	19	10	10	8	6	3	9	8	10	4	2	1	3	8	2	3	6	1	4	4	6	1	8	8
Per cent		2.15	0.65				0.35					0.12				0.1	0.02	0.04	0.07	0.01	0.05	0.05	0.07	0.01	0.1	0.1

*Roguing done at weekly intervals in Oct., Nov., & Dec., 1981, and subsequently at monthly intervals.

opened in all the cardamom growing areas, at taluk level to help the growers in managing the disease.

The Govt. of Bombay tried to eradicate the 'Katte' disease in North Canara district by providing technical assistance at Govt. cost (Varma, 1962). Similarly, Cardamom Board also took up eradication programme in contiguous blocks by giving technical assistance for roguing, and supplying healthy plants free of cost, besides a subsidy of Rs. 0.75 per plant in the form of inputs (pesticides and fertilizers) over a period of five years. However, the disease could not be totally eradicated from plantations (Anon., 1981). The response from the growers for the Katte clinic in a short period clearly suggests that charging them for the technical assistance given in tracing the affected plants may help in the sucessful implementation of eradication programme, rather than giving inputs free of cost or on subsidy basis. Plant disease clinics for rendering diagnostic services on payment system are quite common in the advanced countries (Gail Evans–Ruhl, 1982).

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SESSION VI

Special Discussion on Mycorrhizae

Chairman : **Dr. C. L. Powell**

Rapporteurs : **Dr. C. R. Ramesh**

Dr. (Mrs.) Rohini Iyer

Report on Special Discussion on Mycorrhizae

During the PLACROSYM–V following the Session VI on Plant Pathology, a special discussion on Mycorrhizae was organized on 17–12–1982, under the Chairmanship of Dr. C. L. Powell of the Ruakura Social & Plant Research Station, Hamilton, New Zealand, who was in India as a Visiting Professor of Microbiology at TNAU, Coimbatore. Invited speakers included, Dr. K. R. Krishna from ICRISAT, Hyderabad, Dr. A. Manjunatha from GKVK, Bangalore, Dr. D. Kandaswamy from TNAU, besides Dr. C. R. Ramesh of CPCRI, Kasaragod.

Dr. Krishna briefly outlined ICRISAT's work on genotype response to VAM infection, efficiency of VAM strains, use of xylem-sap technique, and hybridizing VAM-sensitive hosts with those possessing other useful attributes. Dr. Manjunatha spoke of their VAM studies concerning, nutrient mobilization, resistance to disease and drought, interactions with rhizobia and nematodes, and efficiency of different inoculation methods. He outlined a procedure for selecting efficient organisms. Dr. C. R. Ramesh described the two programmes in progress at CPCRI, on the role of VAM on nutrient mobilization and their population dynamics in coconut-based multistoreyed cropping sysytem. The areas of future investigations emphasized were, VAM inoculation in nurseries, their ecophysiology in multilevel cropping systems, interaction with soil-borne pathogens and nematodes in the quick and slow wilts of pepper, effect of plant protection chemicals on mycorrhizal load, effect on rooting and field establishment of cashew, nutmeg and cloves, role of small mammals in VAM dispersal, and the mass production and establishment of VAM banks.

Dr. Kandaswamy outlined their programmes on VAM interaction with phosphobacteria, rhizobia, and the effect of plant protection chemicals on VAM ecology, population dynamics, and spore survival. In their studies on nine plantation crops, cinnamon was found to harbour the maximum VAM spores (314/50 ml soil) and nutmeg had the least (15/50 ml soil). *Glomus* was the major species forming 66.6 to 96.1 per cent of the resting spores, followed by *Gigaspora* (3.2–26.6 per cent). Other species like *Acaulospora* and *Sclerocystis* varied in their relative abundance with the crops studied.

The Chairman, Dr. Powell in his concluding remarks emphasized that all plantation crops are already having mycorrhizal infection, and hence for enhancing production as well as protection from root diseases, it is imperative to inoculate nursery plants with an efficient strain since the load required would be only 10–30 kg mycorrhizal soil per ha. The best strain to be used in the nursery mix must be assessed before attempting to produce plants for field trials. He advocated, therefore, nursery and field surveys to be followed subsequently by well planned field trials with adequate plot size, replications, and P–fertilizer rates, so that the long-term economic benefits of VAM inoculation can be assessed.

Discussions

R. D. IYER (CPCRI): How long does the VAM effect last and how often do you have to repeat the inoculation in a perennial system such as *Asparagus*?

POWELL: I have evidence that mycorrhizal inoculation will be needed only once in a perennial crop's lifetime.

K. D. PATIL (CPCRI): Does irrigation increase or decrease the mycorrhizal population?

POWELL: Excess irrigation, leading to waterlogging and consequent anaerobic conditions will greatly reduce mycorrhizal infection.

C. A. JOSEPH (KAU): The efficacy of nursery inoculation for coconut is doubtful since there are not many roots on the seedling at the time of planting. The technique may be useful for polybag nurseries. Since this has its own drawbacks preventing it from wide adoption, effect of inoculation of the planting pits may be studied.

POWELL: Mycorrhizal inoculum will still be present in the remaining root fragments. Mycorrhizal inoculum can be added to the planting hole also.

K. R. KRISHNA (ICRISAT): Host genotype is very impotrant since the natural susceptibility varies even within a species.

POWELL: It is most important that we select VAM fungi for the growth effects they have on plants and not necessarily for the number of spores they produce in soil.

CHANDRAMOULI (UPASI): How do you quantify the infection?

KRISHNA: According to the procedure given by Philips, JM. and Hayman, DS (1970): *Trans. Brit. mycol. Soc.* 55: 158–161.

M. LAKSHMANAN (Madurai Kamaraj Univ.): Is there a natural association of mycorrhizae with arid-zone crops such as maize and sorghum, or do they just respond to artificial inoculation with mycorrhizal fungi? What is the extent of prevalence of mycorrhizal infection?

KRISHNA: Arid-zone plants like sorghum and millets seem to have picked up mycorrhizae through an evolutionary process. In these crops, the infection rate is as follows: Sorghum 28–30%; Millets 30–45%, and chickpea 60%. They also respond to artificial inoculation of VAM.

M. S. SREENIVASAN (CCRI): Can we not use Gymnosperm mycorrhizae as a source of inoculum for other crop plants?

KRISHNA: As we find that there are highly specific combinations which confer greater efficiency, I wonder whether this source could be highly beneficial on crop plants.

C. KURUVILLA JACOB (RRII): Can mycorrhizal fungi and their propagules survive in acidic soils?

R. MANJUNATH: Mycorrhizal fungi can grow in soils having pH ranging from 4 to 8.

K. D. PATIL (CPCRI): How do mycorrhiza help in conferring greater drought tolerance to plants?

R. MANJUNATH: In stray cases, higher uptake of K has been observed which may be responsible for drought tolerance. The extending mycelial strands may help absorb water even below the wilting point. Mycorrhizal plants have revealed higher proline and thus might have imparted higher resistance for stomatal diffusion, compared to non-mycorrhizal plants. Mycorrhizal plants, when subjected to drought recover sooner compared to non-mycorrhizal plants after re-watering.

D. KANDASWAMY (TNAU): What is the extent and mode of survival of mycelium in soil?

R. M.: The fungus can survive in the roots of certain weeds like *Parthenium*, hariyali, nutgrass, etc. during the off-season.

RAJASAB (Gulbarga Univ.): How exactly do mycorrhizae spread from place to place?

R. M.: In a population, plant spread can occur through mycelium. We also have other dispersal agents like water. Animals also help to disseminate the spores.

SESSION VII

Entomology, Nematology and Rodentology

Chairman	:	**Dr. M. J. Chacko**
Rapporteurs	:	**Dr. N. Muraleedharan**
		Shri V. A. Abraham

ATTRACTANTS–AN AID IN RED PALM WEEVIL MANAGEMENT

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ABSTRACT

The red palm weevil (*Rhynchophorus ferrugineus* F.), is an enemy of young coconut palms. It bores into the tissues and ultimately kills the palm. Being a hidden enemy, timely detection is necessary for effecting control. Traps and attractants, by which adults can be trapped and killed have proved to be effective components of integrated pest management. Log traps consisting of tender coconut stems, 50 cm long and spilt longitudinally were found to be superior to metal traps. The cut surfaces were treated with candidate attractants. Macerated fruits, molasses (jaggery from sugarcane) and toddy, singly or in combination, were the test materials. Along with these, yeast and/or acetic acid was mixed to ascertain whether the same will enhance the attractiveness. Out of sixteen combinations tested in the field, logs treated with coconut toddy + yeast + acetic acid were the best, followed by coconut toddy + acetic acid, pineapple + molasses + yeast, pineapple + molasses, and molasses + yeast. The use of coconut log traps treated with the above combination is recommended as one of the effective components of integrated pest management.

INTRODUCTION

Rhynchophorus ferrugineus F., the red palm weevil, damages young coconut palms by boring into the tissues. If they are not detected early and controlled, they can kill the palm. Being a hidden enemy, difficulties in detection reduces the chances for effecting curative and timely control. Hence an integrated approach for the management of the pest is most eseential (Abraham and Kurian, 1975). Trapping the weevils, using a suitable attractant, and killing them form one of the components of pest management. Hagley (1965) reported that a mixture of malt, skatele and iso-amylacetate was significantly better than coconut stem tissue as an attractant for both sexes of *R. palmarum*. Field tests conducted at the Central Plantation Crops Research Institute, Regional Station

Kayangulam, using these in comparisen with toddy-treated log-trap, revealed that adults of *R. ferrugineus* were rarely attracted to the former, whereas the latter trap proved effective (Kurian, 1972). Metal traps filled with coconut petioles were reported to be effective in Sri Lanka and Trinidad (Maharaj, 1973). However, in India coconut logs proved more effective than metal trap (Kurian *et al.*, 1979). In the present study, an attempt was made to enhance the attractiveness of toddy and also to evaluate the attractiveness of various fruits to the weevils with a view to including this as a component of red palm-weevil management. The results of the experiment are presented here.

Material and Methods

Logs of tender coconut palm were cut to 50 cm length and split longitudinally into two equal halves. Coconut toddy, macerated grapes, cashew apple, pineapple, crushed sugarcane and molasses (jaggery from sugarcane) were the candidate materials. These were used either singly or in combination with yeast or acetic acid or both. The doses tried are presented in Table 1. The trap was prepared by smearing any one or a combination of the above materials on the cut surface of the split log. The split halves were put one over the other. Such log traps were kept 200m apart in cultivators' field having medium level of red palm weevil infestation. Traps were set towards dusk and weevils were collected in the early morning. The treatments and observations were continued for three days.

Table 1. Dosage of different test materials used

Toddy	One litre—200 ml/log
Toddy + Yeast	5 g yeast in one litre toddy @200 ml/log
Fruits or Sugarcane + Yeast	5 g yeast for 500 g of pineapple, oil palm fruit, grapes, cashew apple or sugarcane @100 g/log
Toddy + Acetic acid	5 ml acetic acid for one litre toddy @200ml/log
Fruits + Acetic acid	5ml acetic acid for 500g of fruits @ 100g/log
Fruits + Molasses (jaggery)	50 g molasses (jaggery) for 500 g of fruits @100 g/log
Coconut water + Molasses	50 g of molasses in one litre coconut water @ 200 ml/log

Results and Discussion

The mean weevil catch per trap under various treatments is furnished in Table 2, where it is seen that, logs treated with a combination of coconut toddy, yeast and acetic acid was the best with a mean catch of 2.1 weevils per day against nil in control. Logs treated with toddy and acetic acid, pineapple+molasses+yeast, pineapple+molasses and molasses+yeast, followed the same trend. All other treatments attracted weevils, but to lesser degrees.

Table 2. Order of efficacy and mean catch per trap

Treatment	Mean catch of weevil
Log alone—Control	0.00
Log+Toddy+Yeast+Acetic acid	2.10
Log+Toddy+Acetic acid	1.90
Log+Pineapple+Molasses (Jaggery)+Yeast	1.70
Log+Pineapple+Molasses	1.60
Log+Molasses+yeast	1.50
Log+Toddy+Yeast	1.10
Log+Cashew apple	1.00
Log+Sugarcane+Yeast	1.00
Log+Pineapple+Yeast	0.86
Log+Grapes+Yeast	0.83
Log+Toddy	0.81
Log+Grapes	0.75
Log+Pineapple+Molasses+Acetic acid	0.62
Log+Molasses+Acetic acid	0.5
Log+Molasses+Coconut water	0.4

Toddy alone could catch only 0.81 weevil per day and the addition of acetic acid to toddy increased the catch to 1.9 and a further addition of yeast resulted in the maximum catch. Hence it is evident that addition of yeast or acetic acid to toddy is necessary for a better catch.

Molasses+yeast and molasses+acetic acid bagged 1.5 and 0.5 weevil respectively, indicating that along with molasses, yeast is superior to acetic acid. Adding molasess or molasses+yeast along with pineapple resulted in catches of 1.7 and 1.6 weevils but pineapple+yeast alone could catch only 0.86 weevils. This shows that along with pineapple, molasses must be added for enhancing its efficacy. Molasses with coconut water was least effective.

This study has resulted in bringing out the utility of locally available materials for attracting weevils which can be recommended for easy adoption by farmers. One or the other of these will be available throughout the year. They are cheap and leave no hazardous residues in the environment. Pineapple and grapes need not be of edible quality. Even overripe or partilally rotten fruits which do not have any market value could be used. Vinegar and yeast are readily available. Availability of coconut logs can sometimes be a limitation, but palms cut for various reasons could be made use of. Thus, trap collection and killing should form an important component of the integrated pest management programme, along with other control measures like field sanitation and prophylactic and curative insecticidal applications.

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Discussions

M. J. CHACKO, (CCRI): How are the weevils attracted to the trap, killed?

C. KURIAN: Mechanically.

M. J. C.: What is the range and duration of effectiveness of the trap?

C. K.: Two weeks very effectively, but if not completely dried, can be used for a longer period.

M. J. C.: Does any natural enemy get caught in the trap?

C. K.: Earwig predators are common which evidently predate on the eggs laid by females which preponderate over the males in trap in the ratio of 2:1.

N. MURALEEDHARAN, (UPASI): Is there any definite flight period for this weevil?

C. K.: All through the year and mostly nocturnal.

P. P. ZACHARIA, (J.D.A. Pondicherry): The important aspect of this pest is that it escapes detection. Has any attempt been made to develop an electronic device for the detection of this pest?

C. K.: The pest infestation could be detected by the external visual symptoms manifested by the attacked palm, viz. holes on the stem, exudation of a brown viscous fluid and extrusion of fibres from the holes, splitting of bases of leaf petioles and wilting of inner leaves. The feeding sound produced by the grubs of the pest is audible from close proximity. Prof. T. A. Davis had fabricated an electronic device which gave nearly 85 per cent efficacy in detecting pest infestation. Attempts are being made by Shri C. P. Ramachandran of CPCRI to fabricate a more sure detector.

P. S. SREENIVASAN (Palghat): Red palm weevil being nocturnal, has moonlight any effect on the magnitude of collection of weevils with the said trap?

C. K.: No marked difference in collection was observed, and so moonlight may not have definite effect on the nocturnal movement of the weevil.

A BACTERIAL PATHOGEN OF COCKCHAFER BEETLE

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ABSTRACT

The cockchafer, *Holotrichia* sp. (Coleoptera: Melolonthidae) is a serious pest of coffee, cardamom, oil seeds, vegetable crops, pulses, sugarcane and tobacco. A bacterial pathogen has been isolated from naturally infected grubs and it has been developed as a potential biological control agent of this pest. The pathogenic effect of this bacterium on this pest is presented and its feasibility and economic viability discussed.

INTRODUCTION

The adults of root grub (*Holotrichia* sp.) are known as cockchafer beetles. *H. serrata* Fabricius is a severe pest on cereals, pulses, oilseeds, vegetables, sugarcane and tobacco. *H. nilgiria* Arrow is a pest in all coffee growing areas (Sekhar, 1964; Chacko, 1978). The grubs attack the feeder roots of young and old *arabica* and *robusta* coffee (Sekhar, 1964). Various kinds of granular and systemic insecticides were screened against *Holotrichia* sp. (Venkataramiah, 1969; D'Souza *et al.*, 1970; Chacko and Bhat, 1974; Kumar *at al.*, 1982) and satisfactory control achieved.

In view of the problem of resistance developed by insects to chemical insecticides (Anon, 1970) and the toxic effect of pesticides and their metabolites on plants (Cameron, 1972; Chisholm, 1974; Finlyson *et al.*, 1976; Read and Chisholm, 1977), bacterial pathogens could be considered as a potential tool for biological control.

It was recognised that *Bacillus* sp. could cause milky disease and could infect a number of Scarabaeidae in much the same way as *Popillia japonica* (Kawanishi *et al.*, 1974). David and Alexander

(1975) found that sugarcane white grub (*H. serrata*) was infected by milky disease organisms and the percentage of mortality was very low. However, a bacterial pathogen had been isolated from the naturally infected grubs and field studies indicated higher potentiality.

MATERIAL AND METHODS

Preliminary screening for the presence of milky disease in the field populations of *H. nililgiria* was made at different sites in Thandikudi and Lower Pulney Hills (Tamil Nadu). At each site, the soil with plantation and vegetable crops was excavated to a depth of 15 to 17cm and was examined for the presence of grubs. All grubs were taken to the laboratory for identification. Infection was determined by microscopic examination of haemolymph of each grub.

Laboratory studies: *Bacillus* spores were administered to third-instar grubs either by intrahaemocoelic injection of measured dosage or by ingestion of spores mixed with soil. Spore material was prepared by heat-fixing diseased grubs and smearing blood samples on microscopic slides. For mixing with soil, spores were drawn from freshly heat-fixed grubs.

After injection, grubs were incubated individually in earthenware pots containing soil at room temperature for 30 days. Grubs exposed to treated soil were in groups of ten per pot and were incubated for 30 days. Boiled potato slices were added to the soil to provide food for the grubs. The presence or absence of disease in living grubs was detected by microscopic examination of haemolymph.

Field test: Coffee and brinjal seedlings were transplanted into the field 30 days before the test was made. The field was divided into three blocks, and the treatments consisted of: (*i*) check; (*ii*) bacterial spores @0.25g per 10 litres of water; (*iii*) bacterial spores @0.5g per 10 litres of water. Each of the plots measured 7.2×15m. The rate of spray application on an area basis was not calculated, since in the small plots used, speed of application and pressure of sprayer would result in incorrect conversions. In the field test, the dead grubs were collected and their haemolymph examined under a microscope to determine if their death had been caused by the pathogen applied for control.

Results and Discussion

Field survey for milky disease: During the year 1979–1980, the grub density in the field varied from 16–79/m^2. In certain sites, where mixed crops of brinjal, pulses and beans were present, the population of grubs and damage were both very high. Of the grubs identified, 43 per cent were *H. serrata* and 57 per cent *H. nilgiria*. The natural incidence of milky disease among *H. serrata* was only 13–14 per cent, whereas *H. nilgiria* showed a higher percentage of 19–24.

Injection test: This test revealed that both the species of chafer beetles were susceptible to the bacterial disease. However, *H. nilgiria* showed a higher percentage of infection. The concentration of spores showed a direct relationship with the mortality of the grubs. The lower the spore concentration, the lower was the infection (Table 1).

Table 1. Effect of *Bacillus* spores injected into third-instar grubs of chafer beetles[1]

Host insect	Spores/ grub	Per cent disease in		
		1 week	2 weeks	3 weeks
Holotrichia serrata	10^2	0	0	2
	10^3	0	27	32
	10^4	47	89	100
	10^5	100	100	100
Holotrichia nilgiria	10^2	0	0	5
	10^3	1	23	48
	10^4	59	100	100
	10^5	100	100	100

[1]Hundred grubs per treatment, incubated at 30$\pm$2°C.

Ingestion test: A concentration of 1×10^6 cells/grub could cause disease symptoms in the injected grubs, whereas oral infection of the grubs needed a higher number of cells. Of the concentrations used, 1×10^8 and 1×10^9 spores per kg of soil resulted in greater infection (Table 2).

Table 2. Effect of *Bacillus* spores on third-instar chafer beetle larvae infected by ingestion of spores

Host insect	No. of spores/kg of soil	Per cent diseased in			
		1 week	2 weeks	3 weeks	4 weeks
H. serrata	10^6	0	0	0	2
	10^7	0	0	18	22
	10^8	6	40	72	100
	10^9	49	68	75	82
H. nilgiria	10^6	0	0	0	0
	10^7	0	7	26	31
	10^8	16	49	63	69
	10^9	71	78	81	85

The microscopic observations enabled delineation of the symptoms of the field infected larvae into four distinct phases:

Phase I: No visual evidence of infection; haemolymph transparent the beginning of bacterial invasion into the haemolymph

Phase II: The haemolymph turned slightly grey and turbid

Phase III: The haemolymph off-white in color.

Phase IV: The hemolymph turned milky-white containing massive spore population.

The percentage mortality in each of the four phases of the infectious process observed for a period of 30 days is presented in Table 3. The data revealed that all phases of the disease occurred

Table 3. Visual observation on the infectious process of milky disease in larvae of *Holotrichia* sp.

Time of incubation (days)	Per cent larvae in designated phase of infection			
	I	II	III	IV
7	16	75	5	4
14	3	60	25	12
21	3	10	68	19
30	5	2	72	21

throughout the incubation period. Death also occurred at all phases of the disease (Tables 1 and 2). However, the largest percentage of grubs died during phases II and III of the the infectious process, sepecially during phase III, when spores do not predominate in the cell population.

Field test: The effect of this *Bacillus* sp. in the field was observed based on the number of live grubs. After spore application, the soil was excavated and the live and dead grubs were collected and recorded at regular intervals.

During the course of the study, the percentage of live grubs was reduced and that of infected grubs increased (Table 4) in both the populations of *Holotrichia*. However, spore application at the rate of 0.5 g per 10 litres of water showed a higher incidence of the disease symptoms (Table 5). The continual decline in the

Table 4. Percentage of infection caused by *Bacillus* spores in a field population of *Holotrichia* sp.

Day of observation	*H. nilgiria*		*H. serrata*	
	No. of grubs observed	Percentage infected	No. of grubs observed	Percentage infected
1	42	7.14	36	5.56
7	73	28.77	47	38.29
14	30	26.02	27	59.25
21	52	57.69	42	66.67
30	27	81.48	14	71.43
40	39	76.92	16	75.0
50	40	82.05	29	65.51
60	21	85.72	12	75.0

Table 5. Percentage of infection caused by different concentrations of spores in the field, after spray application

Host insect	Percentage of infection at spore concentration of	
	0.25 g	0.5 g
Holotrichia serrata	48	72
Holotrichia nilgiria	59	82

number of live grubs in the treated field compared with check showed that the bacterial spore was effective in the field as well.

Discussion

The disease symptoms are similar to those of *Bacillus popilliae* infection. At the early stages, the diseased grubs showed a turbidity of the blood and as the disease advanced, the infected larvae acquired a milky-white appearance. During the early stage of infection, the activity of the larvae was not affected; however, before death they became sluggish and turned slightly brownish, except for the rectal region, which became chalky-white in color.

The spores showed distinctive lenticular sporangia containing ellipsoidal, excentric spores. The spores and sporangia are larger than those of other milky disease bacteria (Beard, 1956; Steinkraus and Tashiro, 1967). However, they are similar in general appearance and form a morphologically related group of milky disease causing organisms.

It was presumed that *B. popilliae* caused death at phase IV in most of the field-infected larvae (St. Julian *et al.*, 1970). The death of the larvae even before phase IV in the field in the present study, might be due to rapid multiplication of vegetative cells rather than accumulation of spores, as envisaged by St. Julian *et al.*, (1972).

A high incidence of milky disease can be obtained by injecting 1×10^6 spores/grub. However, in the field, the number of spores needed for oral infection was high. Concentrations of 1×10^8 spores/kg of soil were needed to get the maximum incidence of the disease. The necessity for a large number of spores to infect the grubs was probably due to the extremely low germination and outgrowth rate of the bacterial spores in the soil. Presumably, natural build-up of spores in the field from diseased larvae does not occur rapidly. To have effective control of the larvae of *Holotrichia* sp., heavy concentrations of the spores must be applied in such a manner as to become available to the larvae.

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DISCUSSIONS

P. K. RAMDAS (Chikmagalur): What is the precondition for inoculation of pathogen?

N. KANNAN: There is no specific condition for the inoculation; it can be applied in any field conditions.

P. K. R.: What is the effect at different stages of the pest?

N. K.: The study was conducted on third-instars; the other instars namely 1st and 2nd having a shorter life period, it is difficult to assess the mortality in the field.

V. A. ABRAHAM (CPCRI): What was the control mortality in pathogenicity trial in 30 days?

N. K.: 2 to 3%.

V. A. A.: Could you observe any nematode association with diseased grub?

N. K.: No.

M. J. CHACKO (CCRI): Has the pathogen been identified?

N. K.: No, we have sent it for identification to UK.

M. J. C.: What is the relative rate of infection of the pathogen during the various seasons of the year?

N. K.: This has not been studied.

N. MURALEEDHARAN (UPASI): What was the level of infection in *Holotrichia* sp. under field conditions?

N. K.: The level of infection in *Holotrichia* sp. under field condition for *H. serrata* was 13–17% and for *H. nilgiria* it was 19–22%.

S. VARADARASAN (ICRI, Batlagundu): Mention was made about *Holotrichia* as a serious pest on cardamom and other crops. Is it so serious on cardamom? If so what are the areas observed?

N. K.: Yes. It is a serious pest on cardamom and coffee. We have observed the presence of the larvae feeding on the crops from Thandikudi, Lower Palani Hills area.

EAPEN GEORGE (A. V. Thomas & Co. Ernakulam): What is the cost comparison on treatments ?

N. K.: When compared to the cost of other pesticides, synthetic pyrethroides may work out cheaper at the tested dosage.

T. NATARAJ: Difference on the efficacy of treatments employed through high and low volume spraying machine has not been given.

N. K.: Comparison of the data between the two different sprayings was not made but the results clearly showed that both methods were equally effective on the first year tea fields.

GOVINDARAJAN, T. S.: With pyrethroids the significant results were obtained only by 4th week whereas in 1st, 2nd and 3rd weeks, no significant results were obtained. May I know whether any attempt was made to try combination and attracting spray chemicals in 1st or 2nd week while the pyrethroids in 3rd and 4th week? Possibly we may get better control.

N. K.: The performance of synthetic pyrethroids was more pronounced in the later weeks because these chemicals are more persistant than other chemicals.

FIELD EVALUATION OF SYNTHETIC PYRETHROIDS AGAINST *SCIRTOTHRIPS BISPINOSUS* (*BAGNALL*) INFESTING TEA

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ABSTRACT

Several organophosphate and chlorinated hydrocarbon insecticides are known to be useful in controlling thrips attacking tea, *Scirtothrips bispinosus* (Bagnall), which is widely distributed in South India. In the present study, five synthetic pyrethroids, namely, permethrin, cypermethrin, fenvalerate, fenpropathrin and deltamethrin were evaluated at different dosage rates against the pest. Additionally, phosalone, endosulfan, and ethion, which are cleared for residue tolerance levels in tea, were also field tested. All the synthetic pyrethroids gave excellent control of tea thrips even at very low rates of application.

INTRODUCTION

In recent years, thrips have assumed considerable importance as pests of tea in most of the tea growing areas of the world. *Scirtothrips bispinosus* (Bagnall), (Thysanoptera, Thripidae) endemic to South India, infests tea and coffee. The intensity of thrips damage is more pronounced in tea fields recovering from pruning, leading to an inordinate delay in tipping and severe crop loss in the first year (Rao and Murthy, 1976). Several organochlorine and organophosphorus compounds have been recommended for the control of tea thrips, but for large-scale application the choice is limited to endosulfan, ethion and phosalone which have been cleared by the Environmental Protection Agency of the U.S.A. for residue tolerance levels in black tea (Muraleedharan *et al.*, 1982).

The present paper relates to the results of field experiments conducted to evaluate the efficacy of five synthetic pyrethroids namely permethrin, cypermethrin, fenvalerate, fenpropathrin and deltamethrin, against *S. bispinosus*. These chemicals were tested against this species for the first time.

Material and Methods

Field trials were laid out in three tea estates in the Nilgiris (Tamil Nadu) during 1981 and 1982. The experimental fields, of mixed seedling tea, had a bush population of 6750 plants per hectare, and were in their first year after pruning. The trials were in randomized block design with three replications, each block consisting of 100 bushes. The details of treatments are given in Tables 1 to 3. In the first two experiments, spraying was done with motorized air blast sprayers, using a spray volume of 275 litres/ha, and in the third experiment, hand-operated knapsack sprayers were employed at a spray volume of 400 litres/ha. In all cases, two rounds of spray were given at fortnightly intervals.

Post-treatment assessment of thrips populations was carried out at weekly intervals by collecting 25 shoots at random from each block, each shoot consisting of four leaves and a bud. The shoots, collected in polythene bags, were immersed in 70% alcohol for 10 minutes, shaken thoroughly, and the adult and larval thrips counted. Pre-treatment assessment of *S. bispinosus* populations was carried out in a similar manner.

Results and Discussion

The results have shown that all the synthetic pyrethroids were highly effective against *S. bispinosus* (Tables 1 to 3). The lower rates of application of these chemicals were as effective as the higher doses. However, deltamethrin 2.8 EC @ 120 ml/ha was slightly inferior to the higher rate of the same chemical. Thus, deltamethrin when applied at 150 ml/ha gave very good control over thrips, the efficacy being similar to that of other synthetic pyrethroids. Experiments 1 and 3 were laid out in fields with high level of thrips infestation, whereas the second experiment was conducted in a tea field with low incidence of thrips. The results showed that these new group of chemicals have a definite advantage over the others when pest populations are high. Their performance was significantly superior to that of endosulfan, ethion and phosalone. Among these, phosalone and ethoin were found to be superior to endosulfan. The coded compound RH–0995 (O–4 (4–Chlorophenythio) phenyl) O–ethyl S–propyl phosphorothioate was as effective as phosalone.

Table 1. Field evaluation of synthetic pyrethroids against *Scirtothrips bispinosus* (1981)

Treatment	Dosage/ha	Number of thrips				
		Pre-treatment	Post-treatment			
			I week	II week	III week	IV week
Permethrine (Permasect 25 EC)	100 ml	286 (29.4)	10 (6.06)ab	29 (9.43)b	6 (5)abc	7 (5.38)abc
— do —	200 ml	233 (26.44)	4 (4.55)a	14 (7.1)ab	4 (4.46)ab	4 (4.46)a
Cypermethrin (Cymbush 25 EC)	80 ml	234 (26.65)	9 (5.79)ab	15 (7.02)ab	6 (4.86)abc	8 (5.65)abc
— do —	160 ml	312 (30.46)	10 (6.24)ab	9 (5.97)ab	11 (6.48)cd	10 (6.06)abc
Fenvalerate (Sumicidin 20 EC)	100 ml	228 (25.97)	7 (5.38)ab	16 (7.19)ab	7 (5.38)abc	14 (7.07)abc
— do —	200 ml	291 (28.7)	8 (5.59)ab	11 (6.48)ab	9 (5.97)bcd	9 (5.79)abc
Deltamethrin (Decis 2.8 EC)	120 ml	303 (30.16)	12 (6.56)ab	34 (10.48)bc	7 (5.41)abc	6 (5.06)ab

Deltamethrin (Decis 2.8 EC)	320 ml	254 (27.28)	7 (5.41)ab	7 (5.38)a	2 (3.82)a	4 (4.41)a
Endosulfan (Thiodan 35 EC)	1 litre	293 (29.43)	23 (8.18)ab	119 (18.22)de	20 (7.73)de	47 (12.07)d
Phosalone (Zolone 35 EC)	1 litre	258 (27.65)	27 (8.85)ab	36 (10.68)bc	24 (8.94)e	25 (8.57)c
RH–0995 45 EC(C oded chemical)	500 ml	207 (24.9)	14 (6.73)ab	78 (15.3)cd	16 (7.45)de	18 (7.9)bc
Untreated control	—	269 (28.54)	297 (29.89)c	149 (21.15)ef	147 (20.89)f	83 (15.76)e
CD at P =0.05		N.S.	4.06	5.36	1.8	3.4

Table 2. Control of tea thrips with synthetic pyrethroids (1982)

Treatments	Dosage/ha	Number of thrips				
		Pre-treatment	Post-treatment			
			I week	II week	III week	IV week
Permethrin (Permasect 25 EC)	100 ml	69 (16.79)	8 (5.65)ab	2 (3.73)a	2 (3.73)a	1 (3.41)a
— do —	200 ml	102 (17.72)	1 (3.41)a	1 (3.41)a	2 (3.82)a	2 (3.82)a
Cypermethrin (Cymbush 25 EC)	80 ml	75 (15.27)	7 (5.41)ab	4 (4.41)a	0 (3)a	1 (3.41)a
— do —	160 ml	81 (15.86)	3 (4.23)ab	7 (5.38)a	2 (3.82)a	2 (3.82)a
Fenvalerate (Sumicidin 20 EC)	100 ml	89 (16.51)	0 (3)a	4 (4.46)a	2 (3.82)a	2 (3.73)a
— do —	200 ml	87 (16.43)	1 (3.41)a	0 (3)a	1 (3.41)a	0 (3)a

Deltamethrin (Decis 2.8 EC)	120 ml	101 (17.54)	4 (4.41)ab	8 (5.73)a	3 (4.14)a	1 (3.41)a
— do —	320 ml	91 (16.71)	15 (6.28)ab	5 (4.65)a	2 (3.82)a	1 (3.41)a
Enfosulfan (Thiodan 35 EC)	1 litre	94 (17.04)	4 (4.46)ab	1 (3.41)a	0 (3)a	4 (4.41)a
Phosalone (Zolone 35 EC)	1 litre	92 (16.88)	7 (5.46)ab	1 (3.41)a	4 (4.41)a	5 (4.87)a
Untreated control	—	74 (15.19)	131 (20.04)c	121 (19.28)b	43 (11.73)b	65 (14.07)b
CD at P=0.05		N.S.	2.86	2.95	1.45	2.05

Table 3. Efficacy of synthetic pyrethroids against *Scirtothrips bispinosus* (1982)

Treatment	Dosage/ha	Number of thrips				
		Pre-treatment	Post-treatment			
			I week	II week	III week	IV week
Permethrin (Ambush 50 EC)	50 ml	392 (3.41)a	52 (12.72)ab	33 (9.81)a	17 (7.61)abc	25 (9.13)bc
Cypermethrin (Ripcord 10 EC)	200 ml	387 (33.72)a	39 (10.49)a	36 (10.7)a	32 (9.71)abc	13 (6.93)a
Fenvalerate (Sumicidin 20 EC)	100 ml	368 (32.82)a	47 (11.93)a	45 (11.58)a	8 (5.59)a	26 (9.32)bc
Deltamethrin (Decis 2.8 EC)	150 ml	378 (33.73)a	64 (12.8)ab	22 (8.18)a	14 (7.01)ab	18 (7.93)ab
Fenpropathrin (S–3206 20 EC)	50 ml	315 (30.64)a	84 (15.94)abc	50 (12.29)a	16 (7.45)ab	18 (7.85)ab
Ethion (Fosmite 50 EC)	1 litre	428 (35.87)a	188 (22.62)c	125 (19.51)b	63 (13.33)cd	40 (11.33)d
Endosulfan (Thiodan 35 EC)	1 litre	557 (40.98)a	160 (21.81)bc	51 (12.48)a	95 (17.19)dc	97 (17.03)e
Phosalone (Zolone 35 EC)	1 litre	472 (37.72)a	129 (19.78)abc	91 (12.32)a	55 (12.75)bc	32 (10.11)cd
Untreated control	—	539 (40.09)a	461 (36.66)d	226 (26.07)e	170 (22.57)e	152 (20.94)f
CD at P==0.05		N.S.	9.19	5.64	5.83	1.61

The synthetic pyrethroids though costly when compared with other pesticides are economical because the rate of application is low. Das (1982) had shown that these chemicals were cheap and highly effective against *S. dorsalia*, the Assam tea thrips. The quick knockdown effect, lipophilicity and rainfastness of these new chemicals may help in reducing the spraying rounds also.

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Discussions

PERIYAKARUPPAN (Mysore Plantations): What was the interval between the spray rounds?

N. MURALEEDHARAN: Two weeks.

P. K.: Whether pyrethroids could be used on extended spray rounds?

N. M.: The spraying interval is not to be reduced for the first two sprays, but the total number of sprayings can be considerably reduced.

P. K.: Were these experiments carried out on 4th and 5th year fields also, or only in first year fields?

N. M.: The present experiments were conducted only in the first year fields not in older fields since thrips infestation was more pronounced in the first year fields.

P. K.: How can the 15-days round for pyrethroids and conventional chemicals be taken to be the same?

N. M.: The fifteen-day interval for spraying is recommended for conventional pesticides and the same standard was adopted for synthetic pyrethroids also.

P. S. SRINIVASAN (Palghat): What is the relative performance of motorized air-blast sprayer versus hand sprayer?

N.M.: In the first year fields where experiments were conducted, no difference was observed between the two types of spraying; but it would be economical and safe to use hand-operated knapsack sprayers.

EAPEN GEORGE, (A. V. Thomas & Co. Ltd., Cochin): How is the cost comparison on treatments?

N. M.: When compared to the conventional pesticides, synthetic pyrethroids may work out cheaper at the tested dosage.

T. NATARAJ (CRS): Was there any difference in the efficacy of treatment employed through high and low volume spray machines?

N. M.: Comparison of the data between the two different sprayings was not made, but the results clearly showed that both methods were equally effective in the first year tea fields.

T. S. GOVINDARAJAN (Coffee Board, Kalpetta): With pyrethroids significant results were obtained only by 4th week, whereas in 1st, 2nd and 3rd weeks, no significant results were obtained. Was any attempt made to try a combination of spray chemicals in 1st or 2nd week alternating with the pyrethroids in 3rd and 4th week? Possibly we may get better control?

N.M.: The performance of synthetic pyrethroids was more pronounced in the later weeks because these chemicals are more persistent than conventional chemicals.

INFLUENCE OF PREY ON THE BIOLOGY OF *CRYPTOLAEMUS MONTROUZIERI* I. GREEN SCALE AS FOOD

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ABSTRACT

Influence of diet on the biology of *Cryptolaemus montrouzieri* Mulsant was studied, with green scale and mealybug as prey. When the prey was green scale the larval period was longer and the weight and size of larva, pupa and adult and growth index were significantly less than when the prey was mealybug. Studies on reproduction have shown that the beetles fed on green scale throughout larval and adult stages, failed to lay eggs and the longevity was impaired. On the other hand, when mealybug was the prey during larval and adult stages, the fecundity and longevity increased significantly. The fecundity of beetles fed on mealybug during larval stage and on green scale in adult stage, was reduced almost to zero and longevity also was impaired. On the contrary, when the beetles were fed on green scale during larval stage and on mealybug in adult stage, the fecundity increased significantly and longevity was on par with those which fed on mealybug throughout. Alternate feeding on green scale and mealybug during the adult stage has shown that the fecundity was normal whenever mealybug was prey, while the same was impaired whenever the prey was green scale. Dissection of female beetles has shown that the development of eggs was normal only when the prey was mealybug. The present studies have shown the importance of mealybug as food for the normal development and reproduction of *C. montrouzieri*.

INTRODUCTION

The Australian ladybird beetle *Cryptolaemus montrouzieri* Mulsant (Coleoptera, Coccinellidae) was used as a biocontrol agent in many parts of the world against mealybugs attacking coffee (Le Pelley, 1968). However, substantial control was obtained only in Celebes and Hawaii (Van der Goot, 1948; Zimmerman, 1948). This predator was introduced into India in 1898 in an attempt to control the coffee green scale, *Coccus viridis* (Green) (Homoptera, Coccidae), by Mr. H. O. Newport, an amateur entomologist and coffee planter of the lower Pulney Hills in Tamil Nadu (Puttarudriah *et al.*, 1952; Mayne 1953). Rao *et al.* (1971) reported that though this predator did not become established on green scale, it was subsequently recorded from a number of localities in South India as a common predator of mealybugs. Charanasri and Nishida (1973) studied the relative abundance of three Coccinellid predators of *C. viridia* on plumeria trees (*Plumeria robusta*) in Honolulu, and found that population of *C. viridis* remained below economic threshold, which was attributed to these predators, and among them, the population of *C. montrouzieri* was least. In New Caledonia also, *C. viridis* was preyed upon by *C. montrouzieri* (Chazeau, 1981). Chacko (1977) reported the feeding of *C. montrouzieri* on nymphs and eggs of the brown scale, *Saissetia coffeae* (Walker) (Homoptera, Coccidae), attacking coffee on Pulney Hills. The biology of this predator was studied by different workers (Bishop, 1931; Bhat *et al.*, 1979; Fisher, 1963; Hall, 1926; Liotta and Mineo, 1965; Mineo, 1967; Rao and David, 1958; Van der Goot, (1920). In coffee plantations of South India the simultaneous occurrence of mealybugs, green scale and brown scale is common. As the predator feeds on green scale also, the present study was taken up with the objective of understanding the influence of green scale as prey on the biology of *C. montrouzieri*.

MATERIAL AND METHODS

Experiment I: The ladybird beetles were maintained on mealybug cultured on ripe pumpkins. Ten pairs of freshly emerged adults were selected and each pair kept in a Petri-dish with mealybug as food for egg laying. The eggs were collected and kept in cavity blocks, one in each and allowed to hatch. The newly hatched grubs were divided into two batches of 60 each. In one batch, each grub was transferred into a glass vial (8.0 × 2.3 cm) and supplied with bits of coffee leaves infested with green scale and the vials were plugged with cottonwool. Fresh bits of green scale-infested coffee leaves were provided daily till the grubs pupated. In the other batch, the newly hatched grubs were kept individually in a cavity block (5.5 by 5.5 cm) and mealybug was given as food. The cavity blocks were covered with glass plates.

Observations were made on duration of larval period, larval weight, percentage of pupation, pupal period, pupal weight, percentage of adult emergence and adult size and weight. Date pertaining to larval period and weight, pupal period and weight, and adult size and weight, were statistically analysed. Growth index was obtained by dividing the percentage of larvae becoming pupae by average larval period as adopted by Srivastava (1959) and Pandey *et al.*, (1968).

Experiment II: (*a*) The beetles emerging from larvae fed on green scale, were paired and divided into two batches, and each pair was kept in a cavity block. Green scale was given for the first batch and mealybug for the second batch as food. The beetles emerging from the batch fed on mealybug during larval stage were also similarly paired and divided into two batches, and each pair was maintained in a cavity block. Green scale was given as food for one batch and mealying for the other. Observations were recorded on the duration of pre-oviposition, oviposition and post-oviposition periods, longevity, fecundity, incubation period, viability and size of eggs. Data pertaining to fecundity, size of eggs and longevity were statistically analysed.

In each of the four batches there were five replications with two pairs of beetles per replication. The remaining beetles were used for dissection and observation on egg development.

(*b*) To study the effect of feeding alternately on green scale and mealybug and *vice-versa* during the adult stage, on the fecundity of *C. montrouzieri*, beetles that emerged from grubs which fed on mealybug were collected and divided into two batches. In each batch there were five replications of one pair each. Initially, the first batch was maintained on mealybug and the second on green scale. After 18 days, the first batch was shifted to green scale and the second to mealybug. Again after 30 days, the first batch was shifted back to mealybug and the second to green scale. Observations were recorded on fecundity, incubation period and viability.

All the studies were carried out in the laboratory where the temperature varied from 21.5° to 30°C and relative humidity from 76 to 100 per cent.

Results and Discussion

Experiment I: The details of duration of different stages of *C. montrouzieri* which fed on green scale and mealybug during larval stage are presented in Table 1. The data show that the duration of larval stage was significantly more when green scale was food; but there was no difference in the duration of pupal stage (Table 2).

Table 1. Influence of prey on duration of larval and pupal stages of *C. montrouzieri*

Prey	Stage of predator	Duration (days)	
		Range	Average
Green scale	I instar	3–5	3.58
	II instar	3–5	3.40
	III instar	4–7	5.85
	IV instar	7–12	9.73
	Larval duration	17–29	22.33
	Pupal duration	9–12	10.50
	Total larval and pupal duration	26–41	32.68
Mealybug	I instar	3–4	3.30
	II instar	2–4	3.09
	III instar	3–4	3.12
	IV instar	6–7	6.75
	Larval duration	14–19	16.20
	Pupal duration	10–12	10.73
	Total larval and pupal duration	24–31	26.95

The percentage of larvae that pupated was 87.5 with green scale as food, and 95 with mealybug as food. The growth index was 5.864 with mealybug and 3.918 with green scale. The grubs fed on green scale were small and had comparatively poor was threads, and their weight (on 15th day) varied from 2.0 to 5.9 mg with an average of 3.15. The grubs fed on mealybug were robust and profusely covered with wax threads. Their weight (on 15th day) varied from 7.2 to 22.5 mg with an average of 16.72, which was highly significant (Table 2). The pupae of green scale-fed grubs were small, with scanty wax strands, the weights of which (on 6th day) varied from 8.0 to 11.1 mg (average 9.37), whereas the pupae of mealybug-fed grubs were larger and more profusely

Table 2. Influence of prey on different stages of *C. montrouzieri*

Prey	Mean duration (days) of 40		Mean weight (mg) of 20		Mean size of 20 adults (mm)				Mean weight of 20 adults (mg)	
					Male		Female			
	larvae	pupae	larvae	pupae	Length	Breadth	Length	Breadth	Male	Female
Green scale	22.33	10.50	3.15	9.37	4.22	2.80	4.49	2.80	5.96	6.52
Mealybug	16.20	10.73	16.72	16.25	4.81	3.07	4.97	3.20	9.99	11.50
Significance	**	NS	**	**	**	**	**	**	**	**
C.D. at 5%	0.61	—	0.61	0.80	0.11	0.06	0.15	0.12	0.69	0.89
at 1%	0.80	—	0.80	1.06	0.14	0.08	0.20	0.16	0.91	1.17

**Significant at 1% level; N.S.=not significant.

covered with wax strands, their weights (on 6th day) varying from 14.1 to 18.5 (average 16.25) mg which was also highly significant (Table 2). The adult males of grubs fed on green scale measured 4.1–4.5 (av. 4.22) mm in length and 2.5–3.0 (av. 2.80) mm in width and adult females 4.2–5.0 (av. 4.49) mm in length and 2.5–3.0 (av. 2.80) mm in width. Adult males of grubs that fed on mealybug measured 4.4–5.0 (av. 4.81) mm in length and 3.0–3.2 (av. 3.07) mm, in width and females 4.5–5.1 (av. 4.97) mm in length and 3.0–3.5 (av. 3.20) mm in width. The weight of adult males of grubs which fed on green scale varied from 4.35 to 6.4 (av. 5.96) mg and that of adult females from 4.7 to 9.8 (av. 6.32) mg. The weight of adult males of grubs that fed on mealybug vaiied from 8.78 to 12.6 (av. 9.99) mg and that of females from 9.5 to 13.9 (av. 11.50) mg. The length, breadth and weight of male and female beetles of grubs that fed on mealybug were significantly more than those of male and female beetles of grubs which fed on green scale (Table 2). The percentage of adult emergence from the green scale-fed batch was 90, while it was 96 in the case of mealybug-fed batch.

From the foregoing data it is clear that when the prey was green scale, not only the larval period of *C. montroizieri* was extended, but the weight and size of larva, pupa and adult, and growth index were reduced significantly.

Experiment II: (*a*) The beetles which fed on green scale throughout larval and adult stages, failed to lay eggs. The longevity of males ranged from 16 to 41 (35.6) days and that of females from 35 to 60 days (43.5).

The fecundity of beetles which fed on mealybug in larval and adult stages varied from 292 to 1,003, with an average of 725.9. The pre-oviposition period varied from 3 to 5 (av. 4.3) days. the oviposition period from 41 to 126 (av. 96.0) days and the post-oviposition period from 1 to 7 (av. 2.5) days. The longevity of males ranged from 75 to 152 (av. 132.1) days, and of females from 47 to 134 (av. 101.8). The eggs were bold in appearance and yellow in colour. They were 0.75–0.82 (av. 0.78) mm long, and 0.37–0.42 (av. 0.41) mm wide (Table 3). The incubation period varied from 5 to 7 (av. 5.65) days. Viability was 100%.

Table 3. Influence of prey on fecundity, size of eggs, and longevity of *C. montrouzieri*

	Mean fecundity	Mean size of 20 eggs (mm)		Mean longevity (days)	
		Length	Breadth	Male	Female
Larvae and adults on green scale	0	—	—	35.6	43.5
Larvae and adults on mealybug	725.90	0.78	0.41	132.1	101.8
Larvae on mealybug and adults on green scale	2.20	0.70	0.37	40.6	35.7
Larvae on green scale and adults on mealybug	489.60	0.75	0.37	131.5	106.9
Mean	304.43	0.74	0.38	84.9	72.0
Significance	**	**	**	**	**
C.D. at 5%	143.40	0.01	0.1	8.48	14.39
C.D. at 1%	201.05	0.02	0.02	11.86	20.13

**Significant at 1% level.

Out of the ten pairs of beetles fed on mealybug during larval stage and on green scale during adult stage, only four females laid eggs varying from 2 to 10 with an average of 2.2. The pre-and post-oviposition periods were 3 to 6 (av. 4.0) and 25 to 54 (av. 39.5) days. The eggs were supple, the chorion of which was soft and white in colour. They were 0.64–0.76 (av. 0.70) mm long and 0.36–0.42 (av. 0.37) mm wide. The viability was 55 per cent and the incubation period varied from 5 to 7 (av. 5.83) days. The longevity of males ranged from 17 to 60 (av. 40.6) days, and of females from 20 to 60 (av. 35.7) days.

The fecundity of beetles which fed on green scale during larval stage and on mealybug during adult stage, however, ranged from 200 to 822 with an average of 48.96. The eggs were normal except for a slight reduction in size. They were 0.71-0.78 (av. 0.75) mm long and 0.34–0.40 (av. 0.37) mm wide. The incubation period varied from 5 to 8 (av. 6.24) days. The viability was 99%. The pre-ovi-position period ranged from 5 to 8 (av. 6.6) days, the ovi-position period from 62 to 116 (av. 94.8) days, and post-oviposition period from 2 to 11 (av. 5.5) days. The longevity of males ranged from 120 to 132 (av. 131.5) days, and that of females from 72 to 123 (av. 1.069) days.

These studies (Table 3) show that the beetles either failed to lay eggs or their longevity was reduced significantly when they were fed on green scale throughout larval as well as adult stages. On the other hand, when mealybug was the prey throughout larval and adult stages, the fecundity of beetles was significantly high. The fecudity was reduced drastically (almost to zero), and also the longevity when the beetles were fed on mealybug during larval stage and green scale in adult stage. On the contrary, when the beetles were fed on green scale during larval stage and on mealybug during adult stage, the fecundity and longevity increased significantly.

Beetles were dissected on the tenth day. In case of females which fed on green scale throughout larval as well as adult stages, there was no egg development. On the other hand, developed and developing eggs were noticed in beetles which were fed on mealybug during larval and adult stages. Development of eggs was noticed also in case of females which fed on green scale during larval stage, and on mealybug during adult stage. But in case of females, which fed on mealybug during larval stage, and on green scale during adult stage, only very few developing eggs were found. These observations further support the data on fecundity of beetles, with green scale and mealybug as food.

(*b*) The five pairs of adults which were maintained initially on mealybug laid 101 to 232 eggs, with an average of 132 in 18 days. The viability was 100 per cent and the incubation period varied from 5 to 7 (av. 5.6) days. When these beetles were shifted to green scale (for 30 days), they failed to lay eggs normally. The number of eggs laid by 5 females varied from 0 to 5 with an average of 1.8 in 30 days. The eggs were supple with a soft chorion. Only 3 eggs hatched out of 9, the incubation period of which varied from 5 to 7 (av. 5.66) days. When these beetles were shifted back to mealybug from green scale, they laid normal eggs, whose number ranged from 20 to 41, with an average of 27 eggs in 12 days, after which they died. The viability was 98 per cent and the incubation period varied from 6 to 7 (av. 6.6) days (Table 4).

Table 4. Effect of feeding alternately on mealybug and green scale on the fecundity, viability and incubation of *C. montrouzieri**

Prey	Duration of feeding (days)	Fecundity Mean $\pm$ S.E.	Viability: Total no. of eggs laid	Viability: Total no. of eggs hatched	Incubation period (days) mean
Mealybug	18	132$\pm$25.08	660	660	5.60
Green scale	30	1.8$\pm$0.97	9	3	5.66
Mealybug	12	27$\pm$3.64	135	132	6.60
Green scale	18	0.40$\pm$0.40	2	0	—
Mealybug	30	205$\pm$31.24	1025	1018	6.1
Green scale	14	0	0	—	—

*of 5 females.

In the other batch of five pairs of adults which were initially maintained on green scale, only one female laid eggs (2 eggs in 18 days), which failed to hatch. After this, the adults were shifted to mealybug. Within 3 to 5 days of feeding on mealybugs, all the five females started laying normal eggs. The number of eggs laid varied from 124 to 276 with an average of 205 in 30 days. The viability was 99.4 per cent and the incubation period varied from 5 to 7 (av. 6.1) days. When these beetles were again shifted back to green scale, they failed to lay eggs, and died within 14 days (Table 4).

Thus the studies on alternative cycle of feeding on green scale and mealybug during the adult stage, have also shown that the fecundity and viability were normal only when mealybug was the prey, whereas the same were impaired when the prey was green scale.

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DISCUSSION

N. MURALEEDHARAN (UPASI): In the field population did you observe any size variations?

K. VENKATESULU: Field surveys were not conducted in this regard.

OCCURRENCE OF ROOT-KNOT NEMATODES IN CARDAMOM PLANTATIONS OF TAMIL NADU*

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ABSTRACT

A survey was carried out on the incidence of root-knot nematodes in cardamom in Tamil Nadu covering Tirunelveli, Ramanathapuram and Madurai districts. Root-knot nematodes were present in all fields of cardamom as well as in primary and secondary nurseries sampled, indicating that infestation is widespread in Tamil Nadu.

Maximum population of root-knot nematodes was recorded in Rajapalayam Taluk of Ramanathapuram District. ***Meloidogyne incognita*** **was recorded from Tirunelveli, Ramanathapuram and Madurai Districts while** ***M. arenaria*** **was recorded in Ramanathapuram District only.**

INTRODUCTION

Cardamom (*Elettaria cardamomum* (L.) Maton) grown in moist deciduous rain forest of Tamil Nadu at altitudes ranging between 600–1500 metres and occupies over 8110 ha with an annual production of 300 M.T. (Anon., 1978). The conditions under which cardamom is grown in Tamil Nadu are different as it receives lesser rainfall compared to the other cardamom growing states of Kerala and Karnataka. Recently, wide-spread infestation of root-knot nematodes in nursery and fields of cardamom was reported in 4 taluks of Kerala (Ali and Koshy, 1982). A survey was carried out in Tamil Nadu during 1981 to determine the distribution of root-knot nematodes in this crop. This paper presents the results of a survey on the incidence of root-knot nematodes in cardamom nurseries as well as fields of Tamil Nadu.

MATERIAL AND METHODS

Seventy two samples each of soil and roots were collected from fields and nurseries in three districts of Tamil Nadu (Table 1).

*Contribution No. 242 of CPCRI.

Each sample consisted of 250g of soil and 10–15g of root. Nematodes were extracted from soil samples by Cabb's sieving technique, and from root samples (5g) by cutting them into small pieces after fixation in 4% formalin and staining in acid fuchsin-lactophenol for 5 minutes and then dispersing in 150 ml water. Another lot of roots was stained with acid fuchsin-lactophenol, and 15–20 adult females were teased out. Anterior and posterior ends of adults were cut and mounted in lactophenol for species identification.

RESULTS AND DISCUSSION

All soil and root samples from nurseries and fields yielded root-knot nematodes (Table 1). Maximum population of root-knot nematodes was recorded in Rajapalayam taluk of Ramanathapuram district. The higher incidence of root-knot nematodes in nurseries was due to the repeated use of same nursery beds year after year. In general, nurseries had poor percentage of germination (15–25%). Very young seedlings (1–2 months old) had typical knotted appearance on root system, whereas 6 month-old seedlings rarely showed galling, but exhibited excessive branching especially on root-tips. In such seedlings, rosette appearance of leaves was commonly observed. Stunted seedlings with sickly appearance showed poor tillering, yellowing of leaf margin, and drying of leaf tips. The problem was found to be serious when such seedlings were trans planted to infested secondary nurseries resulting in their poor establishment (40% approximately).

Root-knot infested seedlings used for transplantation in the main field served as an important source of inoculum. Besides, the intensity of the infestation was high in places where *Erythrina* sp. were grown as shade trees in cardamom plantations. Shallow rooted cardamom plants exhibited excessive branching near the root tip or all along the entire root at different intervals. A bunch of rootlets emerged a little above the root tip which were readily discernible from other healthy roots by the absence of root hairs and milky white colour. The root tips which were attacked initially by nematodes were more prone to invasion by fungus; hence, decaying and rotting generally started from this point. Maximum population of 2nd stage larvae and adult females of root-knot

Table 1. Occurrence of root-knot nematode (*Meloidogyne*) on Cardamom in Tamil Nadu (Root and Soil)

Area	Sites sampled and average population/g of root and 150g of soil: Nursery, Primary: No. of samples	Nursery, Primary: Root popul-lation	Nursery, Primary: Soil popu-lation	Nursery, Secondary: No. of samples	Nursery, Secondary: Root popu-lation	Nursery, Secondary: Soil popu-lation	Plantations: No. of samples	Plantations: Root popu-lation	Plantations: Soil popu-lation	Total	Positive for: *M. incognita*	Positive for: *M. arenaria*
Tirunelveli District												
Tenkasi Taluk	4	105	47	2	183	49	17	144	35	23	23	—
Ramanathapuram District												
Rajapalayam Taluk	5	530	28	5	576	60	23	343	105	33	30	3
Madurai District												
Periyakulam Taluk	—	—	—	2	205	79	14	174	86	16	16	—
Total	9	635	75	9	964	188	45	743	238	72	69	3

nematodes were recovered from root tips. In severe cases, tips of branch roots exhibited pronounced galling.

Shedding of immature fruits and excessive tillering were also commonly observed in namatode infested plants. In case of excessive tillering, a mass of dwarf tillers emerged among the infested dying tillers, bearing narrow, curled small leaves. These dwarf tillers either dried up or became sterile. Root-knot infested plants further exhibited narrowing of top leaves, yellowing of leaf margins, burning of leaf tips, and stunted tillers.

Root-knot nematodes were present in all fields of cardamom as well as in the nurseries sampled in three taluks (Table 1), indicating that infestation is widespread in Tamil Nadu. Cardamom being a perennial crop, the infestation of root-knot nematodes is not spectacular or of a sudden epidemic type but rather exhibits a slow decline in yields, spreading gradually but steadily. The symptoms caused by nematodes on roots and aerial parts of the clumps were not recognized, and hence attributed to other factors.

Meloidogyne incognita (Kofoid *et* White) Chitw. was recorded from Tirunelveli, Ramanathapuram and Madurai districts while *M. arenaria* (Neal) Chitw. was tentatively identified from Ramanathapuram district only. *M. incognita* is a predominant species causing widespread infestation in cardamom crop of Tamil Nadu.

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DISCUSSIONS

P. S. SREENIVASAN (Palghat): From the tables, it is seen that there is not much relation between number of nematodes in soil and the roots. Thus, the nematode status in the soil at the three selected localities are more or less the same while the cardamom roots affected in Rajapalayam is of the order of ten times while in other two centres it is about twice only. Is this due to variation in soil environment or agronomic practices?

ALI: Maximum population of root-knot nematodes will always be found in root zone. The nematodes enter into roots and become sedentary and lay eggs in roots not in soil. In soil, only 2nd stage larvae can move through soil pores, not adult females and other stages of nematodes. Main inoculum of nematodes are in roots, while in soil they pass only a part of their life-cycle.

R. NAIDU (CPCRI): Narrowing of leaf is common even under field conditions in the plantations. In advanced stage, 6–8 clumps will be reduced to the height of 6 to 19". Such severely infected plants responded to Timek and Darinet application under laboratory conditions. Though the symptoms are similar to the Bunchytop disease of banana, there is no relation to that.

ALI: Narrowing of leaf seems to be a symptom of root-knot infestation. During the survey, heavy populations were recorded from clumps having narrowing of leaf. From visual symptoms, it is almost certain that it is only due to nematodes.

P. T. JOHN: For the control of nematodes in cardamom, whether a control of nematodes in nurseries will alone be sufficient since all the cardamom areas surveyed are already infested by the particular nematode ?

ALI: Control of nematodes in nurseries will alone not be sufficient, as in field the nematodes may occur naturally particularly in virgin soil. Nematode-free seedlings definitely reduce the chance of high build-up of nematode population. In field it is very difficult to eradicate nematodes but in nurseries eradication of nematodes is possible by MBr–fumigation.

B. CHANDRAMOULI (UPASI): What are the species of *Meloidogyne* that you observed in the cardamom tracts of T. Nadu?

ALI: *Meloidogyne incognita* and *M. arenaria only.*

G. P. SHETTY (Multiplex, Bangalore): Nematode attacked plants develop secondary roots, devoid of root hairs. Why root hairs are not developed in newly developed roots?

ALI: In nematode-free roots which are newly developed plenty of root hairs along with small rootlets can be observed, whereas nematode-infested roots showing excessive branching never have root hairs because these roots are developed in response to the attack by root-knot nematodes.

GPS: Can we grow some plants like sunflower whose root exudates will control the spread of nematodes—It has been observed in Simla that sunflower grown in between the main crop of *Capsicum* reduced nematode attack.

ALI: We do not have any report about sunflower's tolerance to root-knot nematodes in cardamom.

C. KURUVILLA JACOB (RRII): For the control of root-knot nematode Dr. Ali has suggested 2.5 kg of nematodes like Aldicarb, Carbofuran and Phorate. But much higher doses of 10–15 kg ai/ha were tried by us, and the latter two chemicals could not give effective control even at such high rates of application. In this connection attention is invited to the results of our trials presented in the poster session.

ALI: Dr. Koshy has also used 10–15 kg/ha of Aldicarb and carbofuran in nursery. From your studies, now we know that dosage must be high, but we don't know about residual toxicity of such high doses of nematodes.

R. CHANDRASEKHARAN (UPASI): The narrowness of leaves is often found in nurseries where the soils are poor with extensive nematode damage. The narrowness of leaves is not noticed when the nutritional status of the soil is high even with high intensity of nematodes.

ALI: This is a wrong belief that due to poor soil, narrowing of leaves is occurring. As far as I know there is no data available to prove that narrowing of leaf is due to nutrient deficiency. Clumps having narrowing of leaf contain high population of nematodes, and show excessive branching. Perhaps due to nematode infestation, roots are not able to take up these nutrients.

R. C.: The narrowing of leaves disappears in the following year, and if the narrowing is attributed to the nematode, what is the explanation for the normal leaves?

ALI: Every year new roots are coming up which are able to take water and nutrients. This is the only reason we are getting broader leaves but as soon as these roots are attacked again by nematodes, narrowing of leaf can be observed.

P. K. RAMESH (Chikmagalur): Are there any alternate hosts for nematodes in cardamom fields?

ALI: *Erythrina* sp. are better hosts for root-knot nematodes than cardamom.

BIO-ECOLOGICAL STUDIES ON CACAO MEALY BUG, *PLANOCOCCUS LILACINUS* CKLL.

C. P. RADHAKRISHNAN NAIR[1] AND M. R. G. K NAIR[2]

ABSTRACT

The biology, seasonal abundance, nature and spread of infestation, association with ants, and nature of damage caused by the cacao mealy bug *Planacoccus lilacinus Ckll.* (Homoptera: Pseudococcidae) were studied. Life cycle of the female mealy bug was completed in 20 to 25 days and of male in 17 to 20 days. The peak period of infestation occurred during summer months, and with the onset of rains the population declined. There was significant positive correlation between temperature and pest incidence, and significant negative correlation between pest incidence and rainfall and relative humidity. The pest caused wilting of cherelles to an extent of 85.35 per cent, abortion of cushions, and stunted growth of seedlings. A new strategy for the control of the pest has been suggested.

INTRODUCTION

Cacao (*Theobroma cacao* L.), is susceptible to infestation by a large number of insects in different countries. In India, more than 54 insect species have been reported as pests of cacao (Nair, 1981). Among the various insects found on cacao, the mealy bug *P. lilacinus* is the most destructive (Nair, 1976). This bug is widely distributed in Sri Lanka, Philippines, Java and Papua New Guinea (Entwistle, 1972). It is persistent on cacao in India and at times attains high numerical densities causing serious damage to the crop. The biology, nature of damage, host range, seasonal abundance, nature and spread of infestation and association with various symbionts have been studied, and the observations made are presented in this paper.

MATERIAL AND METHODS

The mealy bug culture was maintained on sprouted potato in the laboratory. To study the life history of the mealy bug, a

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known number of newly emerged crawlers were introduced on sprouted potato. The nature of oviposition and incubation period were studied by periodic observations. The period taken by the crawlers to become adult male or female was recorded. The larval and pupal duration, and male longevity were studied using 10 individuals in each case. Fecundity was studied both by counting the number of eggs present in gravid females after dissection, and also by counting the total number of crawlers produced by gravid females each day, using 10 females in each case. Sex ratio was determined by observing the development of 160 crawlers.

The nature of damage, host range, nature and spread of infestation and the association with symbionts were studied by periodical field observations. For studying the seasonal abundance, the population of the pest was assessed in terms of the percentage of shoots, cushions and pods infested by the pest at monthly intervals on 25 plants for 21 months, avoiding insecticide sprays on these plants. The data were correlated with meteorological factors such as maximum and minimum temperatures, relative humidity and rainfall. The symbiont ants were got identified by the Commonwealth Institute of Entomology, London.

Results and Discussion

Life Cycle: The adult female had a mean pre-oviposition period of 2.7 days, oviposition period of 9.0 days and post-oviposition period of 2.6 days. The female bug laid eggs within a mass of tangled waxy strands without forming an ovisac. Observations on fecundity showed that the number of eggs laid ranged from 47 to 286, averaging 144.3 per female. The number of eggs as revealed by dissection of a gravid female ranged from 275 to 361 with an average of 313 4 eggs. Probably due to starving and other unnatural conditions in the laboratory, all the eggs were not laid by the females

The eggs hatched in less than six hours after oviposition. The nymphal period lasted 20 to 25 days in females with an average of 22.8. In males it lasted 17 to 20 days with an average of 18.7. The male nymph had a pupal period which lasted 4 to 5 days with an average of 4.5. The adult male had a longevity of 2 to 3 days with an average of 2.2. The female had a longevity of 12 to 16 days with an average of 14.3. Observations on sex ratio showed that on an average, 57.5 per cent of the crawlers developed into females.

The eggs were oval with rounded ends and yellowish brown when freshly laid; crawlers were light brown in colour and elongated on emergence. Within a day or two they settled and began feeding. After settling, the body produced white mealy secretions. A full grown crawler was 1.80 mm long and 1.12 mm broad. The pupa measured on an average 1.20 mm in length and 0.45 mm in width. It had distinct body parts, such as head, thorax and abdomen. The antennae were not free. Pupa had a pair of conspicuous red compound eyes.

The adult female was oval with flat ventral and humped dorsal sides. The body was completely covered with waxy secretions. It measured on an average 3.90 mm in length, 2.25 mm in width. The male had well defined head, thorax and abdomen, and measured 2.55 mm in length and 0.55 mm in width. It had a pair of transparent and membranous wings.

Nature of damage: *P. lilacinus* infested all tender parts of the plant such as shoots, terminal buds, cushions, cherelles and pods. On the shoots, the mealy bug preferred to infest the growing tip. The feeding resulted in the suppressed growth of tender leaves which became deformed into tender hair-like processes, giving the shoot tip the appearance of a brush. The jorquetting of the plant was also adversely affected. Colonization and feeding in the cushion resulted in its abortion. The infestation on the cherelles caused wilting and they ultimately dropped. Observations recorded on 10 plants from October to May 1979–1980, indicated that shedding of cherelles occured to an extent of 85.35 per cent. On an average, 77.82 per cent of the young cherelles infested by *P. lilacinus* dropped within one month of infestation. On larger pods, the site of infestation turned brownish. Irregular minute cracks and pitting developed on the pod surface.

Alternate host plants: *P. lilacinus* was found to feed on *Glyricidia maculata* and crotons, besides cashew and coffee reported earlier (Nair, 1975).

Population fluctuation of *P. lilacinus*: Studies on the population fluctuation of *P. lilacinus* in relation to meteorological factors were carried out at Karukachal (Kottayam District, Kerala). The lowest levels of population were observed during June, July and August. From August onwards there was a gradual increase in the population reaching peak levels during April and May. The lowest levels of 3.01 to 10.88 per cent infestation of plant parts was observed from June to August and highest levels of 48.12 to 60.48 per cent during April and May.

Studies showed a significant positive correlation (r=0.854) between maximum temperature and mealy bug infestation; minimum temperature also had significant positive correlation (r= 572). Higher temperatures favoured the population build up. There was significant negative correlation between mealy bug infestation and climatic factors like rainfall and relative humidity (r=0.506 and –0.418 respectively).

The mealy bug population started its first congregation on the inner canopy levels and on the cushions on main trunk, soon after the monsoon rains in September-October. As the temperature became very congenial for its rapid multiplication in summer months, the infestation spread to the outer canopy as well.

Attendant ant species and nature of spread of infestation by *P. lilacinus*: Observations on the symbiont ant species and the pest in a cacao garden at Vittal, Dakshina Kannada, Karnataka, indicated that on an average, 66,18 per cent of the plant population showed mealy bug infestation during May, and 5.75 per cent during July. It was observed that the build-up from August to January was more or less static with the highest incidence during this period at less than 25 per cent. Various species of attendant ants associated with *P. lilacinus* in this region were, *Oecophylla smaragdina* Fab., *Technomyrmex* sp., *Anoplolepis longipes*J., and *Solenopsis geminata* F. The first two were the major species found in all cacao gardens in the area. The ant activity was maximum after January.

These observations warrant the need for developing new strategies for the control of mealy bug, such as the use of poison baits for ant control, indirect control of the pest build-up, and the spot application of insecticides to the first pockets of infestation during post-monsoon period. These may help in avoiding the blanket application of insecticides which is recommended at present for the control of the pest.

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DISCUSSION

EAPEN GEORGE (A. V. Thomas & Co.): Would you comment on the identification of plants infested in Sept. October for mealy bug control, i.e. before spread and subsequent crop loss in April–May?

C. P. R. NAIR: The build up of the insect starts soon after the monsoon in October–November. Along with this the symbiont ants also build up. The spot application of insecticide can be done at this stage on the initial foci of infestation. Hence we may be able probably to avoid repeated blanket application which is practised at present.

N. MURALEEDHARAN (UPASI): Have you recorded any parasites?

C. P. R. NAIR: Only the predator *Spalgis epius* has been recorded so far.

N. M.: Is your recommendation on the new control strategy based on field trials?

C. P. R. NAIR: The new strategy is only a proposal for consideration.

ECOLOGY, STATUS AND POST-NATAL DEVELOPMENT OF THE BLACK RAT INFESTING COCONUT AND CACAO

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ABSTRACT

The common Black rat, *Rattus rattus wroughtoni* Hinton (Rodentia: Muridae) is a predominant pest (72.5% relative abundance) of cacao and coconut crops, along with seven other species of rodents, three species of bats and one species of shrew. The weights and measurements of head and body were significantly ($P<0.01$) more in males than in females. Of the total free living populations, females (54%) predominated. The highest prevalence of pregnant females, subadult populations and high densities of *R. rattus wroughtoni* coincided with tne low rainfall period from September to October. Low levels of reproduction and subadult population were encountered during high rainfall periods from June to August, since rainfall had an adverse effect on reproduction of rats.

INTRODUCTION

Rodents inflict heavy losses from sowing to storage, in all agricultural crops. The infestation patterns of rodents and damages caused to different crops prevalent in North India like vegetables (Advani and Mathur, 1982), wheat (Advani, 1982; Advani *et al.* 1982) and millets (Advani *et al.* 1981) are well documented. The cost-benefit ratios of rodent pest management varied from 1:220 (stored grains) to 1:900 (vegetables). Similar studies have been carried out by the author on plantation crops.

The present communication deals with the ecology, biology and economic status of the predominant rodent pest *Rattus rattus wroughtoni* on coconut and cacao crops.

MATERIAL AND METHODS

Samples of rodents were collected from coconut and cacao plantations continuously for 180 days from June to November,

1982. The habitat included experimental plots of CPCRI, Kasaragod, and some nearby villages like Kudlu, Mogral Puttur, Kuntur, Muliyar village, Muttul Farm, and Madhur. The mean annual rainfall of this biotope is 3700 mm, and mean number of rainy days, 118. The average mean annual minimum and maximum temperatures are 23.1°C and 33.8°C respectively. The sunshine hours of this region vary from 3.3 in June to 9.5 in January and February.

Some farms have coconut as single crop while in others cacao is planted as mixed crop with coconut. Other crops prevalent in this habitat are arecanut, banana, pineapple, paddy, pepper and oil palm.

Rodents were collected in live Sherman wooden traps baited with banana, grape or coconut. After every 6 hours the traps were checked for rodents during which time they were rebaited with fresh baits. Traps were fixed on the top of coconut trees or tied to branches of cacao in a grid manner, and the population levels, species composition and relative abundance of rodents were evaluated following the standard method of Barnett and Prakash (1975). The live trapped rodents were killed with chloroform and after taking their body weights and measurements of head, body, tail, hind foot and ear, they were dissected. The condition of vagina (perforate/imperforate) and of teats for lactation was checked. The number of embryos implanted per pregrant female was counted and measured for crown rump length. The number of corpora-lutea was counted to find out pre-implantation losses. In males, the condition of testes (abdominal/scrotal) was noted. All the rodents were identified (Ellerman, 1961) and later got confirmed by the Zoological Survey of India, Calcutta. After dissection, the rodents were preserved in 6 per cent formalin and registered in the Museum of Rodent Research and Control Centre at CPCRI, for further observations on bionomics. Post-natal development of *R. rattus wroughtoni* was studied in the laboratory for 15 weeks. Assessment of damage to cacao and coconut was made following the methods of Barnett and Prakash (1975), and Flotow (1979).

Results

Association of *R. rattus wroughtoni* with other small mammals: Among the rodents trapped from the coconut and cacao crops,

Table 1. Species composition and relative abundance of various rodent species in plantation crops

Rodent Species	No. of samples collected	% Occurrence
Rodentia: Murinae Blackrat, *Rattus rattus wroughtoni* Hinton	1756	72.5
Common house rat, *Rattus rattus rufescens* Gray	370	15.27
Soft furred field rat, *Rattus meltada* Gray	3	0.12
Field mouse, *Mus booduga* Gray	2	0.08
Long tailed tree mouse, *Vandeleuria oleracea*	4	0.16
Lesser bandicoot rat, *Bandicota bengalensis*	6	0.24
Larger bandicoot rat, *Bandicota indica* (Bechstein)	1	0.04
Rodentia: Gerbillinae: Indian gerbil, *Tatera indica* Hardwicke	4	0.16
Rodentia: Sciuridae. Western Ghat squirrel, *Funambulus tristriatus* Waterhouse	277	11.43
Total	2423	100.00

R. rattus wroughtoni was a predominant species (relative occurrence—72.5% Table–1). It was followed by *R. rattus rufescens* Gray, and the Western Ghat squirrel, *Funambulus* tristriatus Waterhouse (Rodentia: Sciuridae). Other species competing with *R. ratus wroughtoni* for food and space in these crops were, the soft furred field rat, *Rattus meltada* Gray (Rodentia: Muridae), long tailed tree mouse, *Vandeleuria oleracea* Bennett (Rodentia: Muridae), field mouse, *Mus booduga* Gray (Rodentia: Muridae) and the larger bandicoot rat, *Bandicota indica* Bechstein (Rodentia: Muridae). Groupwise, murids predominated the rodent fauna (88.41%) over other groups such as sciurids (11.43%) and gerbils (0.16%). Along with rodents, three species of bats, the Indian flying fox, *Pteropus giganteus* (Brunnich) (Chiroptera: Pteropidae); Short-nosed fruit bat, *Cynopterus sphinx* Vahl (Chiroptera: Pteropidae), and the Indian false vampire bat, *Megaderma lyra* Geoffroy (Chitroptera: Megadermatidae), which frequently visit cacao and coconut plantations after dusk, were also captured in rodent traps.

An insectivore, the Mouse shrew, *Guncus murinus* Anderson (Insectivora: Soricidae) was also collected in the rat traps kept in cacao crop.

Variations in body weight and parts: The body weight of male was significantly ($P < 0.01$) higher than that of the female. Regarding measurements of various taxonomically important external features except the length of head and body ($P < 0.01$), there was no significant variation between tail, hind foot and ear of male and female.

Sex ratio and population structure: In the free-living population of rats, the males predominated from June to September, whereas females outnumbered males in the post-monsoon months of October and November. However, the females predominated (54%) in the total collection.

Recruitment of sub-adults in the *R. rattus* population was parallel to the prevalence of pregnancy among females. The highest percentage of sub-adults was encountered in November (about 25%) followed by October. The highest body weight class (171–200g) was captured only during July, September and October. The major segment of rodent population in all months belonged to the age group of 81–110g.

Population and reproduction as related to rainfall pattern: During high rainfall periods, the pregnant females as well as the number of pests collected was in least frequency. On the other hand, with gradual decrease in rainfall and number of rainy days from August to November, the per cent pregnancy as well as density of rodents per hectare increased, the highest being in October and November.

Damage assessment and cost benefit analysis of rodent trapping: The rodent damage to coconut (mainly by *R. rattus*) and to cacao (by the mixed population of *R. rattus* and *F. tristriatus*) varied from 70.4 to 79.4 per cent. There was a relationship between population level and damage magnitude in the respective months. When coconut plantations had cacao as a mixed crop, the rodent damage was significantly higher (average of 6 months—28.53%), than when the coconut was cultivated as a single crop (average damage—21.03%). In case of cacao, in several farmers' fields, 95–100% damage had occurred, according to their records of harvest, and after successful trapping, the production had increased five-fold. Overall, with trapping for 180 days, the rodent damage to coconut and cacao could be reduced by 92.21 and 76.20 per cent respectively.

While evaluating economics of rodent trapping (2423 rodents trapped) in relation to reduction in losses to cacao and coconut, keeping in view the feeding and damage habits (daily food intake of rodents), the cost benefit ratio for one year, after trapping, was estimated to be about 1:490 (in rupees).

Post-natal development: Newly born young ones were naked but had vibrissae measuring about 1.5 mm. Internal viscera was visible under the translucent pink skin. Eyes were closed. The body length and breadth varied from 35 to 40 mm, 7 mm and 5.1 mm. The mother transported the young ones to the cotton nest made in a corner. However, the infants were able to make wriggling movements. The planter pads and nails were poorly developed.

In the first week, ears unfolded with darkening of dorsum and growth of hairs. A narrow cleavage appeared in between two eyelids. Incisors developed as a rough area in gums. Sucking continued and the young ones could crawl over cage surface. In the second week, pelage of short hairs developed on dorsum and tail. Planter pads also appeared. Teats appeared in the form of spots while vibrissae increased to 6.5 mm in length, and suckling continued. In the third week (19th day) eyes opened and looked prominent and round. In the fourth week, tail length equalled the combined length of head and body (each 70 mm). Ears became prominent (12 mm) with an average of 8 g body weight. Suckling continued and during the 5th week grooming and digging started. In the 6th week, in addition to suckling, young ones (36 days old) started self-feeding attaining 15.2g average body weight. Incisors became 3.95 mm long (average) in the seventh week. Tail (11.5 mm) and body length (90.3 mm) also increased further. After two months, young ones attained 42.55g body weight. The head+ body, tail, hind-foot and ears measured on an average 98mm, 24 mm and 19 mm respectively. During the subsequent period, the growth rate was very slow as compared to the first seven weeks. However, development of tail (about 165 mm) was completed only after the 14th week, the body weight being about 85.5g. This period also coincided with the development of testes which showed the presence of sperms.

Discussion

Occurrence of a varied (nine species) and dense rodent fauna in the plantation area is regulated by the presence of diversified habitat (various crops and grasslands) and regular availability of food in the form of coconut and cacao. Therefore, in comparison to north India (Rajasthan) the trap indices obtained in plantation crops of Kerala (28.21) was about twice that in Rajasthan (14.5, Advani *et al.*, 1982). The predominance of *Rattus rattus* depends upon the high rainfall of this area, which provides enough water needed for its survival, reproduction and multiplication (Collins and Bradshaw, 1973). The predominance of females in the population of *R. rattus* is an additional favourable factor for infesting plantation crops in higher number.

On the basis of 6 monthly observations, June to August is considered to be suitable for control operations with rodenticide, as during this period, the prevalence of pregnancy as well as proportion of sub-adults are very low compared to that during September and November. However, as June, July and August months receive high rainfall, a suitable technology should be developed and evaluated for rodenticide formulations, least affected by rains and having short term action. Relatively more damage recorded in coconut mixed with cacao, than in coconut cultivated as single crop, is due to the availability of cacao as additional food source which results in higher densities of *R. rattus* populations damaging coconuts. The cost benefit ratio achieved during trapping (1:490) can be increased, if the traps used (180 in number) are maintained and used for 5 to 7 years continuously.

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POSTER PRESENTATIONS

EVALUATION OF CERTAIN SYSTEMIC PESTICIDES FOR THE CONTROL OF ROOT-KNOT NEMATODE IN CARDAMOM

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ABSTRACT

Certain systemic pesticides like aldicarb (Temik 10 G), thiodemeton (Solvirex 5 G), Carbofuran (Furadan 3 G), phorate (Thimet 10 G), and neem cake were evaluated for their effcacy in the control of root-knot nematode (*Meloidogyne* sp.) in cardamom (*Elettaria cardamomum*), both in the nursery and in the main field at different dosages. Observvations recorded after 60 days on galling, and nematodes in the root system (in case of nursery plants), showed overall superiority of aldicarb. Phorate also showed its superiority under field conditions. Neem cake was inferior to all other pesticides tried.

INTRODUCTION

The infestation of root-knot nematode (*Meloidogyne* sp.) in cardamom (*Elettaria cardamomum* (L.) Maton) and its control received scientific attention only very recently (Koshy *et al.*, 1976). This genus was recorded as the most common plant parasitic namatode in cardamom (Sundararaju *et al.*, 1979). Little work has been done on the evaluation of granular systemic pesticides for the control of this nematode. This paper reports the results of investigations undertaken to test the efficacy of the commonly available granular pesticides, both in the nursery and in the field.

MATERIAL AND METHODS

Nursery trial: Two separate trials were undertaken for the evaluation of granular pesticides in the nursery and in the field. In the nursery trial, Temik-10G, Furadan-3G, Solvirex-5G coated and neem cake were included. Three levels of Temik and Furadan namely, 20, 25 and 30 g/m^2, two levels of neem cake, 2000 and 5000 g/m^2, and Solvirex at 90 g/m^2 were tried. The pesticides were broadcast on the secondary nursery bed and dibbled into the top soil. The treatments were replicated thrice and a guard row of plants was left between each plot. Sampling was done after 60 days from the middle of each plot.

Field trial: In the field trial, Temik-10G at the rates of 10 and 15 kg ai/ha, Furadon 3G at 3 and 10 kg ai/ha, Thimet-10G at 10 and 15 kg ai/ha, and neem cake at 2000 and 3000 kg/ha were included. All the granular pesticides were mixed with 500 cc of river sand and broadcast in the drip circle of the plant. Neem cake was broadcast and dibbled into the top soil. There were three replications in each treatment. Sampling was done from six loci in each plot to a depth of 10 cm. Only the feeder roots within the drip circle of the plants were sampled. Nematodes in root samples were stained, the roots macerated and the population assessed. Hundred cubic centimeter of soil samples were washed through a bank of sieves and collected over a 400 mesh sieve. The *Meloidogyne* larvae were extracted by Baermann funnel technique modified by Schindler (1961), and counted.

Results and Discussion

In the nursery trial, all the pesticide treatments reduced the number of galls compared to control, the maximum reduction being effected by Temik-10G at 30 g/m^2. The other two levels of Temik, namely, 20 and 25 g/m^2 were superior to the other chemicals (Table 1). The number of namatodes per g root weight was least in case of Temik-treated plants. Furadan has also helped in reducing the nematode population in the roots when applied at the rate of 25 and 30 g/m^2. Although Solvirex reduced the gell count, no reduction in the nematode population in roots could be observed. The population of the nematode in roots was found to increase in the plots treated with neem cake at both the levels.

In the field trial, maximum reduction in the population of uveniles of *Meloidogyne* sp. in the rhizosphere was observed after 30 days in the plots which received Thimet-10G at the rate of 15 kg ai/ha; followed by Temik-10G at the rate of 15 kg ai/ha, and Furadon 3G at the rate of 10 kg ai/ha (Table 2). These treatments were superior to all other treatments. Within 65 days, Temik-10G at the rate of 15 kg ai/ha could reduce the population of juveniles by

Table 1. Gall count and population of *Meloidogyne* sp. associated with cardamom nursery plants*

Treatment	Rate of application (g/m^2)	Percent decrease in gall count/g root wt.	Percent nematodes/g root wt. over control
Aldicarb (Temik 10 G)	20	84.5	—80.8
Aldicarb (Temik 10 G)	25	95.1	—64.2
Aldicarb (Temik 10 G)	30	95.2	—86.2
Carbofuran (Furadan 3 G)	20	46.4	—15.2
Carbofuran (Furadan 3 G)	25	15.3	—61.7
Carbofuran (Furadan 3 G)	30	42.8	—50.5
Thiodemeton (Solvirex 5 G coated)	90	52.9	6.2
Neem Cake	2000	22.1	18.9
Neem Cake	5000	44.0	33.3

* Observations recorded 60 days after imposing treatments.

Table 2. Population of *Meloidogyne* sp. in 100 cc of soil from the rhizosphere of cardamom plants in the field*

Treatment	Rate of application kg ai/ha	Percent juveniles ± over control	
		30 days	65 days
Aldicarb (Temik 10 G)	10	—40.3	—14.0
Aldicarb (Temik 10 G)	15	—56.3	—73.2
Carbofuran (Furadan 3 G)	3	—29.6	—21.5
Carbofuran (Furadan 3 G)	10	—54.4	—59.4
Phorate (Thimet 10 G)	10	—49.3	— 9.8
Phorate (Thimet 10 G)	15	—58.5	—44.7
Neem Cake	2000 kg/ha	—42.9	—18.9
Neem Cake	3000 kg/ha	—38.5	6.8

*All values [illegible]

73.2% followed by Furadan 3G at the rate of 10 kg ai/ha (59.4%) and Thimet 10G at the rate of 15 kg ai/ha (44.7%). No consistent results could be obtained with regard to neem cake application in the field trial. Observations on percent gall count and percent nematodes per gram root weight, were also found to be inconsistent with regard to all the treatments.

Unlike field crops, the control of root-knot nematodes in plantation crops like cardamom poses problems as the plant is continuously exposed to the inoculum. However, attack of root-knot nematodes observed in cardamom is normally in isolated patches of varying sizes. Pesticides like aldicarb and carbofuran were used in tomato without any phytotoxic effects upto 16 kg ai/ha (Reddy, and Seshadri, 1971). Aldicarb at the rate of 15 kg ai/ha and carbofuran at the rate of 3 kg ai/ha were also reported to be very effective in controlling *M. incognita* in brinjal (Yadav, *et al.*, 1978). No phytotoxic effects could be observed in the present study with respect to any of the chemicals at the levels tried.

As the granular pesticides like aldicarb and carbofuran have no ovicidal action (Reddy and Seshadri, 1971), the reduction in the population of juveniles could be attributed to their contact toxicity. These treatments at higher doses must have also helped in preventing the entry of juveniles into the roots thus reducing the total number of nematodes per g root weight and the number of galls.

Unlike earlier observations in other crops like okra and tomato (Singh and Sitaramiah, 1971; Hameed, 1970), and soils (Gour and Prasad, 1970; Khan, *et al.*, 1974) addition of neem cake could not give any appreciable reduction in the population of *Meloidogyne* sp., but only increased their number in the nursery trials. Hence, the effectiveness of neem cake as an organic amendment for reduction of *Meloidogyne* sp., in cardamom soils, requires further investigation.

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A TECHNIQUE TO ESTIMATE FIELD POPULATIONS OF COCONUT LEAF EATING CATERPILLAR[1]

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ABSTRACT

A study was carried out at Kayangulam during 1967–70 with a view to evolving a sampling technique for estimating the population of *Opisina arenosella* Walker one of the serious pests of the coconut palm in India. Leaflet-wise and leaf-wise counts of the pest were recorded from 50 young palms, for 36 months. The middle leaves and leaflets were found to lodge more number of caterpillars than the other parts of the palm (with minimum C. V.%). Linear regression equations were fitted for estimating the total pest population of a palm by counting the pests in the middle 41–60 per cent of leaflets of the first 20 per cent of leaves from the bottom.

INTRODUCTION

Coconut leaf eating caterpillar, (*Opisina arenosella* Walker syn. *Nephantis serinopa* Meyrick, Lepidoptera) is a major pest of the coconut palm occurring in the coastal and back-water belts of the country. Sathiamma *et al*., (1974) observed that the pest population was maximum during April-June, medium during February-March and September-October, and low in November-January. Assessment of the pest population and adoption of suitable and timely control measures are indispensable to contain the sporadic outbreaks of the pest. A sampling technique was, therefore, attempted to estimate the total pest count in a palm, the results of which are presented in this paper.

MATERIAL AND METHODS

The absolute population of the pest was recorded in 1967–70 by the direct counting method on 50 young palms planted on

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the bunds in single rows in the lake area of Kayangulam, Alleppey district, Kerala State. The total number of leaves, infested leaves, number of leaflets, infested leaflets, and larval population on each leaflet, were recorded at monthly intervals for 36 months from June 1967 to May 1970.

As great variation existed in the number of leaves per palm and the number of leaflets per leaf, the determination of sample size of leaves and leaflets in a palm became rather difficult as experienced in *Stephanitis* estimations by Mathen *et al.*, (1973). Hence, a scoring procedure was adopted. The groups of leaflets were divided into five zones in a leaf from the base. First score group comprised twenty per cent of the leaflets from the base on either side, second score group being the next twenty per cent of the leaflets, and so on. Similarly, the leaves were also divided into five score groups from the bottom, first score group of leaves comprising twenty per cent of the leaves from the bottom, second score group being the next twenty per cent, and so on. Pest population in each score group of leaflets and leaves was calculated and its correlation with the total pest population in the palm worked out for individual months, and then computed for the different seasons. Depending upon the trends in population density of the pest, July-October and February-March periods had medium, April-June high, and November-January, low levels of population. These periods were, therefore, treated as separate groups.

Results and Discussion

Seasonwise data on the larval population which was present in each score group of leaves and leaflets (Table-1) showed that the middle leaves and leaflets harboured the maximum number of pests (C.V.% being the minimum). Simple correlations of the counts of pests in the five score groups of leaves to the total counts of pests in the entire palm worked out for each month separately, revealed that the correlations were higher in the third score group followed by the fourth, second, and first. When the correlation coefficients were worked out season-wise (Table 2), except for February-March 1970, all were highly significant for the first score group. The counting of pest population other than that from the

Table 1. Percentage distribution of *Opisina arenosella* caterpillars in the different score groups of leaves and leaflets (seasonwise)

Period	Leaves (%)					Leaflets (%)				
	1–20	21–40	41–60	61–80	81–100	1–20	21–40	41–60	61–80	81–100
July–Oct.:										
Mean	17.1	29.4	32.9	16.0	4.5	3.2	18.2	35.3	34.2	9.1
C.V. (%)	51.6	45.9	38.0	52.4	149.3	143.7	77.2	46.1	47.0	106.0
Nov–Jan.:										
Mean	15.5	28.3	35.6	16.5	4.0	2.3	13.6	41.2	32.7	10.1
C.V. (%)	86.8	56.2	45.7	98.8	194.3	249.7	109.0	52.5	62.8	161.0
Feb–Mar.:										
Mean	12.2	30.8	33.4	17.7	5.9	1.8	16.8	41.9	33.2	6.2
C.V. (%)	84.0	55.0	42.7	79.6	119.5	222.9	105.8	54.3	69.2	159.1
Apr.–June:										
Mean	11.8	30.6	32.2	19.1	6.4	3.3	20.4	40.4	27.3	8.6
V.V. (%)	74.4	50.2	41.7	61.9	112.1	373.2	92.1	52.2	59.7	114.1

Table 2. Correlation of larval population of *Opisina arenosella* in different score groups of leaves with the total population of pest in the palm (Y), season-wise

Year	Period	$r_{1,Y}$	$r_{2,Y}$	$r_{3,Y}$	$r_{4,Y}$	$r_{5,Y}$
1967	Jul—Oct	0.61**	0.82**	0.81**	0.79**	0.32*
1967—68	Nov—Jan	0.62**	.077**	0.77**	0.63**	0.37*
1968	Feb—Mar	0.45**	0.60**	0.83**	0.61**	0.60**
	Apr—Jun	0.79**	0.87**	0.75**	0.68**	0.43**
	Jul—Oct	0.40**	0.70**	0.78**	0.79**	0.47**
1968—69	Nov—Jan	0.50**	0.42**	0.56**	0.84**	0.36*
1969	Feb—Mar	0.55**	0.77**	0.90**	0.65**	0.25
	Apr—Jun	0.69**	0.89**	0.88**	0.59**	0.38**
	Jul—Oct	0.77**	0.79**	0.71**	0.65**	0.19
1969—70	Nov—Jan	0.84**	0.86**	0.90**	0.44**	0.26
1970	Feb—Mar	0.23	0.63**	0.85**	0.62**	0.52**
	Apr—May	0.51**	0.77**	0.77**	0.79**	0.57**

* Significant at 5% level; ** Significant at 1% level.

Table 3. Correlation of larval population of *Opisina arenosella* in different score group of leaflets in 1–20% of leaves, to the total pests in the palm (pooled season-wise over the years)

		Leaflet score groups (%)					Number of palms infested
		1–20	21–40	41–60	61–80	81–100	
Feb—Mar	(1968–70)	0.68**	0.52**	0.45**	0.39*	0.04	43
Apr—Jun	(1968–70)	0.63**	0.68**	0.77**	0.52**	0.51**	47
Jul—Oct	(1967–69)	0.36*	0.61**	0.65**	0.46**	0.33*	50
Nov—Jan	(1967–70)	0.21	0.49**	0.58**	0.44**	0.39**	39

* Significant at 5% level; ** Signficant at 1% level.

first score group is cumbersome and destructive. Hence, further analysis was done taking the first group of leaves only.

Table 3 gives the correlation coefficients between the number of caterpillars in different score groups of leaflets in the 1–20 per cent of leaves and the total counts of caterpillars for the entire palm pooled over three years. Highly significant correlations were obtained in the case of second (21–40%), and third (41–60%) score groups of leaflets to the total count of pest in the whole palm, and in most cases maximum correlations were obtained for the middle score group. During February-March, higher correla-

Table 4. Linear regression coefficients and intercepts for estimating the total counts of *Opisina arenosella* per palm in different seasons from the first three score groups of leaflets of 1–20% of leaves

	Leaflets %	a	b	S.E. (b)	r^2	Number of palms infested
Feb–Mar (1968–70)	1–20	22.00	144.48**	24.32	0.46**	
	20–40	25.89	8.75**	2.27	0.27**	43
	40–60	22.59	5.75**	1.80	0.20**	
Apr–Jun (1967–70)	1–20	61.32	41.86**	7.63	0.40**	
	20–40	46.81	14.74**	2.35	0.47**	47
	40–60	38.40	9.70**	1.19	0.59**	
Jul–Oct (1967–69)	1–20	28.91	37.78*	14.14	0.13*	
	20–40	21.98	13.31**	2.51	0.37**	50
	40–60	20–57	6.20**	1.05	0.42**	
Nov–Jan (1967–70)	1–20	14.04	8.22	12.27	0.01	
	20–40	10.56	11.46**	3.39	0.24**	39
	40–60	6.36	8.99**	2.10	0.33**	

*Significant at 5% level; **Significant at 1% level tion (0.68) was observed between the number of caterpillars in the first score group of leaflets than in the second or third score groups of leaflets, with the total number of caterpillars in the palm. Table 4 gives the linear regression coefficients and intercepts for estimating the total pests present in the palm from the first three score groups of leaflets together with the SE's. The regression coefficients were found to be heterogeneous between seasons and hence a general formulae is not suggested. As the pest intensity and spread varied much between seasons it will be advantageous to use different formulae for estimating the pest population accurately. All the regression coefficients and the coefficients of determination were highly significant for all the seasons for the first score group except for November-January (1967–70), when the population was very meagre.

As the pest outbreak is sporadic in different localities, immediate assessment of the pest population has to be made for resorting to control measures. The above formulae would help in the quick assessment of the pest population and timely adoption of effective control measures. It is cumbersome to count the total pest population in a palm without cutting down the leaves/leaflets from grown-up palms. Sampling can, therefore, be restricted to the middle portion of the lower leaves (1–20% score group of the leaves).

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FIELD CONTROL OF CARDAMOM THRIPS

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ABSTRACT

Various insecticide formulations including some synthetic pyrethroids, tested against the cardamom thrips in "neem based application" trials yielded information on the effective chemicals, number of spray applications required, spraying interval, and the time of application for the economic control of the pest. Quinalphos (Ekalux 25 EC), at 0.025%, and monocrotophos (Nuvacron 40 SC) at 0.03% were found to be effective against the thrips, followed by phenthoate (Elsan 50 EC) at 0.075%, fenthion (Lebaycid 1000) at 0.06%, and Permethrin (Ambush 50 EC) at 0.01%. Phosalone (Zolone 50 EC) at 0.07%, was effective only after trashing operation. Seven or eight rounds of insecticide application were required for effective control. The interval between spray applications depended upon flower production; the greater the flower production, shorter was the interval and vice versa. Normally, the spraying interval ranges from 21 to 50 days. The first round of insecticide application is to be started soon after the pre-monsoon shower. Further sprayings are to be continued at 21–27 day intervals until July, and at 35–50 day intervals thereafter till December end.

INTRODUCTION

Sciothrips cardamomi Ramak. (Thysanoptera: Thripidae) the cardamom thrips is one of the most serious and very important pests of cardamom, *Elettaria cardamomum* (L.) Maton, ever since the pest was first recorded on it (Ayyar, 1935; Ayyar and Kylasam, 1935). The damage inflicted on the capsule by the thrips not only reduced the yield but also its market value. The first attempt on the control of this pest was made during the early forties (Jones, 1943). Though BHC was the first synthetic chemical to be recommended (Subbiah, 1949), its use could not be advocated beyond the fifties due to resurgence of the pest.

Though certain insecticides were evaluated for the control of thrips (Pillai and Abraham, 1978; Kumaresan, 1982), information was lacking on the minimum effective dosage, the number of spray applications required, and the exact time of application. The present study was carried out to test various insecticide formullations including certain synthetic pyrethroids like permethrin and cypermethrin, against cardamom thrips. Experiments were designed to yield information on the choice of the chemical, correct dosage to be used, the exact time of application, and the interval between spray applications.

MATERIAL AND METHODS

All the experiments were conducted in fields at Vandiperiyar, Idikki District with predominantly *Vazhukka* type (semi-erect) of cardamom mixed with some *Malabar* clumps. The experiments were laid out in simple completely randomized block and randomized block designs. Plot sizes varied from five to twelve plants. Insecticides were applied with hand-operated knapsack sprayers, using 300 to 500 ml of spray solutions per plant, depending upon the clump size.

Frequency of insecticide application was need based, and decided after periodic assessment of thrips infestation on the flower buds. Insecticides were applied to the base of the plant to cover all the panicles and also on the tillers upto the loose basal sheath reaching a height of 135cm. The effectiveness of the insecticide was assessed by flower bud sampling and recording the actual percentage of infested flower buds. The following criteria were employed to compute the effectiveness of the insecticides.

0% infestation—excellent
1–5% infestation—very good
5–10% infestation—satisfactory
above 10% infestation—unsatisfactory

The data in all the Tables are presented as per cent infestation of flower buds.

RESULTS AND DISCUSSION

The result of a field experiment conducted in 1980 is presented in Table 1. Only a single application was imposed on July 14, 1980 and the effectiveness assessed upto 41 days from the date of spraying. Among the insecticides screened, Ekalux (00.25% a.i.) and Ambush (0.016% a.i. and 0.014% a.i.) proved excellent in their performance upto 41 days. Nuvacron (monocrotophos) at 0.02% a.i. was very effective. Though the performance of phosphomidon (Dimecron–100) at 0.05% a.i. was excellent upto 14 days its effectiveness progressively decreased thereafter. Fenitrothion (Folithion 50 EC) at 0.065% a.i. gave good control upto 21 days, while dichlorvos (Nuvan) was good only upto 14 days.

In atrial conducted during 1981 (Table 2), Dimecron, Ekalux, Ripcord, Permasect 25 EC (Permethrin), Nuvacron (Cypermethrin) and Monocil were screened. All the treatments except Nuvacron at 0.012% a.i., and Dimecron at 0.014% a.i. were effective. However, the performance of Nuvacron at 0.03% was superior to all other treatments, recording the lowest per cent infestation of thrips upto 30 days after spraying.

The results of another experiment conducted during 1981 (Table 3), indicate the overall superiority of Ekalux at 0.025% a.i. over other insecticides. Phenthoate (Elsan 50 EC) at 0.075% a.i. Permethrin (0.01% a.i.), and Lebaycid (0.06%) were satisfactory. The effectiveness of Zolone (Phosalone) at 0.07% a.i. improved from third spraying onwards, which coincided with trashing operation. Endosulfan, Ethion, Dursban and Tamaran were found to be unsatisfactory in their performance against cardamom thrips.

The maximum infestation of thrips in the flower buds occurs during monsoon months—which corresponds with the maximum flowering period—as observed by Subbiah (1949), but interestingly in contrast to the findings of Pillai and Abraham (1978). We observed that greater the flower production higher was the incidence of thrips which coincided with the rainy months. It is essential that sprays are undertaken particularly during the rainy months i.e. from April through August to protect the maximum number of capsules against thrips infestation.

During May, June and July reinfestation occurred in the

Table 1. Trial of 1980 on Performance of Insecticides against Cardamom thrips

Treatment	Conc. % a.i.	% infestation pre-treatment	% Infestation of thrips in flower buds days after spraying					
			3	7	14	21	27	41
Folithion	0.065	50	2.5	0	5.0	2.5	10	20.0
Permethrin (Ambush)	0.016	42.5	0	0	0	0	0	2.5
Permethrin	0.014	47.5	0	0	0	0	0	0
Dimecron	0.05	45.0	0	0	0	5.0	7.5	7.5
Nuvan	0.1	45.0	0	2.5	5.0	25.0	2.5	17.5
Endosulfan	0.07	45.0	2.5	7.5	7.5	12.5	17.5	10.0
Ekalux	0.05	55.0	0	0	2.5	0	2.5	5.0
Ekalux	0.025	47.5	0	0	0	0	0	0
Nuvacron	0.02	35.0	2.5	0	2.5	0	7.5	2.5
Nuvacron	0.01	52.5	1.00	2.5	2.5	0	7.5	2.5
Untreated control	—	47.5	37.5	35.0	35.0	35.0	25.0	32.5

Table 2. Results of 1981 experiment on relative performance of different insecticides

Treatment	Conc. % a.i.	% infestation pre-treatment	% Infestation of thrips in flower buds days after spraying 7	18	30
Permasect 25 EC	0.01	55.8	2.2	4.5	6.7
Nuvacron	0.012	60.3	4.5	17.9	6.7
Nuvacron	0.02	60.3	2.2	6.7	2.2
Nuvacron	0.03	60.3	0	2.2	0
Dimecron	0.014	53.6	15.6	26.8	17.9
Dimecron	0.02	58.1	8.9	6.7	6.7
Monocil	0.04	53.6	2.2	2.2	4.5
Ripcord	0.01	62.5	4.5	6.7	6.7
Ekalux	0.05	62.5	0	4.5	6.7
Control	—	55.8	53.6	46.9	58.1

Table 3. Results of 1981 experiment. Reelative efficacy of chemicals and the reinfestation of thrips

Treatment	Conc. % ai	% Infestation of flower buds											
		Days after 1st spraying			Days after 2nd spraying	Days after 3rd spraying							Days after 4th spraying
		7	23	37	28	7	14	21	28	35	42	47	23
Ekalux	0.025	0	6.7	40.0	10.1	0	0	0	3.4	0	13.4	16.8	3.4
Permethrin (Voltas)	0.01	0	10.1	25.0	10.1	0	6.7	13.4	10.1	16.8	20.1	33.5	13.4
Endosulfan	0.11	0	13.4	85.0	50.3	6.7	23.5	26.8	23.5	36.9	36.9	26.8	13.4
*Endosulfan	0.07	—	—	—	70.4	16.8	50.3	56.9	53.6	46.9	60.3	73.7	26.8
Zolone	0.07	10.0	20.1	52.5	30.2	0	6.7	10.1	13.4	3.4	13.4	3.4	3.4
Ethion	0.1	6.7	26.8	65.0	43.6	6.7	16.8	46.9	16.8	20.1	16.9	26.8	30.2
Ethion	0.075	0	10.1	80.0	33.5	13.4	23.5	16.8	20.1	30.2	40.2	40.2	36.9
Elsan	0.075	0	10.1	42.5	16.8	0	10.1	3.4	10.1	3.4	16.8	23.5	13.4
Dursban	0.05	0	26.8	52.5	30.2	13.4	30.2	36.9	33.5	50.3	26.3	—	26.8
Tamaran	0.03	6.7	13.4	62.5	33.5	3.4	10.1	26.8	23.5	13.4	36.9	33.5	23.5
Lebaycid	0.06	3.4	26.8	30.0	10.1	0	10.1	6.7	6.7	6.7	33.5	13.4	6.7
Untreated control	—	50.3	67.0	92.5	96.9	93.8	96.9	87.1	93.9	100	97.0	93.3	93.3

*included from 2nd spraying onwards.

Table 4. Schedule of spraying.

Month	Interval between spraying rounds	Choice of chemical[1]	Concentration % a.i.	Spray[2] volume/plant in ml
March	10 days after premonsoon rain	Ekalux (25 EC)	0.025	300—400
April	27 days	Nuvacron (40 EC)	0.03	300—400
May	27 days	Ekalux	0.025	300—400
June	21 days	Nuvacron	0.03	400—500
July	30 days	Nuvacron	0.05	300—500
August	35—50 days	Ekalux	0.025	300—400
Oct. and Nov.	can be skipped, if thrips build up is noticed one round of spraying may be required.			
December to March	45—50 days	Ekalux or Nuvacron	0.025 / 0.03	300—400

[1]Ekalux and Nuvacron can be interchanged and alternated depending on the availability and convenience.
[2]with hand operated knapsack sprayer.

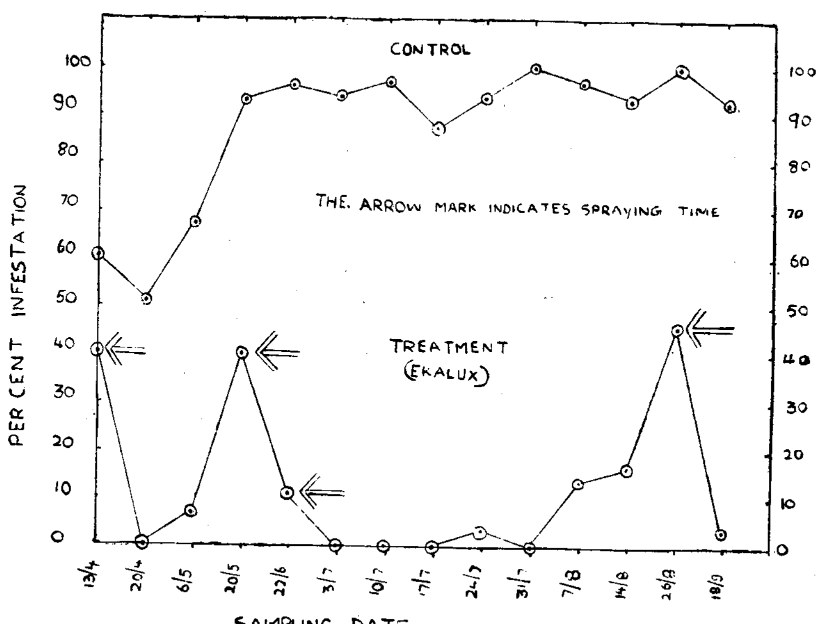
treated plots, within three weeks from the date of spraying, which synchronized with the maximum flowering period. During August, reinfestation was delayed upto 35 days and so also during September, obviously due to decreased flower production. Flowering was over in October-November and new panicles start emerging in January–February.

Based on the results presented here, it is suggested that seven or eight rounds of insecticide applications judiciously sprayed and correctly timed will effectively conrol cardamom thrips.

Ekalux 0.025% or Nuvacron at 0.03% could be selected as the first choice. Elsan at 0.075% a.i., Permethrin at 0.016% a.i., Lebaycid at 0.06% a.i., and Ripcord 0.01% a.i., can also be used. Zolone at 0.07% a.i. givese ffective control of thrips only after trash-

1981 EXPERIMENT

INFESTATION TREND OF THRIPS AFTER SPRAYING



ing. Regarding the time of spraying, (Table 4), the first spraying is to be done within ten days of the first pre-monsoon rain and subsequent spraying at 27 day intervals upto June. In June, a shorter spraying interval of 21 days is advocated to contain the 'quick' reinfestation. During July, 30 days interval between spraying rounds are to be adhered, to and in August and September an interval of 30–50 days could be maintained depending on flower production. Spraying against thrips during October and November may be skipped and thereafter the emerging new penicles are to be protected by undertaking spraying at 45 to 50 day intervals upto March.

Acknowledgement

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Plenary Session

Chairman: **Dr K. V. Ahamed Bavappa**

Convener : **Dr R. D. Iyer**

PLENARY SESSION

Report on Plenary Session of PLACROSYM V held on 18–12–1982

The plenary session of Placrosym V started with a discussion on the need for establishing a National Information Centre for Plantation Crops (NICPLAC), chaired by Sri S.V. Sangameshwaran, Head of the Division of Library Sciences, CFTRI, Mysore. In his opening remarks, Sri Sangameshwaran pointed out that as a result of the population explosion, the needs of the people had increased enormously. Similarly, with the information explosion, there has been a rise in R & D expenditure. He referred to the efforts of CPCRI to have a phased programme of library development to include documentation and information services which would cater to the needs of scientists working in this field.

The lead paper on NICPLAC was presented by Sri D. Kamalavijayan, Librarian & Documentation Officer of CPCRI, wherein he outlined the scope of a scientific library and the objectives of establishing NICPLAC to bring about greater co-ordination between different information centres on plantation crops and develop a data base which can be drawn upon by all the interested parties through a network of computerized information channel. Clarifying the objectives, the General Chairman Dr Bavappa said, that what is meant by this exercise is to have some loud thinking on organizing the available information on plantation crops so that it becomes easily available to the Scientists irrespective of their affiliation. It is by no means the idea to replace the existing system but only to supplement the efforts in this direction.

Dr P. K. Das was of the view that for the different category of users, the library should endeavour to make available more effective services rather than highly sophisticated computerized systems. Dr Powell, FAO Consultant in Microbiollogy at TNAU said that the TNAU Library receives over 700 periodicals, and considering this high level of acquisition, the retrieval of information did not seem to be as good. It may be worthwhile, therefore, to evolve a system of retrieval for a more effective use of this tremendous acquisition. Dr E.V.V.B. Rao referred to the Current Contents and ISI System, which he said, should be made full use of in the first instance. Dr A.V. George of CWRDM, Calicut, presented a brief outline of the 'Bibliography on Irrigation for Plantation Crops' prepared by him. He said that such bibliographies would help in reducing what he called the 'irritation' in the research workers in gathering information.

The Chairmen of various Sessions presented the summaries of their respective Sessions, details of which are given below.

Dr P.K. Das presented the review of Session I; Dr. C.L. Powell summarized the group discussion on Mycorrihizae; Dr V.S. Sharma presented the review of Session II on behalf of Dr N.M. Nayar; Dr. M.R. Sethuraj reviewed Session III; Dr S. Ramaswamy reviewed Session IV on Technology & Processing on behalf of Dr. E.V. Thomas; Sri V. Ranganathan summarized Agronomy & Soil Science Session; Dr C. Rajendran presented the summary of Session VI on Plant Pathology on behalf of Prof P.V. Rai; Dr M.J. Chacko presented the Session VII report on Entomology, Nematology & Rodentology.

Finally, in his concluding remarks, the General Chairman expressed happiness at the heartening response to Placrosym-V from different workers in the field of plantation crops research. Although crop-wise and dicipline-wise analysis of papers may not be relevant right now, such an effort should reveal the pace of research progress. Reviewing the highlights and future thrusts, the General Chairman said that with regard to economics, marketing, statistics and extension, the quality and market acceptance of all products are very important, and hence there is a need for quality oriented approach in all the programmes. He also referred to the importance of plot size for reducing cost of field experimentation and forecasting of yield, and cost-benefit-ratio analysis for R & D efforts. He also emphasized the need for formulating viable projects to attract investments from bankers and other agencies.

In the field of genetics and plant breeding, there was an increasing need for improved seed and planting-material for the whole country, and new crop varieties in plantation crops. He referred to the offer by the DDG (CS), ICAR for inter-organizational collaboration through All-India Co-ordinated Projects, and called for stepping up of seed production in coconut, pepper and cashew.

To meet the demand of 50 million coconut seedlings for replanting at the rate of 5 million per year in Kerala alone, 2000 ha of seed garden is required. This showed the magnitude of the problem and calls for a very comprehensive action plan in this sector.

With regard to Physiology & Biochemistry the General Chairman said that although isolated efforts are in progress, production physiology needs a more comprehensive approach in order to support other related disciplines. The 'Treephysindia' meeting held at Kottayam had generated a good deal of interest among tree physiologists, and hence, more such group meetings would be desirable.

In the field of technology and process engineering, particularly for the tropical belt, processing and packaging are vital for value added products. Citing the Sri Lanka experience with polythene packaging of spices resulting in loss of flavour and hence reduction in export prices, he said, this is a vital area requiring immediate attention. He also stressed the importance of intermediate exploitation of produces such as mushroom production and biogas generation, using plantation crop wastes. The gadgets such as tree-climbing devices evolved by the scientists are by no means meant to replace the climbers, but may be useful for the farmers and scientists alike in situations of labour shortage.

With regard to agronomy and soils research, he was of the view that the future of plantation crops was in the hands of agronomists. More realistic experiments are needed with regard to interaction between N, P, K and irrigation and varieties with different management inputs. It was significant that the D×T coconut hybrid yields much higher than WCT under identical conditions.

In the Session on plant pathology he referred to the interesting discussions held on bio-fertilizers, *Cercospora coffeicola*, and Thanjavur wilt of coconut. Use of neem cake needs to be investigated more deeply. With regard to diseases of uncertain etiology, he said that we should learn to live with these diseases and reduce the microbial load which is antagonistic to the host plant,coupled with good agronomic management. This is an inter-disciplinary area which calls for co-ordinated efforts.

In the field of entomology, nematology and rodentology, the use of attractants, nutritional requirements of pests, effectiveness of pyrethroids, and integrated pest management, are priority areas of work. The fact that there were not many papers on the integrated system of pest control and management, underlines the need for greater emphasis in this area.

In the special group discussion on Mycorrihizae, the future thrust area has been identified in respect of nursery and field surveys, to assess the extent of mycorrihizal association in different plantation crops. It was felt necessary to lay out field trials with phosphate application to make a direct assessment of the role of mycorrhizae in the productivity of these crops.

With regard to library and documentation, he said that our efforts are now directed towards making the present services more useful to the scientists wherever they are. Any facility available at CPCRI can be made use of by any scientist irrespective of affiliation, though there are some constraints with regard to space at present.

Commenting on the future outlook of Placrosyms, the General Chairman called for a careful assessment of the past five years of these meetings and suggested that future symposia should be planned accordingly. It was clear that there was a definite scope for improving the standard of papers and this has been taken stock of by the Standing Committee which decided to declare a holiday for Placrosym during 1983 and hold the symposium only once in 2 years on all the disciplines. Placrosym VI is scheduled for December 1984. It was pointed out that if high standards of papers are not ensured, it will discourage good papers from being sent to Placrosyms. The time schedule of printing of the Proceedings was also a vital factor for ensuring priority of publication for the authors.

Reviewing the benefits, he said the Placrosym movement has helped to foster a better understanding and interaction among researchers in plantation crops working in diverse institutions, and to assess and share the available facilities in different laboratories. There are about 400 scientists working on plantation crops and the Placrosymis a source of moral strength for all of them. He suggested that for bridging the gap of two years between the Placrosyms, group discussions on specific area may be thought of. The Director of the concerned Institute may forward such proposals to the Standing Committee which will consider financing these discussions, that may be organized on the pattern of the one on Mycorrhizae which was held during the current symposium. He also suggested the instituting of awards for best papers presented in Placrosyms to promote healthy competition, which will be open to all disciplines.

A vote of thanks was proposed by Dr A. Ramadasan, to the General Chairman, Conveners and Members of the local Organizing Committee, who had toiled all along to make Placrosym-V a grand success. Dr M.R. Sethuraj offering thanks on behalf of the participants, said that all the arrangements for the Symposium were excellent.

The meeting came to a close at 1 PM.

R. D. Iyer

Appendix I

SUSTAINING MEMBERS OF PLACROSYM-V

1. Messrs. T. Stanes & Co. Ltd.,
   8/24, Race Course Road,
   COIMBATORE-641 018.

2. Messrs. Karnataka Agro-Chemicals,
   P. B. No. 1031,
   Rajajinagar,
   BANGALORE-560 010.

3. Messrs. Travancore Chemicals &
   Manufacturing Co. Ltd.,
   KALAMASSERRY-683 104.

4. Messrs. Consolidated Coffee Ltd.,
   Pollibetta-571 215,
   Coorg District,
   KARNATAKA.

5. Messrs. Shaw Wallace & Co. Ltd.,
   7/Lingi Chetti Street,
   MADRAS-600 001.

6. Messrs. Rajagiri Rubber & Produce Co. Ltd.,
   W-21/674, Beach Road,
   Alleppey-688 001,
   KERALA.

7. Messrs. Technotran, Ltd.;
   110, West Sandaipettai Street,
   MADURAI-625 001.

8. Messrs. Pyrites, Phosphates &
   Chemicals Ltd.,
   Palai Road, Dehri-on-Sone,
   Rohtas District,
   BIHAR.

9. Messrs. Madras Fertilizers Ltd.,
Manali, Post Box No. 2,
MADRAS-600 068.

10. Coconut Development Board,
ERNAKULAM, Cochin-682 011.

11. Plantation Corporation of Kerala,
KOTTAYAM-KERALA.

12. Kerala Co-operative Central Bank,
TRIVANDRUM.

DONORS

1. The Coorg & Mysore Coffee Co. Ltd.,
Chamundi Curing Works,
Metagalli P. O.,
MYSORE.

2. Aries Agro-Vet Industries Pvt. Ltd.,
53-54-B, Nanda Bhavan Estate,
Mahakali Caver Road,
Andheri East,
BOMBAY-400 093.

3. UBS Publishers and Distributors Ltd.,
10, First Main Road, Gandhi Nagar,
Post Box No. 9713,
BANGALORE-560 009.

4. Sandoz India Ltd.,
Agro-Chemical Field Research Unit,
9/36, Dr. Nanjappa Road,
COIMBATORE-641 018.

5. Union Carbide India Ltd.,
Shamla Hills,
BHOPAL-462 013.

APPENDIX II

LOCAL ORGANIZING COMMITTEE

General Chairman: KV Ahamed Bavappa

General Convener: RD Iyer

Finance & Registration

Convener: MV George

Members: MC Nambiar
MK Nair
NP Jayasankar
MK Muliyar
Aloka Saikia
N Govinda Pillai
A Ramdas
A Krishnankutty
AC Leelavathy
KS Subhash Babu
C Leela
Jainamma Job

Reception, Transport and Accommodation

Convener: Jacob Mathew

Members: P Gopalasundaram
SJK Annamalai
K Sivaraman
K Vijaya Kumar
PM Shaefe
KK Nambiar
CH Usha Rani
CH Amarnath
T Vasudeva

Food & Refreshment

Convener: A Ramdas

Members: PC Jacob
OP Joshi
RV Pillai
D Kamalavijayan
P Benny
V Radhakrishnan
MA Ismail

Exhibition & Entertainment

Convener: RV Pillai

Members: Rohini Iyer
S Shivashankar
D Kamalavijayan
C Kailasam
AS Sukumaran
VP Nityananda
ATK Nambiar

Hall, Projection & Programme

Convener: P Rethinam

Members: OP Joshi
EVV Bhaskara Rao
HH Khan
RN Brahma

Poster Session

Convener: A Ramadasan

Members: S Shivashankar
P. Prakash Kumar
KV Kasturi Bai
CR Ramesh

CR Raju
K Madhavan
KV Raghavan
PS Shiva Prasad
BP Vinayachandran
NP Sreenivasan
MS Antony

RT Patil
M Narayanan
N Venkitachalam
AK Kamalakaran
P Balakrishnan
VK Damodaran