IMPROVEMENT OF PLANTATION CROPS

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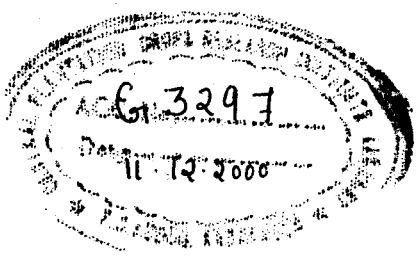
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FOREWORD

Plantation crops are important cash crops of the country. They occupy about 4 million hectares area and contribute significantly to the GDP as well in export earning. The crops covered under this group are coconut, arecanut, cocoa, oil palm, cashew, tea, coffee and rubber, spices and medicinal plants. The improvement of plantation crops is comparatively more difficult in view of their heterozygosity, long gestation period and perenniality.

Central Plantation Crops Research Institute has been the pioneering institute in the country doing commendable research on the plantation crops. Only recently CPCRI has been the venue for the Kerala Science Congress with a focal theme on plantation crops. Coping up with the challenges facing these crops, yet another attempt has been made to organize a Summer School to impart training on "Improvement of plantation Crops". The institute now plans to bring out a volume with compilation of papers presented during the summer school. The publication covers among others the latest methodologies including biotechnological approaches, IPR issues and statistical techniques. I am sure that this publication will be very useful to all those who are involved in R&D of activities of plantation crop. I complement the editors for their dexterous editing.

S. P. Ghosh

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PREFACE

This publication is the compilation of lecture notes prepared in connection with the Summer School on Crop Improvement of Plantation Crops held at Central Plantation Crops Research Institute, Kasaragod, Kerala during 8-28 June, 1999. The topics of the Summer School were chosen to cover the major disciplines (genetics, plant breeding, biotechnology and biometrics) as well as the allied subjects (physiology, biochemistry, disease and pest management and post-harvest technology) involved in the crop improvement programmes. Few general topics of interest such as IPR, bioinformatics, role of co-ordinated research projects and participatory plant breeding programmes were also included.

All the plantation crops (coconut, arecanut, oil palm, cocoa, cashew, spices, tea, coffee and rubber) were represented in this compilation. Besides summarizing the achievements in each crops, research priorities were also highlighted. It is hoped that this compilation will be valued by the planters, development agencies, research workers and students.

We wish to place on record our gratitude to Dr. K.U.K. Nampoothiri, Director, Central Plantation Crops Research Institute, Kasaragod under whose inspiration and guidance this whole venture blossomed to glory. But for the help of Dr. V. A. Parthasarathy, Head of Division, and other scientific and technical staff of the Division of Crop Improvement, we wonder whether we would have taken this initiative to its logical end. To Mr. C.H. Amarnath and Mr. K. K. Nair we owe a great deal as they helped in word processing of these materials.

The efforts of all the resource personnel in preparing the exhaustive notes are acknowledged with thanks. We also thank the Indian Council of Agricultural Research, New Delhi for sanctioning the Summer School and for the financial assistance.

CPCRI, Kasaragod **Editors**
September, 1999

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Improvement in Plantation Crops

K.V.A. Bavappa

Introduction

Plantation crops (tea, coffee, rubber, coconut, arecanut, oil palm, cocoa, cashew, cardamom, clove, cinnamon, nutmeg, pepper, vanilla, ginger and turmeric) having high commercial value play a vital role in the agricultural economy of the country and export trade. They are grown over an area of about 3.2 million ha (1.82% of the total cropped area) generating an annual income of over Rs.40,000 millions and contributing about Rs.15,000 millions to export earnings. Though historically tea, coffee and rubber were raised as industrial crops in large estates, currently sizeable areas under these crops are in smaller holdings in diverse farming systems. Barring the price of rubber in the recent past and that of coconut intermittently, the price of almost all the plantation crops was either steady or showed an upward trend. In spite of this, the profitability has remained static or even declined due to the enhanced cost of production demanding a higher and steady yielding under varying environmental situations to offset this situation. Crop improvement research, therefore, needs continued attention with well-set goals.

Improvement Objectives

In spite of the fact that improvement in yield is the most sought after objective of crop improvement, the quantification of this parameter is so casually done that the figures quoted seldom indicate the intrinsic yield level of the variety. This makes comparisons between varieties of the same crop almost impossible. For e.g., in coconut, arecanut, cashew and even pepper per plant yields are generally reported. There are a wide range of factors such as age, spacing, manuring and cultural practices that influence yield. It is essential that such variables that affect yield are kept as uniform as possible and the yield expressed on unit area (preferably/ha) basis as the most popular commercial end product. For coconut it should be copra or oil, for arecanut, chali, oil palm oil etc/ha.

Under the fast changing scenario in processing and end product utilization on one hand and the ever-increasing cost of production on the other, it has become imperative to discern the crop improvement objectives with much better clarity so that the varieties so developed meet the objectives for which they were evolved. Even in the case of yield improvement programmes there are specific qualitative traits such as high active principle, stress tolerance, shelling percentage and kernel weight in cashew etc. That could be concurrently considered, targets fixed and selection pressure applied to reach that target. In the absence of such an approach it is observed that most of the released varieties have in general the same yield level and quality characteristics in many of the crops.

Generally speaking most of the released varieties are prone to the attack of pests and diseases for which repeated application of plant protection chemicals are needed making these varieties unfriendly with environment. To quote one example, hybrids in coconut are prone to the attack of rhinoceros beetle more than the local varieties. A much more concerned effort is needed to breed environment friendly varieties incorporating genes for major pests and diseases. The biotechnology tools and approaches should also be made use of in breeding. The run to release varieties should be discouraged and every effort concentrated to evolve environment friendly varieties with high and sustainable yield.

Yet another area of great concern to the breeders should be mixed cropping situation that have come up extensively in the plantation crops sector. Varieties that are evolved for monocropping cannot be expected to perform with the same level of efficiency under mixed cropping situations since these systems vary very widely. There are factors such as competition for light, physical space, nutrients and moisture, which are by and large different in different mixed cropping systems. Varieties having morphologic frames that will fit into the system, which can respond to low PAR and partition without undue competition for the available moisture and nutrients are some of the major factors that should be looked into while breeding varieties for such systems.

Improvement Pathways

Gene pool collection and conservation

While the importance of germplasm has been well understood and vast facilities created for conservation, the collection efforts still remain haphazard in many of the plantation crops. The availability of the local gene pools for yield and disease resistance has been well demonstrated in the case of coconut, the super palm yielding 471 nuts per palm compared to the national average of 44 nuts and average of 110 nuts per palm for the released varieties. In the case of

root (wilt) disease the unaffected WCT palms in the endemic areas of disease have shown considerable promise as a gene source for resistance. This wide variability provided by nature is now threatened with extinction due to replacement with the 'so called' high yielding varieties, urbanization, deforestation etc. starving the posterity for ever of such gene sources. If we do not take a quick look at these gene pools and develop a system for total collection and conservation, disastrous consequences are likely to follow. The vast cryo-preservation facilities should be quickly tapped to conserve the coconut germplasm as embryos. In every crop the protocol for crop preservation if not already available should be perfected and a collection and conservation programme against a time frame formulated. This need be done early to arm ourselves against the ever-increasing maladies that threaten crop production. In coconut alone tendernut fall and eriophyid mite are two major production problems which have come up during this decade.

Novel methods for germplasm collection is yet another area which should be tapped. In the case of cashew large quantities of fresh raw nuts are being imported annually from different countries. If a planned programme is developed to raise populations from such landings substantial gain can be achieved. One of the largest germplasm of cashew now available at the Wildman Cashew Plantation of N T, Australia was collected through unofficial channels on payment basis from Brazil. Every possible effort to collect and conserve germplasm should be mounted on a war footing. It is equally important that methods and programmes are also developed to systematically evaluate such collections. This should include description using the approved descriptor, the more important economic characters and biochemical characteristics (particularly for spices) wherever relevant.

In view of the piracy that has become rampant in the recent past in patent rights, DNA finger printing and registration of the materials should also be undertaken concurrently. Since many of the plantation crops and products have essential oils and active principles of high commercial value, quality attribute profiles of such products should be studied and incorporated in the descriptor. Nodal agencies for each crop or groups of crop should be identified to take leadership in germplasm collection, conservation and evaluation work and jointly with NBPGR and other centres involved in this programme, constantly exchange information through internet/E-mail and maintain updated lists.

Breeding for targeted yield levels and qualitative traits

The yield levels of all the released varieties are much lower than that observed in the germplasm of these crops (Table 1). Since yield targets are not fixed there can be slackness in the choice of parents and methods adopted. In this context it is also relevant to consider other parameters directly connected with yield. Taking the example of coconut, the variability that has been observed for dry matter partitioning in favour of oil, including this parameter would be useful. Thus in breeding a coconut variety for the future the following criteria may be kept in view:-

a) Yield (200 nuts equivalent) ton oil/ha

b) High dry matter partitioning for copra and oil

c) A compact dwarf to semi dwarf plant type to accommodate more plants/unit area.

d) Better efficiency to use the available moisture and nutrients.

e) Ability to tolerate moisture stress

f) Resistance/tolerance to Root (wilt), Eriophyid mite/tender nut fall.

g) Any other more relevant and exploitable parameter.

At this point, breeding would become the task for a

Table 1. Yield range and potential yield in various crops

Crop	Unit	No. of varieties	Yield range	Super potential yield
Coconut	Nuts/palm	14	93-151	471
Cashew (20-30 years old)	Raw nuts kg/tree	8	15-19	125
Cardamom	Kg/tree (dry)	5	260-409	900
Pepper	Kg/tree	9	1242-2352	13465
Rubber	Latex (Kg/ha)	9	850-2500	2500
Tea	Made tea (kg/ha)	45	1819	2300
Coffee	Berries (t/ha)	16	1.25-2.50	2.5

and competent inter-disciplinary team. In the case of such as pepper, cashew etc., which can also be ively propagated, production of large number of hybrid ations involving lines with diverse and desired ers so as to exploit locked up variability should prove rewarding. Net worked programmes are needed in this

Biotechnology Tools

The more recent biotechnology innovations such as ingerprinting, marker assisted selection and genetic ation through expensive and time consuming ures are indeed handy to evolve genetically tailored ypes to suit specific needs. Transgenics to overcome ck wilt of pepper, rhizome rot of ginger, 'Katte' of rdamom 'chirke' and 'foorke' of large cardamom etc., be easy to realize.

Testing of Varieties

The yield gap between the research station yield and tained in the farmers field of most of the released varieties ed wide. While this could be partially due to variations in gement practices, a better insight about this problem would ible to the breeders if the varieties likely to be released are ently field tested in farmers' fields taking the co-operation ing farmers. This will enable the development of an ate package of practices for the variety when released. for this is not currently available for any of the released es in the absence of such trials.

ing Material Production Strategies

In many of the crops, even long after the variety is released, enough planting material of the variety is not available for planting in adequate numbers for want of scion sources/seed gardens. It is essential that scion banks/seed gardens of the varieties that are likely to be released are organized well in advance so that the farmers are able to avail of the benefits of the variety rather quickly.

Summary

In conclusion, it is pointed out that the challenges in the field of plantation crops production are on the increase and to meet these challenges and make plantation crops production remunerative on a sustainable basis innovative methods with precision are to be adopted in crop improvement. These should include:

1. Time targeted action in gene pool collection, conservation, cataloguing and registering which of late has become a highly sensitive area.

2. Defining breeding objectives including yield targets and qualitative traits, identifying sources of gene and outlining methodologies to be adopted.

3. Commissioning such well defined programmes as inter-disciplinary projects to evolve eco-friendly varieties which are efficient in resources utilization and stable in production.

4. Determining the environment for the optimal performance of the varieties.

5. Ensuring the adequate availability of the planting materials of such priced varieties.

Coconut and Arecanut Development - A Futuristic Approach

M.K. Nair

COCONUT

The coconut sector is dominated by small-holding farmers around the world to whom coconut palm is the means of livelihood. The coconut palm has a special role in the social, cultural and economic life of millions of people of the major coconut growing countries. The value of coconut palm cannot be assessed only in terms of its potential to produce oil, but as a versatile tree which plays a major role in the wealth, health and welfare of coconut farming community.

Changing Trend in Area, Production and Productivity

The area under coconut as well as production in India has been showing a steady increase during the last few decades. The area under coconut was 0.63 million hectares during 1950-51 which increased to 1.16 million ha during 1983-84. The final estimate for coconut during 1996-97 indicates that India has an area of 1.886 million ha with a production of 12988 million nuts. Taking 1983-84 as the base year, the increase in area is up to the extent of 0.64 million hectares. In the early nineties, India ranked third in the world in area and production among 86 coconut growing countries in the tropical belt. However, the latest estimate indicates that India has attained the first position in area, production and productivity.

Kerala, Tamil Nadu, Andhra Pradesh and Karnataka are the major coconut producing states in the country. Kerala accounts for 54.7 per cent of the area and 42.3 per cent of the production. Tamil Nadu stands second in area followed by Karnataka and same trend is followed in production also.

There has been tremendous increase in productivity also. In 1983-84 productivity was 4982 nuts/ha which increased to 6887 nuts during the year 1996-97. The maximum productivity of 20621 nuts/ha has been reported from Maharashtra followed by 13862 nuts/ha from Andhra Pradesh. The production target of 9360 million nuts fixed for VIIth Plan has been achieved while the production fell short of the projected figure of 15,000 million nuts during the VIII Plan period.

Inputs Available for Increasing Production & Productivity

Varieties

CPCRI, Kasaragod has the largest germplasm collection of coconut in the world with 86 exotic cultivars from 22 countries of South and South-East Asia, Carribean Islands, Indian Ocean Islands, Pacific Ocean Islands and African countries. Recently 15 accessions were also added through embryo collection from three Indian Ocean Islands, viz., Mauritius, Madagascar and Seychelles. The Institute also maintains 46 indigenous germplasm collection.

These varieties were under evaluation for morphological, yield and quality characteristics at various centres. Varieties selected based on the preliminary evaluation were further evaluated in multilocation trials at 10 Co-ordinating Centres under the All India Co-ordinated Research Project on Palms and based on their superior performance Laccadive Ordinary, Benaulim Green Round and Philippines Ordinary were released for cultivation in 1985, 1987 and 1995 respectively.

In the history of coconut improvement, the discovery of hybrid vigour by J. S. Patel in 1937 is a significant landmark. He reported that hybrids were characterized by early germination, increased collar girth, higher leaf number, early bearing habit and high yield. The hybrid vigour was reported in both Tall x Dwarf and Dwarf x Tall combinations. Evaluation carried out under diverse soil and climatic condition indicated that both these group of hybrids were consistently superior over the respective parental forms in terms of nut yield and copra output. Between 1955 and 1982 CPCRI evaluated 87 different hybrid combinations and this evaluation trials established the superiority of Chowghat Orange Dwarf x West Coast Tall, West Coast Tall x Chowghat Orange Dwarf and Laccadive Ordinary x Chowghat Orange Dwarf hybrids. In addition to increase in yield, the hybrids involving Laccadive Ordinary was also found to perform well under drought conditions. On the basis of yield performance of these three hybrids were released for commercial cultivation. Laccadive Ordinary x Gangabondam, Andaman Ordinary x Gangabondam, West Coast Tall x Gangabondam, West Coast Tall x Malayan Yellow Dwarf and West Coast Tall x Straight Settlement Apricot produced and evaluated at Kerala Agricultural University; East Coast Tall x Green Dwarf and East Coast Tall x Malayan Yellow Dwarf evaluated at Veppankulam Centre of Tamil Nadu Agricultural University; and East Coast Tall x Gangabondam produced at Ambajipet Centre of Andhra Pradesh Agricultural University were also found to be superior to the local cultivars and were released for cultivation between 1985 and 1994. Economic

evaluation of these hybrids under rainfed condition has shown that the pay-back period in the case of hybrids is eight years compared to 10 years in the case of West Coast Tall. These hybrids were also found responding to the recommended dose of fertilizer of 500 g N, 320 g P_2O_5 and 1200g K_2O/palm/year with increased efficiency indicating that these hybrids are suitable for small holdings environment prevailing in Kerala, Karnataka and Tamil Nadu.

Manure and fertilizer

For sustained productivity the palms are to be manured from the first year of planting itself. Productivity of the palms is adversely affected when the plantation is neglected in the beginning. At a later stage even if fertilized palms do not respond to achieve the level of productivity expected from the recommended fertilizer application. The optimum dose of fertilizer recommended for an adult palm is 0.5 kg N, 0.32 kg P_2O_5 and 1.2 kg K_2O/palm/year. The first dose of fertilizer is applied after 3 months of planting and the dosage is gradually increased and the full dose of the fertilizer is to be applied from 4th year onwards. The details of fertilizer recommendation is given in Table 1.

Table 1. Fertilizer recommendation (g/tree)

Age	May-June			Sept-Oct.		
	N	P_2O5	K_2O	N	P_2O_5	K_2O
First Year	-	-	-	50	40	135
Second year	50	40	135	110	80	270
Third year	110	80	270	220	160	540
Fourth year onwards	170	120	400	330	200	800

It has to be ensured that the fertilizer is applied under the optimum soil moisture condition. CPCRI recommends application 1/3rd of the fertilizer immediately after the onset of South-East monsoon and remaining 2/3rd towards the end of the monsoon. A shallow trench (20-25 cm) of 1.8 m radius around the base of the coconut is taken after the receipt of first monsoon and 1/3rd of the recommended dose of fertilizer broadcasted around the basin covered with organic manure followed by soil. Application of organic manures (farmyard manure) @ 50 kg/palm is required to supplement inorganic fertilizer. In addition to improving the soil condition, organic manures also supply the required micro-nutrients. Organic manures also improve the physical and water holding capacity of the soil. The same procedure is followed for the second dose of fertilizer (2/3rd) during September-October also. As a source of phosphatic fertilizer, rock phosphate is found to be cheapest and best particularly for acidic soil. Field trials conducted at CPCRI, Kasaragod has indicated that the phosphorus application can be skipped for few years if the available phosphorus is more than 20 ppm. Basin cultivation of green manure crops like *Calapogonium* and *Mimosa invisa* during the monsoon season can generate upto 25 kg green manure which can be incorporated into the basin before flowering.

Compared to the Local Talls, the hybrids particularly D x T are found to be most efficient users of applied nutrients. Field trials conducted at CPCRI, Kasaragod has revealed that the hybrids are not only efficient users of applied nutrients both under rainfed and irrigated conditions but also have higher yield potential at the lower levels of fertilizer application in comparison with the West Coast Tall.

Irrigation

Response of coconut palms to irrigation is location-specific and depends on climate, soil, topography, ground water table etc. Efficient water management aims at making adequate soil moisture available to the crop through irrigation and soil moisture conservation. Moisture stress results in increased leaf fall, lower growth rate of reproduction resulting lower leaf area and reduction in light interception. The effect of moisture stress is reflected in the reduction of yield due to reduction in number of bunches, number of female flowers/ inflorescence and setting percentage besides shedding of tender nuts. The size of nut and copra content are also reduced due to moisture stress. Water transpired by coconut palm is estimated to range from 28 litres/palm/day to 200 litres/palm/day. The estimated mean transpiration is 53 litres/ palm/day under coastal Kerala condition and 90 litres under interior Tamil Nadu. During summer months in coastal Kerala and Karnataka 200 litres of water once in four days in the basin of 1.8 m radius has been recommended. The irrigation requirement of coconut depends on several factors such as amount of rainfall, its distribution, soil characteristics, climatic condition, annual temperature, relative humidity, pan evaporation etc. Among different methods of irrigation the drip irrigation is found to economize the use of water, besides improving the efficiency of water use. The recommendation given by CPCRI is allowing the water to drip at 3-4 points at a depth of about 30 cm below the soil located at 1 m away from the base. This not only helps to supply water to the root zone but also prevents surface evaporation. For drip irrigation about 30-40 litres of water per day is found to be quite sufficient under West Coast condition. Sprinkler or perfo spray is recommended in coconut plantations with inter and mixed crops and under the coconut based cropping system the quantity of water for irrigation should be about 75 per cent of the pan evaporation. Mulching with coconut husk, coir dust, green leaves and dry coconut leaves not only improves the water retention but also reduces the soil erosion hazards.

Intercultivation is the most important operation in the management of coconut plantation next to manuring. Intercultivation itself is found to increase the yield substantially. A common practice of intercultivation is ploughing the land periodically once in a year or once in two years. The intercultivation also helps in controlling weeds apart from conservation of soil moisture. However excessive intercultivation is reported to cause rapid depreciation of soil organic matter through enhanced decomposition and adversely affects the soil structure. Response of West Coast Tall palms to different management practices at CPCRI, Kasaragod is given in Table 2.

Table 2. Response of West Coast Tall palms to different management practices at CPCRI, Kasaragod

Treatment	Nut yield/palm/ year
Organic and inorganic manuring and tillage	110.4
Inorganic fertilizers and tillage	96.7
Inorganic fertilizers and forking basins	90.5
Tillage only	53.1
Weed control using herbicides only	27.3
Control (no manuring and no tillage)	9.7

Management of Pests and Diseases:

Pests

Rhinoceros beetle (*Oryctes rhinoceros* L.), red palm weevil (*Rhynchophorus ferrugineus* F.), coconut leaf eating caterpillar (*Opisina arenosella* Wlk.) and cockchafer beetle (*Leucopholis coneophora* Burm.) are the major pests occurring in coconut growing tracts and affecting not only the yield but also the life span of coconut.

Rhinoceros beetle is one of the most destructive pests which burrows into the growing points and feed on unopened fronds, causing damage to inflorescence and reduction in photosynthetic area. Intensified attack can also kill mature palms by defoliation and young palms if the growing point is destroyed. The infestation can be managed by integrated pest management techniques which include cleaning of the crown, extraction of adult beetles with beetle hooks, treatment of breeding sites with 0.01% carbaryl 50% WP and crown treatment with and Carbaryl and r-HCH 8G + sand mixture at 1:8 ratio during the pre and post monsoon period at 45 days interval. Among biological control, release of Baculovirus infested rhinoceros beetle @ 10-15 beetle/ha has been found effective in isolated gardens.

Rhynchophorus ferrugineus the red palm weevil lays eggs on spindle and tender leaf through injuries caused by rhinoceros beetle. The larvae tunnel into the terminal bud or trunk of the tree and feeds on the inner tissues of crown and upper portion of trunk, leading to the death of the palm. Young palms of 5-20 years are more susceptible than adult palms. Recommended pest management programme includes crown cleaning, prophylactic leaf axil filling with mixture of Sevidol 8G 25 g and sand 200 g and injection of 0.1 per cent Thiodon/dichlorvos or 1 per cent carbaryl.

Leaf eating caterpillar is distributed among the coastal and backwater areas and the pest outbreak occurs during summer months. The caterpillars live in galleries made of silken threads and their faecal matter on the lower surface of the leaflets. Continuous feeding of the green tissues results in reduction in photosynthetic area and the leaves dry up giving a burnt up appearance. Cutting and burning of heavily affected outermost 2-3 leaves and release pre-pupal and pupal parasitoids and spraying with dichlorvos 0.02 per cent and root feeding of monocrotophos (10 ml in 10 ml water/palm) are recommended as integrated package for controlling of this pest.

The coconut cockchafer beetle attacks the roots of coconut and other intercrops which result in reduced vigour of the palms and yield. The beetle lay eggs in the soil, immature grubs feeds on the grass roots and organic matter. The second and third instar grubs feed on growing coconut roots. Integrated pest management recommended include ploughing during pre and post monsoon period to expose the pest for predation and also to collecting and destroying the grubs. Collection and destruction of adult beetles during emergence, installation of light traps and application of phorate 10g @ 100 g/palm during pre and post monsoon period are the effective control measures.

Coreid bug (*Paradasynus rostratus* Dist.) which caused button shedding and sometimes in development of undersized and malformed nuts, mealy bugs which infest developing spindle, spathe, inflorescence, young buttons and leaves and scale insect which attacks the underside of leaflets and suck the sap are pests of minor importance. Coreid bug can be controlled with spraying of 0.06 per cent carbaryl/ endosulfan and mealy bugs and scale insect by spraying of dimethoate/monocrotophos/fenthion at 0.1 per cent.

Diseases

Coconut root (wilt), leaf rot, bud rot, Thanjavur wilt/Ganoderma wilt, stem bleeding and Thatipaka disease are the more important diseases causing significant loss in yield and in certain cases even death of the palm.

Root (wilt) disease reported more than a century back contiguously present in eight southern districts of Kerala the estimated annual loss due to the disease is about more 968 million nuts. The consistent symptom of the disease bending of the leaflets termed 'flaccidity' followed by er yellowing, marginal necrosis, rotting of the root system, ng of the spathe and nut loss. Reduction in nut yield upto per cent are symptoms expressed in disease advanced es. Through Electron Microscopy and transmission trials etiology of the disease has been established as due to toplasma transmitted by lace-bug (*Stephanitis typica*) and nt hopper. The disease can be managed by adoption of tegrated management practices i.e., removal of disease vanced and juvenile diseased palms, balanced fertilizer plication, addition of organic matter, raising of green nure crops in basins and incorporation and irrigation during mmer months. Breeding for evolving disease tolerant rieties initiated in 1987 using disease tolerant high yielding lms in hot spot areas have started giving positive results.

Stem bleeding disease is characterized by exudation of reddish brown viscous liquid generally at the base of the trunk and in advanced stages the bleeding patches cover the entire stem. The leaves in the outermost whorl become yellow droop and dry. Trunk gradually tapers and the production of bunches is adversely affected. The disease is caused by *Thielaviopsis parodoxa*. In the early stage of the diseases, it is possible to save the palm by cutting the infected tissues and dressing the wounds with Calixin 5% followed by hot coal tar application. Application of neem cake @ 5 kg/ palm in the basin and root feeding of calyxin 5% thrice in an year were found to be beneficial in limiting the spread of the disease.

Basal stem rot disease found mostly in Tamil Nadu and Karnataka is caused by *Ganoderma lucidum* and *G. Applanatum*. Withering followed by yellowing and drooping of older leaves are the initial symptoms. In advanced stages the root decay starts accompanied by exudation of reddish fluid followed by drooping of leaves, reduction in spindle size and nutfall. Finally the crown topples over.

The management practice recommended include cutting and burning after uprooting the disease advanced palm, making isolation trenches to avoid infection to neighbouring palms, root feeding of Aureofungin @ 1.3 g + 1g copper sulphate in 100 ml water thrice in an year. Calyxin 5% root feeding was also found effective in controlling the disease.

Bud rot is one of the fatal diseases of coconut that affects palms of all ages particularly younger palms. The earliest visible symptom is the withering of the spindle which later on turns dull and bends over. The base of the spindle is rotten and emits a foul smell. Finally the palm succumbs to the disease leaving only the fully matured leaves on the crown. The disease is caused by *Phytophthora palmivora*, a soil borne fungus which can survive for a long time in deeper layers. As a preventive measure all palms below the age of 20 years should be sprayed with 1% Bordeaux mixture at the onset of monsoon. The infected portion of the palms in the early stages should be cut neatly with a sharp knife and burnt. The wood is to be treated with 10% Bordeaux paste and protected from the rain by covering a polythene sheet.

Conventional Developmental Work

Production and distribution of planting materials

Production of seedlings are being undertaken by the seed gardens established in various states by the State Govt., Coconut Development Board and Central Agencies.

The Coconut Development Board has established Demonstration-Cum-Seed production farms (DCS) in Kerala, Karnataka, Madhya Pradesh, Bihar, Assam, Tripura and Andhra Pradesh. The area of each farm varies from 20 ha to 40 ha. While the concept of establishing seed farms is laudable in practice, it has only become a mini germplasm. The farms have a collection of Dwarfs and Talls in rows or blocks. The tall and hybrids seednuts are collected from the palms and nurseries are raised and distributed. While the seedlings raised here are superior do unregistered nurseries, there is no precaution against open-pollination, particularly in the case of talls and dwarfs. The DCS farms all over the country have the same design. The purpose would have been better served, if only blocks of suitable talls and dwarfs for each state are raised in blocks and the seed nuts of both the varieties and hybrids are raised under controlled condition.

Another developmental programme undertaken by the Board is assisting various State Governments. and other agencies in the procurement of seeds of desired cultivars from disease free locations through their seed procurement units. This also has inherent drawbacks. The desirable attributes of mother palms from which the seednuts collected are doubtful. The seed procurement units often do not have trained personnel to identify the good mother palms and also seed nuts. Often these units are subjected to pressure to meet the target of procurement.

The seed gardens established under the state and central sectors seldom meet their objectives. Often these farm do not have the minimum infrastructure facilities like fencing, irrigation. List of the farms established till 1990 is given in Table 3. None of the seed gardens including the seed farm at Kidu under CPCRI have met the targeted production.

Table 3. The seed gardens in the country

Location	Area (ha)
CDB Demonstration-cum-seed production farm	
a) Mandya	20
b) Neriyamangalam	20
c) Tripura	40
d) Bihar	40
e) Assam	40
f) Madhya Pradesh	40
CPCRI Seed Farm Kidu	120
CSF Aralam	250
Dharmaveera Farm	200
Elite Seed Farm Biswanagani Orissa	50
Elite Seed Farm Navlok and Ettankulam	200
Total	1120

Expansion of area under coconut

The objective of this project under Coconut Development Board is to bring more and more areas under cultivation in the traditional as well as non-traditional areas.

Incentive in the form of subsidy of Rs.3000 per ha to farmers who own a minimum of 0.1 ha are eligible for this subsidy. As indicated earlier, there has been considerable increase in area under coconut during the last decade, which indicates the success of this programmes.

Integrated control of major pests and diseases

The CDB sponsored programmes mainly concentrates on the control of black headed caterpillar in the states of Kerala and Karnataka. Under this scheme, parasite breeding centres were established for multiplication and release of parasites. The success of this programme has been limited since the parasite breeding and release require technically competent people. The parasite breeding centres were not able to fulfill the mandate due to this handicap.

Developmental programme under states

Many of the states have been implementing separate programmes for production and distribution of planting materials, subsidized distribution of plant protection chemicals and fertilizers and establishing parasite breeding stations for production and distribution of parasites against black-headed caterpillar.

Suggested strategies

It is a misnomer to classify coconut as a plantation crops. Coconut in the major coconut growing state of Kerala is a homestead crop. In Southern Kerala the size of the coconut homestead garden was found to vary from 0.4 ha to 3.6 ha, with 95 per cent having the size of less than 0.80 ha (Jacob John and Nair, 1995). The small holdings also implies that coconut is not grown as a monocrop in the homestead gardens but one of the major component crops, to ensure that within the available area the farmer gets his basic requirement of nut, fruit, vegetables, oil, tubers etc. The small size of the holdings ensures that adequate income is not generated to support the family. This obviously lead to neglect of the crop, farmers opting for more income generating occupation. Neglect of the homestead garden leads to loss of productivity and high cost of production.

Another feature of the neglected small homestead garden is high density planting combined with a number crop combination planted without proper spacing. The crowded backyard garden with poor management results in low productivity. A recent survey organized by Peekay Tree Crops Development Foundation (Thampan, 1999) indicated that as the holding size increases the palm population decreases, with improved cultural practices proper spacing, intercropping contributing to increased productivity and increased income from unit area.

Various surveys conducted in earlier years have indicated that irrespective of the size of holding about 90 per cent of the holdings received organic manures, while the application of inorganic fertilizers was only upto 40 per cent. The main reason cited by farmers is the low income from the holdings and inadequate income to meet the cost involved in fertilizer application. The surveys have also indicated that not more than 30 per cent adopt plant protection measures. Lack of adequate knowledge to handle poisonous pesticides, non-availability of climbers and sprayers and reluctance of the farmers to use poisonous chemicals in homestead gardens as a precaution against domestic animals/birds and even children.

Irrigation constraints are scarcity of water during summer and lack of finance to develop water sources and installing irrigation systems.

Though the developmental agencies are aware of these problems, the thrust area has been in terms subsidies and supplying planting materials. Research Institute and Agricultural Universities concentrate on developing varieties, schedule for fertilizers application and plant protection measures. As the studies have indicated, we the researchers have not concentrated on research to develop technologies to meet the demand of small holding farmers

Planting materials need and availability

It is of interest to examine the availability of improved/released hybrids vis-a-vis its requirement. About 10 years back, the requirement of seedlings per annum was estimated at 15 million per annum. It was also assessed that there is a wide gap between demand and supply. The annual production of coconut seedlings during 1991 through Govt. Sector was estimated as about 1.2 million hybrids and 4.5 million talls. In recent years, seedling production in coconut has increased considerably though the availability of quality seedlings are limited. Thus there is a wide gap between demands and supply of quality seedlings and this situation is being exploited by private nurseries. Though CPCRI, and four southern Agricultural universities have released nine high yielding hybrids and three varieties, the availability of planting materials in these hybrids/varieties are meager. One cannot expect the CPCRI and Agril. Universities to meet the requirement. The developmental agencies will have step in here and make an earnest attempt to meet the quality planting material requirement. As indicated earlier, attempt made so far has been far from satisfactory due to poor or non-performance of the seed farm under Govt. Sectors. Probably this is a fit case for private entrepreneurs to step in not only to exploit the situation but also to meet the genuine need of the quality planting material. However, a word of precaution. The Developmental agencies will have to ensure that the private agencies do not become unscrupulous to exploit the situation and supply poor quality seedlings.

Input technology vs. productivity

The coconut farmer in the country requires specific recommendation to suit his farming situation. While there is a necessity for recommendations to suit different agroclimatic conditions in the country, there are several situation for which it has not been possible to prescribe the needed recommendation. CPCRI has a mandate on a national level, and may not be able to tackle all the location specific problems. The optimum dose of 0.5 kg N, 0.32 kg P_2O_5 and 1.2 kg K_2O/palm/year recommended is at best applicable to West Coast of India for Local Talls which gives about 80 nuts/palm/year under good management. But is this dose of fertilizer holds good for palms giving 300 nuts/palm/year under East-Coast condition?

Response of coconut palms to irrigation is location specific and depends on climate soil, topography, ground water level etc. While the quantum of water to be applied and method of irrigation have been standardized for West Coast condition, location specific recommendations based on yield potential are not available. It is estimated that the two states of Andhra Pradesh and Orissa have potential of 1,25,000 ha for coconut. To tackle the location specific problems, the State Agricultural Universities could play a vital role in association with the developmental agencies of the central and state sector to increase the production and productivity on the following lines.

1. Developing high yielding hybrids suitable to regions involving local talls and dwarfs and establishing seed farms to produce quality planting materials.
2. There is a need to develop location specific fertilizer and irrigation recommendations according to targeted yield levels taking into consideration soil nutrient status, ground water level.
3. Evolving suitable coconut-based farming systems, developing and popularizing management practices for different crop models.
4. Developing IPM techniques for the control of location specific pests and disease.

Area expansion vs. productivity

Area for expansion of coconut culture is available only in East Coast and North Eastern region. Coconut Development Board has identified about 2,70,000 ha as potential area in these region (Table 4). Coconut Development Board has been extending financial assistance for area expansion eversince its establishment in 1981. Over 50,000 ha was covered during the VII Plan and Over 25,000 ha during the VIII Plan period. In addition the Board has also been providing financial assistance for integrated farming in coconut holding for productivity improvement. Under the programme unproductive trees are removed and replanted, adopting mixed cropping and scientific crop management.

What should be our emphasis in future for coconut development? Whether area expansion or increasing the productivity through intensive management. The fear in traditional coconut growing states that unchecked area expansion may lead to excessive production leading fall in

Table 4. Potential area for expansion of coconut cultivation in East Coast and North Eastern Region

State	Area (ha)
Tamil Nadu	75,000
Andhra Pradesh	50,000
Assam	15,000
Manipur	10,000
Orissa	75,000
Tripura	15,000
West Bengal	25,000
Meghalaya	5,000
Total	2,70,000

price seems to be not justified. India faces even now shortage of edible oil. Besides coconut and coconut oils have many other uses. The demand for coconut is bound to increase continuously. Area expansion as well as rehabilitation of existing plantations will have to go together to increase production and productivity of coconut.

ARECANUT

In arecanut, crop improvement and developmental programmes started simultaneously with the allotment of annual grants of few lakhs of rupees by the Indian Council of Agricultural Research in the mid 40s. To tackle the urgent problems facing arecanut industry and also to consider setting up a standard organization to undertake systematic crop development and marketing of arecanut an ad hoc.committee was set up in 1947. The committee initiated an All India Arecanut survey in 1948 to understand the Agricultural practices adopted in different arecanut growing regions in the country. The recommendations made based on the survey were: (1) the need for intensive cultivation adopting effective cultural and manurial practices, (2) control of pests and diseases, (3) setting arecanut research station to initiate work on fundamental and applied research programmes, (4) establishing regional arecanut nurseries to supply quality planting materials, (5) to gather statistics on areca , production and productivity, and (6) to initiate extension programmes to improve production.

The Govt. of India constituted the Indian Central Arecanut Committee in May 1948 to undertake programmes on crop improvement, development and marketing of arecanut. The Central Arecanut Research Station was established at Vittal in 1953 by the Indian Central Arecanut Committee, which subsequently merged with the Central Plantation Crops Research Institute in 1970.

Success Story of Arecanut Research

The crop improvement research on arecanut for the past five decades at Vittal and various regional research stations (under CPCRI since 1970) have not only contributed to increasing the production and productivity in the country but also achieving self-sufficiency. The success has been achieved by adopting a highly interdisciplinary research approach to develop suitable techniques for selecting seednuts and seedlings, standardizing agro-techniques for raising nurseries, standardizing input technologies for establishing arecanut plantations, evolving control measures against pests and diseases and evolving high yielding varieties.

The salient research results which contributed to increase the production and productivity are:

- Introduction of arecanut accessions from other arecanut growing countries on exchange basis, starting from 1957 onwards. Evaluation of these accessions resulted in selection and release of high yielding varieties Mangala (Southern China), Sumangala (Indonesia) and Sreemangala (Singapore). Evaluation of indigenous accessions resulted in selection of high yielding variety Mohitnagar.
- Standardization of spacing (2.7 x 2.7m) and optimum fertilizer input (100 N: $40P_2O_5$:140 K_2O) to be applied in two split doses and application of green manure/compost/ FYM at the rate of 12 kg/palm/year.
- Water requirement of arecanut palm has been found to be 15-20 litres per day applied through micro-irrigation.
- A number of arecanut based cropping systems have been identified, which if properly followed could substantially increase the income of farmers from unit area.
- Development of integrated pest control measures against mites, tendernut bug, inflorescence caterpillar, spindle bugs and white grubs.
- Prophylactic spraying and control measures against fruit rot, foot rot, inflorescence die back, stem bleeding, bunch and nut split.

Impact of research in stabilizing the arecanut industry in the country has been tremendous as indicated by the unique success story of arecanut industry in the country.

Impact of Development

Trend of increase in area, production and productivity of arecanut in the country starting from 1961-62 shows that in the sixties, the area under the crop increased at the rate of 4.3% per annum and the production at 4.8% and productivity at 3.4 per cent. In the next decade (1971-72 to 1980-81) the area increased at the rate of 2.0 per cent whereas the production increased at the rate of 3.5 per annum. The productivity increased during the decade to 23 per cent compared to 3.4 per cent in the previous decade. The spurt in productivity could be attributed to the impact of research results achieved during the previous two decade. The increase in production by more than 100 per cent during the same period can also be attributed to increase in area to the extent of 57.9 per cent.

The yield gap analysis attempted by Bavappa (1981) indicated that by bridging the extension gap alone i.e. by transferring the established arecanut management technology to the farmers effectively, almost three fold increase in production of arecanut in the country could be achieved. This is a good pointer for taking up concentrated developmental efforts in more favourable areas of arecanut cultivation through investment oriented programme with all input

components such as high yielding varieties, optimum fertilizer inputs, irrigation and timely plant production measures. The reduction in area from 1,89,000 ha during 1974-75 to 1,70,000 ha during 1977-78 has been attributed to sharp decline in arecanut price towards the end of 1973. In contrast the cost of various inputs required for arecanut cultivation increased, making arecanut industry a loosing venture. Inspite of reduction in area, however, there was no appreciable reduction in production indicating that it would be practically possible to bring down the area under arecanut considerably, and divert the land for other commercial crops.

The National Commission on Agriculture had projected the requirement of arecanut in 2000 A.D. as about 1,90,000 tonnes. The commission also indicated that a reduction in area under arecanut may be thought of at later state. In the case of arecanut the production projection made by the commission has been very much on the lower side since the latest production (1996-97) is about 2,80,000 tonnes. The present price of Rs.140-145/kg of *Chali* has been much above the expectation of arecanut farmer.

Today arecanut is the most remunerative commercial crop in the country with a gross income of about Rs.3,00,000/ ha. The increase in production and sky rocketing of arecanut price shows that our internal capacity to utilize the increased production is much higher than the projection made by the National Commission on Agriculture. The increased price is the most attractive incentive for the arecanut and during the last five years, large scale area is being converted into arecanut in the coastal regions of Kerala and Karnataka and maidan part of Karnataka. In the existing situation, the farmer is looking to the research institute for better varieties, and better and effective plant protection measures. The developmental agencies have to put in only minimum efforts to catalyse the increase in production and productivity.

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Prospection and Collection of Coconut Diversity

V.Arunachalam

Introduction

Coconut is one of the important multipurpose perennial palm that sustains the livelihoods of millions of resource poor families in coastal ecosystems. The crop has been improved to serve the human needs using methods like gene pool enrichment, selection and hybridization. Prospection and collection of coconut diversity is an important step in improvement. The present paper details the techniques available, variability reported and earlier attempts made so far, along with hints on practical problems. In India, the crop is grown in wide range of agroclimatic and sociocultural-economic conditions. Indian area represents latitude (23.83^0 N to 6^0 S) and longitude (94.78^{0}E to 60^0 E) ecosystems such as high rainfall zones (North east) to arid zones (99 % to 46 % relative humidity) , extremes of temperature (35 ^{0}C to 4 ^{0}C) , presence of biotic stress (root (wilt) disease, tatipaka disease and mite) and abiotic stress (wind damage in coastal Andhra Pradesh, drought in major cultivation zones) association of faunal diversity such as robber crab (*Birgus latro*) as seen in South sentinel (Andman) and Nicobar group of islands. Wide range of cultural systems such as home garden even amidst concrete jungles as lone crop or with other companion crops, growing in bunds and channels , growing with multistorey high density intercropping with other perennials or annuals. Management of the crop ranging from unutilised plants of uninhabited - remote islands , total neglected cropping to highly intensified management practices and industrial processing of product(s). Planting density also varied from high dense stands of Lakshadweep to recommended level of 7.5 m x 7.5 m . Culture of the human races and ethnic groups benefited by multitude of the products offered by the crop also varies ranging from aboriginal tribes of bay islands to highly civilized groups.

Crop Spread in India

North East: Manipur state (10 ha. of bearing plants available presently) Other parts such as Nagaland are being recently planted with coconut by CDB).

East: Andaman & Nicobar islands

West: Lakshadweep islands

South: Kanyakumari (TN)

South -East: Camp bell bay (Great Nicobar)

Distribution of Crop

The crop is distributed throughout the humid areas of 30 degrees south and north of equator. New Caledonia (20 8' to 22 25 ' S), Pitcairn is. (25^{0}S) & Brazil (27 ^{0}S) and Hawaii is. & Bonin islands of Pacific (26 ^{0}N) are the known south and north extremes in which coconut crop is seen.

Sampling Strategies

IPGRI has provided many protocols for the collecting and conserving the diversity of the crop. They recommend coarse grid sampling strategy thereby entire region is divided to grids of 40 km square and population representative of each grid wherever crop is available could be studied and collected. They also advise to select 30 (Tall) or 10 (Dwarf) individuals per site. Collection from more sites is better than more individuals at one site. A minimum of 200 seednuts or 600 embryos is must to represent a population. The principle behind this is to include the various latitude, longitude differences and the adaptive behavior of the plant to such differences. Knowledge of sampling the crop variability to obtain true genetic diversity eliminating the effects of environment, age, cultural differences is a pre-requisite for an explorer. Biased fine grid sampling helps to get rare types and sub-samples within a population.

Earlier Attempts

CPCRI erstwhile CCRS had carried out systematic surveys inside and outside the country from 1916. Whitehead (1966, 1968) of Jamaica has made worldwide survey for obtaining lethal yellowing resistant accessions. Rao and Koshy (1981) Koshy (1984) and Koshy and Kumaran (1997) are the collection missions carried out in Pacific, Malaysia and Indian Ocean regions respectively. Harries (1978) reviews the earlier attempts made by different countries in coconut seed material movement. Dwyer (1938) explains the seednut movement between Samoa and New Guinea. During 1905-10, seeds from Ceylon including King coconut were brought to Seychelles. Some of the reports on indigeous coconut variability available in different countries are as follows.

Country	Reference
Western Samoa	Leach, 1977
Seychelles	Durocher, 1953
Madagascar	Prudhhome, 1906
Maldives	Wickramasuriya, 1975
Rangiroa & other Frech Polynesian is.	Millaud, 1959 & Sproat, 1967
South Pacific	Parham,1960, Ashburner *et. al.*, 1997
Phillipines	Zuniga *et al.* 1980 & Gruzeo,1990
Indonesia	Tammes,1955; Liyanage, 19 74 Tampake *et al.*, 1982 and Davis *et al.* 1985
Costa Rica	Richardson *et al.* 1978
Brazil	Romney and Dias , 1981
Mexico	Zizumbo-Villareal *et al.*, 1993
Sri Lanka	Liyanage,1958
Papua New Guinea	Ovasuru,1993
Bangladesh	Islam *et al.*1994
Nigeria	Akpan, 1994
Thailand	Harries *et al.* 1982
World varieties listed	Gangolly et al. 1957

In India, survey and collection from Andaman and Nicobar region was carried out by Balakrishnan and Nair (1979) and Dhanapal & Jerard(1999 unpublished). In Orissa state the work was taken by Panda (1982) , Dash et al. (1995) and Kumaran Arunachalam and Dash (1998 unpublished.) . In West Bengal the work was taken up by CPCRI, 1998-99 in collaboration with BCKV. Jacob and Krishnamoorthy (1981) made survey in Lakshadweep islands and listed the types available. AICRP (Palms) centres and CPCRI have collected many interesting types. To mention a few, Uddagangapani and Chittagangapani which were Tall and Dwarf forms of tendernut types respectively. Among Tiptur Tall (T.T) populations, two sub-populations could be identified T.T .I having large sized round nuts with 250 g copra and T.T .II having small angular nuts with 200 g copra/ nut. From Konkan/Goa region, Banawali types were collected and being maintained at Ratnagiri centre (Maharashtra).

Harries (1978) classified dwarfs into three groups viz.,

Type	*Stem*	*Pollination*	*Fruit size*
Nana	Slender	Self	Small
	Example: Coconino, CGD, COD		
Javanica	Medium	Self	Medium
	Example: Malayan dwarfs, Ganagabondam		
Allogamous	Stout	Cross	Large
	Example: Niu Lekha, Tambulilid		

Objective(s) of collection: Objective of the collection mission could be for 1. yield of copra or nuts, 2. tendernut type, 3. to protect the hitherto unknown forms from extinction. 4. to obtain resistance sources for biotic and abiotic stress (lethal yellowing disease , root (wilt) disease , mite, drought and storm) .5. samples to represent latitude/ longitude locations :6. Improving product quality of copra, desiccated coconut etc., But, when the survey is made for one purpose, we also come across types with other desirable traits. Based on the objective the selection of mother palms could be carried out. Pankajakshan et al. (1963) recommended the selection of best 10 % of the palms in a farm based on annual nut yield records of 4 years. This could be used in farms wherever yield records are available and good palms could be selected for yield.

Major Coconut Populations Cultivated in the World

(Batugal and Rao,1998) list the different local coconut populations dominant in different coconut growing countries viz.

India: West Coast Tall, East Coast Tall, Tiptur Tall, Sakhigopal
Sri Lanka: Sri Lankan Tall,
Indonesia: Mapanget, Bali, Tenga,
Phillipines: Bay Bay Tall, Bago- oshiro, Laguna
Thailand: Maphhreao Yai/Thai Tall, Pak Chok
Vietnam: Ta, Dau
Fiji: Fiji Tall
Africa: East African Tall, West African Tall,
Jamaica: Panama Tall, SanBlas
Mexico: Atlantic Tall, Pacific Tall
Malaysia: Malayan Tall, Malayan Dwarf

Some of the coconut accessions so far reported in India:

Andaman & Nicobar islands :
(CPCRI ,1973, Balakrishnan and Nair, 1979 and Chander Rao, unpub. 1985)
*[1]Portbliar Tall
Andaman Ordinary
Andaman Giant
Andaman Yellow Dwarf
Andaman Orange Dwarf
Car Nicobar
*[5] Kinmai
*[5] Katchal
*[5] Kimos
*[5] Auck Chung
*[5] Tamaloo
*[5] Campbell Bay
Recent survey adds 17 accessions to this.

Karnataka:
Tiptur Tall I and II
Uddagangapani
Chiddagangapani
Arsikere Tall

Kerala :
Kappadam
*[2] Komadan
Chavakkad Dwarfs (Green , Orange)
Kaithathali
Spicata
West Coast Tall

Tamilnadu :
Arasmapatti Tall
*[3]Salem
Aliyarnagar Tall
Kulasekharam Dwarf (Yellow, Orange, Green)
Pattukottai Dwarf (Red, Green)
East Coast Tall
Ayiramkachi
Adirampattanam Tall

Gujarat :
Gudanjali Dwarf
Gujarat Zanzibar

Lakshadweep:
*[4] Lakshadweep Orange Dwarf
*[4] Lakshadweep Green Dwarf
*[4] Lakshadweep Yellow Dwarf
Lakshadweep Ordinary
Lakshadweep Small
Lakshadweep Micro
Lakshadweep Mini-micro

Maharashtra / Goa
*[7] Banawali Green Round (Pratap)
*[7] Banawali Green Long
*[7] Banawali Red Round
*[7] Banawali Yellow Long
*[7] Banawali Yellow Round
*[3] Bombay

Orissa
Sakhigoapl local
*[6] Triangular
*[6] Dhanei
*[6] Bana
*[6] Jahaji
*[6] Dhilla
*[6] Suryabana
*[6] Bangera
*[6] Chaka
*[6] Khila
*[6] Goja
*[6] Ladehi
*[6] Haladi
*[6] Orissa Green Dwarf
*[6] Odissi Giant
*[6] Dhila
*[6] Jahaji Yellow

West Bengal :
Hazari Tall
Navasi Tall
Mondouri Tall
Recent survey adds 11 accessions which include
Chandannagar Tall ,
Badajaguli Dwarf .

Assam :
Kahikuchi Tall

Andhra Pradesh :
Gangabhavni
Gangabondam
Gangapani

*1 - CARI , Port Blair
*2 - Gopimony, 1982
*3 KAU - Nileswar
*4 ICAR RC (CPCRI) Lakshadweep, Minicoy
*5 WCGC - CPCRI, Sipighat, Port Blair
*6 Dash *et al.* 1995, AICRP (Palms). Konark Centre.
*7 AICRP (Palms) Ratnagiri Centre.

Data to be recorded
1. **Location data** (edapho-climatic parameters)
Soil texture :
Soil type
Rain fall (mm)
Latitude
Longitude
Altitude (m above msl)
Distance from sea (kms)

2. **Plant data** :
Stem characters :
Plant height (m)
Collar girth (cm)
Internodal length (cm)
Leaf characters :
Length of leaf bearing portion (cm)
Length of petiole (cm)
Cross sectional area of petiole (cm^2)
Length of leaflet (cm)
Breadth of leaflet (cm)
Length of petiole (cm)
Number of leaflets
Leaf sheath fibre thickness (mm)
Number of sheath strands/10 cm
Inflorescence characters :
Length of inflorescence (cm)
Length of stalk (cm)
Number of spikelets
Length of spikelet (cm)
Number of female flowers/ inflorescence
Setting per cent
Yield data :
Annual nut yield /pl.
Number of bunches with nuts
Number of bunches with buttons
Nuts/bunch

Fruit component analysis :
Length of fruit (cm)
Breadth of fruit (cm)
Weight of fruit (GM.)
Weight of husked nut weight (GM.)
Volume of nut water (ml)
Thickness of kernel (mm)

Thickness of shell (mm)
Cavity diameter (cm)
Cavity volume (ml)
Weight of shell (GM)
Weight of copra (gm.)
Husk %/ fruit ([wt. of fruit -wt. of nut]*100/wt.of fruit)
Copra (%) /nut [wt. of nut - wt. of copra]*100/ wt. of nut
Shell (%)/nut [wt. of nut - wt. of shell]*100/ wt. of nut
Water (%)/nut [wt. of nut - wt. of water]*100/ wt. of nut

3. In case of remote island situations where the time is available is very limited it could be restricted to few characters of conservative nature :
Collar girth (cm)
Leaflet number
Leaflet length (cm)
Leaflet breadth (cm)
Inflorescence length (cm)
Husk proportion (%)
Husk thickness (cm)
Biometric analysis of data:

Data entry into computer

Principal Component Analysis
or
Mahalonobis D^2 distance
divergent types identification
use in core collections / hybridisation program.

Biometric Analysis

The data so recorded could be fed into computer using any spreadsheet program. Using the methods like UPGMA (Ovasuru, 1993) or Mahalonobis D^2 distance or Principal component analysis as used by Kumaran et al. (1998), Sugimura et al. (1997), Zizumbo-Villareal and Pinero (1998) the divergent accessions could be identified. Principal component analysis is best among these methods.

Source of Information

Information on variability of coconut could be obtained from farmers, Agricultural extension officers, marketing agents, field staff in Govt./ Private research / development coconut farms and local people in the area. Sometimes rare occurences, abnormalities of coconut are given as news in newspaer.

Quarantine Problems

Crop genetic diversity hotspots are often associated with faunal and floral diversity, which could be parasitic or symbiotic. Thus, one should be careful not to introduce a serious pest or disease into the region along with germplasm material. There are serious threats for which effective curative measures are yet to be developed in the crop. They occur in some areas where care should be exercised to prospect and maintain the diversity within the region (Frison *et al.*, 1982)
Cadang cadang disease : Phillipines
Lethal yellowing disease : Jamaica and Carribean region
Root (wilt) disease : Central and south Kerala, India
Tatipaka disease : Andhra Pradesh, India
In case of internally seed borne diseases like seedling blast observed in Western Samoa (Rao and Koshy,1981) also care is needed.
Treatment of seednuts using suitable pesticides or fungicides is essential wherever the problems are seen.

Success Stories from Germplasm Collections

India
Release of varieties Chandrakalpa (Laccadive Ordinary)
Pratap (Banawali Green Dwarf)
Chavakkad Orange Dwarf (for tendernuts)
Suitable male parent : Gangabondam
Field tolerance to root (wilt) disease : Few palms in hot spot area of
Chavakkad Green Dwarf
West Coast Tall
Jamaica:
Malayan Dwarf (resistance to lethal yellowing disease)
Phillipines :
Makapuno type (industrial use)
Indonesia :
Kopyor type (industrial use)

Mode of collection

Embryos
Seednuts
Pollen
Embryos are the safest mode of collection from quarantine point of view. But, depending upon the financial position and tissue culture lab facilities available at the center, this could be thought of. Seednuts are the universal way of collection from 1900s. Pollen could be collected if the type is male palm, barren nut type or seednuts are not available due to various reasons. Based on biometric analysis if the type is found suitable as a breeding material , pollen could be used to effect hybridisation directly.

Constraints

1. Transport and communication
When the survey is conducted at a far -off place, prior intimation is a must to ensure proper transport, staff and other requirements.
When the site is situated in remote islands, knowledge of

various transport facilities available and their frequency is important.

Unavailability of boats in remote islands and isolated coasta is another problem. National institute of Ocean technology, IIT Campus, Chennai has two marine vessels for research purpose (Oceanography) which are operated throughout the coasts of main land and bay & lakshadweep groups of islands. If collaboration is made with them, this problem could be tackled.

2. Natural calamities

a) Rain

b) Hot wave

c) Cyclones

A breeder should know the seasonal occurrence of these calamities in a region before attempting the survey. This could help in performing the survey in a good way.

3. End use of the crop :

Another problem faced by coconut breeders while collecting the germplasm is the unavailability of mature nuts at the time of visit . This is especially noticed in dwarf types where most of the nuts are harvested during summer as tendernuts. To avoid this, knowledge of the season of mature nut harvest in the region is a must. Arranging the survey during the favourable season could help.

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Appendix: Coconut variability documented so far

Character	Commonly observed	Peculiarities observed	Reference
Germination	3-4 months after sowing	Vivipary to 6 months after sowing	
Polyembryony	One plant / seed	Twins to 5 plants /seed @	
Seedling leaf colour @	Green,normal	yellowish , viridis	
Flowering in seedling	Absent	1)Axillary (midget) 2) Terminal (hapaxanthic	Davis *et al.* 1985
Branching	No branches	upto 27 branches	
Leaflets of bearing plant	Split	Fused / Fetish / Plicate*	
Growth habit	Tall	Dwarf	
Persistence of leaves and inflorescence	Fall off	Remain in plant (Andaman) (Mozambique)	Rao and Kumar, 1998
Shedding of nuts	Fall off	Remain in plant (Takame)	Gangolly *et al.* 1957
a) Inflorescence b) Spahte	Branched Single	Spicata, Bispatheate multi (5) spatheate	Jacob, 1941 Michael,1963
Spadix	Flowers	bulbils of leafy shoots	Davis *et al.* 1985
No. of flowers/ inflorescence		ten thousand in Idi village of Indonesia , Ayiramkachi of TN , India	
Sex expression	Monoecious	Male palm Abnormal male flowers Dioecy Hermaphrodite flowers (0 to 4 /inflorescence in Nias Yellow Dwarf of Indonesia) Male sterile palm	John and Narayana,1942 Puskhran and George, 1990 Ninan and Ratnam, 1962 Davis *et al.* 1985 Ninan and Louis, 1972
Pollination behavior	Allogamous predominated talls	Autogamous predominated dwarfs except Niu Lekha	

Continued in next page

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Continued from the previous page

Character	Commonly observed	Peculiarities observed	Reference
Interspadix overlapping		Nil in Solomon Tall	
Intraspadix overlapping		100 % in Niu Oma Dwarf	
Endosperm a) Texture b) Fragrance	Liquid nut water +solid kernel No fragrance	Makapuno (Phil.), Kopyor (Indonesia), Thayiru tengai (India) (gelly like) Klapawangi (fragrant)	Tahardi , 1997 Menon and Pandalai, 1960 Gangolly *et al.* 1957
Colour - nut/ I nflorescence / petiole	Green	Brown – red - orange - yellow - green - Apricot, stripes of green and white	Menon and Pandalai, 1960
Husk (a) texture (b) colour	Hard Brown	Soft & edible (Kaithathali) Pink: Kalambahim (Phil.), Narangi (Orissa)	
Shape of nut	Round -	Triangular - Boat shaped Lanceo-late	
Size of nut	medium	Biggest (SanRamon of Phil.) Giant (Andaman) - medium - micro - mini micro (Lakshadweep)	
Fruit components a) High liquid endosperm content b) Long fibres	Less water Less weighing fibre	max. water in Niu Vai (998 g /nut) max. fibre in Niu Afa (1608 g / fruit)	Ashburner *et al.* 1997
Shell hardness	2-4 mm	Tough shell Dikri Pol (Sri Lanka) Ladehi (Orissa)	Dash *et al.* 1995
Absence of fibrous peri-carp		Absence reported in East Africa Peeling off like onion in kelapa bawangi of Indonesia	Davis *et al.* 1985
Stylar end of fruit	Round	Beaked or constriction as in CGD	Balkrishnan and Nair,1979
Colour of fruit pericarp	Brown or green or yellow	White (coco blanc) in Madagascar	Pruddhome,1906
Presence of horns on fruit	Absent	Horns on pericarp	Balkrishnan and Nair,1979
Oil content	65- 68 %	75 % in Laccadive Micro	

* Possible causes other than genes (Boron def. / 2, 4 -D injury / hispid beetle attack)

Embryo Culture for Prospection and Safe Movement of Coconut Germplasm

Anitha Karun

Introduction

Large size of the seed, water content and stringent phytosanitary requirements are the major problems in coconut germplasm collection, transportation and storage. The technical guidelines finalized recently by the FAO/IPGRI for the safe movement of coconut germplasm emphasize collection and transportation through embryo cultures instead of seed nuts (Diekmann, 1997). A commercial application of embryo culture is the rescue and culture of Macapuno variety in the Philippines (de Guzman 1970; del Rosario and de Guzman 1976, 1982). The three components of an embryo culture protocol for germplasm movement are field collection of embryos, *in vitro* active conservation and retrieval and *ex vitro* establishment of the seedlings.

Field Collection And Pre-Disinfection Techniques

Zygotic embryos of coconut are collected by splitting open the dehusked nut. Simple and portable equipment can be used for collection and direct inoculation of embryos in the field. Sossou *et al.* (1987) used a portable collapsible glove box instead of a laminar flow hood. The endosperm enclosing the embryo was surface sterilized with 5% calcium hypochlorite for 15-20 minutes and the excised embryos were treated with 2% calcium hypochlorite for 2-5 minutes. Embryos were transferred to the culture flasks, whose inner surface was swabbed with alcohol.

Raju and Bavappa (1987) used a simple portable equipment to collect embryos asceptically in the field in a culture tube and subsequently transferred them to fresh media. The risk of contamination of embryos can be reduced if inoculated individually. The field collection procedure was therefore modified by Anitha Karun *et al.*(1993). The embryos were scooped out with a portion of endosperm in the field by using a cork-borer from the dehusked and split open nut. The extracted embryo from the endosperm was placed in distilled water followed by surface sterilization with 50 % chlorine water for 20 minutes. Embryos were washed with sterile water 3-4 times and directly inoculated individually to vials containing 5-10 ml of Y3 medium/sterile water. The entire operation was done in the field using a folding type portable inoculation hood made of plexiglass, surface sterilized with alcohol.

Many an attempt in zygotic embryo culture has been reported in the past (Cutter and Wilson 1954; Abraham and Thomas 1962; Ventura *et al* 1966). Application of embryo culture to rescue the Makapuno embryo was first demonstrated by Dr. E. V. de Guzman at University of Philippines, Los Banos in the early 1960s when she successfully isolated and grew the embryos of the 'makapuno' coconut. This type is characterized by a soft endosperm that almost fills the nut. This phenomenon is reportedly governed by a single recessive gene and therefore is a heritable trait. This type of coconut is generally borne by the Laguna Tall variety of Philippines. Similarly, embryo rescue of Dikiri coconut (like 'makapuno' type) was done at Coconut Research Institute, Sri Lanka (Vidhanaarachchi *et al* 1998).

In vitro Active Conservation

In vitro active conservation (short-term storage) of coconut zygotic embryos becomes necessary when the collection sites are located in far-off places. Assy-Bah *et al.* (1987) could store the endosperm cylinders in KCl solution (16.2 g/l) for a period of 14 days. Various studies indicated that germination of coconut embryos and their further development depended greatly on the levels of activated charcoal and sucrose. The absence of either charcoal or sucrose is therefore expected to inhibit germination of embryos and their further growth (de Guzman *et al.*, 1971; Karunaratne *et al., 1985*; Assy-Bah *et al.*, 1987 and Rillo and Paloma ,1990).

Karunaratne (1988) could store the embryos in slow growth phase for 5 months in an agar based medium containing nutrient barely sufficient for their survival. After 2, 3 and 5 months of storage, embryos were transferred to retrieval medium for resumption of growth and germination was found to be 53, 40 and 32 % respectively against 61 % germination in embryos without storage.

Assy-Bah and Engelmann (1993) stored dwarf coconut embryos for 6 months in a medium containing 2 g/l activated charcoal without sucrose and obtained 77 % germination. They also found that increased levels of sucrose in the absence of charcoal affected the viability of embryos and germination was negligible in the absence of charcoal and sucrose.

Anitha Karun and Sajini (1994a) observed that zygotic embryos can be stored in sterile water for 2 months.

Compared to nutrient media, the chances of contamination of cultures are minimum in sterile water. About 80 % of the stored embryos germinated when cultured in retrieval medium. Germination dropped to 13 % when stored for 6 months. Embryos can also be stored for 2 months in sterile coconut water (Anitha Karun *et al.*, 1997).

Prolonged storage of cultures at 10°C and 4°C for 3 months caused irreversible damage to the coconut embryos and no plants were recovered when transferred to the germination medium (Karunaratne, 1988). Mature and immature embryos of West Coast Tall variety stored at 10°C for one month did not germinate on transfer to retrieval medium (Anitha Karun *et al.*, 1997)

Cryopreservation of coconut germplasm

Coconut genetic resources are traditionally conserved *ex situ* in the gene banks. The use of *in vitro* culture techniques including slow growth and cryopreservation, represents an important additional option for the safe medium and long term conservation of coconut germplasm. Engelmann (1997) studied these techniques in detail. They could successfully cryopreserve and retrieve plantlets from nuts of 7-8 months after pollination. Performance of immature embryos is good due to their small size (2-3 mm length, 10-20 mg in weight) and low degree of differentiation. Immature embryos can withstand rapid freezing in liquid nitrogen after 4 hours of pretreatment on a semi solid medium containing 600 g/l sucrose and 10-15 % glycerol or sorbitol. Large size and advanced differentiation of mature embryos render their potential use in cryopreservation problematic. The technique developed for immature embryos was successfully applied to mature embryos of four varieties (Hybrid PB 121, Cameroon Red Dwarf, Indian Tall, Renell Tall) (Engelmann, 1997). After 4 hours of desiccation period in the air current of laminar flow cabinet, embryos were pre- treated for 11-20 h on a medium containing 600 g/l sucrose and 15% glycerol, then rapidly immersed in liquid nitrogen. Whole plants could be produced from 73-93 % of cryopreserved embryos, depending on the variety, with only a slight delay in their regrowth rate in comparison with the control embryos.

Bajaj (1984) studied the survival of frozen WCT zygotic embryos of 1-1.5 cm size. Following storage for one month, the embryos were partially dehydrated and then cut into two transverse halves. After pretreatment with cryoprotectants (7 % DMSO +7 % sugar in MS liquid), the embryos were blotted dry, wrapped in sterile aluminium foils, and frozen by gradually lowering into liquid nitrogen for 5 minutes. They were thawed in warm water (35°C to 40°C), washed and cultured on MS + 2, 4-D (0.2 mg/l)+NAA (0.5 mg/l) + kinetin (0.1 mg/l). The retrieved coconut embryos and their segments showed a lag period of 4 months without any sign of growth. This indicated the possibility of long-term conservation of coconut germplasm.

***In vitro* Retrieval**

Basal medium

The Y3 medium was specially formulated for coconut tissue by Dr. C.J. Eeuwens of Wye College, University of London in 1976 (Eeuwens 1976). The Y3 basal medium supplemented with 60 g/l sucrose and 1 g/l charcoal has been used for coconut embryo retrieval studies at CPCRI, India.

Retrieval medium: Basal medium +NAA (0.05 mg/l) +BAP (0.05 mg/l)

Rooting medium: Basal medium + NAA (1.0 mg/l) + IBA (5 mg/l)

Culture conditions

Initially, the cultures are incubated in a dark room at 27±1^{0}C, 85% RH till the plumules emerge. The emergence of plumule depends on the variety, (the tall took about 35-45 days and dwarf 15-25 days for germination). The embryos are subcultured once every 4-6 weeks. The weight gain (gms), contamination rates and germination rate are recorded. Coconut embryo having no dormant period, the swelling and elongation of embryos are observed from 5th day of culture initiation. Germination and contamination percentages of field collected coconut embryos are shown in Table 1.

A number of reports have appeared on the use of liquid nutrient medium for *in vitro* retrieval of coconut embryos (Sossou *et al.*, 1987; Karunaratne, 1988; Ashburner and Thompson, 1991; Rillo and Paloma, 1992). However, Anitha Karun *et al* . (1993) observed better germination and survival in solid medium. Lack of adequate rhizogenesis was one of the main reasons for the poor performance of embryo culture-derived seedlings. Increase in rooting induction has been achieved by transfer of cultures from liquid to solidified medium (Balaga and de Guzman, 1971), increasing the sucrose levels (de Guzman *et al.*, 1971; del Rosario and de Guzman, 1976), supplementing the medium with NAA (Ashburner *et al.*, 1993) and transferring the cultures to liquid medium supplemented with IBA (5 mg/l) and NAA (1 mg/l) (Anitha Karun *et al.*, 1993). Inorganic constituents of culture

Table 1. Germination and contamination percentage of field collected embryos

Age of the embryos	No of embryos inoculated	Germination (%)	Contamination (%)
8 months	26	84.6	3.36
9 months	30	70.0	3.39
11 months	30	70.0	3.39

medium have been used by Balaga and de Guzman (1971); del Rosario and de Guzman(1976) and Miniano and de Guzman(1978).

D'Souza (1980), Jagadeesan and Padmanabhan (1982), Gupta *et al.* (1984), Padmanabhan (1982, 1988) Mascarenhas *et al* . (1988) and Kalamani and Sree Rangaswamy (1990) have also attempted to develop protocol for coconut embryo culture.

Most of the aforesaid experiments were with mature embryos (about 11 months old). Such a restriction, however may limit the number of available nuts during germplasm expeditions. Anitha Karun *et al.* (1993) therefore investigated the feasibility of collecting embryos of 8 to 10 months age. Germination percentage of 8-month old embryos was lower than the matured ones. Better response could be obtained when sucrose was replaced with glucose in the medium.

Effect of rooting hormones on rhizogenesis

The rooting of the germinated plantlet was observed to be a major problem in *in vitro* retrieval. In a number of experiments the *in vitro* retrieved seedlings were reported to suffer high mortality on transplantation to soil due to poor root development. At CPCRI, the observations revealed that the same basal medium supplemented with IBA 5 ppm and NAA 1 ppm induced rhizogenesis.

***Ex vitro* Studies**

A positive correlation was observed between root intensity and survival in pots (Anitha Karun *et al.*, 1993; Anitha Karun and Sajini 1994b). The potting mixture consisting of sterile soil, sand and coir dust in equal proportions was used. As a precautionary measure before transplanting to the pots, the seedlings were treated with Bavistin (1 g/l) and thereafter with IBA solution (1000 ppm) for one hour each. The leaves were trimmed before transplanting to reduce transpiration. Higher humidity condition was maintained initially by covering plantlets with polythene bags. Humidity was reduced gradually by providing perforations to the polythene bag and later lifting the bag during night time and thereafter completely. Macro nutrients solution of Eeuwens Y3 medium was given to the plantlets once a month. The establishment of the plantlets in the pots, polybags and field was found to be very satisfactory and comparable with true seedlings (Anitha Karun and Sajini, 1994b).

The status of research on coconut embryo culture and acclimatization technique of various countries were presented at International workshop at PCA Philippines during Oct 27-31,1997. The status paper of India was also presented. (Anitha Karun *et al* 1998). Different protocols for embryo culture have been published with varying degrees of success. To improve the protocol for various genotypes, four laboratories were identified. Currently around 4-5 labs of different institutes have their own protocols for field collection and retrieval of embryos *in vitro*. The main objectives of this workshop was to upgrade the excisting embryo culture protocols for *in vitro* culture of mature and immature embryos with high survival rate for larger number of genotypes.

Applications

Germplasm collection

The protocol for embryo culture developed by Anitha Karun and Sajini (1994b) was successfully used in two germplasm expeditions. The first was the collection and transportation of 87 embryos of six Pacific Ocean accessions maintained at the World Coconut Germplasm Center (WCGC, CPCRI) Sipighat in Andaman and Nicobar Islands. The embryos were retrieved *in vitro* at Kasaragod and successfully transplanted to the field (CPCRI, 1994-95). Twentythree established plantlets were field planted at IGB-SA (International Gene Bank for South Asia) at Kidu.

The same protocol was also used for the collection of 15 exotic coconut germplasm accessions from Mauritius, Madagascar and Seychelles (Kumaran *et al.*, 1998). This was the first attempt in the world, the germplasm collected in the form of sterile embryos directly from the field..

***In vitro* Screening for drought tolerance**

Karunaratne *et al* . (1991) studied the feasibility of developing an *in vitro* technique for screening drought tolerance in coconut germplasm. Water stress in the culture system was progressively increased with each passage, by incorporating polyethylene glycol (PEG-6000), mannitol and sodium chloride into culture medium. PEG and mannitol were found to have growth inhibitory action even at low concentrations. About 20% of embryos of Sri Lankan Tall variety died before reaching water stress level of 170 mM NaCl. About 78% survived at 170 mM NaCl concentration and only 12.6% were able to resist a concentration of 320 mM NaCl. When zygotic embryos derived from two known drought susceptible cultivars of coconut, CRIC-65 and Dwarf (from *Punila)* were tested using the technique, 29% and 73% of embryos respectively died due to stress damage at 170 mM NaCl concentration and none of either cultivar survived 230 mM salt concentration. However, embryos, which originated from two putative drought tolerant cultivars showed a higher survival rate when subjected to salt stress. At 170 mM NaCl concentration all the embryos developed into seedlings. In fact, germination percentage of embryos was higher at 170 mM NaCl concentration than the control devoid of NaCl. Survival percentage gradually dropped with increase in salt concentration and about 18% survived the 330 mM Nacl level.

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Genetic Resources and Conservation Strategies in Coconut

M.J. Ratnambal

duction

Coconut (*Cocos nucifera* L.) belongs to the family ceae under the Class Monocotyledons. *Cocos* is a typic genus and there are no known wild forms and the variability exists only within local types/population. ut has a pantropic distribution mainly in coastal regions at her side of the equator. Grown in more than 80 countries tropics, India is the leading country in area and uction of coconut in the world. The area and production coconut in the country are estimated (1996-97) at 1.89 n ha and 12,987 million nuts respectively. Coconut is ted in 17 states and three union territories in India and a alone accounts for 53.4 per cent of the area and 44.3 ent of the production.

in and Distribution

The original home of coconut is still uncertain. gh there is still much debate on this subject, ethnological mation as well as diversity of the local types indicate -East Asia to be the most probable centre of diversity Melanesian Origin has been advocated (Harries, 1990). over, it is generally agreed that coconuts have moved Asia in both directions, to the Pacific and America in the nd to Africa in the west. The dispersal of coconut might been effected through humans or through ocean currents seglove, 1972; Child, 1974). Recent studies using restricted ment length polymorphisms (RFLP) confirm the movement coconut from South-East to the Pacific and then to the west t of America (Leburn *et al.*, 1995).

netic Variability and Varieties

Coconut can be broadly classified into two varieties d on stature – the Talls and the Dwarfs.

l palms

Tall palms are sometimes referred to as var. *typica*. e are the most commonly planted cultivars for mmercial production. Tall palms grow to a height of 20- n and are slow maturing, first flowering in 6-10 years after nting. The talls are sturdy and long-lived and they may in an age of 80-100 years. These palms are normally ss-pollinated and hence highly heterozygous. The fruit is edium to large in size with the shape varying from round, val to oblong. The colour of the fruit varies from green, yellowish green to brown. The copra content is usually above 150g per nut and oil content varies from 66 to 70 per cent. The tall palms are hardy and can thrive on different soil types and varying environmental conditions. The palms are identified by the name of the localities from where they are collected or cultivated...Among the indigenous talls, the cultivars West Coast Tall, East Coast Tall, Tiptur Tall, Benaulim, Andaman Ordinary and Laccadive Ordinary are popular. Some of the popular exotic tall cultivars are Fiji Tall, Philippines Ordinary, Sri Lankan Tall, Rennel Tall, West African Tall, Panama Tall, Malayan Tall, San Ramon etc.

Dwarf palms

Dwarf palms are sometimes referred to as var. *nana* (Griff.) Nar. They are of shorter stature, 8-10m high when 20 years old and begin bearing about the 3rd/4th year after planting. They are in full bearing in the ninth year and have a short productive life of 30-35 years. Some trees may give economic yield even up to 50 years. The dwarf palms are more homozygous than talls, due to a high degree of self-pollination. The fruits are small and the colour of fruits vary from green, yellow to orange and brown. Though the palms yield heavily, they have a tendency for irregular bearing. The copra in dwarf palms ranges from 90-120g per nut and oil content is about 65%. The dwarfs are less hardy than the talls, requiring better soil and climatic conditions. They cross with talls and the hybrids show considerable vigour. The dwarfs are presumed to have originated from talls either through mutation (Menon and Pandalai, 1958) or by inbreeding (Swaminathan and Nambiar, 1961).

The dwarf cultivars are not commercially important. They are grown to a limited extent for ornamental purpose as well as for their sweet tendernut water. Recently they are being planted on large scale in isolated seed gardens for the production of Dwarf x Tall (D x T) hybrids.

The popular dwarf cultivars grown in India are Chowghat Green Dwarf, Chowghat Orange Dwarf, both from Kerala and Gangabondam Green Dwarf from Andhra Pradesh.

Among the exotic dwarf cultivars, Malayan Yellow Dwarf, Malayan Orange Dwarf and Malayan Green Dwarf have become popular in all the coconut growing countries of the World. In India, these cultivars have been introduced from Malaysia in 1985 and planted in isolated blocks in Seed Garden Complex, Nilambur, Kerala, for being utilized as

parental material in hybrid seed production.

Germplasm Collection

Research on coconut improvement programme in India, was given considerable attention as early as 1916. The initial research activity conducted during this period was the introduction of some of the cultivars from Malaysia, the Philippines, Indonesia, Sri Lanka and the Carribean and African regions. In 1927, few more introductions were made from the above countries and also from Vietnam, Thailand and Papua New Guinea. In 1952, the exchange of germplasm was intensified. The first indigenous survey for germplasm collection was initiated in 1958 by the erstwhile Indian Central Coconut Committee, Kasaragod. In subsequent years, more emphasis was given for local collection.

In 1981, CPCRI under Indian Council of Agricultural Research (ICAR) intensified the exploration work by obtaining financial assistance from the International Board of Plant Genetic Resources (presently IPGRI). Collection was made during 1980, in six Pacific Ocean Islands, and 24 accessions of 100 nuts each were collected and planted in World Coconut Germplasm Centre (WCGC), Andamans. Subsequently in 1997, CPCRI conducted a survey collection in three Indian Ocean Islands *viz.,* Mauritius, Madagascar and Seychelles which yielded 15 accessions. The financial assistance for this survey collection was provided by ADB (Asian Development Bank) under COGENT (Coconut Genetic Resources Network). A total of 1369 zygotic embryos from 15 accessions were collected by the method developed by Anitha Karun *et al.,* (1993). Recently, the indigenous survey collection was intensified and 21 collections were made which includes 10 accessions from Orissa and 11 from West Bengal.

Present status of coconut germplasm bank

The cultivated varieties and their relatives, which are the sources of variation for crop improvement programmes, are maintained in live genebanks at CPCRI, Kasaragod, Kerala, and at the World Coconut Germplasm Centre, Andamans. Subsamples of these populations are being maintained at different Agricultural Universities.

At present, CPCRI has 132 accessions, which is considered to be the largest coconut germplasm collection in the world, being maintained as a field genebank. The 86 exotic collections consists of 68 talls, 16 dwarfs and 2 semitalls. The 46 indigenous collections comprise of 34 talls and 12 dwarfs (Table 1).

The newly collected accessions *viz.,* those collected from Madagascar, Mauritius, Seychelles, Orissa and West Bengal are under various developmental stages. These accessions will be field planted in due course.

Characterization of germplasm

Studies were undertaken to distinguish coconut accessions based on nursery characters such as number of days for germination, height of seedlings, number of leaves, length of petiole and length and breadth of last fully opened leaf at 12th month in the nursery. Bhaskara Rao and Mathew (1981) developed an index using mean value and CV of these characters for characterisation of germplasm at the nursery stage. This enabled identification of accessions with higher heterozygosity (accession with the highest CV) as well as those with relatively more homozygosity (low CV). This procedure will enable the germplasm collector to assess the population status in a given region based on which, whether sampling should be extensive or intensive can be decided.

Characterization of germplasm was also attempted (Bhaskara Rao and Pillai 1984) from fruit component analysis as proposed by Harries (1978). Among the South East Asian groups – 'Niu Kafa' types had high husk percentage ranging from 41-52% with copra ranging from 7-11%, while 'Niu Vai' types had a much lower husk percentage (28-38%) with copra content of 16-30%. Collections from Pacific and African regions showed both 'Niu Kafa' and 'Niu Vai' types.

Pollen isozyme (Benoit and Ghesquiere, 1984) and leaf polyphenol analysis (Jay *et al.,* 1989) have been used for characterisation of germplasm. Chempakam and Ratnambal (1993) estimated polyphenols in 36 cultivars belonging to 8 geographical origins and found significant variations among cultivars. Recently very exhaustive descriptor using 14 vegetative, 21 reproductive, 24 fruit and 2 biochemical characters have been prepared for 48 cultivars (Ratnambal *et al.,* 1995). Restriction fragment length polymorphism and isozyme analysis have been given priority in research programmes at CPCRI.

Utilization of Germplasm

Direct selection

Based on the preliminary as well as multilocation trials, the cultivar Laccadive Ordinary was selected and released by CPCRI in 1985 under the name 'Chandrakalpa' for commercial cultivation in Andhra Pradesh, Tamil Nadu, Kerala and Maharashtra. Another cultivar, Banawali Green Round from Ratnagiri (Maharashtra) was released by Konkan Krishi Vidyapeeth, Dapoli, Maharashtra, in 1987, under the name 'Pratap'. Recently a high yielding exotic cultivar – Philippines Ordinary was recommended for release in 1995, as a National Variety for large scale cultivation in the West Coast including Konkan region, coastal Andhra Pradesh and West Bengal. The performance of the released varieties is given in Table 2.

Table 1. Coconut Germplasm Holding At CPCRI

Exotic - 86 Accessions				
Place of Collection	Tall	Semi-tall	Dwarf	Total
South East Asia	16	1	3	20
Central and South America, Atlantic Region	6	-	1	7
African Region	4	1	2	7
Pacific Ocean Islands	39	-	6	45
Indian Ocean Islands	3	-	4	7
Total	68	2	16	86
Indigenous – 46 Accessions				
Kerala	4	-	2	6
Tamil Nadu	4	-	5	9
Karnataka	1	-	1	2
Andhra Pradesh	4	-	1	5
Goa	3	-	-	3
Gujarat	1	-	1	2
Orissa	4	-	-	4
West Bengal	1	-	-	1
Andaman & Nicobar Islands	10	-	1	11
Lakshadweep Islands	2	-	1	3
Total	34	-	12	46

Table 2. Performance of the released varieties of coconut (rainfed)

Cultivar	Mean annual yield (No. of nuts/ Palm)	Percentage increase over Local Tall	Mean copra yield		Percentage increase of copra yield over Local Tall
			Per nut (g)	Per palm per year (kg)	
Chandrakalpa (Laccadive Ordinary)	100	25.0	176	17.6	27.5
Pratap (Banawali Green Round)	150	87.5	152	22.8	65.2
Kerachandra (Philippines Ordinary)	110	37.5	198	21.8	57.9
Local Tall	80	-	172	13.8	-

Utilization for hybridization programme

Utilization of germplasm for hybridization programme received considerable attention in India as early as 1930s. The hybrid vigour in coconut was first demonstrated by J.S. Patel in 1937. This has been successfully exploited and so far 11 hybrids involving tall and dwarf parents have been released in the country for commercial cultivation..

The cultivar West Coast Tall (WCT) from west coast regions, East Coast Tall (ECT) from the east coast regions, Andaman Ordinary (ADOT) from Andaman and Nicobar Islands and Laccadive Ordinary (LCOT) from Lakshadweep Islands have gained importance as parental material in hybridization programmes. Among the dwarfs, Chowghat Orange Dwarf (COD), Chowghat Green Dwarf (CGD), Gangabondam Green Dwarf (GBD) and Malayan Yellow

Dwarf (MYD) have gained popularity in hybrid seed production.

Till today, over 90 hybrid combinations have been evaluated over the years at CPCRI and at various Coordinated Research Centres as well as at various Agricultural Universities. CPCRI has released three hybrids *viz.*, COD x WCT (Chandrasankara), WCT x COD (Kerasankara) and LCOT x COD (Chandralaksha). Kerala Agricultural University has recommended five T x D hybrids viz., Lakshaganga (LCOT x GBD), Keraganga (WCT x GBD), Anandaganga (ADOT x GBD), Kerasree (WCT x MYD) and Kerasowbhagya (WCT x SSG). The hybrids VHC-1 and VHC-2 were released by Tamil Nadu Agricultural University, Coimbatore. Andhra Pradesh Agricultural University has released one hybrid, Godavariganga (ECT x GBD).

Utilization of germplasm for tendernut water

The study to identify a suitable variety for tendernut purpose culminated in the release of Chowghat Orange Dwarf. Tendernut water in seven month old nuts of this cultivar contains 7g/100ml total sugars, 4.7g/100ml reducing sugars, 1.8 mg/100 ml amino acids, 20 ppm sodium and 2000 ppm potassium content. The quantity of tendernut water varies from 280 ml to 450 ml per nut.

Utilization of germplasm for tolerance to drought and pest/diseases

Germplasm is also being screened against drought and pests and diseases and some tolerant genotypes have been identified.

Conservation Strategies

The two basic approaches to the conservation of plant genetic resources are *ex situ* and *in situ* conservation. *Ex situ* conservation involves conservation of plant genetic resources outside their original habitat in the form of seeds, embryos, tissues or plants. *Ex situ* conservation includes cold storage, *in vitro* storage and field genebanks.

In situ conservation involves the maintenance of genetic diversity in the habitat in which the diversity evolves. This includes the maintenance of diversity in the farmers' fields and orchards, which is termed as 'on-farm conservation'.

***Ex situ* conservation**

Field genebanks are the most feasible *ex situ* conservation method that can be used for coconut. Being a perennial crop, the maintenance of coconut germplasm in a field genebank is extremely difficult. It requires large area and may be relatively expensive to maintain. Besides, field genebanks run the risk of being damaged by natural calamities, infection, neglect or abuse. Moreover, in coc the fruits are large and embryos survive only for a li period in the nut. Coconut belongs to the group of sp producing recalcitrant seeds which cannot be dried w killing the embryos. The seeds are sensitive to humidity temperature and hence they cannot be preserved u ordinary conditions for a long period. In spite of all t difficulties, field genebanks provide easy and ready acce conserved material for research as well as use.

Field gene banks (FGBs)

There are a number of field collections of coconut in various countries, usually connected with coconut research institutes. In India, under the Indian Council of Agricultural Research (ICAR), CPCRI has the responsibility to provide the lead in all the activities like collection/introduction, exchange, evaluation, documentation, safe conservation and suitable management. This ensures the continuous availability of coconut germplasm for use by breeders and for other research activities in the country. CPCRI has been designated as the 'National Active Germplasm Site' for coconut. Under this, the Institute is maintaining 132 accessions, which is considered the largest in the world. The germplasm is also being maintained at 11 centres in different states under the All India Co-ordinated Research Project on Palms (AICRPP) by State Agricultural Universities.

According to FAO database on coconut germplasm holding, 950 accessions have been reported (Ramanatha Rao *et al.*, 1998). COGENT – The International Coconut Genetic Resources Network under IPGRI, has approved the establishment of multisite International Coconut Genebanks (ICG) at Indonesia (for South-East Asia), India (for South Asia), Papua New Guinea (for the South Pacific) and Cote d' Ivoire (for Africa and the Indian Ocean region). The site selected for the ICG for South Asia is CPCRI Seed Farm, Kidu, Karnataka. All the 132 accessions are proposed to be planted at the ICG. In addition, about 100 accessions viz., collections from Indian Ocean Islands, Lakshadweep Islands, Andaman and Nicobar Islands and also the accessions received through exchange basis from Malaysia, the Philippines and Indonesia, are expected to be added to the national collection.

***In vitro* conservation**

Another method of *ex situ* conservation of germplasm is through the tissue culture. The use of *in vitro* culture techniques including slow growth and cryopreservation, represents an important additional option for medium and long-term conservation of coconut. Slow-growth technique for medium conservation and cryopreservation technique for long-term conservation have been developed for coconut.

Coconut with big fruits, lack of dormancy period and

ick germination of seeds, drastically limit the material that n be collected during collecting missions. A simple and ficient *in vitro* field collecting technique has been developed Assy Bah *et al.*, 1987) which involves extracting the embryos om the nuts and inoculating them directly into the culture edium. Embryos can be kept for 2 months before they are ultured in a controlled laboratory environment (Assy Bah *et* , 1987). Anitha Karun *et al.* (1993) developed a modified hnique, in which the embryos can be collected under field *conditions* and can be stored in sterile water for three months before culturing in nutrient medium. Slow-growth protocols e currently not available for coconut. However, short-term ervation of zygotic embryos has been achieved by ing culture conditions which delay their germination for onths (Assy Bah and Engelmann, 1993). For long-term rvation, preliminary experiments have led to the lopment of a cryopreservation protocol which has been essfully applied to zygotic embryos of four different vars (Assy Bah and Engelmann, 1992). The work on this ct is in progress in many laboratories around the world.

servation of pollen

In coconut, assisted pollination is adopted in ridization. This requires that pollen be conserved until it is for crossing. It is reported that coconut pollen can be ed at room temperature without loss of viability for 3 nths (Whitehead, 1966) to 6 months (Bernard, 1973). eliminary studies indicated that coconut pollen can be ccessfully cryopreserved. More experiments on this aspect e to be undertaken.

***n situ* conservation**

Programmes to establish *in situ* (on-farm) conservation of coconut have not yet been initiated. Coconuts grown in small scale have several features that should make *in situ* conservation feasible (Ramanatha Rao *et al.*, 1998). For this, systematic documentation of farmers' knowledge of coconut diversity and its uses is needed.

Issues Involved in Developing FGBS

Genetic issues: In a highly heterozygous crop like coconut, if its genetic integrity has to be maintained, the population has to be grown in isolation. Available information indicates that coconut pollen does not move long distances and they could travel only to a distance of 350m and maximum dispersal was about a height of 6 m (Mantriratne, 1965). Leaving a border of few meters around the plot will help to avoid pollen contamination. To establish a regional collection, accessions with a range of diversity are to be planted. For this, random sampling procedure in the source population should be adopted.

Genetic drift: Another risk involved in establishing genebank is the genetic drift or loss of rare but important population or accession. In coconut, minimum 40 to 60 individuals will be required to maintain alleles with a frequency greater than 0.05 (Ramanatha Rao *et al.*, 1998) and this helps to mitigate the effects of genetic drift. However, according to STANTECH manual (1994), a minimum of 90 palms are required for an accession/population, with 6 rows of 5 palms replicated three times.

Security: In most of the countries, coconut faces a risk of genetic erosion due to urbanization and industrialization along with abiotic stresses like drought, cyclone, hurricanes etc. and the biotic stresses like pests and diseases or wild animals. So it may be appropriate to establish regional genebanks including safety-duplication of a national collection, facilitating joint multilocational collections. From the safety point of view, the germplasm site should not be located in an area known for natural calamities or disasters.

Climatic adaptation: Adaptability of accessions to location may be important to consider long-term conservation, especially in the case of regional genebanks as it may contain introduced or unadapted material. It is important that the plants in field genebanks should be able to flower, fruit and set viable seeds. The genebank should act as a centre from which planting materials can be supplied for commercial planting.

Access to FGB: The site chosen for the FGB should be easily accessible and preferably near a research station – so that the material can effectively be used for direct selection or breeding programmes.

Supply of material from field genebank: For obtaining progeny from an accession in the field genebank, hand pollination is to be affected. As mentioned earlier, coconut pollen can travel a distance of maximum 360m. It was also observed that the insects like bees, wasps and ants which pollinate coconut flowers tend to return to the same palm or to the neighbouring palms of the same population affecting mostly selfing. Hence, if the plot size is fairly large, it may be possible to obtain fewer uncontaminated nuts (by the foreign pollen) from the middle of the plot (Ramanatha Rao *et al.*, 1998).

Quarantine issues: An effective quarantine system should act as a filter and not as a barrier to the germplasm exchange (Ramanatha Rao *et al.*, 1998). However, field genebank managers should restrict the international movement of seednuts and allow only the movement of embryos. Germplasm should be exchanged only for immediate use or for conservation and care must be taken to collect germplasm from healthy trees. In the course of regeneration and multiplication, protective measures including pesticide

application should be undertaken.

Prevalence of root (wilt) disease in Kerala, Tatipaka disease in Andhra Pradesh, Tanjavur and Ganoderma wilts (*Ganoderma lucidum*) in Tamil Nadu, restrict the movement of germplasm especially exchange of germplasm with other countries. However, coconut germplasm from India can be obtained with the approval of ICAR. The nodal agency for coordinating germplasm exchange in the country is NBPGR, while CPCRI is the authorized agency for phytosanitary clearance. At the international level, COGENT under IPGRI is responsible for introduction and exchange of coconut germplasm with the financial support from FAO and ADB. COGENT restricts the movement of coconut germplasm through seeds, however, they allow coconut germplasm exchange in the form of zygotic embryos.

Future Priorities

Future priorities for coconut genetic resources in the country include collection of germplasm from Micronesia and Melanesia; screening the collected germplasm for biotic and abiotic stresses; exchange of germplasm from Malaysia, Indonesia and the Philippines; utilizing the germplasm especially those collected from Pacific Ocean Islands for production of new cross combinations for evaluating them for yield as well as for tolerance/resistance to drought and pests/diseases. Also, there is considerable scope for enlarging the indigenous collection which now number only 46, comprising 34 talls and 12 dwarfs.

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Genetic Improvement of Coconut

P.M. Kumaran

Introduction

The crop improvement in coconut through selection and hybridization has been one of the major objectives of coconut research workers for the last 67 years. The genetic improvement in coconut is a difficult and time consuming process because of the long pre-bearing age, perennial habit, breeding system, heterozygous nature, the time-lag involved in the study of progresses, lack of reproducible clonal propagation technique and requirement of large area for experimentation. With all these limitations India was the first country in the world to exploit hybrid vigour in coconut in a cross between *Tall* x Dwarf palms (Patel, 1937).

As in other field crops, the genetic improvement of coconut has been made by the research workers all over the world by introduction of germplasm, mother palm selection, seedling selection and tissue culture.

Germplasm Collection of Coconut

The earlier exotic introductions of coconut germplasm into India was in 1924 from the Philippines, Malaysia, Fiji, Indonesia, Sri Lanka and Vietnam which formed the nucleus population for many of the research programmes. The germplasm exchange programme was further intensified in 1952 and in 1958 survey for collection of indigenous germplasm was started. India is having the largest collection of coconut germplasm (132) in the whole world and the same is being maintained in the field at Central Plantation Crops Research Institute, Kasaragod. This collection consists of 86 exotic and 46 indigenous cultivars which include 24 accessions planted at world coconut germplasm centre in Andamans. Apart from this a total of 15 collections were made by the survey and collection of coconut germplasm from Indian Ocean Islands and the same are being cultured in the laboratory/green house. Another set of 21 indigenous collections were also made from Orissa (10) and West Bengal (11) recently and they are maintained in the nursery. The germplasm collection of coconut available are being evaluated for the economic characters such as number of nuts produced per palm per year, number of bunches, average number of female flower production, setting percentage, weight of copra/nut, percent of oil content in copra etc.

Selection

Varieties evolved out of selection

Selection aims at retention of desired genotypes and elimination of undesirable ones in the population and this is considered as one of the important processes in crop improvement programme in any field crop. Based on the preliminary evaluation of cultivars available at Central Plantation Crops Research Institute, Kasaragod, a multilocation trial was started in 1972 in Andhra Pradesh, Kerala, Tamil Nadu and Maharashtra. Based on the over all performance of Laccadive Ordinary in all the experimenting centres, this cultivar has been recommended for commercial cultivation in these four states in 1985 under the name "Chandrakalpa".

Another variety "Benaulim" (Banawali Green Round) from Ratnagiri in Maharashtra has been selected and released in 1987 by Konkan Krishi Vidyapeeth, Dapoli for cultivation in Konkan Coast under the name "Pratap", very recently, the coconut research workers identified Philippines Ordinary as a potential one and recommended for release under the name "Kerachandra". Based on the organoleptic as well as biochemical studies conducted, the cultivar Chowghat Orange Dwarf has been identified as the best tender nut variety.

Mother palm selection

Selection of consistently high yielding palms and making such palms for the generation of seedlings for the upgrading of tall populations was the main method adapted earlier for yield improvements.

The procedure for mother palm selection evolved identification of potential high yielders using some of the easily observable traits which are considered to be associated with yield potential. Most important among the characters are - straight stought trunk with even growth, spherical or hemispherical crown, short and stought bunch stalks, more number of leaves and inflorescence produced, high and consistant yield of nuts, high copra out turn and free from diseases and pest. In India, 80 nuts/palm/year is taken as the standard, with an average husked nut weight of 680g. Studies indicated that the mean nut weight of copra per nut and weight per nut showed high heritability values of 0.67 and 0.95 respectively (Liyanage and Sakai, 1961). Hence selection

pressure should be exercised towards weight of copra in addition to yield of nuts (Bavappa and Sukumaran, 1983). The yield in coconut being a complex character controlled by a number of components and their interaction, studies on path coefficient and regression analysis indicated that the average number of female flowers, number of functional leaves on crown, internodal distance at a fixed mark, total leaf production upto three years after sowing and the time taken for flowering are the important components that showed the largest direct influence on yield and thereby indicating their value in selection programme (Sukumaran *et al.*, 1982).

Seedling selection

Roguing out of inferior and unthrifty seedlings in the nursery is as vital as selecting mother palms and seednuts. The seedling selection based on characters that have been seen to correlated with high yield of adult palms, such as early sprouting, faster growth rate, early splitting of the unexpanded leaf into leaflets, seedling vigour in terms of girth at collar, height and number of leaves besides freedom from pest and diseases (Menon and Pandalai, 1958). Liyanage (1953) has shown clearly the breeding value of the seedling selection in the nursery. Thus the selected seedlings produced palms that yielded 12% more copra compared to the unselected group comprising all type of seedlings ranging from good to bad.

Exploitation of hybrid vigour

The discovery of hybrid vigour in coconut by Patel (1937) between West Coast Tall and Chowghat Green Dwarf cross is a significant landmark in the history of coconut improvement. This important finding has paved the way for the successful breeding programmes for high yield in many of the coconut growing countries.

More than 90 hybrid combinations have been evaluated over the years at CPCRI, Kasaragod, and the various centres at the All India Co-ordinated Research Project on Palms. In the view of the superior performance of Chowghat Orange Dwarf (COD) x West Coast Tall (WCT), and Laccadive Ordinary (LCT) x COD developed at CPCRI, these hybrids were recommended for release under the name "Chandrasankara" and "Chandralaksha" respectively. Another hybrid "Kerasankara" (WCT x COD) was also recommendced for large scale cultivation in Kerala. Besides, Kerala Agricultural University has deveLCTped four hybrids viz., Lakshaganga (LCT x GBGD), Anandaganga (ADOT x GBGD), Keraganga (WCT x GBGD) and more recently, Kerasree (WCT x MYD) has been recommended for large scale cultivation in Kerala state. The other two hybrids, VHC-1 and VHC-II were released by Veppankulam Research Station for cultivation in Tamil Nadu.

These hybrids were found to give 20-40% more nuts and 40-103% more copra/palm/year, over the local tall. The performance of the released hybrids are given in Table 1.-

Breeding for Special Characteristics

Drought tolerance

An average monthly rainfall of 150 mm is necessary for ideal growth of coconut and the production of nut yield. Any erratic distribution and low average rainfall will adversely affect the yield of the palm.

Studies carried out at CPCRI have revealed the possibility of identifying desirable traits of drought tolerant cultivars in coconut field conditions (Rajagopal *et al.*, 1988). Some of the traits identified are – accumulation of epicuticular wax on the leaf surface (ECW), low stomatal frequency (SF), low stomatal resistance (S) and leaf water potential. Some other traits like soil moisture depletion, activity of enzymes like glutamate oxalacetic transminase (GOT) and acid phosphatase (APH) are also found to have their influence on drought tolerance (Rajagopal *et al.*, 1988).

A total of 23 genotypes of coconut which include 10 talls, six dwarfs and seven hybrids were subjected to the drought tolerant studies and identified certain drought tolerant cultivars like Fedarated Malay States (FMS), Java Giant, Fiji Laccadive Ordinary and Andaman Giant. Laccadive Ordinary was found to be relatively more tolerant to drought than other cultivars. Among the hybrids, LCT x COD and LCT x GBGD are more drought tolerant.

Disease Resistance

Coconut root (wilt) disease is the most serious problem causing an annual loss of 968 million nuts in eight southern districts of Kerala. The investigations conducted at CPCRI have shown that the disease is due to the presence of mycoplasma like organisms (MLO) in the sieve tubes of roots, tender stem and inflorescences and petiole (Solomon *et al.*, 1983). As no effective control measures are not available, for this disease, developing resistant/tolerant genotypes is the identification of sources of resistance.

Screening of 48 cultivars and 62 hybrid combinations has not so far yielded any resistant/tolerant type. Hence, a survey for the identification of diseased - free palms in 'hot spot' areas (heavily diseased tracks) has been undertaken through an ICAR Cess Fund Scheme operating at CPCRI (RS), Kayangulam, and 140 palms were selected as 'disease free' based on the serological and physiological tests. Also 19 CGD palms were identified as disease free in 'hot spot' areas.

These palms are being utilized in the breeding programme for the production of tolerant/resistant hybrids.

Table - 1: Performance of released coconut hybrids

Hybrids	Nut yield/ palm/year	Copra yield		Oil content (%)	State for which recommended	Agency responsible
		Mean/ nut (g)	Mean/ palm (kg)			
Chandrasankara (CODx WCT)	116	215	24.9	68	Kerala	CPCRI
Kerasankara (WCT x COD)	108	187	20.2	68	Kerala, Coastal Maharashtra, A.P.	CPCRI
Chandralaksha (LCT x COD)	109	195	21.2	89	Kerala	CPCRI
Lakshaganga (LCT x GBGD)	108	195	21.1	70	"	KAU
Anandaganga (ADOT x GBGD)	95	216	20.5	68	"	KAU
Keraganga (WCT x GBGD)	100	201	20.1	69	"	"
Kerasree (WCTx MYD)	130	216	28.0	66	"	"
VHC-1 (ECT x DG)	98	135	13.2	70	Tamil Nadu	TNAU
ECT x GBGD	140	150	21.0	68	Andhra Pradesh	APAU
WCT	80	176	14.1	68	-	-

Among the different combinations identified CGD x WCT was found to be tolerant to root (wilt) disease and steps have been taken to produce these hybrids on a large scale for planting in disease endemic areas and to screen them for field tolerance to root (wilt) disease, in the hot spot districts of Alappuzha, Kollam, Pathanamthitta and Kottayam.

Tissue culture

A technique for the production of clonal plantlets from tender-leaf segments from 1-2 year old seedlings was attempted and successful but the results could not be repeated subsequently. The work with adult palm tissues is in progress. When this is perfected, one can hope to achieve a production break through by clonal multiplication of elite, disease-free palms showing unusually high productivity. Field collection, storage and retrieval of zygotic embryos have been standardized for use in the collection and conservation of coconut germplasm.

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Breeding for Resistance/Tolerance to Coconut Root (Wilt) Disease

P.M. Jacob and R.V. Nair

Introduction

Coconut root (wilt) disease prevalent predominantly in Kerala, is a serious malady severely affecting coconut production in the state. This disease was reported for the first time from Erattupetta area of Meenachil Taluk in Kottayam District, in 1884 (Butler, 1908; Pillai, 1911). It is believed to have significantly manifested after the great floods of 1882 (Menon and Pandalai, 1958). It has since then spread from the original foci of infection, and currently occupies a contiguous area covering eight out of fourteen districts of Kerala. It has also been reported from some isolated pockets in Tamil Nadu.

Symptoms

The diagnostic symptoms of the disease are, the characteristic bending of the leaflets termed as 'flaccidity', yellowing and necrosis (Radha and Lal, 1972). The disease is pathogenic in nature, as extensive investigations have ruled out nutritional deficiency, hormonal imbalance and water stress as factors directly involved in symptom expression. Palms of all ages are susceptible to the disease. It occurs in all soil types in varying intensities. The disease is only debilitating, causing a slow decline, but not lethal. The first symptom expression is exhibited generally 18 months after planting in the field.

With the progress of the disease, there is a gradual reduction in the number of leaves and successive leaves become smaller, shorter and narrower resulting in the shrinking of the crown (Varghese, 1934; Menon and Pandalai, 1958). They may grow weaker and produce fewer buttons and nuts which may be shed. The endosperm of the nuts is thinner than usual, uneven in thickness and when dried remains leathery. The husk of the nut is thinner than normal. If the trees get affected by the disease before flowering they may not flower at all (Ramadasan *et al.*, 1971). Younger plantations in infected areas also deteriorate faster than older plantations.

Rotting of roots is considered to be one of the symptoms of the disease by many workers (Butler, 1908; Menon and Nair, 1949; Menon and Pandalai, 1958; Michael,1964; Anon., 1971). Percentage of root decay varied from 12.0 to 94.4 depending upon the intensity of the disease, (Michael, 1964). Maramorosch (1964) noticed root rotting only in a few cases and not in all palms.

Etiology

The etiology of the disease remained an enigma till the early eighties. Recent studies have ruled out the involvement of biological agents such as fungi, bacteria, nematodes and viruses, as well as nutritional and physiological factors, in the etiology of the disease (Jayasankar and Bavappa, 1986; Solomon, 1991).

Detection of phytoplasma in ultra thin sections of developing leaves, unopened inflorescences, root tips and terminal bud tissues in disease affected palms and their abscence in samples taken from the healthy palms is highly significant (Solomon *et al.*, 1983). Supporting evidence in favour of phytoplasmal etiology has also emerged from transmission trials using dodder (*Cassytha filiformis)* and periwinkle *(Catharanthus roseus).* Indications on the nature of probable insects transmitting the pathogen are also encouraging (Sasikala *et al.*, 1988; Mathen *et al.*, 1990). The role of lace-bug, *Stephanitis typica*, the insect vector transmitting phytoplasma from diseased to healthy palms has been unequivocally established and phytoplasma has also been detected in the brain and salivary glands of the vector (Mathen *et al.*, 1987).

Screening of Coconut Cultivars/Hybrids for Resistance/Tolerance to Root (wilt) Disease

Studies on identifying coconut genotypes resistant/tolerant to root (wilt) disease were initiated by Varghese in 1934. He surveyed about 10 sq. km in and around Kayangulam, a highly root (wilt) affected area and could not locate genotypes resistant to root (wilt) disease.

Trials conducted at CPCRI, Kayangulam during 1951 to 1968, have shown that open-pollinated progenies of healthy palms from disease endemic areas had higher yields and lesser disease incidence than the progenies from disease affected palms (Menon *et al.*, 1981).

Attempts to screen the available coconut cultivars were made as early as 1961 at CPCRI Kayangulam. The cultivars tested were Andaman Ordinary, Andaman Giant, Cochin China, Ceylon Tall, Laccadive Dwarf, Laccadive Ordinary, New Guinea, Philippines, Strait Settlement Apricot, Strait Settlement Green, St. Vincent and Spicata. All these cultivars evaluated in the field developed typical symptoms of root

(wilt) disease (Menon *et al.*, 1981)

Rawther and Pillai (1972) reported that Natural Cross Dwarf coconuts (NCD hybrids of COD) exhibited higher tolerance to the disease as compared to West Coast Tall (WCT) cultivar. These hybrids also gave higher yields inspite of contracting the disease. However, the survey had some limitations on account of insufficient number of hybrid population in the field.

Large scale field experiments were undertaken during 1972 in CPCRI Kayangulam and also in cultivators' gardens in different soil types in 63 villages of Alappuzha, Kollam and Kottayam districts. Under this programme, one year old open pollinated progenies of 36 cultivars and 43 hybrid combinations were planted in gardens that had 40 to 70 percent incidence of root (wilt) disease. The data collected from these experiments revealed that all the cultivars and hybrids contracted the disease irrespective of the soil type. However, the percentage of incidence was comparatively high in alluvial and reclaimed soil types (Table 1).

Table 1. Percentage of incidence of root(wilt) disease in cultivars/hybrids planted in different soil types

Cultivar/ hybrid	Sandy loam	Laterite	Alluvial	Reclaimed
WCT	34.0	22.0	50.0	52.0
COD	22,0	9.5	26.0	47.5
CODxWCT	38.7	31.0	45.5	51.7
WCTxCOD	27.2	36.0	53.1	71.0
WCTx Ganga-bondam	30.5	25.0	60.0	53.6

Analysis of the data collected for ten years from 21 cultivars and 15 hybrid combinations along with WCT as control, planted at CPCRI Kayangulam in a replicated trial during 1972, revealed that none of the cultivars and hybrids has tolerance to root (wilt) disease. It may be noted that all the above cultivars and hybrid seedlings were taken from disease free area of Kasaragod.

The percentage of disease incidence ranged from 33.3 to 100. The average annual yield was maximum in WCT x COD hybrid (52.5 nuts per palm)though the disease incidence was as high as 91.6%, followed by Java Giant x KGD with 43 nuts and 83.3% disease incidence and Laccadive Ordinary with 40 nuts and 58.3%disease incidence in the sixteenth year of planting.

Information gathered from the screening experiments laid out during 1972 in cultivator's gardens (sandy loam soil) indicated that the hybrid combination CODxWCT had the average yield of 80 nuts/palm/year with 50% disease incidence, followed by WCT x COD with 70.3 nuts and 94% disease incidence and WCTx Gangabondam with 52.5 nuts and 87.5% disease incidence compared to 70 nuts and 37.5 % disease incidence in West Coast Tall.

New trials involving 27 cultivars, 10 hybrid combinations, F2 (OP) of DxT and TxD, progenies of elite palm, high yielding WCT and prepotent WCT, were laid out in cultivator's gardens during 1982. Among these, 27cultivars were planted in 5 locations and the remaining in 8 locations. Data collected from the above trials have shown that among the 27 cultivars, all except Kenthali have taken up the disease and the disease index ranged from 7. 1 to 55.6%. All the ten hybrid combinations, F2(OP) of TxD and DxT, progenies of elite palm, prepotent and high yielding WCT were affected by the disease ranging from 12.5 to 66.7% at the fifth year of planting. Of the two hybrid combinations and the three cultivars planted during 1983, MYD contracted the maximum disease incidence (48.3%), followed by Laccadive Ordinary (33.3%) and the minimum by COD x WCT (2.6%) as compared to WCT (6.9%) at the fourth year of palnting.

Twenty four exotic accessions collected in 1981 from South Pacific Ocean Islands were planted at the World Coconut Germplasm Centre at Sipighat in Andamans, with the main objective of producing *inter se* and selfed seed nuts; and also making crosses using pollen collected from them, on disease free palms located in the 'hotspot' areas in South Kerala. These seed nuts will be planted in 'hot spot' areas for screening for resistance to root (wilt) disease.

A large scale screening trial with three replications was initiated in 1985, in the Kayangulam Kayal farm, 16 km from CPCRI Regional Station involving 33 talls, 6 dwarfs and 9 hybrid combinations with plot size of 16 seedlings have been laid out. The cultivars and hybrids were monitored regularly for their reaction to root (wilt) disease. The first symptom was noticed 30 months after planting. Of the 17 cultivars and five hybrids planted during 1985, twelve cultivars and all the five hybrids have been affected by the disease with the disease incidence ranging from 2.3 to 11.6%, the maximum being recorded in WCT x Gangabondam hybrid. Among the 10 cultivars and four hybrids planted during 1986, Markham Tall and Fiji Tall contracted the disease with an index of 2.1 and 2.3 percent, respectively. The trial was discontinued.

The elite disease free palms identified in the diseased tract (Iyer *et al.*, 1979) were monitored for their yield and reaction to root (wilt) disease. Among the elite palms under observation, three have been affected by root (wilt) disease

[Thazhava, Champakulam and Krishnapuram (Kappil)] and their yield level ranged from 96 to 156 nuts per palm per year (Anon., 1988). All the open pollinated progenies of these elite palms planted in CPCRI Kayangulam during 1980, have contracted the disease ranging from 40% to 100%. However, the progenies of Thazhava palm showed their superiority over the others in yield with an annual average yield of 100 nuts in the eighth year of planting.

As an initial step towards breeding for resistance/ tolerance to root (wilt) disease, an intensive survey covering the heavily root (wilt) affected areas ('hot spots') of Kottayam, Alappuzha, Pathanamthitta and Kollam districts of Kerala, was initiated during 1985 to identify disease free and high yielding palms (Anon., 1986). Occurrence of high yielding palms among the heavily diseased palms was reported as early as 1953 by Davis. The survey was further intensified during 1988. Chowghat Green Dwarf (CGD) which was reported to show maximum field tolerance (over 90%) to root (wilt) disease (Anon., 1972) was also included in the survey. The criteria for the selection of West Coast Tall (WCT) and Chowghat Green Dwarf (CGD) mother palms were as follows:

West Coast Tall (WCT)

1. Should yield 80 or more nuts per palm per year
2. Should be regular bearers, the bunches being well supported by the petioles
3. Should be free from all diseases and pests
4. Should show negative reaction to root (wilt) disease in the sero-diagnostic tests
5. Should be 35 or more years of age
6. Should be surrounded by 80% or more root (wilt) affected palms preferably in the advanced stages of disease
7. Should have all typical characters of WCT confirmed by the progeny test to make sure that no hybrid palm is selected as mother palm.

Chowghat Green Dwarf (CGD)

1. Annual yield should be over 100 nuts per palm per year.
2. Age of the palm should be 20 years or more
3. Should be serologically negative to root (wilt) disease
4. Should be free from all diseases and pests
5. Should posses all the typical characters of CGD with regard to stem, crown, leaf, nut and inflorescence
6. Should be surrounded by 80% or more rot (wilt) affected palms preferably in the advanced stages of disease

A total number of 187 mother palms were selected and employed in the crossing programme (Table 2).

Table 2. Yearwise details of mother palms under artificial pollination in hotspots

Year	No. of mother palms used in crossing work.		
	WCT	CGD	Total
1988-89	25	-	25
1989-90	30	6	36
1990-91	32	-	32
1991-92	40	8	48
1992-93	67	10	77
1993-94	104	5	109
1994-95	95	30	125
1995-96	85	20	105
1996-97	76	111	187

Hybridization involving disease free elite WCT and CGD) mother palms in 'hot spots' of Kottayam, Alappuzha, Pathanamthitta and Kollam districts was carried out in the following cross combinations for generating progenies to study their reaction to root (wilt) disease (Nair *et. al.*, 1996).

1. WCT x WCT (*inter se*)
2. WCT x WCT (mixed pollen)
3. WCT selfed
4. WCT x CGD (TxD)
5. CGD xCGD (*inter se*/ selfing)
6. CGD x WCT (DxT)

Artificially pollinated seedling progenies of different cross combinations mentioned above were underplanted since 1991 in different blocks at CPCRI Regional Station, Kayangulam, where more than 80% of the existing palms were affected by root (wilt) disease. A total of 2423 artificially pollinated progenies raised by crossing the disease free elite WCT and CGD mother palms selected in 'hotspots' have been planted so far, from 1991 to 1997 (Table 3).

Table 3. Details of seedlings planted in CPCRI Farm, Kayangulam for screening

Year	Block	WCT x WCT			WCT x CGD	WCT O.P.	CGD x WCT	CGD x CGD	Total
		B.P	M.P.	Self					
1991	4	74	-	-	-	-	31	-	105
1992	1,4	286	172	79	-	20	14	20	591
1993	4, 6, 7	86	206	46	-	124	-	24	486
1994	3, 5, 6, 11	105	390	53	-	47	88	24	707
1995	3, 4, 5	257	-	15	23	40	15	-	350
1996	2, 3	37	-	77	26	36	44	-	220
1997	6,7	166	-	-	65	-	-	-	231
	Total	1011	768	270	114	267	192	68	2690

B.P. – Biparental; M>P> - Mixed pollen; O>P> - Open pollinated

Observations on the first batch of 31 CGDxWCT hybrid progenies planted during 1991 at CPCRI Regional Station at Kayangulam revealed that the palms have an yield potential of over 100 nuts per palm per year in the fifth year of planting and came to flowering in 30 to 40 months after planting. The copra content was 215 g/nut. Characteristic symptoms of the root (wilt) disease were noticed only in 5 palms in the eighth year of planting (16%).

On the other hand, the performance of 50 CGDxWCT hybrid progenies brought from a disease-free area (Kasaragod) and planted in 1990 at Kayangulam revealed that the percentage of disease incidence was 60 in the fifth year of planting itself. This has highlighted the scope of developing the CGDxWCT hybrid from the disease-free CGD and WCT mother palms identified in disease endemic areas, as the ideal planting material.

The *inter se* crossed and selfed progenies of WCT from disease-free elite mother palms in 'hotspots' are also being evaluated. The first batch of progenies planted during 1992 are in the initial stages of flowering. Preliminary indications show that the root (wilt) disease incidence is nearly 30% as compared to 50% in the progenies raised from open pollinated seednuts from mother palms under crossing. This has clearly demonstrated the better performance of the artificially pollinated progenies over the open pollinated progenies in the disease endemic areas.

Two seed gardens, one each at CPCRI Research Centre, Kannara (Thrissur Distritct) and Coconut Development Board Farm at Neriamangalam (Ernakulam district) have been established for large scale production of disease tolerant planting materials such as WCT x WCT, WCT x CGD and CGD x WCT hybrids for distribution to farmers in the disease endemic districts in Kerala State. Details of the planting are given in Table 4.

Thus breeding programme for evolving resistance/ tolerance to coconut root (wilt) disease initiated at Central Plantation Crops Research Institute is showing encouraging results and indicates the possibility of evolving resistant/ tolerant high yielding CGD x WCT and WCT x WCT hybrids for replanting the root (wilt) disease ravaged gardens, utilizing the natural resistance/tolerance already existing in CGD and WCT mother palms in 'hot spots' to evolve new hybrid combinations.

Future thrust

Establishing more seedgardens in the disease endemic districts for large scale production of disease-free and elite planting materials may be given the highest priority. This will help in reducing the disease intensity in a phased manner which inturn will result in boosting the coconut production in the root (wilt) disease affected districts. Another attempt also be made to identify the rare prepotent mother palms among the tolerant palms identified in 'hot spots'.

Table 4. Details of seedlings planted for establishing seed gardens

Location	Year of start	No. of seedlings planted			Total
		WCT x WCT	WCT selfed	CGDxCGD *inter se*/selfed	
CPCRI(RC) Farm, Kannara	1995	650	285	250	1185
CDB Farm Neriamanga-lam	1996	250	50	100	400
Total		900	335	350	1585

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Disease Management with Special Reference to Varietal Response in Coconut

Rohini Iyer

Introduction

Diseases contribute a major share towards crop losses in coconut. Some of these damages are direct as in the case of budrot or basal stem rot where the life of the palm is lost resulting in abrupt losses while diseases like root (wilt) and stem bleeding cause debility of the palm which lead to gradual yield loss in the beginning which goes unnoticed till the crown symptoms begin to manifest and button shedding becomes very apparent. A slow debilitating disease like the root (wilt) has far-reaching effects. The affected palm becomes prey to leaf rot which is a disfiguring disease causing acute yield loss. As a result of the disease, the leaf lamina thickness reduces and so does the strength of the other tissues. This leads to increased attack by pests. However, diseases like bud rot can be prevented and yield losses can be minimized in many other diseases by integrated management practices. This article attempts to give a comprehensive picture about the symptoms, causes, disease cycle and integrated management practices with special reference to varietal response in coconut to the diseases that are prevalent in India.

Phytophthora Diseases

Bud rot

Bud rot is a fatal disease of the coconut palm, characterized by the rotting of the terminal bud and surrounding tissues. It affects palms of all ages, but young palms in low and moist situations are more susceptible to the disease. The incidence of the disease has been reported from almost all coconut growing countries of the world.

Bud rot is reported from East Africa, Central America, Trinidad, Fiji etc. In India, bud rot is quite common on the West Coast and East Coast tracts. Radha and Joseph (1974) reported a disease incidence of 1.2 to 10.9 per cent in Kerala and 35 to 40 per cent was observed in certain gardens having large number of palms.

Bud rot has been the subject of intensive investigations in several countries from the time it was first reported. The causative organism was first suspected to be *Pestalotia palmarum* (Busck, 1902). Later workers favoured the theory of bacterial origin for the disease (Earle, 1903; Petch, 1906; Stockdale, 1907; Fredholm, 1909; Johnston, 1910) and considered the causal organism as *Bacillus coli* (*Escherichia migula*). In 1906, Butler reported that the bud-rot of palms in India is caused by *Pythium palmivorum* which was later renamed as *Phytophthora palmivora* Butl.

The genus *Phytophthora* was erected by Anton de bary in 1876. In this genus both heterothallic and homothallic sps. are reported. Both sexual and asexual reproduction are present in *Phytophthora*. The studies have clearly shown the existence of two dominant *Phytophthora* sp. *P. palmivora and P. katsurae* in relation to bud rot of coconut. The occurrence of *P. Katsurae* causing bud rot has been reported from Hawaii and also Ivory Coast. Recently Veena (1997) reported *P. katsurae* from Kuttiadi area in Kerala.

Palms of all ages are susceptible to the disease, but it is more rampant in palms which are below 20 years of age. The period elapsing between the first infection and withering of heart leaf depends on a number of factors, the more important of which are relative humidity and the point of infection. It might vary from three to nine months or longer. With the onset of dry weather, the infection becomes less severe and pathogen remains dormant. The fungus was found to survive in the frond base or basal part of the crown (Menon and Pandalai, 1958; Radha and Joseph, 1974) or in roots (Harris *et al.* 1984).

Seasonal factors are found to be associated with the incidence and spread of the disease. The incidence is found to be severe during monsoon when the relative humidity is high. Studies conducted at CPCRI Regional Station, Kayangulam revealed that the favourable period of infection is when relative humidity is above 94% and temperature is below 24°C. An infection cycle of *Phytophthora palmivora* in coconut is completed within 6 days under favourable conditions of humidity (98-100%) and temperature (22-24°C).

The disease is primarily disseminated by wind and wind blown rain and to a lesser extent by insect, birds and climbers.

Management: Control measures are effective only when they are adopted in the initial stage of the disease. If the disease is detected when the central shoot is just withering, chemical control by the application of 10 per cent Bordeaux paste on

the affected portion can check the disease. Bordeaux paste has to be applied after thorough cleaning and removal of infected material. The treated portion should be given a protective covering to prevent washing off of the paste during rain. As a prophylactic measure, adjacent healthy palms should be sprayed with 1% Bordeaux mixture. It is reported that stem injection with systemic fungicides, Aliette/ Aureofungin sol/Calixin is effective in protecting the palm from bud rot. Regular spraying with copper fungicides at 40-day intervals especially before and after monsoon is an effective preventive measure. In copper sensitive palms, keeping perforated sachets containing mancozeb in the leaf axils during rainy season is useful.

Antagonistic fungi like *Trichoderma* sp., *Myrothecium roridum* and *M. verrucaria* are reported to suppress the growth of *P. palmivora* and *P. katsurae*. It has been reported that antibodies produced by these fungi may have a role in the suppression of the pathogen in the soil.

Another method of control is through the identification of resistant sources. Characterization of the resistant sources can be made by assessing the field performance of planted varieties. The performance of coconut varieties depends on the regions where they planted.

In Indonesia, among tall varieties, the West African Tall (WAT) is most susceptible to bud rot, and in Dwarf varieties, Nias Yellow Dwarf (NYD) seems to be most susceptible one. Bud rot is also observed predominantly in areas planted with PB 121 (MYD x WAT) coconut hybrids. Exotic talls such as Rennel Tall and local talls are more tolerant. Dwarf x WAT hybrid is highly susceptible to bud rot. Hybrids of Malaysian Yellow Dwarf x Rennel Tall or Local Tall were found to be less affected than PB 121. The NIWA hybrids obtained by crossing NYD x WAT are susceptible to bud rot.

In Asia, local ecotypes are generally more tolerant to *P. palmivora* than introduced ecotypes, although the Polynesian Tall and Rennel Tall are less severely affected than the Bali Tall in North Sumatra.

Malayan Red Dwarf (MRD) is susceptible to bud rot caused by *P. katsurae* in Cote-de-Ivoire and is also susceptible to the same damage in Jamaica. Where as Red Dwarf x Tall coconut hybrids are more tolerant of bud rot than the Red Dwarf parent. Both Malayan Red Dwarf and West African Tall were susceptible to bud rot, whereas the Malayan Yellow Dwarf (MYD) and the Polynesian, Rennel and Malaysian Talls are hardly susceptible or even highly tolerant in Jamaica.

In Philippines, MAWA hybrid (Malayan Yellow Dwarf x West African Tall) was found to be susceptible to bud rot infection. For avoiding high economic loss, it is recommended that the choice of planting material should be done by taking into account the environmental conditions.

Proper spacing between the palms is important for the management of the disease. Too close planting encourages spread of the disease. A good spacing between palms favours air movement and dissipation of the excess humidity that can build up in the gardens. Proper drainage is also important for reducing the disease incidence.

Organic matter application favours the growth of a variety of microbes including antagonists such as *Trichoderma* and *Gliocladium* sps. which multiply on organic matter and help in reducing the population of pathogens like *Phytophthora*. Biological control is geared towards identifying microorganisms effective against *Phytophthora*.

Permanent use of site specific fungicide is not recommended because fungicide resistant isolates or strains of *Phytophthora* spp. may occur through their continued use. At present there is a need for effective, broad-based integrated control of *Phytophthora* diseases. This control may combine the use of resistant varieties, improvement of cultural practices, new translocation fungicides and development of biological control methods.

Nut Fall.

Fruit rot or nut fall is an important coconut disease. Nutfall does not kill the palm but substantially reduces the production. This disease has been reported from various coconut growing countries. A table showing the chronology of nut fall incidence is given below:

Table 1. Reports on nutfall in chronological order

References	Country
Sundararaman and Ramakrishnan 1924	India
Turner, 1965	Malaysia
Sanchezpotes, 1966	Colombia
Bennet *et al.*, 1986	Indonesia

The disease is characterized by rotting of immature nuts during rainy season, resulting in nut fall. Nuts, 2 to 5 months old, can be attacked. Symptoms begin as water soaked lesions usually appearing near the perianth. These turn brown and become irregular in shape. This may spread into the husk and may reach the endosperm (Concibido, 1990; Quillec and Renard, 1984).

The causative organism of nut fall is *Phytophthora*

spp. Two species of *Phytophthora, P. palmivora* and *P. katsurae* are most important in relation to the nut fall disease (Ooka and Uchida, 1984; Steer and Coates- Beckford, 1990).

Climatic factors are found to be associated with the incidence and spread of the disease. The disease incidence is higher when rainfall and the humidity is high. The disease is most active during wet weather. Spores are dispersed by rain splash and air currents. Resistant chlamydospores can survive in soil and in coconut debris including nut tissue.

Dissemination of the disease is by simple contact between fruits or via dissemination agents that maintain isolated infections on coconut palms.

Management: The disease can be effectively prevented by prophylactic spray with 1% Bordeaux mixture during pre-monsoon period. Test trials conducted reveal that fungicides like Fosetyl-A1 are very effective against nut fall and bud rot. To avoid the spread of the disease, the diseased nuts should be burned. Proper spacing of palms in garden is important to avoid high humidity which is favourable to the pathogen.

Genetic control is through the identification of resistant sources. The performance of coconut varieties depends on the regions where they are planted. In the Philippines, the disease was first observed on Cameroon Red Dwarf plantation and later on the Malayan Red Dwarf and Malayan Yellow Dwarf plots. Rillo and Paloma (1988) claimed that red and yellow nut coloured populations are more susceptible to nut fall compared to green coloured cultivars. A decrease in production due to nutfall is observed in Indonesia, nearly where ever the hybrids of PB 121 (MAWA) and local dwarf coconuts are planted.

Observations showed that the resistance of coconuts to nut fall is variable. In North Sumatra, premature nut fall has been found on hybrids and on West African Tall coconuts, but other varieties such as Bali Tall, Tahiti and Rennel Tall have not yet been affected by nut fall.

In Cote d' Ivorie the West African Tall was highly susceptible to bud rot, whereas its nuts remained unaffected; on the other hand the MYD x WAT hybrids (PB 121) were not much affected by either bud rot or nut fall.

The dwarf varieties are definitely the most susceptible to immature nut fall in Indonesia. Serious nut fall is seen in Nias Yellow Dwarf (NYD) in certain regions in Indonesia. The cultivars most tolerant to nut rot include the Cameroon Red Dwarf (CRD) the Malayan Red Dwarf (MRD) Malayan Yellow Dwarf (MYD) and Vanuata Tall (VTT). The hybrids with the WAT (West African Tall) suffer the great losses.

In India too, the Chowghat Orange Dwarf (COD) and its DxT hybrids with WCT showed higher incidence of bud rot, particularly in Kidu Seed Garden where the COD palms were earlier planted in alternating rows with WCT palms. WCT shows comparative resistance to bud rot.

The heavy incidence of the disease can be checked by planting of coconut hybrids tolerant to nut fall, a good spacing between palms, proper drainage and judicious use of fungicides.

Stem Bleeding Disease of Coconut

'Stem bleeding' is a debilitating disease of coconut, which is prevalent in almost all coconut growing areas of the country causing considerable economic loss. The first report on stem bleeding disease of coconut was made by Petch (1906) from Sri Lanka. Later it was reported in India (Sundararaman, 1922), Philippines (Lee, 1922), Malaysia (Sharples, 1923), Trinidad (Briton-Jones, 1940), Papua New Guinea (Dwyer, 1953), Fiji (Mc Paul, 1962), Indonesia (Reynard *et al.*, 1984) Bangladesh (Rahman *et al.*, 1989) and Mexico (Noriega *et al.*, 1991). In India, stem bleeding disease is known to occur in Kerala, Karnataka, Tamil Nadu, Goa, Orissa, Maharashtra, Andamans and West Bengal.

The typical symptom of the disease is the exudation of reddish brown gummy fluid from growth cracks on the trunk which later turn black on drying.

Although several types of stem bleeding are there, the basic disease is caused by a soil borne fungus, *Thielaviopsis paradoxa* (de Seynes) von Honnel. Though this fungus was suspected as an incitant of stem bleeding disease by many workers (Menon and Pandalai, 1958 and Ohler, 1984) for a long time, it was only recently that Nambiar *et al.* (1986) confirmed the etiological role of *T. paradoxa.*

T. paradoxa is a fungus commonly present in the soils of the coconut growing regions. This fungus enters the coconut tissues through growth cracks/injuries and multiplies in the infected tissues, producing two types of spores, viz., endoconidia (phialospores) and chlamydospores (Petch, 1908). The chlamydospores are able to survive in the soil to tide over the unfavourable conditions. These spores again germinate producing mycelium which is capable of infecting the host.

Development of growth cracks, poor drainage, soil moisture stress, hard pan formation in soil, imbalance in nutrition, excessive soil salinity, stem injury, lightning attack and insect attack are some of the predisposing factors reported to be responsible for disease incidence (Nambiar and Kalpana Sastry, 1988). The fungus enters the stem tissues through

growth cracks or wounds occurring naturally on palms (Petch, 1908). Sudden heavy manuring (Briton-Jones, 1940) or heavy rains followed by extensive dry period (Ohler, 1984) were reported to cause development of more growth cracks on stem. Radha (1962) reported that undue fluctuation in soil reaction and moisture or ill-drained soil conditions could cause severe stem bleeding disease leading to death of the palms.

Nambiar *et al.* (1989) studied the effect of seasons on infection by *T. paradoxa* through artificial inoculation studies at Kasaragod. Maximum lesion development was recorded in palms inoculated during South-West monsoon or post monsoon period (July-November) and lesser lesion development during summer months (April-May). This indicates that high humidity and low temperatures favoured enhanced infection during S-W monsoon period, while high temperature and reduced moisture during summer restricted the disease development.

Management: Since the etiology of the disease was not clearly understood earlier, Sundararaman (1922) recommended removal of the affected tissues on the stem and painting the wound surface with hot coal tar as a control measure. After the establishment of the etiological role of *T. parodoxa* in the stem bleeding disease, studies on the control of disease using fungicides have been initiated. Radhakrishnan (1990) observed that soil drenching with calixin 0.1% was effective in controlling stem bleeding disease. Ramanujam *et al.* (1993) observed that root feeding with calixin 5% or Bavistin 5% was comparatively more effective than in reducing the disease and increasing the yields of the stem bleeding affected palms.

Another area of research that is gaining importance in stem bleeding disease management is biological control. Sanal Kumar (1990) studied *in vitro* interaction of mycoflora associated with stem bleeding lesions and identified local isolates of *Trichoderma viridi*, *T. harzianum* and *Aspergillus niger* to be inhibitory to *T. paradoxa*.

Genetical investigations

Radhakrishnan and Potty (1980) studied the natural incidence of stem bleeding disease on fifteen coconut cultivars in Kerala and observed that the most susceptible cultivars were Philippines (40%), Java (40%), West Coast Tall (40%) and Gadipuli (40%), whereas Mysore (10%) Cochin China (10%) and Godavari (12.5%) were less susceptible. At CPCRI, a technique of inoculating the detached mature fronds with *T. paradoxa* had been standardized to evaluate the reaction of various varieties to infectionby *T. paradoxa* This helps in evaluating the varieties under controlled conditions and also eliminates the risk of exposing live plants in the to artificial inoculation with a plant pathogen. Vitiation of results due to weather variables can also be eliminated.

Among the 16 talls, 6 dwarfs and 4 hybrids scre against *T. paradoxa*. Banawali Green Round, Ban Brown Round and Laccadive Ordinary among talls, Ma Orange Dwarf and Gangabondam among dwarf and L Ganga among hybrids show smaller lesions.

Philippines Ordinary, S.S. Green, Andaman and Fiji Tall among Talls, Malayan Green Dwarf, Chow Orange Dwarf among Dwarfs and Chandra Sankara Kerasankara among hybrids recorded larger lesions.

Basal Stem Rot/Ganoderma Wilt/Thanjavur Wilt

Basal stem rot is one of the destructive diseases coconut occurring in various coconut growing regions of world. The disease is known as 'Ganoderma wilt' in And Pradesh, 'Anabe' in Karnataka (Venkatarayan 1936; Rao a Rao, 1966), and as 'Thanjavur wilt' in Tamil Nadu (Vijay and Natarajan, 1972).

The disease was first reported on areca palm Mysore by Coleman in 1911. Peries et al .(1975) report the disease from Sri Lanka. Nambiar and Rethinam (1987 reported the disease in some parts of Kerala. Bhaskaran an Ramanathan (1984) found that the disease incidence ranged from 0.6 percent to 4.9 percent in Tamil Nadu. In the severely affected gardens in Thanjavur district of Tamil Nadu, the disease incidence was as high as 31.4 per cent (Bhaskaran *et al.*, 1984).

Though the root system is affected first, visible symptoms are seen in the crown as wilting of leaflets. The outer whorl of leaves turn yellowish, then gradually become brown and droop to form a skirt around the trunk apex. In course of time, the apex of the trunk shows tapering with the advancement of the disease, and the stem base shows bleeding symptoms. The tissues beneath the lesions are decayed and this decay can be traced into the bole region. The drooped leaves fall off one by one leaving only a few leaves at the apex. The crown is easily blown off by wind (Bhaskaran *et al.*, 1982). At the base of the affected palms, sporophores of the *Ganoderma* spp. appear, generally after the death of the palm (Bhaskaran *et al.*, 1989). Usually it takes six months to two years for the affected palms to die (Rethinam, 1984).

In India, *Ganoderma lucidum* was reported to be the causal agent of the disease (Rao and Rao, 1966). However, later reports (Bhaskaran *et al.*, 1989) show that *G. aplanatum* is also involved. Peries *et al.* (1975) on the other hand, reported *G. boninense* as the causal agent of basal stem rot in Sri Lanka.

The fungus has a wide host range attacking a variety of palms and several forest avenue and fruits trees. According

to Naidu *et al.* (1966), hosts belonging to 19 families, 36 genera and 48 species have been recorded. Some of these hosts are: *Areca catechu, Cocos nucifera, Cassia siamea, Pongamia glabra, Eucalyptus, Azadiracta indica, Morus alba, Artocapus fraxinifolius, Cassia javanicus, Acacia catechu, Casuarina equisetifolia* and *Dalbergia sisso.*

Rao and Rao (1966) reported low incidence of the disease in heavy soils of Andhra Pradesh, probably due to their high moisture retention capacity. Peries *et al.* (1975) also found that the disease progressed rapidly in dry areas, the distruction of the palm being faster (six to 30 months) in areas receiving less rainfall (1000 mm) as compared to areas receiving 2000 mm rainfall (upto six years). Lewin *et al.* (1983) reported that soil moisture stress during the summer predisposed the palms to infection. A positive correlation between mean maximum temperature and the number of bleeding palms has been observed by Jagannathan and Rangaswamy (1975). Vijayan and Natarajan (1972) reported that the trees in the age group of 10 to 30 years were more susceptible. The disease spread was from a central point towards outside (centrifugal) and the linear spread was found to be influenced by low rainfall and relative humidity (Ramapandu *et al.*, 1980).

Since diagnosis of the disease at a very early stage is essential for taking up effective control measures, work has been done on Colorimetric methods (Natarajan *et al.*, 1986) or on methods employing physiological parameters like transpiration rate and stomatal diffusive resistance (Vijayaraghavan *et al.*, 1987) which have given encouraging results. Diagnostic method using fluorescent antibody technique was developed against Ganoderma disease in arecanut (Reddy and Ananthanarayanan, 1984) is being employed in coconut also (Sampath Kumar,1993)

Management: Destruction of the bole of the diseased palm and isolation of neighbouring healthy palms (Briton Jones, 1940), by digging out trenches 50 x 50 cm around the palm has proved useful. Peries *et al.* (1975) recommended removal of the affected tissues and applying fungicides. Among fungicides, aureofungin sol and calixin have been reported to give very encouraging results. Chiselling the bleeding patches and applying bordeaux paste is also recommended. Ploughing and flood irrigation should be avoided to prevent the spread of infective propagules. Irrigation may be provided through drip or channel. Application of neem cake at 5 kg per palm was found to be beneficial in inhibiting the disease (Bhaskaran *et al.*, 1988). The use of *Trichoderma* spp. for biological control of the pathogen has been reported (Bhaskaran *et al.*, 1989).

Efforts have been made to locate sources of resistance to this disease. Screening of coconut cultivars (6 varieties and 4 hybrids) for their reaction to Thanjavur wilt, was conducted at TNAU's Veppankulam Research Station (Bhaskaran *et al.*, 1984) by planting them in wilt sick soil at Thambikkottai. The percentage of survival, disease incidence and nut yield were recorded. Evaluation done eight years after planting revealed that the hybrid East Coast Tall x Wilt tolerant ECT is more tolerant to Thanjavur wilt, with 66.7% survival as compared to other cultivars.

Root (Wilt) Disease

The coconut root (wilt) disease (RWD) has been prevalent in the State of Kerala for over 100 years and is believed to have made its first appearance after the great floods of 1882. It has now established itself almost continuously in a contiguous manner in 4,10,000 ha. in eight Southern Districts of Kerala, stretching from Trivandrum in the South to Trichur in the North. A comprehensive survey made in 1984-85 shows that the lowest disease intensity of 1.52 per cent is observed in Trivandrum District followed by 2.6 per cent in Trichur District. The highest intensity was noticed in the district of Kottayam (75.63 per cent) followed by Alleppey (70.69 per cent). The annual loss caused by the disease is of the order of 968 million nuts. RWD is also observed in sparse manner in isolated pockets in the remaining five northern districts including Kasaragod and also in the adjoining districts of Kanyakumari and Coimbatore in the State of Tamil Nadu.

The disease is not a fatal one but is a slow decline disease. The important visual diagnostic symptoms are, abnormal bending or ribbing of leaflets, termed as "flaccidity", a general yellowing and marginal necrosis of leaflets. Flaccidity is regarded as the earliest consistent visual symptom seen in the central and outer whorls. Yellowing and necrosis occur in varying intensities in the outer whorl. In advanced stages, paling of the younger leaves is also seen. Inflorescence necrosis, production of little or no female flowers, pollen sterility, shedding of immature nuts, poor quality nut/copra, thinner husk, less firm shell, uneven thickness of kernel etc. are also observed. The yield is reduced considerably on account of the disease.

Involvement of biotic agents like fungi, bacteria, viruses, viroids and nematodes in the root (wilt) disease was ruled out after a series of inoculation experiments and electron microscopic studies. Extensive studies have ruled out the role of physiological and nutritional disorders as the primary cause of the disease. Studies with electron microscope showed the presence of phytoplasma (MLO) consistently, in the seive elements of diseased palms, and their absence in the healthy palms which supports the phytoplasmal etiology of the disease. Remission of the disease symptoms by tetracycline treatment and insect and dodder transmissibility of the disease

further confirmed the phytoplasmal etiology.

Studies on the role of insects in the disease spread, through electron microscopic studies indicated that the lace bug (*Stepanitis typica*) and the plant hopper (*Proutista moesta*) have the potential to acquire phytoplasma and sustain their propagation in the salivary gland tissues. The vector role of these two insects were confirmed through transmission experiments done under insect proof conditions.

Management: No curative measures are so far been available. However, based on research results accrued in the past, a strategy has been formulated for containing the disease in its present geographical limits and managing the disease by improving the condition of the affected palms and increasing the yield.

Eradication in mildly affected areas: In the mildly affected areas of Northern Kerala and Tamil Nadu, total eradication of all the disease affected palms should be taken up to check the spread and contain the disease to Southern Kerala.

Management of the disease in Southern Kerala.: The following strategies should be adopted for the management of the disease in heavily diseased areas of Southern Kerala.

1 In the heavily disease-affected tracts, eradication of all severely affected uneconomic adult palms (those bearing less than ten nuts per year) and all diseased palms in the prebearing age, and adoption of the recommended package of practices, are the strategies suggested for the management of the affected gardens.
2 Replanting with the progenies of field tolerent, disease-escapes located in 'hot spot' areas like hybrids involving disease free CGD palms and *inter se* material of disease free CGD.
3 A balanced dose of NPK fertilizers (1000 g Urea, 1700 g Super Phosphate and 3000g Muriate of Potash) and Magnesium Sulphate (3000 g) per palm per year is applied.
4 Mixed farming is adopted (raising fodder crops in the inter spaces and maintaining milch cows) and recycling the organic matter (50 kg of farm yard manure/palm/year). Growing green manure crops like *Pueraria phaseoloides* in the basins during April-September and incorporating them during September-October.
5 Adopting mixed cropping with cocoa, which increases soil fertility through litter production. Raising inter crops like yam and elephant foot yam in RWC affected coconut gardens.

As the disease cannot be controlled by conventional plant protection measures, development of resistant/tolerant cultivars is the only practical solution. Trials conducted at CPCRI Kayangulam during 1951 to 1968 have shown that open-pollinated progenies of healthy palms from disease endemic areas had higher yields and lesser disease incidence than the progenies from disease affected palms (Menon, Thommen and Sukumaran, 1981).

Attempts to screen available coconut cultivars were made as early as 1961 at CPCRI Kayangulam. The cultivars tested were Andaman Ordinary, Andaman Giant, Cochin China, Ceylon Tall, Federated Malay State, Fiji, Java, Laccadive Dwarf, Laccadive Ordinary, New Guinea, Philippines, Strait Sekttlement Apricot, Strait Settlement Green, St. Vincent and Spicata. All these cultivars evaluated in the field developed typical symptoms of root (wilt) disease (Menon, Thommen and Sukumaran, 1981).

Rawther and Pillai (1972) reported that natural cross dwarf coconuts (NCD hybrids) exhibited higher tolerance to the disease as compared to West Coast Tall (WCT) cultivar.

Analysis of the data collected for two years from 21 cultivars and 15 hybrid combinations compared with WCT as control, planted in CPCRI Kayangulam in a replicated trial during 1972, revealed that none of the cultivars and hybrids has tolerance to root (wilt) disease. The percentage of disease incidence ranged from 33.3 to 100. Analysis of yield data collected for ten years indicated that the average annual yield was maximum in WCT x COD hybrid (52.5 nuts per palm) though the disease incidence was as high as 91.6%, followed by Java Giant x KGD with 43 nuts and 83.3% disease incidence, and Laccadive Ordinary with 40 nuts and 58.3% disease incidence in the sixteenth year of planting.

Information gathered from the screening experiments laid out during 1972 in cultivators gardens (sandy loam soil) indicated that the hybrid combination COD x WCT had an average yield of 80.1 nuts/palm/year with 50% disease incidence and WCT x Gangabondam with 52.5 nuts and 87.5% disease incidence compared to 70 nuts and 37.5 per cent disease incidence in West Coast Tall.

As an initial step towards breeding for resistance/tolerance to root (wilt) disease, an intensive survey covering the heavily diseased traits (hot spots) of Alleppey, Kottayam, Quilon and Pathanamthitta Districts, was conducted to locate disease-free palms. A total of 162 high yielding apparently healthy WCT palms in the age group of over 35 years were initially selected. Serological and physiological tests (stomatal resistance) were conducted on these palms, and 26 palms which showed the negative reaction to both the tests were finally selected as parents for breeding programme.

Chowghat Green Dwarfs (CGD) selected from 'hot spots', showed maximum field tolerance (over 90%) to root

(wilt) disease. In view of this, a survey was conducted in Thiruvalla (Pathanamthitta District) and Kumarakom (Kottayam District) to locate high yielding and disease free CGD palms to be used as parents in the breeding programme. A comprehensive breeding programme has been initiated involving disease free WCT and 19 CGD palms identified in 'hot spots'. Crossing is in progress in the following combinations: (1) WCT x WCT, (2) CGD x WCT (3) WCT x CGD and (4) WCT (self).

The elite palms identified in the diseaed tract (Iyer *et al.*, 1979) were monitiored for thier yield and relation to root (wilt) disease (Thazhava, Champakulam and Krishnapuram (kappil) and their yield level ranged from 96 to 156 nuts per palm per year. All the open pollinated progenies of these elite palms planted in CPCRI Kayangulam during 1980, have contracted the disease ranging from 40 to100%. However, the progenies of Thazhava palm showed their superiority over the others in yield with an annual average yield of 100 nuts in the eighth year of planting.

The possibility of locating resistance/tolerance to root (wilt) disease lies more on the disease free palms located in the disease endemic area, and their hybrid progenies. The CGD X WCT hybrids planed at Kayangulam during 1991 have so far remained healthy and yield over 100 nuts from the third year of planting. Thus there is every hope of evolving genetic resistance/field tolerance in natural populations.

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Genetic Resources and Conservation Strategies for Arecanut (*Areca catechu*)

Anuradha Sane

Introduction

Arecanut (*Areca catechu* L.) is one of the cash crops of South India mainly grown for its masticatory nuts popularly known as betelnut or 'supari'. Arecanut has been a very auspicious commodity in ceremonial and religious occasions in our country. It holds a place of honour at all occassions including births, weddings, rejoicing and deaths. In the Vedas, the arecanut palm is described as 'Devajutha' or 'Kalpa Vriksha', a creeper like grass, which has assumed an upright position after attaining strength and is thus facing the skies.

The *Areca* palm, a monocot, belongs to the family Palmae. A tall unbranched slender stem with dense crown is the typical characteristic feature of this palm. The genus *Areca* includes 76 species that are distributed widely in tropics of South East Asian countries (Murthy and Bavappa, 1960). The commonly cultivated species in almost all the countries is *A. catechu*. In Srilanka, however, the fruits of *A.concinna* are reported to be occasionally chewed as a substitute for arecanut. According to ancient medicinal literature Vagbhatta (4th century AD) has described its use against leucoderma , leprosy, cough, fits, worms, anaemia and obesity. It is reported to be used as antihelminthic and purgative.

At present, arecanut is commercially grown only in India and Bangladesh. Even though arecanut cultivation is fairly ancient in India, it is primarily a small holder's crop occupying only negligible percent of the total agricultural land. In peninsular India particularly in the Canara and Konkan regions, its cultivation has been developed to a high level of specialization. At the same time in many parts of south and South East Asian including several Pacific Ocean countries, it is typically what we may call as a protected plant, that is a plant that comes up naturally from self-sown seeds or raised by planting one/few seeds in the backyard, or in the borders of the homesteads, which are then allowed to grow up by the homestead owner.

India ranks first in the world in area and production of arecanut. Hence, it becomes very essential to give a high priority for conservation of genetic resources of this crop. Arecanut is cultivated mainly in Assam, Karnataka and Kerala on commercial scale since it is typically tropical crop. However, it is also cultivated in the states of Maharashtra, Tamil Nadu, Goa, West Bengal and Tripura.

Even though India occupies first position in area and production, the commercial varieties are limited to a few in comparison with other plantation crops. Since 1957, several accessions of arecanut have been collected from South East Asian countries and within India and are maintained in the field gene bank at CPCRI, RS, Vittal.

Origin and distribution of arecanut

Areca catechu is classified under the tribe Arecae of the family Palmae. Linnaeus in his *Species Plantarum* (1753) used the term *catechu* for the specific name of the arecanut palm. Based on the greater usage and provisions in the international code of botanical nomenclature, *A.catechu* is to be accepted as the correct botanical name of arecanut palm (Bavappa, 1964). As to the origin of arecanut palm, many opinions have been put forward. There is no record of fossil remains of the genus *Areca,* but the abundance of the palm genera discovered in the form of leaves and stems from the tertiary period probably indicates that this genus was in existence as far back as that period. Bavappa (1963) studying the distribution pattern of *Areca* species observed that the contiguous areas of Malaya, Borneo and Celebes having a maximum of 24 species could well be the area where the greatest diversity and wealth of forms of *Areca* are concentrated. Thus, the East Indies group of islands may be taken as the center of maximum diversity.

Evolutionary significance

Based on clustering pattern of *A.catechu* cultivars from countries such as India, Sri Lanka, Saigon, Singapore and Indonesia, Bavappa (1974) reieterated that both *A. catechu* and *A triandra* had their origin in the Archipelago of Indonesia. He presumed that probably these species moved to west through Malaysia to India, Srilanka and as far as Mauritius, all through maintaining their specific identity. Bavappa (1974) based on evolutionary course of *A. catechu, A triandra* and *A. concinna* concluded that probably *A.catechu and A.triandra* were the putative parents *of A. concinna.*

Status of germplasm collection

The genetic resources programme in arecanut is being handled at CPCRI, Vittal to undertake collection and conservation. The exotic collection consists of five species viz., *A. catechu, A triandra, A. macrocalyx, A . normanbyii, A*

concinna and two related genera *Actinoryhtis calapparia and Pinanga dicksonii.* Though these different genera of palms are not economically important they are reported to be resistant to pests and diseases of arecanut (Table 1). Incorporation of these characters along with the other characters like size of nut and hardiness into the commercial varieties of arecanut for further progress. (Murthy and Bavappa,1963). A systematic collection of germplasm within the country and abroad have been in progress since the inception of Central Arecanut Research Station at Vittal in 1957. The germplasm repository at CPCRI, Vittal consists of 23 exotic and 89 indigenous types.

Table 1. Specific characteristics of different species / genus

Species/Genus	Characteristics
A. catechu Linn.	High yield, Edible nuts
A. concinna Thw.	Dwarf habit
A. triandra Roxb.	Flowers throughout the year, suckering, tolerance to mites, more number of female flowers/bunch and high percentage of fruit set (57%), high chali recovery (27%),short stature and less astringent taste compared to *A. catechu*
A. macrocalyx Zipp.ex.Bl.	High arecoline content
A. normanbyii F.Muell	Sweet pulp, semitall
Actinoryhtis calapparia Wendl.&Drude	Bold nuts, extraction of tannins

Exotic collection

The early part of collection from 1957 to 1967 involved collection of exotic germplasm from South East Asian countries of the world. A total of 23 types consisting of the cultivars of *A.catechu* and related species from the countries such as Sri Lanka, The Philippines, Indonesia, Singapore, Malaysia, Thailand, South China, Fiji, British Solomon Islands and Mauritius are being maintained (Table 2).

Yield evaluation of exotic collections resulted in the release of three high yielding varieties namely Mangala, Sumangala and Sreemangala (Table 3). Mangala gave outstanding performance with a number of desirable characters viz., semitall, early bearing (3 years after planting), quicker stabilization of yield (8 years), higher nutset, higher initial and cummulative yields with good chewing and marketing quality of nuts. Sumangala ,a tall variety, produces medium sized oval shaped nuts with high percentage of chali recovery. Sreemangala produces compact bunches with bold

Table 2. Arecanut species and cultivars (exotic collection)

Accession number	Country/place of collection	Name of the species
VTL-1	Fiji	*Areca catechu*
VTL-2	Mauritius	*Areca triandra*
VTL-3	China	*Areca triandra*
VTL-5	Ceylon-1	*Areca* species
VTL-6	Indonesia-1	*Areca triandra*
VTL-7	Indonesia-2	*Areca triandra*
VTL-9	Indonesia-4	Areca species
VTL-11	Indonesia-6	*Areca atechu*
VTL-12	Saigon -1	*Areca* species
VTL-13	Saigon –2	*Areca* species
VTL-14	Saigon –3	*Areca* species
VTL-15	Ceylon-2	*Areca* species
VTL-17	Singapore	*Areca* species
VTL-18a	Br.Sol.Islands-1	*Areca* species
VTL-18b	Br.Sol.Islands-2	*Areca* species
VTL-18c	Br.Sol.Islands-3	*Areca* species
VTL-21	Ceylon-3	*Areca concinna*
VTL-23	Australia	*Areca normanbyii*
VTL-26	Fiji	*Areca catechu*
VTL-27	Saigon	*Actinoryhtis callaparia*
VTL-28a	Saigon-1	*Areca* species
VTL-28b	Saigon-2	*Areca* species
VTL-28c	Saigon-3	*Areca* species

Table 3: Comparative yield performance of arecanut

Vaiety	Country of Introduction	Year of release	Mean ripenut Yield (Kg/palm)	Chali yield (Kg/palm)
Mangala	China	1972	8.82	2.02
Sumangala	Indonesia	1985	12.93	3.28
Sreemangala	Singapore	1985	12.82	3.10

and round shaped nuts .Both Sumangala and Sreemangala were released for cultivation in coastal Kerala, Karnataka and W.Bengal.

Indigenous collection

Till now five expeditions undertaken to different parts of the country resulted in the collection of 89 accessions (Assam (27), Andaman Is. (23), West Bengal (12), Karnataka (11), Meghalaya (10), Maharashtra (4), Kerala (1), Tamil Nadu (1), and Gujarat (1)). Evaluation of these accessions for yield performance showed that maximum yield of ripenuts was recorded by Mohitnagar, Thirthahalli, Cal-17 and SAS-1.

Mohitnagar : An introduction from Mohitnagar area of W. Bengal recorded highest yields as indicated by the data from several gardens of Dakshina Kannada district. It produces a mean yield of 15.08 kg/palm/year ripenuts and 3.67 kg chali/ palm/year. It produces an average of 6.67 bunches/year with 809094 nuts/bunch, 38.86g fruit weight and 6.5 g kernel weight. It was released in 1991 for cultivation in coastal Kerala,Karnataka and W. Bengal.

Cal-17: **It** has been recommended for release in Andaman and Nicobar islands. It has high yield potential of 18.89 kgs fresh nuts/palm/year with kernel weight of 4.34 kg/palm/year.

SAS-1: The Sirsi Arecanut Selection (SAS-1) is recommended for cultivation in Sirsi area (hilly area). It has an yield potential of 24.03 kg fresh nuts/palm/year.

Genetic Variability

Arecanut is a highly cross pollinated crop. It is an allotetraploid with chromosome number, 2n=32. Even though *A. catechu* Linn. is the only cultivated species, it has been observed that there is a wide range of variation existing in size, shape, and colour of fruit, fruit set, size and shape of the kernel between different arecanut growing regions and in the same region between different palms. In Southern states of Mysore, Kerala and Bombay a detailed survey of arecanut gardens revealed that there is a gradual increase in size of nuts from south to north as far as the west coast region of Kerala and South Kanara (Murthy and Bavappa, 1963). The nuts in this region are medium to big in size. In Malnad parts of Shimoga and Chikmagalore districts of Karnataka, the nuts are small in size, whereas the region of North Kanara, Ratnagiri and Kolaba districts show altogether a different size i.e., nuts are broader than long. Incidentally, all the above three regions form three distinct topographic zones isolated by natural barriers. It is thus evident that the nut size of cultivars/ecotypes which are under cultivation in these distinct zones for the past many centuries have been maintained.

The areca palms based on the visual estimates height attained, could be classified broadly into tall, and dwarf types (Table 4). The height ranges between and 360 cm as recorded at the seventh year of age (M and Mohan,1984). A dwarf arecanut mutant was rep from Hirehalli, Karnataka. It was reported that 40 ye palm attained a height of only 4.57m. Other character features of this palm are suppressed internodal distance w makes annual scars appear superimposed, erect crown sh and dark green colour of the leaves. It produces erect bun with a yield of 5-6 kg ripenuts / palm / year.

Table 4. Distribution of characters in different cultivars *A. catechu*

Cultivars	Specific characters
High yield	Mangala, Sumangala, Sreemangala, Mohitnagar, Cal-17 and SAS-1
Early bearing	Mangala
Greater number .of fruits/bunch	Thirthahalli
Better quality	Sreevardhan
Fruit size (large)	South Kanara Local
Regular bearing	South Kanara Local
Semitall	Mangala, Shrivardhan
Dwarfness	Hirehalli Dwarf

Field gene bank

Primary collection of arecanut resources is commonly maintained in field gene banks. These field trees allow confirmation of their morphological identity. Besides, the performance of the genotypes can be evaluated for resistance to pests and diseases. The response of the trees to the environment conditions can also be compared. Crop genetic resources are conserved by two main means off–site (*ex situ*) collections using frozen seed, while plants growing in field gene banks and *in vitro* collections ;or in their natural habitats (*in situ*).For crops like arecanut with racalcitrant seeds, which cannot be dried and frozen without killing the embryos, seed gene banks are not an option. In arecanut with unorthodox seeds, species for which no *in vitro* techniques exist, the conservation stategy would be storage in field gene banks as well as analyses to designate *in situ* reserves.

Space limitations and operating costs will prevent field gene banks from becoming the main conservation

strategy for most perennial crops in the tropics and subtropics. Unfortunately, field trees are vulnerable to environment catastrophes viz., high wind, rain, drought, freezing or below average temperature, pests and diseases outbreaks. For secure combination of these collections, alternate center at gene bank has been established at Mohitnagar.

The present germplasm holding represents considerable variability procured from South East Pacific Region. So far germplasm collection and documentation has been significant which resulted in the release of high yielding varieties namely Mangala, Sumangala, Sreemangala, Mohitnagar and Cal-17. The cultivation of high yielding varieties with adoption of improved agronomic practices helped the country in attaining self sufficiency in arecanut production.

Future Thrust

There is a need for enriching germplasm and screening the germplasm for abiotic (Drought tolerance) and biotic (Resistance to yellow leaf disease) stress. *In vitro culture* including cryopreservation holds promise for germplasm activities. *In vitro* techniques are important not only for conservation of genetic resources, but can also be used for the creation of new variability. In order to complement *ex situ* conservation of arecanut, *in vitro* conservation should be developed and adopted.

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Genetic Improvement in Arecanut

K.S.Ananda

Introduction

India is the largest producer and consumer of arecanut and it continues to dominate world in area under cultivation and production and productivity. Arecanut is one of the very few examples, wherein crop improvement work combined with improved input technologies contributed to revolutionized production and productivity within the last 40 years (Nair, 1994 and Ghosh and Nampoothiri, 1999). Prior to initiating research on crop improvement, the area under arecanut in India was 1.06 lakh hectares during 1955-56 which increased to 2.64 lakh hectares during 1996-97 recording an increase of 149 percent over a period of four decades. The production for corresponding period has increased from 0.81 lakhs tonnes to 3.13 lakh tonnes (286 percent increase). The productivity increased from 850 kg per hectare in 1955-56 to 1186 per hectare during 1996-97. Thus the increase in production was not only due to increased area under cultivation but also increased productivity contributed by improved varieties, supply of quality planting materials, advanced agro-techniques and plant protection measures.

Variability in the Crop

Nuts varied in size and shape under different geographical and economical regions. Nuts from North Malabar and Mysore are big and oblong in shape and are proportionately less in number on bunch. In South Malabar, Travancore, Cochin and Maidan area of Karnatka, the nuts are medium and oblong, while in Mettupalayam, the nuts are very small and roundish. Wide range of variability in size and shape of nuts were observed in Assam and Meghalaya (Anon., 1994).

***Areca catechu* cultivars:** Beccari (1919) reported four botanical varieties of *Areca* namely *A. catechu* var. *communis, A. catechu* var. *silvatica, A. catechu* var. *batanensis* and *A. catecnu* var. *longicarpa* based on the size and shape of fruits and kernels. In addition to that, Rao (1915) described a new cultivar *A. catechu var. deliciosa*. Raghavan and Baruah (1956) described different cultivars of *A. catechu* occuring in Assam based on variation in flowers, size and shape of the fruits. Bavappa (1966) identified cultivars of arecanut based on the number of stomata per unit area. Later, Bavappa and Pillai (1976) found significant difference in respect of number of leaves shed, female flowers produced, fruit set, number of nuts harvested and weight of nuts among 13 cultivars of arecanut from eight countries. A dwarf palm natural mutant found in Hirehalli, Karnataka was reported by Naidu (1963).

***Areca triandra*:** The species has orginated in India and Malaysia. The trunk is multiple, 5-10" tall, 1-2" thick, green and distnictly annulate, petiole 1" long, leaf pinnate, 3.5" long and dropping. Spathe is green, smooth with a short blunt point, size 6"-12" long. Female flowers are relatively more in number. Fruits are oblong, distinctly mammillate, smooth, orange when ripe later becoming red. Nuts are edible.

***Areca concinna*:** It is a native of Sri Lanka, suckering type, trunk 8-12" tall, 1-2" in diameter, cylindrical, green, leaves are few, 3-3½" long, leaflets 2" long, spadix 1" long with short peduncle. Fruits are 1½" long, subfusiformly ovoid and scarlet in colour.

***Areca normanbyii*:** Revised name of this species is *Normanbya normanbyii*. It is a monotypic genus, popularly called as 'black palm', originated in Australia. Trunk is slender, enlarged at base, leaves pinnate, 6-8' long, petiole very short, leaflets arranged in groups of two or three attached a the base but divided and spreading outward, flower stalk below the crown shaft, much branched, fruits 1½" long, pear shaped, colour of peach, fleshy seeds are broadly ovoid, ¾" in diameter and roughly ridged.

Floral Biology of *Areca* Palm

Arecanut palm is a essentially a cross pollinated species (Bavappa and Ramachandran, 1967) and monoecious. The spadix is enclosed in a boat-shape spathe. Male and female flowers are separate. Female flowers are confined to the territory rachis and to the distal end of the secondaries. The male flowers are produced on filiform branches, which arise below and beyond the female flowers. The male phase begins on an average about 4 days after the spadix has emerged from the spathe and the phase lasts for about 26 days. Whereas, the female phase lasts only for 3 days in 84 per cent of the cases after the completion of the male phase (Murthy and Bavappa, 1960; Bhat, 1963). It was found that the areca pollen can travel about 1.2 kilometers (Murthy and Bavappa, 1961).

Cytogenetical Studies

Sharma and Sarkar (1956) reported the phylogenetic

in palms. The somatic chromosome number (2n) of *catechu* L is 32 (Venkatasubban, 1945). Bavappa and 82) made a comprehensive review of the cytology and of *Areca*. Detailed cytological information on some number, meiotic behaviour, chromosome size orphology have been reported (Bavappa and Raman, Bavappa, *et al.*, 1975).

Areca catechu is reported to have two pairs of satellite chromosomes (Venkatasubban, 1945). The nosomes were categorized into seven groups based on hology. There are considerable differences between pes of *A triandra* showed higher frequency of edian and median chromosomes as compared to *A chu*. Detailed meiotic studies have also been reported. chromosome pairing in meiosis of *Areca triandra* rded partial desynopsis of varying degrees in the different s. Among the recorded deviations from normal omosome pair desynapsis constitutes one of the most portant meiotic phenomena. *Areca triandra* is apomictic avappa and Nair, 1975) and this character can be expected be maintained in the population. Observation on pollen female fertility show that *Areca catechu* has a high pollen tility, while the nutset is less than 50%. The average nitset in the species has been reported to be 37.6% (Murthy Bavappa, 1960). Various events that prevent pollination fertilization have been listed by Raghavan and Baruah (1956) as possible causes of female sterility in this species.

Chromosome association in *Areca macrocalyx* during microsporogenesis was observed by Nair and Ratnambal (1978). Sharma and Sarkar (1956) reported only 16 bivalents in the first metaphase for *Areca catechu* and *Areca triandra*. Bavappa and Raman (1965) observed mostly bivalents with a rare quadivalent in *A. catechu* and only bivalents in *A. triandra* and suggested a secondary allotetraploid origin for *A. catechu*.

Crop improvement

Evolving high yielding improved varieties of arecanut has been successful through the introduction of indigenous and exotic types and refinement of selection procedures for mother palm, seed nuts and seedlings (Nair, 1994). In the recent years, hybridization and exploitation of dwarfing genes for breeding Dwarf and high yielding varieties have been initiated (Anon., 1992).

Introduction of Germplasm

Germplasm repository at the CPCRI RS vittal consists of 113 accessions (Ananda and Anuradha Sane, 1999). Out of which, 23 exotic accessions were introduced to this Station from countries *viz.*, Fiji, Mauritius, China, Sri Lanka, Indonesia, Saigon, Singapore, BSI, Australia, which represents, *Areca catechu* Linn., *Areca triandra* Roxb., *Areca normanbyii, Areca macrocalyx, Areca concinna* and related genera *Actinorhytis calapparia*. Besides, about 90 indigenous collections were also made from Karnataka, Kerala, Tamil Nadu, West Bengal, Assam, Maharashtra, Gujarat and Andaman and Nicobar islands and Meghalaya (Nampoothiri *et al.*, 1999). About 39 accessions of germplasm have been described based on the descriptor consisting of 17 morphological and 4 inflorescence and 14 fruit characteristics

Evaluation and Selection

Exotic and indigenous collections have been under evaluation for morphological, nut characters and yield since 1957. The comparative yield trial of cultivars was initiated during the first decade of introduction of exotic germplasm from South East and Asian countries of the world and yield evaluation for nine years (Anon., 1974) showed that five accessions viz., VTL-3, VTL-11, VTL-12, VTL-13 and VTL-17 have high yield potential in comparison with the South Kanara Local cultivar. Evaluation of exotic collections resulted in identifying high yielding varieties such as Mangala, Sumangala and Sreemangala.

Mangala

A selection from VTL 3, introduced from China, this cultivar was released under the name Mangala during 1973. The Mangala variety is characterized by semi-tall nature, partially drooping crown with well spread leaves and having more number of leaflets than the local type. The leaflets are dark green in colour with characteristic crinkling at the tip. The fruits are medium sized with good chewing and marketing quality (Bavappa, 1977).

Sumangala(VTL-11)

Sumangala is an introduction from Indonesia. Palm is tall partially dropping habit. Under ideal condition, palm flowers in 4-5 years. The colour of the nuts is deep yellow to orange and oblong to round in shape. Sumangala gives average yield of 17.25 kg of ripenuts per palm per year at the age of 10 years. The increase in yield of this cultivar over the local South Kanara variety is 63 per cent. This variety has been recommended for commercial cultivation during the year 1985 for cultivation in all the arecanut growing areas in general and Dakshina Kannada in particular.

Sreemangala(VTL-17)

This variety was selected from an introduction from Singapore. Palm is tall with partially drooping habit and comes to flowering in the 5 years. It is high yielder with an average yield of 15.63 kg/palm/year and the increase in yield over the local variety is 48 per cent. Ripe nuts are oblong to round and deep yellow in colour. This variety has been recommended for commercial cultivation in Karnataka during the year 1985.

Mohitnagar

Indigenous collections of 13 cultivars from Thirthahalli, Chickmagalur, Hirehalli, Peechi, Mohitnagar, Assam, South Kanara and Gujarat were under comparative evaluation from 1964 onwards and four more types were added to the evaluation from Shriwardhan, Dapoli, Thirthahalli and Assam during 1966. The yield evaluation of these cultivars indicated the high yield potential of Mohitnagar, an indigenous cultivar from North Bengal (Bavappa and Nair, 1982). Further, it was confirmed that yield performance of Mohitnagar was better (3.7 kg chali/palm/year) as compared to Sumangala., Sreemangala at Kidu (Anon., 1991).

This variety has been recommended for release during 1991 for cultivation in North Bengal, coastal Karnataka and Kerala. The important feature of this variety is its greater uniformity. The bunches are well placed and nuts are loosely arranged on spikes which help in their uniform development and also enable efficient plant protection measures. Early stabilization of yield as compared to Sumangala and Sreemangala is also noticed. This variety is consistent high yielder with an average yield of 15.08 kg ripe nuts per palm per year.

Calicut-17

This variety (indigenous to Andaman and Nicobar islands) is talll in hature with longer internodes and crown as compared to Mangala. The striking feature of the cultivar is its consistent and high yielding potential (average of 18.89 kg ripe nuts per palm per year with a kernel weight of 4.34 kg per palm per year), well placed bunches with round and bold nuts. This cultivar has been released for commercial cultivation in Andaman and nicobar islands during 1995 where it has exhibited the best performance as compared to Mangala and other cultivars.

SAS-1

This variety is characterized by tall palms with compact canopy and is a regular bearer. Nuts are round and even sized and closely arranged on compact bunches. This variety has higher procuring percentage. It is suitable for both tender and ripenuts processing. It has got the potential to yield about 4.60 kg chali per palm per year and has been recommended for traditional arecanut growing valleys of Sirsi hill zone of Karnataka.

Selection

Seedling selection

Studies have shown that considerable yield increase can be obtained by judicious selection of seedlings at the time of planting and in subsequent stages (Bavappa and Ramachandra, 1967a, Bavappa, 1970). Among the vario seedling characters correlated with heritability estimates, was found that the number of leaves at the time of plantin girth at collar after planting and number of nodes two yea after planting have positive genotypic and phenotypic correlations with yield and high heritability. All these have negative correlation with age at first bearing indicating that selection of seedlings based on these characters, a standard for seedling selection has been established selecting seedlings with four or more number of leaves a girth of 20 cm or more after than one year and four or more number of nodes two years after planting (Bavappa and Ramachander, 1967a, 1967c). Bavappa (1970) also suggested selection of seedlings with maximum number of leaves and minimum height for transplant to the main field. A simple selection formula was computed by him based on number of leaves present at the time of planting to be multiplied by 40 and subtracting height of the seedlings. Seedlings having higher values based on this computation selected for establishing high yielding plantations.

Mother palm selection

The regularity in yielding behaviour of the mother palms had no relation with the performance of the progenies (Bavappa and Ramachander, 1967c). Further, it is observed that mother palms having high progeny performance were distinct almost all the gardens and hence giving emphasis for selection of seednuts particular garden as practiced by the farmers has no scientific validity (Bavappa and Ramachander, 1967c). Yield pattern of the palms of different bearing ages indicate that palms come to bearing earlier are always better yielders (Bavappa and Ramachander, 1967c). They also observed that selection of seedlings for number of the leaves girth at collar and number of nodes as per standard fixed totally eliminated late bearing palms in a garden established with such seedlings. Selection based on yield alone may not be worth practicing since heritability values for the number of nuts and weight of nuts are very low.

Mass pedigree selection

Bavappa and Ramachander (1967c, 1968a, 1968b) initiated a modified mass pedigree selection with the primary objective of attainment of increase in yield in a garden was established with about 2,966 palms selected from 41 farmers from the farmers garden. Families and palms within the selected families were selected by applying bulk and individual norm tests (Harland, 1957). The screening of selection of 10 palms belonging to three families and the second generation established from the progenies of these selected palms indicated the expected genetic gains were very low for wet weight of nuts as well as for the number of nuts, it was concluded that such a selection procedure of applying bulk norm and individual testing as in the case of cotton is ineffective in improving the yield of arecanut (Anon., 1981).

Bavappa and Ramachander (1967b) suggested a refinement of selection procedure superimposing characters of high heritability and correlation with yield, prepotency, selection index and desirable characters such as resistance to pests and diseases in addition to the bulk norm test and single norm test. However, advantages of such selection procedure is yet to be adopted.

Correlation, heritability and path analysis

As the heritability for yield in arecanut is very low (0.20), practically no improvement in yield could be achieved by direct selection for this character (Bavappa and Ramachander, 1967a). Among various characters considered, age at first bearing alone was found to have high heritability and correlation with yield followed by percentage of inflorescence to leaves shed. Though the percentage of nut set is highly correlated with yield, heritability was found to be relatively low (Bavappa and Ramachander, 1967c). Bhagavan (1985) studied the direct and indirect effects of seed weight days taken for germination, seedling girth, seedling height and number of leaves, time taken for flowering on yield characters of arecanut by path analysis suggested that the selection of heavy nuts (35 g and above) plays a major role for raising better seedlings resulting in higher yield. The seedling which comes to early flowering (less than $4^1/_2$ years) resulted in better yield. The thinner seedlings must substantiate with early flowering for better yield (Bhagavan, 1985).

Selection index

Selection based on age at first bearing may not lead to a very significant improvement in yield due to limited variation for this trait. An attempt to refine selection method was made by Ramachander and Bavappa (1972) adopting selection index techniques. For this, 17 growth measurements taken at stages of growth measurements giving an efficiency of 47.6 per cent straight selection index based on yield indicating significance of growth measurements over the yield components. They also worked out a simple index using only two characters viz., number of leaves and height at the time of transplanting, which gave genetic advancement 90 percent and relative improvement of 332% (Bavappa, 1970).

Hybridization

Hybridization work in *Areca* was initiated with the specified objectives taking into consideration the existing variability/donor genes (Bavappa and Nair, 1982). To evolve varieties with high yield and regular bearing(high yielding released varieties X SK Local), combining large sized fruit with more number of nuts per bunch (Sreemangala/Calicut-17/Kahikuchi X T. Halli/Sagar), combining semi-tall early bearing and high yield with quality (Mangala X Shriwardhan), evolving varieties tolerant to yellow leaf disease (released varieties x H. Dwarf and vice-versa), transferring suckering habits more number of female flowers and high percentage of nutset (interspecific crosses: High yielding varieteis of *A. catechu* X *A. triandra*), studying the genetics of dwarfness, and their exploitation in breeding dwarf varieties (released varieties X H. Dwarf and *vice-versa*), studying the combing ability for exploitation of hybrid vigour (intervarietal) crosses for desirable traits.

Performance of Hybrids

Inter-varietal crosses

The hybrid Mangala X Shriwardhan was more vigorous than the cross Mangala X SK Local as observed from increased height and girth of stem and number of leaves.

Seedlings from inter-varietal crosses among Mangala, Sumangala, Sreemangala, VTL-12, VTL-13, Mohitnagar, Thirthahalli, Shriwardhan and Hirehalli Dwarf mutant were screened for their reaction to Yellow Leaf Disease (YLD) of arecanut and it was found that hybrid seedlings derived from crosses involving dwarf mutant have some degree at tolerance (Anon., 1981).

Inter-specific crosses

The F1 hybrids of *A. catechu* X *A. triandra* had only one stem as *in A. catechu* indicating the dominance of single stem. Reciprocal hybrids did not show such genetic effect and failure of *A. catechu* pollen to germinate on stigma of *A. triandra* indicated/confirmed that *A. triandra* X *A. catechu* nuts might not be of sexual origin. Apomixis in *A. triandra* was indicating by the limited degree of meiotic irregularities, reduced pollen fertility, low quality of pollen and low chiasma frequency (Bavappa and Nair, 1982).

Multilocation trials

Comparative yield evaluation trial of released varities of arecanut *viz.,* Mangala, Sumangala, Sreemangala, Mohitnagar and Thirthahalli Local under malnad conditions at Thirthahalli registered lower height with high percentage of flowering and found to be superior in ripenut yield in the initial years of bearing closely followed by Thirthahalli local (Ananda and Anuradha Sane, 1999).

Bhadraiah *et al.* (1985) studied the performance of seven areca varieties *viz.,* VTL-3, VTL-11, VTL-12, VTL-13, VTL-17 Mohitnagar and Thirthahalli at Sirsi with Sirsi Local as control. Among the cultivars studied VTL-11 and Sirsi Local appeared to be more precocious in bearing.

In order to find out the suitable variety for Konkan region, a varietal trial consisting of eight promising varieties VTL-3, VTL-11, VTL-12, VTL-13, VTL-17, Mohitnagar, SK Local and Shriwardhan Local as check conducted at Dapoli resulted in identifying Shriwardhan Local as high yielder followed by Mohitnagar (Salvi *et al.,* 1985) and further

observed the earliness in bearing in variety Mangala.

A trial on the comparative yield trial of 5 cultivars of the arecanut VTL-3, VTL-11, VTL-12, VTL13 and VTL-17 and Mettupalayam Local at Coimbatore, Thangaraj *et al.* (1985) reported that the variety Mangala consistently maintained the highest yield over others with 14.81, 17.65 and 16.27 kg of ripenuts for the years 1979, 1980 and 1981; respectively with 43.0, 15.7 and 3.03 per cent increase in yield over the Mettupalayam Local in three years.

Secondary selection in arecanut

Among the varieties, maximum variation for different characters in subsequent progenies was noticed in Mangala and hence secondary selection was adopted in bringing the homogeneity in the population. Secondary selection was carried out at Seed Farm, Kidu (Karnataka) by screening the progenies of 15 *inter se* combinations and 100 per cent typical Mangala palms were recovered from three combinations(Anon., 1991).

Exploitation of Dwarfing Genes in Breeding Dwarf Varieties

Arecanut (*Areca catechu* L.) palms normally attain a height of 18-20 m. They are not only difficult to manage but also prone to frequent wind damage. Various farm operations like spraying and harvesting become relatively easy with dwarf palms. 'Hirehalli Dwarf' a natural mutant identified earlier (Naidu, 1963) is being utilised in arecanut improvement. Dwarfs are supposed to be mutants of tall variety by some change in genetic factors. Its short stature and relative tolerance to Yellow Leaf Disease (Bavappa and Nair, 1982) are indicative of its use as a good genetic source for improvement. However, Hirehalli Dwarf is a poor yielder (4-5 kg ripe nuts/palm/year).

An attempt (Ananda, 1998) was made to study the genetics of dwarfism in arecanut and its exploitation in breeding dwarf varieties using a natural mutant 'Hirehalli Dwarf". Maximum dwarfs and intermediates were recovered in crosses Sumangala X Hirehalli Dwarf followed by Mohitnagar X Hirehalli Dwarf and Mangala X Hirehalli Dwarf crosses among the twelve hybrid combinations. Hirehalli Dwarf and released varieties/promising cultivars classified based on height, colour intensity and vigour of seedlings to work out segregation pattern and distribution ratios. The absence of pure homozygous materials of released varieties is a handicap in studying the genetics of characters in case of arecanut (Ananda, 1998). Biometrical observations recorded in eight cross combinations involving Hirehalli Dwarf and released varieties under evaluation for high yield and dwarfness showed intermediate height as compared to tall parents in general and produced more or less equal number of leaves. However, stem girth was more in Hirehalli Dwarf X Sumangala and Mohitnagar X Hirehalli Dwarf. The maximum number of palms flowered (67%) was noticed in parent Mangala and the cross Mangala X Hirehalli Dwarf, since the variety Mangala is an early bearer and might have inherited genes responsible for this character. Hirehalli Dwarf X Sumangala cross found to be promising in yield (2.65 kg chali/palm) in the first year of bearing (fifth year after planting) and retaining the dwarfness (Ananda, 1998).

Future Thrust

Future research activities has to be intensified in some of the following important/priority areas viz., (1) broadening the genetic base of arecanut through introduction and selection for desirable traits; (2) breeding high yielding and regular bearing varieties; (3) evolving high yielding disease (YLD) and pest (scales etc.) resistant varieties through hybridization and selection; (4) purifying varieties/promising cultivars through secondary selection; (5) identification high yielding locations specific varieties through multi-locational trials under various agro-climatic conditions; (6) exploitation of dwarfing genes in breeding dwarf varieties with high yield potential; (7) breeding varieties for quality components; (8) genetical and molecular characterisation of accessions and also characterizing diversity; and (9) somatic embryogenesis and *in vitro* plant regeneration through tissue culture would help in further improvement of arecanut.

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Oil Palm Development - A Futuristic Approach

K.U.K. Nampoothiri

Introduction

Oil Palm *(Elaeis guineensis)* entered world trade only by the end of 18th Century. Presently it is cultivated in Africa, South East Asia and America (Hartley, 1988). Though the crop is known to have existed in India as botanical specimens since 1886 its commercial cultivation started only in 1971. The potential for high yield per hectare and the special characteristics of the palm oil enable it to compete with the other dozen major vegetable oils in the market. Globally palm oil is the leading oil in the export trade accounting for 35% of the total oils and fats bought and sold the world over. Oil palm is recognized as a crop of prime importance in wiping out the edible oil deficit in India.

History

Oil palm was first brought to the National Botanical Gardens, Calcutta. Maharashtra Association for Cultivation of Sciences planted *dura* palms in Pune during 1947-1949. The progenies of these were raised in many locations in Maharashtra. The first systematic plantation of 40 hectares was established during 1962-64 at the erstwhile Oil Palm Station at Thodupuzha under the Department of Agriculture, Kerala (Rethinam, 1996).

The initiative for commercial cultivation was again taken by Kerala when the State Government established a plantation of 3700 hectares at Yeroor during 1971-1982. The seeds for the purpose were imported from Nigeria, Papua New Guinea, Cote' d' Ivoire and Malaysia. Due to inexperience and marginal management practices the yields in the initial years were low. However the situation was improved by introduction of pollinating weevil and adoption of proper agro-techniques.

Simultaneously, a 1600 ha garden was established in Hutbay, Little Andamans by the Andaman Forest Development Corporation. Since the climatic conditions in the Island are ideal for the crop, higher yields are possible with proper management.

Oil palm cultivation was extended to non-traditional areas in 1987 when small scale plantings were taken up by farmers of East Godavari District (Andhra Pradesh) under DRDA. Under the scheme an area of 160 hectares was covered. A small scale processing unit (one tonne/hr) was also set up.

Research Efforts

Realising the prospects of oil palm industry in India, Central Plantation Crops Research Institute (Indian Council of Agricultural Research) took up research on the crop from as early as 1968. Initial efforts were confined to identification of *dura* mother palms and *pisifera* pollen parents from the exotic population available at Oil Palm Station, Thodupuzha. *Tenera* hybrids using these parents were planted in 1976 at the CPCRI (Research Centre), Palode. Palode Research Centre lead the research on the crop for the next two decades from where the following significant findings emerged (Nair and Nampoothiri, 1996).

1. Identification of high yielding *tenera* hybrids capable of yielding 4.6 t oil/ha even under rainfed conditions.

2. Indigenous production of hybrids to the tune of three lakhs per year.

3. Developing agro-techniques for maximum yield realisation.

4. Introducing pollinating weevil *(Elaedobius kamerunicus)* to increase yield of Fresh Fruit Bunches (FFB) through improved fruit set.

5. Recommending plant protection measures including very cheap methods to control avian pests.

6. Design and development of small scale extraction units of one tonne/ha capacity in collaboration with Regional Research Laboratory (Council for Scientific Research) and micromills with a capac

7. Establishing the nutritional quality of and popularising its use for edible pu

The research work was intensified with th establishment of NRC for Oil Palm at Pedavegi, Andhra Pradesh in 1995. Multilocational trials are also taken up under the All India Co-ordinated Research Project (Palms).

Development Strategy

Various individuals and committees have investigated possibilities of growing oil palm in India in the past. But did not have much impact in view of the difficulty in clearing the

reserve forests for planting large areas as recommended by them.

A definite strategy on oil palm development was framed by the Central Working Group on Oil Palm, constituted by Government of India (Anon., 1988). This Committee as well as subsequent ones identified areas suitable for oil palm cultivation in the country as follows (Rethinam, 1998).

Table 1. Area identified for oil palm cultivation

State	Area* (lakh ha)
Andhra Pradesh	4.00
Assam	0.10
Goa	0.10
Gujarat	0.61
Karnataka	2.50
Kerala	0.05
Maharashtra	0.10
Orissa	0.10
Tamil Nadu	0.25
Tripura	0.05
West Bengal	0.10
Total	7.96

* *Includes additional areas identified subsequent to submission of the Committee report.*

Plantation Development

State Department of Horticulture, Karnataka, took up 55 demonstrations in 15 districts to study its performance under varied conditions in the State. It was observed that the crop could come up even at a pH of 8.0-8.5. The yields were good wherever care was taken and proper management practices were adopted. This gave the Department enough confidence to support plantation development in Karnataka. Demonstration plots of 1000 hectares each in Andhra Pradesh (East Godavari, West Godavari and Krishna Dt.), Karnataka (Shimoga Dt.) and Maharashtra (Sindhudurg Dt.) were established in 1990-91 by the Department of Biotechnology using seed material from CPCRI. These demonstrations paved the way to scientifically establish the feasibility of growing it under irrigated conditions.

Based on the performance of oil palm in the above areas, it was decided in principle to go ahead with large scale cultivation under irrigation. In Andhra Pradesh, Karnataka, Maharashtra and Tamil Nadu some 30 agencies were identified for development of the crop in a defined area. They are expected to identify the beneficiaries, give necessary technical advice, arrange for finance and seeds as well as other materials. These agencies should establish processing units in their respective areas on the understanding that the farmers will sell the FFB produced to these units at a price fixed by the Price Fixation Committee.

A general method adopted for price fixation is given below (Udayakumar, 1998).

$$PF = \frac{(PO)ERO}{100} + \frac{(PK)ERK-M}{100}$$

where PF = Price of one tonne of FFB

PO = Net price of one tonne of CPO

ERO = Extraction rate of palm oil

PK = Net price of one tonne of palm kernel

ERK = Extraction rate of kernel

M = Charges for milling including profit margin and general expenses.

Modification of the formula is felt necessary to suite Indian conditions.

The development programmes are supported by Technology Mission on Oilseeds and Pulses with the involvement of the Department of Horticulture/Agriculture and monitored through Project Management Committee. Oil palm Act comprising of the above guidelines has been passed by the Government of Andhra Pradesh and Tamil Nadu and other States are expected to take up similar measures soon.

Progress Made

Many agencies came forward to organise plantations especially in Andhra Pradesh and Karnataka. However, the area so far covered is much lesser than what was envisaged. (Table 2).

There are at present four approaches to oil palm development.

(1) The agribusiness concept as in Andhra Pradesh, Karnataka and Tamil Nadu involving growers, entrepreneurs and State Governments.

(2) State Government sponsored programmes where growers are directly supported by the Government as in Gujarat and Goa.

(3) State Government sponsored programmes as in Assam, Orissa, Tripura and Kerala where only State Governments are furthering the cause of the crop. Neither the entrepreneurs nor the growers are involved.

(4) Private sponsored: Certain private farmers or group of farmers in a co-operative model take up oil palm cultivation without any Government support as in Kerala.

It is apparent that different organizations and management strategies are required for such varying conditions.

An ideal model would be where an entrepreneur has his own nucleus plantation who also encourages enterprising farmers to grow the crop around that area with the support from the Government as indicated in Fig. 1.

Table 2. Area covered under oil palm till April, 1999

Sl No.	State	Planted area (ha)	Target (ha)	
			VIII Plan	IX Plan
1.	Andhra Pradesh	24000	47000	50000
2.	Karnataka	8000	18000	20000
3.	Tamil Nadu	6000	8000	8000
4.	Andaman & Nicobar Is.	1600		
5.	Goa	664	1000	
6.	Gujarat	302	3100	
7.	Kerala	3900		2000
8.	Maharashtra	1000		
9.	Orissa	527	1700	
10.	Assam, Tripura, West Bengal and others	1029	1200	
	Total	47022	80000	80000

Constraints in Development

It is clear from Table 2 that the total coverage of area is less than 50% of the target. It is therefore wise to examine some of the impediments in achieving the target.

1. New Crop: Oil palm is a comparatively new crop for Indian farmers. Therefore it is natural that it takes time before they are convinced of the wisdom of raising oil palm plantations. Unless very agressive extension measures adopted, this process is likely to be slow which necessa means that targets of expansion fixed should be moderate the initial years.

2. Profitability: The most important factor for popularisati of any crop is its comparative profitability. A minimum pro of Rs.50,000 per hectare is to be ensured to compete wi other traditional crops of the area. While such profits are ob tainable in well managed gardens, there are many other where the yields are poor and such gardens spread wrong signals to even willing farmers.

3. Processing facility: Since the FFB should be processed as early as possible after the harvest (at least within 24 hrs) it is necessary to have the palm oil mills within the vicinity (say 50 km) of the plantation. There are only 8 or 9 mills established so far (Arya, 1998). Unfortunately many of the agencies do not take adequate initiative to start the processing units in time. This has a definite dissuading effect on the growers in the area. Fabrication of small scale units of one tonne/hr and 200 kg/ha capacity should enable them to go in for such units at a lesser capital investment so that farmers are assured of an organised market and induced into oil palm cultivation (Sundaresan *et al.*, 1989; Bosco *et al.*, 1999).

4. Price of FFB: International price fixation for FFB is generally based on crude palm oil price (10%). In India different prices exist in different states and often not based on the CPO price. The rates have been raised twice or thrice. Still the farmers demand better prices. Since there is a limit to which they can be obliged, ways and means to increase profitability through increased yield, better efficiency in extraction etc. are the correct measures.

5. Suitable areas: Being a new crop it is necessary to select the best area for oil palm cultivation. But in the anxiety to expand the area marginal lands are also cultivated with oil palm. This acts as a handicap in increasing yield levels and discourages other well meaning farmers. Therefore even if the committee has recommended an area as suitable it is necessary to examine each holding and ensure that the stipulated conditions are not compromised.

6. Irrigation facilities : Moisture availability is the most important single factor determining FFB yield. In most of the areas identified, oil palm is to be cultivated under irrigated conditions. Unfortunately in many cases farmers are unable to ensure adequate irrigation either due to non-availability of water sources or due to interrupted power supply. Such situations need rectification on priority.

7. Planting material: Even if an area of 10,000 hectares is to

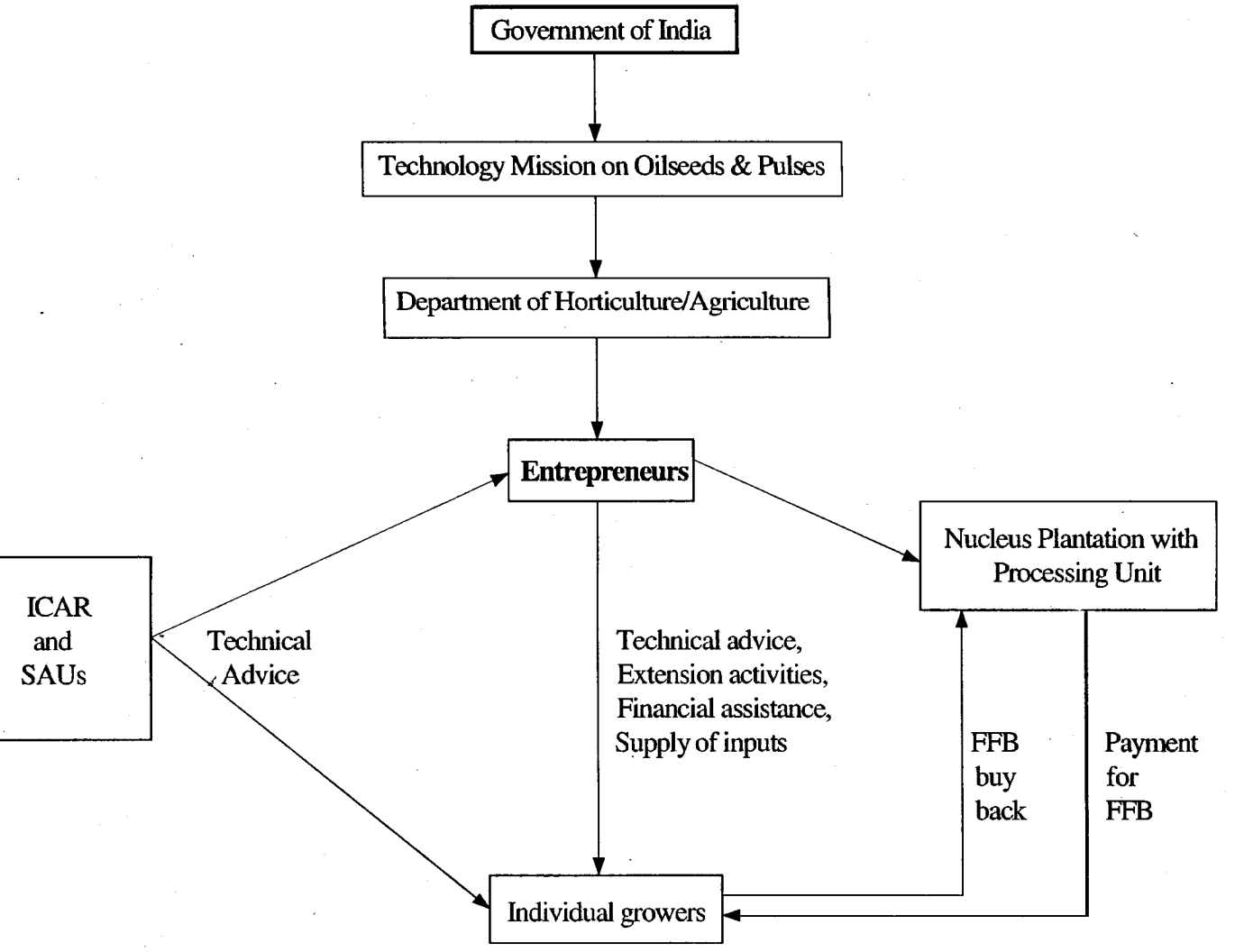


Fig. 1. An ideal model envisaged to achieve progress in oil palm cultivation

be covered annually the seed requirement is 2 million. The availability of indigenous seeds is only around 0.5 million. The rest of the requirement will have to be met through import which has its own demerits. Therefore the seed gardens established at five sites in Andhra Pradesh, Karnataka and Kerala should be fully utilised. It will be necessary to establish new gardens where parents are selected to produce the high yielding released varieties.

Mattoo and Ramachandran (1998) pointed out the 'mismatch' between the seedling availability and the needs of area coverage. If proper planning is lacking in terms of matching area coverage and planting material requirement with seed availability there will be a paradox of excess seedlings on one hand and acute shortage on the other. This results in distributing overaged substandard quality seedlings. It is recommended that the responsibility of maintaining the nurseries should be given to the entrepreneurs and not to the State Government as is done now.

8. Intercropping: Intercropping was discouraged in the initial stages of oil palm development. However, it was found necessary to have intercrops to sustain the farmer's income during the juvenile period of the crop. Since the palms planted at 9 m x 9 m spacing offers scope for growing other crops, it is wise to adopt a system involving other compatable intercrops. However it is necessary to select the suitable crops so that there is no competition with the main crop, plant them properly using only the area outside the basins as well as fertilize the main crop and the intercrops separately.

It was observed that these criteria are often not properly taken care of by the farmers. In their anxiety to earn maximum income, crops are raised very near or even inside the basins. Overpruning is resorted to so that the oil palm leaves do not disturb the subsidiary crops, cultural practices are adjusted to suit the intercrop even if it is deleterious to oil palm. These undesirable practices are more pronounced when the land is leased out for growing intercrops since the tenant has no interest in the main crop. Therefore this is another important area to be looked into and parameters well defined with a view to ensuring viability of oil palm cultivation and continued economic returns to the growers.

9. Nutrition: Fertilizers are applied as per the recommendations based on field experiments under rainfed conditions. Till specific recommendations for irrigated oil palm are available it will be wise to judiciously apply nutrients based on leaf analysis. The soil and leaf analysis laboratories established by TMOP is a right step in this direction. Replacement of inorganic fertilizers with organic ones to a great extent is possible through recycling of 15 to 17 tonnes of organic waste materials available from one hectare plantation (Anon.,1997).

10. Import Policy: Import of palm oil can seriously jeopardize indigenous production. The reduction in import duty on palm oil from 60% to 35% and then to 20% in 1996, caused a fall in price of crude palm oil. The processors and farmers are naturally afraid of further free imports resulting in lower prices and subsequent reduction in profits (Vasanth Kumar and Pattanayak, 1998). Since this is highly deterrent to the enthusiasm of oil palm growers the import duty needs to be raised suitably.

Apart from these, there are other problems relating to non-availability of bank finance since most of the farmers are defaulters of earlier loans, reluctance to recommend direct loan to farmers, non-uniform implementation of policies of Government of India by different State Governments, assuring minimum raw material to factories not having its own captive plantation, non-implementation of the recommendations of the advisory bodies like Agricultural Finance Corporation and non-establishment of an Oil Palm Board (Abraham, 1997).

Futuristic Approach

The future of any crop will depend upon the demand for its products. India's present edible oil consumption is over nine million tonnes. Since the production always falls short of the requirement we are forced to resort to import resulting in huge drain on foreign exchequer (vide Table-3). For e.g., in India the consumption was over 9 million tonnes during 1996-97 and the edible oil production was about 7.5 million tonnes. The deficit was made good by import. India's population increase is 15 million each year. The per capita consumption rate of oils and fats is only 8 kg as against the world average of 16 kg. The growth in consumption of oils and fats in India was 2.1 per cent against a population growth of 1.9 per cent indicating the growing affluence in India which was backed by a GDP between 5 per cent and 6 per cent. With the rise in standard of living and burgeoning population the consumption is likely to tremendously increase. At a consumption rate of 10 kg almost 10 million tonnes of edible oil will be required to cater to the needs of a population of 990 million people.

The Indian edible oil industry is the third largest in the world, next only to USA and China, harvesting over 22 million tonnes of various oilseeds against the world production of 250 million tonnes. A distinctive feature of Indian oilseeds production is its large variety of oilseeds including minor oilseeds and those of tree origin. The disadvantage is that oilseeds are generally cultivated in rainfed conditions and are subjected to vagaries of weather conditions resulting in poor yields. A crop like oil palm which gives steady income is the best answer to circumvent this problem. Moreover this palm can produce ten times the yield of any other annual crop obviously reducing the area required for production of required quantity of oil.

Table 3. Imports of edible oils by State Trading Corporation of India.

Year	Quantity (Lakh tonnes)	Value (Rs. in crores)
1982-83	11.50	507.00
1983-84	16.34	1310.99
1984-85	13.68	1122.13
1985-86	11.79	488.95
1986-87	14.97	667.67
1987-88	18.19	1060.95
1988-89	3.73	245.71
1989-90	6.07	328.32
1990-91	1.02	73.49
1991-92	2.15	178.13
1992-93	0.52	45.34
1993-94	1.46	210.23
1994-95	8.40	175.00
1995-96	10.00	2083.33
1996-97	12.00	2500.00

Source: Department of Civil Supplies, Consumer Affairs and Public Distribution.

Inspite of the constraints enumerated in this article, oil palm area has gone up from 5090 ha in 1989-90 to 47,022 ha in 1999 which indicates the future expansion possibilities if the problems confronted now are solved. We have hybrids which can yield 4.6 tonnes of oil/ha (Nampoothiri, 1998). Basic technical know-how is available which can be refined through intensified research based on future needs. The development programmes have the State and Central Government support. Therefore the future scope for oil palm development is very bright and its contribution to the edible oil pool of the country will be substantial in view of the crop's many advantages like highest oil yield, eco-friendliness, sustainability of income, freedom from theft and buy back guarantee.

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Oil Palm Germplasm Conservation and Utilization

R.S.N. Pillai and M.J. Ratnambal

Introduction

The oil palm (*Elaeis guineensis* Jacq.) originated in the Guinea coast of West Africa, is regarded as the highest oil yielding crop. Semi-wild and wild oil palm groves still exist in the tropical West African countries. In the 15th century, oil palms were introduced to Brazil and other tropical countries by the Portuguese. But it did not flourish in these countries till the 19th century. During 1848, the Dutch people imported oil palm seeds from West Africa via Amsterdam and four seedlings were planted at Bogor, Indonesia. The progenies of these palms were planted as ornamental palms in Delhi and are later known as *Deli dura.* Commercial planting of oil palm started in Malaysia during 1917.

Varieties

The fruit in oil palm is a sessile drupe varying in shape from heavy spherical to ovoid or elongate. Based on the difference in fruit structure, three varieties of oil palm have been identified. They are *dura, pisifera* and *tenera.*

Dura: The percentage of mesocarp to fruit is variable usually within the range of 35-50 per cent. The shell is comparatively thick with a 2-8 mm range. The kernel is usually large. Oil content of *dura* mesocarp in proportion to bunch weight is quite low at 17-18 per cent. The *dura* is used as the female parent in breeding programme.

Pisifera: In this, the fruit is characterized by the absence of a shell, the vestiges of the shell is being represented by a ring of fibres around the kernel, the latter being quite small. In the absence of shell, there is a high rates of mesocarp to total fruit and the mesocarp oil content is also high. *Pisifera* is usually described as female sterile since the majority of bunches abort at an early stage of development. Therefore, *Pisifera* material cannot be used for commercial planting but is used as male parent in breeding programme. By crossing *dura* and *pisifera* types, *tenera* is produced.

Tenera: This type is the only one, which combines the characteristics of the parent material currently planted on commercial scale. Shell thickness ranges from 0.5 mm to 4 mm around which a ring of fibers is present. The ratio of mesocarp to fruit is comparatively high, usually within the range of 60-96 percent. *Tenera* palms produce more fruit bunches than *dura* palms, although mean bunch size is usually smaller. The ratio of oil to bunch is about 22-24 per cent.

Germplasm Collection

World collection

A number of expeditions were organized by PORIM to collect *E. oleifera* germplasm from Columbia, Panama and Coasta Rica in 1967, 1969 and 1980 respectively. In 1967, the United Brands Company in Central America initiated collection of *E. oleifera* found in Costa Rica, Panama, Columbia, Surinam, Honduras, Nicaragua and Brazil. During 1981, PORIM in collaboration with IBPGR collected *E. oleifera* from Central and South America. Collections were made from Surinam, Columbia, Panama, Costa Rica, Nicaragua and Honduras.

Indian collection

In India, oil palm was introduced towards the end of 18th century as a botanical collection at National Botanic Gardens, Calcutta. Maharashtra Association for Cultivation of Sciences (MACS) introduced African Oil Palm (*dura*) in Pune during 1947-1959.

The Department of Agriculture, Kerala purchased *Dura* and *tenera* types from Malaysia and Nigeria and these were planted at the Oil Palm Research Station, Thodupuzha, Kerala, CPCRI Research Centre, Palode (now National Research Centre for Oil Palm - NRCOP) under ICAR started systematic collection of Oil Palm during 1979. The collection includes random samples of *teneras* introduced by various agencies in the country and also. *E. oleifera* introduced from Malaysia and Costa Rica. The present germplasm holding at Palode consists of 80 accessions from 11 countries (Table 1).

Conservation of Germplasm

The oil palm germplasm has been conserved in *ex situ* field gene banks. It is being maintained at Research Centre of NRC for Oil Palm at Palode (Kerala) and Pedavegi (Andhra Pradesh). Sub population of a few accessions are being maintained at Aduthuri (Tamil Nadu); Gangawathi (Karnataka); Vijayarai (Andhra Pradesh) and Mulde (Maharashtra) under All India Co ordinated Research Project (Palms). Very little work has been done for *ex vitro* field conservation. Englemann *et al.* (1988) were the first to

Table 1 Oil Palm germplasm holding at Palode

Source	Year of collection	Remarks
Nigeria (NIFOR)	1979	*Tenera*
Cote'd Ivorie	1981	*Tenera*
India (CPCRI)	1982	*Tenera*
Republic of Zaire	1982	*Tenera*
Indonesia	1986	*Deli dura* X *Pisifera*
Indonesia	1986	*Dumpy dura* X *Pisifera*
Malaysia	1987	*Tenera*
Cameroon	1988	*Tenera*
Costa Rica (ASD)	1990	*Tenera*
Costa Rica	1992	*E. oleifera*
Cameroon	1994 & '96	Drought and cold tolerant material
Guinea Bissau	1994	-do-
Zambia	1995	-do-
Tanzania	1995	-do-

standardize the technique of cryopreservation in oil palm. They were able to store the embryos for 15 months in liquid nitrogen and then could generate plantlets from the frozen materials.

Utilization of Germplasm

Selection

The germplasm materials are being evaluated for yield and yield attributes under uniform conditions. Comparative early performance of the four collections planted in 1981 and 1982 is given in Table 2.

Production of hybrids

The possibility of commercial exploitation of oil palm was not realised in the country till the eighties. The first conscious import of breeding material, purely for observational trials was made during 1963-67. The material consisting of *dura x dura, dura x tenera, dura x pisifera and tenera x tenera* seed materials imported from Malaysia and Nigeria, were planted at the oil palm station, Thodupuzha (Kerala) during 1963-67.

A boost in oil palm breeding in the country was given with the systematic trials taken up in 1976 at Palode (Kerala) Centre of CPCRI (now NRC for oil palm). The trial consisted of 11d x p combinations involving 5 *duras* of Malaysian origin and four *pisiferas* of Nigerian origin. The best yield was obtained in combinations involving 65d, 92d, 120d and 125d. The hybrids were raised under rainfed conditions. The estimated oil yield in 65d x 30. 103 p and 120d x 30.103p combination was 4.6 and 4.5 MT/ha respectively (Nampoothiri, 1998). Based on the superior performance of these two combinations, they have been recommended for release in 1998.

Interspecific hybridization

Elaeis oleifera (previously referred to as *Corozo oleifera*) is found mostly in South and Central America and hence is known as 'American oil palm'. This species is of interest to breeders because of its dwarfness, oil fluidity and resistance to disease noticeably bud rot in Latin America as well as vascular wilt and reduced susceptibility to the pest *Coelaenomenodera elaeidis* (Le Gueny *et al.*, 1991). Only *dura* fruit form has been located in this species. Therefore the crosses are mostly made with *E. guineensis, pisifera.*

The F1 hybrids are not directly exploited because they are low in fruit/bunch ratio, oil percentage and oil to bunch extraction (17 per cent). Certain hybrids have been found to be susceptible to freckle (*Cercospora elaeidis*) in Africa. Therefore a series of back crosses and selection in further

Table 2 Performance of oil palm introductions (1992)

Accessions	Year of planting	No. of palms	No. of leaves	No.of male inflorescences	No. of female inflorescences	No. of bunches (kg)	Wt. of bunches
NIFOR	1981	47	24.9	6.6	4.3	3.8	69.4
Cote'd' Ivorie	1981	45	23.9	5.9	3.9	6.4	116.6
CPCRI	1982	34	23.6	7.5	3.5	3.9	47.2
Republic of Zaire	1982	43	24.5	8.2	3.1	3.6	41.9

Note : Values are for average/palm/year.
Tenera: Palms of Cote' d' Ivoire Coast have shown their superiority over NIFOR palms. The indigenous material (CPCRI) outyielded the one from Republic of Zaire.

generations have been necessary (Corley *et al.*, 1976). So far, the inter specific hybrids have not been commercially exploited.

Reciprocal recurrent selection

A breeding programme based on Reciprocal Recurrent Selection was initiated in 1984. The programme is directed towards selection of elite *duras* and *pisiferas* separately and crossing them to produce d x p seeds. Palms with good combining ability are selected as parents in seed production. An improved set of D x Ds and T x Ts has been planted as a part of the programme. The most serious handicap in this country's breeding programme is the narrow genetic base, available. Although the germplasm collection has 80 accessions from 11 countries, most of them are *teneras*. However, recent collections made from Cameroon, Tanzania and Zambia will provide valuable gene for cold tolerance and drought resistance (Pillai, 1994). A large number of hybrids are being field tested in plantations of oil palm India (Kerala), Nava Bharat Enterprises (Andhrapradesh) as well as in the State Agricultural Universities under the All India Co-ordinated Research Project on Palms network. More intensified work has been launched at National Research Centre for Oil Palm established at Pedavegi (Andhra Pradesh) by ICAR (Rethinam and Murugesan, 1998).

Breeding for Special Features

Dwarfness

Shorter palms are preferable for easy harvesting and likely better longevity. Two sources considered for dwarfness are 'Dumpy' *Deli* from Berdang and a dwarf selection from Pobe. Variations in height is observed between lines.

The most important source of dwarfness is the American oil palm, *Elaeis oleifera* which has extremely low annual height increment with a tendency for procumbency. The interspecific crosses are fertile and the F1 hybrids are less than intermediate between the parents in height. Trials involving back crosses are underway in many countries. 'Super compact palms' being developed by ASD Costa Rica is of special interest in this regard. Both *E. oleifera* and dumpy palms have been introduced to India only recently and the work in this direction has just been initiated.

Disease resistance

Vascular wilt caused by *Fusarium oxysporum* F. Sp. *elaeidis* is very serious in African countries. Though no tolerant/resistant crosses are available, evidences indicate that parents which consistently gave crosses with a high degree of tolerance can be used in producing tolerant progenies (Rajagopal *et al.*, 1978).

Lethal bud rot of unknown etiology causes serious damage in Central and South America. Planting of *E. guineensis* X *E. oleifera* is the best known method of combating the disease. No control measures are available for spear rot disease noticed in certain parts of India. Resistance breeding is the only solution. Efforts have already been taken to identify individual palms, which are tolerant/resistant to the disease for use in hybrid production.

Drought tolerance

Although oil palm can withstand drought conditions to a great extent, its performance is seriously affected when there is a moisture stress. Differences in the severity of drought symptoms between different progenies have been suggesting the possibility of selection for drought tolerance/resistance.

Oil quality

An oil rich in unsaturated fatty acid (particularly with less palmitic and more linoleic acid) giving a large liquid fraction would be of high economic value (Corley, 1982). Attempts are made to improve the quality of the oil in *Elaeis guineensis* by using *E. oleifera*, which has a lower melting point (22-22°C), an iodine value above 80 and higher unsaturated acids (upto 80 per cent). The F1 hybrid is intermediate between the parents. Further selections are necessary before the hybrids can be commercially exploited.

Vegetative Propagation

Clonal propagation through tissue culture would be highly valuable for multiplying the elite outlets with exceptional characters like high FFB (fresh fruit bunch) yield, and oil percentage, disease and pest tolerance/resistance as well as superior oil quality. Since some evidences are available in the Malaysian clonal plantations, regarding variations among the clones for fatty acid ratio in terms of the degree of saturation, possibilities for multiplying clones possessing high ratios of saturated and unsaturated fatty acids, are open.

Micro Propagation

The advantages of producing good clonal propagation of selected high yielding trees in oil palm have been described by Corley *et al.* (1981). Besides obtaining uniformly high yielding clones of individual trees, clonal propagation will also facilitate the propagation of proven *dura* and *pisifera* parents to produce desirable *tenera* combinations. The major work on *in vitro* culture of oil palm was carried out in France. (IRHO), the UK (Wye College), University of London and Unifield University/Harisson and Crossfield, Malaysia (Palm oil Research Institute of Malaysia) and Indonesia (Marihat Research Station).

Future Thrust

Direct usefulness of *teneras* available in the germplasm collections is very limited. It is necessary to collect *dura* parents which have proven to produce high yielding hybrids. Efforts have to be made for a systematic collection of oil palm germplasm materials by prospections in the original habitat of *E. guineensis* and *E. oleifera.* It would be worth while to obtain seed materials of proven performance for augmenting the breeding programme. Identification of dwarf oil palm and incorporation of the dwarfness into the breeding programme should be intensified..

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Oil Palm Breeding

K.U.K. Nampoothiri

Introduction

Till 1950s oil palm breeding was confined to the thick-shelled *dura* variety. Efforts to improve wild genes in Africa as well as the work in Malaysia and Indonesia on the progenies of the four famous Bogor palms resulted in various breeding populations of restricted origin. Since the discovery of Beirnaert and Vanderveyan (1941) that the *tenera* is a hybrid between *dura* and *pisifera* full attention was diverted to production and improvement of d x p crosses. Salient features of some of the most important breeding programmes with special emphasis to Indian work are reviewed in this paper.

Botany

Oil palm is monoecious, with male and female inflorescence produced separately on the same palm. Rarely hermaphrodite inflorescences are also seen.

It is a cross-pollinated crop with the female and male inflorescence being produced in alternate cycles (Hartley, 1988). Artificial pollination is resolved to when specific hybrids are to be produced. Fruits ripen within six months after pollination.

The fruit of oil palm is a drupe. It consists of a pericarp, made up of exocarp (skin), mesocarp (husk) and endocarp (shell) surrounding the kernel. Kernel has a testa (skin), a solid endosperm and an embryo. Shell thickness is of direct relevance to breeding. This is controlled by a single gene (Beirnaert and Vanderveyen, 1941). The homozygote *pisifera* (Sh-Sh-) is shell-less. Generally, they are sterile, though some palms set fruit and varying degrees of sterility are observed. The other homozygote *dura* (Sh+Sh+) has a thick shell. The hetrozygote *tenera* (Sh+Sh-) has a thin shell surrounded by a ring of fibres in the mesocarp. *Tenera* is the only form used for commercial planting because of higher mesocarp content.

Major Breeding Programmes

Although the endosperm of ripe fruit contains oil (kernel oil), palm oil of commerce is extracted from the mesocarp. Therefore the main emphasis of breeders is to evolve varieties with high palm oil yield potential. Better oil quality, reduced height increment, drought, pest and disease tolerance as well as precocity are also becoming important considerations. The salient features of the major breeding programmes in Cote d'Ivoire, Republic of Zaire, Nigeria, Costa Rica Malaysia and Indonesia are outlined and the Indian programme is described in detail.

The IRHO (IRAFED) programme - Cote d'Ivoire

The first step for oil palm improvement was taken in 1924 when over 60 open pollinated progenies from comparatively thick-shelled *teneras* (20% shell) were planted. The best palms from these were selfed and planted at La Me. As the performances of these were disappointing this line of work was not continued. A deli *dura* plantation (Sumatra origin) was established at Dabou by IRHO. Crosses were made between selected deli palms and some of the original *tenera* palms at La Me and at Sabiti. IRHO also organised an exchange programme with INEAC at Yangambi and SOCFIN in Malaysia. The same comparative trials were planted at five different stations. The results showed clearly that inter population crosses were superior to intra population crosses. Another finding was that bunch number and mean bunch weight are controlled by quantitative factors whose effects are generally additive (Noiret *et al.*, 1966). Gascon and de Berchoux (1964) outlined a comprehensive breeding programme based on reciprocal recurrent selection. This involved one population with 80 Dabou deli *duras* and Sumatran and Malaysian *duras* and another one made up of 172 *tenera* x *pisifera* selections from La Me and Sabiti. 446 *tenera* x *dura* and *dura* x *pisifera* test crosses as well as 85 *dura* x *dura* and 79 *dura* x *tenera* crosses and selfings of best progenitors were planted between 1958 and 1965 at La Me.

The results after two cycles of breeding published by Gascon *et al.* (1988) showed that an yield improvement upto 36 per cent could be obtained through this programme.

The INRA (formerly INEC) programme - Republic of Zaire

Improvement by selection started in 1922 when Yangambi (the main station of the INEAC) laid out the first experiment with illegitimate seeds of nine *tenera* palms selected from nearby palm groves and one *tenera* palm from the Ela Botanical Garden. This palm generally referred to as Djongo palm had a good mesocarp content (80-85%). During 1933-39, a legitimate F1 generation involving crosses between the best *tenera* characterized by well filled bunches of large ovoid fruits with a thin shell and comparatively large kernel was found. The demerit of this type is its relatively rapid rate

Table 1. Progress in yield in Cote d'Ivoire (6-9 years)

Stage	Year	No. of progenies	FFB (t/ha)	Oil/ bunch	Oil/ ha	Progress
Inter-Origin Crosses	1960	529	15.0	22.2	3.33	100
First cycle	1972	74	16.7	23.2	3.93	118
Second cycle	1984	14	19.0	24.0	4.52	136

of stem increment. Another selection programme for specific combining ability carried out during 1950-56 consisted of 36 progenies produced by diallel crossing and selfing of best selected six *tenera* palms from the F1 generations. Due to political unrest in the nineteen sixties, this programme was not fully implemented.

Though selection for yield of bunches would have been affected by the inbreeding involved, it helped in clarifying the single gene inheritance of shell thickness and in studying the variation in fruit and bunch characteristics. INEAC material has proved to be a major source for improvement in these characters in breeding programmes in Cote d'Ivoire, Indonesia and Malaysia (Gascon and de Berchoux, 1964).

Costa Rica

Contributions to oil palm breeding in Central America are solely that of United Fruit Company (Now ASD). They initiated the germplasm collection in 1920. The finding that Deli *dura* types had better oil and kernel yields than the African types resulted in ignoring African introductions (Richardson, 1995). Deli *dura* seed of Lancetilla origin was the main source of planting material till 1966 (Richardson, 1995).

Starting from 1967, a series of oil palm germplasm exchanges were carried out with African and Asian oil palm breeding units and a collection of *E. guineensis* germplasm was assembled at Coto. Experiments were set up in 1989 with materials from Deli x Ekona type and Deli x Calabar in addition to the traditional Deli x AVROS. Results have shown that Ekona and Calabar materials are as productive as AVROS. Calabar materials have a shorter leaf length and a higher leaf area/leaf dry weight ratio than traditional materials. Ekona materials have greater oil to bunch ratio (Sterling and Alvarado, 1995).

The yield of present day hybrids supplied for commercial planting is claimed to be 30 MT of FFB/h/year with an extraction ratio of 22.5%. ASD de Costa Rica is one of the largest oil palm seed suppliers in international market having supplied 60 million seeds to 34 countries (Anon., 1996).

NIFOR (Nigeria) programme

The breeding materials used in Nigerian breeding programme included introductions of Deli *duras* from Sumatra (1926), Serdang (1939), Deli *duras* and pollen from IRHO Programme (Nineteen fiftees and sixtees), from INEAC Programme in Zaire (1950-1960), Unilever programmes in Nigeria and Cameroon as well as Angolan material from sierra Leone (1942 and 1961). This along with indigenious collections gave a wide genetic base to start with.

The programme is somewhat similar to IRHO programme. In Nigeria six groups were formed based on yield and fruit characters. 53 *duras* and 65 *teneras* were thus classified. *Dura* x *tenera* and *tenera* x *tenera* crosses were made between palms of various categories. At the same time, the best *duras* and *teneras* were selfed within groups and *dura* x *dura* and *dura* x *tenera* crosses were made. This type of assortative mating is especially opportune for characters showing negative genetic correlations. This system also enables to increase genetic differences between populations (Corley, 1976).

Results of the breeding programme based on a modified reciprocal recurrent selection scheme started in 1962 is given below (Okwuagu, 1986).

Indonesia and Malaysia

Planting of four oil palms in the Botanic Garden at Bogor, Java in 1848 marked the introduction of the crop to south East Asia. Progenies of these four palms were planted as avenue in Sumatra (Indonesia) around 1890. The first commercial plantings were established between 1911 and 1920 on Sumatra's East Coast and in Malaysia using illegitimate seeds collected from the avenue palms. Through selection of these *dura* palms, deli *duras* characterized by a high production potential and a uniform good bunch and fruit characters were identified. This was followed by selection for high number of bunches in some cases and for high single bunch weight in some other cases. The population of Deli *dura* is most commonly used around the world as a female line for the production of seeds. The AVROS line is at the same time the source of *pisiferas* used in Malaysia and Indonesia owing to its good production capacity when it is combined with Deli *duras*. The hybrids have vigorous vegetative growth and precocity in addition to their potential for high yield and good rate of oil extraction (Rosenquist *et al.* 1990).

Table 2. Improvement in NIFOR planting material.

Period	Type of material	Yield t/ha/year	
		FFB	Oil
1930-1950	Open and control pollinated DxD, DxT and DxP crosses of Selected grove palms.	2.5-5.0	0.5-1.0
1960-1970	DxP control pollinated materials from first stage of oil palm breeding programme.	5.0-10.0	1.0-2.0
1970–present	DxP controlled reproduction of elite *tenera* progenies from the first cycle of reciprocal recurrent selection programme.	15.0-20.0	3.0-4.0

PORIM (Palm Oil Research Institute of Malaysia) gathered a large oil palm germplasm collection. The collections made from Nigeria in 1973 provided valuable genes for high yield, dwarfism and unsaturation (Rajanaidu *et al.*, 1993). The work was then concentrated on inter se crossing of materials from various origins to form a new breeding population (Hardon, 1970).

In addition to Deli *dura* x AVROS *pisifera*, a limited propagation of progenies produced using Yangambi, La Me, Nigeria (NIFOR), Serdang and Sibitisourels were also tested. As a result of these conscious programmes *tenera* hybrids are available which has tremendous yield potentials of up to almost 9 MT oil/ha as detailed in Table 3 (Lee Chong Hee, 1997).

India

The possibility of commercial exploitation of oil palm was not realized till the eighties. The first conscious import of breeding material, purely for observational trials, was made during 1963-67. These materials consisting of DxD, DxT, DxP and TxT seed material imported from Malaysia and Nigeria were planted at the Oil Palm station, Thodupuzha (Kerala) during 1963-67. The performance of this plantation, which was in general encouraging, prompted Government of Kerala and Andaman Forest Development Corporation to raise large-scale plantations.

Table 3. Yield potential of Malaysian hybrids

Material	Year of planting	No. of pro-genies	FFB yield (t/ha)	Oil/ bunch ratio	Projected oil yield (t/ha)
DDxAVROS	1964	22	31.0	23.5	7.3
DDxAVROS	1968	16	31.1	22.1	6.9
DDxAVROS	1970	29	31.6	24.1	7.6
DDxAVROS	1979	5	34.5	25.8	8.9
DDxDumby AVROS	--	10	33.3	25.8	8.6

A boost in oil palm breeding in the country was given with the systematic trials taken up in 1976 at the Palode (Kerala) Centre of Central Plantation Crops Research Institute. This trial consisted of 11 d x p combinations involving 11 *duras* of Malaysian origin and five *pisiferas* of Nigerian origin. The design adopted was RBD with three replications and 16 palms/lot. The hybrids were raised under rainfed conditions (Nampoothiri, 1994). The results of this trial are given in Table 4. From this experiment two high yielding *teneras* viz., 65 d x 30.103p and 120d x 30.103p have been recommended for release (Anonymous, 1998).

A breeding programme based on Reciprocal Recurrent Selection was initiated in 1984. This programme is directed towards selection of elite *duras* and *pisiferas* separately and crossing them to produce d x p seeds. Palms with good combining ability are selected as parents in seed production. An improved set of DxDs and TxTs has been planted as a part of the programme. The most serious handicap in this country's breeding work is the narrow genetic base available. Although the germplasm collection has 18 accessions from eight countries most of them are *teneras*. However, recent collections made from Cameroon, Tanzania and Zambia will provide valuable genes for cold tolerance and drought resistance (Pillai, 1994).

A large number of hybrids are being [illegible] plantations of Oil Palm India (Kerala

Table 4. Performance of *tenera* hybrids

Combination	Average No. of bunches/year		Average FFB (kg) per palm/year		Oil (t/ha/yr)	
	During 1980-93	During 1986-93	During 1980-93	During 1986-93	Best Yield	Estimated
65d x 30.103p	4.89	6.24	73.44	114.38	164.10	4.59
271d x 30.4336p	4.09	5.30	60.03	93.71	146.43	4.10
139d x 24.3087p	3.13	4.68	47.57	78.35	115.95	3.25
156d x 30.4336p	2.37	3.48	35.54	58.39	96.29	2.70
61d x 30.4336p	3.81	5.28	59.10	94.28	155.15	4.34
125d x 30.103p	4.57	6.29	66.27	105.80	157.28	4.40
108d x 30.4336p	4.23	5.66	58.68	92.21	139.83	3.92
92d x 30.3154p	3.56	4.85	62.85	100.19	161.18	4.51
269d x 30.4336p	2.84	4.02	42.69	69.24	107.22	3.00
187d x 24.3087p	2.58	3.87	35.40	58.49	85.43	2.39
120d x 30.103p	4.59	5.88	76.90	117.16	159.27	4.46
Average	3.72	5.07	56.84	90.23	-	-

Enterprises (Andhra Pradesh) as well as in State Agricultural Universities under the All India Co-ordinated Research Project of Palms Network. More intensified work has been launched at the National Research Centre (Oil Palm) established at Pedavegi (Andhra Pradesh) by Indian Council of Agricultural Research (Rethinam and Murugesan, 1998).

Seed Production

Since only hybrids are used for commercial planting growers will have to depend on recognized seed producers for the planting material. The world wide requirement of quality *dura* x *pisifera* (tenera) seeds is estimated as 80 million per year with Indonesia (61 million) and Malaysia (50 m), Costa Rica (12 m) and Papua New Guinea (10 m) as the main producers.

It was originally estimated that 80 million seeds would be required by the turn of the century for undertaking oil palm area expansion in India. This is based on the assumption that 50% of the 0.8 million hectares of area, identified as suitable for oil palm cultivation will be covered by 2000 AD. However the rate of expansion has been only around 0.01 million ha/year thereby reducing the demand to two million seeds/year. India has been importing seeds from Malaysia, Cote d'Ivoire, Nigeria, Papua New Guinea, Republic of Zaire and Costa Rica since 1962.

Though indigenous production of *tenera* hybrids was initiated in the country by 1974 for experimental purposes, commercial production was started only in 1982 (Nampoothiri *et al.* 1993). The Research Centre of Central Plantation Crops Research Institute at Palode and Oil Palm India, Kottayam are the only centres from where seeds are sold now. These are produced using 40 *dura* mother palms identified at Thodupuzha and 20 *duras* at Palode. The present capacity is restricted to 0.5 million seeds annually. Sprouts are sold at the rate of Rs.10/-.

To meet the additional requirement, import has to be resorted to. The cost is generally 0.4 to 0.45 US $ per sprout. To obviate this constraint five seed gardens have been established in Andhra Pradesh, Karnataka and Kerala States. A twenty ha seed garden will enable production about three million seeds annually.

Disease Resistance

Since diseases are the major single factor limiting yield, breeders have been very eager to evolve tolerant hybrid combinations.

The most systematic and effective work pertains to vascular wilt disease caused by *Fusarium oxysporum* F. sp. *elaeidis* that is a major problem in Africa. The genetic control of wilt resistance is not well-known, but a polygenic control is suggested (Hardon, 1976). An elaborate programme is underway at IRAFED involving identification of parental material with improved resistance and breeding with such material (Renard *et al.* 1972). Clonal material with potential resistance is also now under field screening. Unilever claims to have progenies with "exceptional resistance to vascular wilt and foliar diseases". In the case of blast (caused by

Rhizoctonia lamellifera and *Pythium* sp.) it is reported that material originating in arid regions of Nigeria is more sensitive than that from forest zones. Those from deli origin are more susceptible than African materials. In Deli x African crosses, the resistance is dominant. However selection for resistance is of limited use since the disease affects the palm only for a short period of its life for which there is a feasible control method.

Elaeis oleifera is largely resistant to a form of spear rot (Sudden wither - *Marchitez sorpresiva*) recorded in Columbia and Peru. This resistance is inherited to *E. guineensis* x *E. oleifera* hybrids. Certain *E. guineensis* progenies have remained healthy in plantations devastated by this disease suggesting the scope for selecting for resistant progenies within the species.

Cercospora leaf spot caused by *Cercospora elaeidis* is prevalent in Africa. Though *Elaeis oleifera* progenies are highly susceptible, interspecific hybrids are less susceptible (Hartley, 1988). Since satisfactory control is obtainable by using some of the newer fungicides, it is doubtful if such work will receive priority in breeding programmes.

Lethal bud rot (fatal yellowing) of unknown etiology occurs in Central and South America. It was reported from La Arenora (Coldesa) plantations in Columbia that *E. oleifera* and its interspecific hybrids were immune or resistant to the disease. Field trials and experimental plantings clearly showed that in areas subject to lethal bud rot, planting of *E. oleifera x E. guineensis* crosses is the best known method of combating the disease.

Breeding for resistance to Ganoderma trunk rot has been attempted and differences of incidence between West African and Deli materials and between *dura* and *tenera* have been reported (Akbar and Kusnadi, 1976). But Turner (1981) considers that any natural resistance is likely to be overcome by the volume of inoculum.

Work on dry basal rot in Nigeria (Robertson, 1962) indicated that the incidence was confined to progenies having the same parent and that there are differences in incidence between progeny lines. Selection for resistance was considered as a promising line of work in controlling the disease. However, no concerted further work was taken up since natural recovery was usual and serious outbreaks have not been reported.

Detailed work has been done on genetic nature of crown disease by Gascon and de Berchoux (1964) in Cote d'Ivoire and by Blaak (1970) in West Cameroon. Crown disease susceptibility is postulated to be due to monofactorial recessive genes (aa) whose expression is prevented if an inhibitor gene is present in homozygous condition.

White stripe is another disease attributed to genetic disorder. A certain *tenera* x *dura* cross showed similar percentage of white stripes when planted in Cote d'Ivoire and East Cameroon. So also certain Deli selfs in Cote d'Ivoire showed the symptoms while others did not (Gascon and Meunier, 1979). Some forms of chlorosis are genetic. One condition is characterized by leaves, which may be wholly or partly pale or bright yellow.

The only serious disease encountered in India is the spear rot disease caused by phytoplasma. This malady is confined to the Kerala State. Search for resistant lines have not so far yielded any encouraging result (Kochu Babu, 1994).

It can therefore be seen that while some efforts have been made and the importance of resistance breeding in oil palm is recognised, the results obtained so far do not commensurate with the importance of this line of work.

Breeding for Short Compact Palms

The objective of this programme is to evolve lines which are short and compact in stature so that more number of palms can be accommodated per hectare and harvesting operations are much easier. The main source of dwarfness in oil palm are given below:

(1) Dumpy: This is a deli *dura* selection (E 206) identified by Jagoe (1952) in Malaysia. Dumpy *dura* selfed progenies have been introduced to germplasm collections of many countries. Although these were comparatively short and produced large bunches with a good fruit-bunch percentage, the palm was not quite upto the selection standards set.

(2) Pobe dumpies: There are dwarf palms identified at Pobe Station of IDEFOR.

(3) Indian dwarf: One dwarf *tenera* palm was identified from a Nigerian introduction at GPCRI (Research Centre), Palode. This had a height of only 7.54m in the 14th year compared to 13.77m height of palms of similar age in the same plot. This is incorporated into the breeding programme.

(4) *Elaeis oleifera*: This species (previously referred to as *Corozo oleifera* and *Elaeis melanococea*) is currently the most useful parent in breeding for dwarfness. Efforts have been made to prospect and establish *E. oleifera* collections in Malaysia, Cote d'Ivoire, Dahomey, Cameroon, Columbia and Indonesia. In addition to low height increment the species is a good donor parent for oil quality and disease resistance. As no *pisiferas* have been identified in *E.oleifera*, the interspecific

crosses are always between *E. oleifera dura* and *E. guineensis pisifera.*

These species are easily crossable and there are no strong interspecific isolation barriers. The F1 hybrids have offered some immediate and remarkable improvements in oil quality, resistance against some diseases and reducing trunk height (Table 5).

Until the *E. oleifera* collections are fully utilized and studied in detail it will not be possible to evaluate the actual potential of the interspecific hybrids.

Table 5. Features of interspecific hybrids

Character	*E. guineensis*	*E.o.* x *E.g.*	*E. oleifera*
Height increment (m)	0.34	0.18	0.09
No. of leaflets	321	256	188
FFB weight (kg)	148	190	120
Bunch weight (kg)	18	12	12
Oil percentage	50	34	30
Unsaturated fatty acids	52	66	79

(5) Compact palms: In Costa Rica a natural *E. oleifera* x *E. guineensis* hybrid was pollinated with *E. guineensis* and planted in Coto. This progeny had an abnormal palm with a short trunk and short bunch which was called the 'original compact palm'. This was back crossed to materials of proven agronomic characteristics and further selection was practiced for short stem and leaves. Some exceptional compact palms (super compact) were identified in the second back cross of compact palms x Ekona. These are short compact crowns permitting a higher planting density. However, planting materials of this line are not yet available (Nampoothiri, 1988).

Oil Quality

Improving the oil quality through production of higher level of unsaturated fatty acids will increase the market share for palm oil. Breeding programmes are in progress using various *E. guineensis* and *E. oleifera* sources to achieve the above objective.

Vegetative Propagation

Clonal propagation through tissue culture would be highly valuable for multiplying the elite ortets with exceptional characters like high FFB (fresh fruit bunch) yield and oil percentage, disease and pest resistance/tolerance as well as superior oil quality. Since some evidence is available in the Malaysian clonal plantations, regarding variation among the clones for fatty acid ratios in terms of the degree of saturation, possibilities for multiplying clones possessing high ratios of saturated or unsaturated fatty acids are open. Use of modern tools of gene mapping would further facilitate the unraveling of the genetic architecture enabling us to precisely analyse the genetic basis of desirable traits.

Micro-propagation

As oil palm is an outbreeder, natural clonal propagation is not possible because the axillary buds give rise to the inflorescences. The advantages of producing good clonal population of selected high yielding trees in oil palm have been described by Corley, *et al.* (1981). Besides obtaining uniformly high yielding clones of individual tress, clonal propagation will also facilitate the propagation of proven *dura* and *pisifera* parents to produce desirable *tenera* combinations. This is particularly important to a country like India, which is poised for expansion of oil palm cultivation, and availability of quality planting material is a constraint.

The major work on in vitro culture of oil palm was carried out in France (Institute Recherche de Huiles et Oleagineux or IRHO), the UK (Wye College), University of London and Unifield TC Unilever/Harrison and crossfield), Malaysia (Palm oil Research Institute of Malaysia or PORIM); and Indonesia (Marihat Research Station).

It has been claimed that through clonal propagation yields of palm oil would be increased by as much as 30% over the seedling progeny. Progress in commercialization of clonal propagation suffered a set back when abnormal flower development (mantled) was reported in palms transferred to field (Corley *et al.*, 1986). The French group (IRHO-ORSTOM) experiments at La Me, Cote-d'Ivoire have now resulted in reducing floral abnormalities to only 3.1% (Durand-Gasselin *et al.*, 1990).

Using the same technique (Lubis *et al.*, 1993) observed normal vegetative growth and flowering of clones in Indonesia. The Fresh Fruit Bunch (FFB) yields were about 20% higher in clones over those of seedling origin. Bakar *et al.*, (1993) have reported uniform true-to-type performance of cloned materials of diverse genetic origin in Malaysia.

Successful vegetative propagation of oil palm through tissue culture has been reported by Jones (1984), Rabachault and Martin (1976), Paranjothy (1984; 1986), and many others from the United Kingdom, Cote'd'Ivoire, France and Malaysia. The first attempt in India to develop a protocol for clonal multiplication of oil palm from tender leaf explants through somatic embryogenesis was by Thomas and Rao (1985) at Bhabha Atomic Research Centre, Bombay. They used young leaves from 6 months old *tenera* seedlings. Somatic

embryoids were produced within one week. About 50-60 embryos per culture were obtained which gradually developed into shoots. Thomas and Rao (1985) could obtain embryogenesis in both liquid and solid media. Shoots of 10-12 cm size with 2-4 leaves were isolated individually and maintained in tubes with filter paper bridges containing MS liquid medium supplemented with 1mg/lNAA and 1mg/l GA3 to initiate root growth. Plantlets containing 3-4 leaves with roots were transferred to paper cups with pre-sterilised soil compost.

Raju *et al.*, (1989) reported the successful culturing of explants from tender leaf of three year old *tenera* seedlings. The tender leaf column of seedlings was dissected out along with growing apices and after sterilizing with 70% ethanol, the tender leaf was cut into explants of 5mm length. Somatic embryoids were obtained from one explant with a few cell layers of primary callus when cultured in media in which 2,4-D was gradually replaced with NAA.Development of somatic embryoids were obtained in 8-20 weeks.Small white club shaped structures attained the size of 3-5mm length within 608 weeks of their appearance. They also claimed that, on a germination medium, about 50% of embryoids developed shoots, 30% showed simultaneous shoot and root development, and 15% with root development followed by shoot. The plants after development of lateral roots were transferred to a mixture of sand and vermiculite moistened with Hoagland's solution with 0.01mg/l IBA in pots kept under high humidity condition. Subsequently, these were transferred to the garden soil mixture and kept under shade. These plantlets were field planted at Palode, Kerala and their performance indicate no difference from that of seedling progenies.

Plantlet development was achieved from leaf explants of 18-month-old *dura* and 6 month old *tenera* oil palm seedlings (Anitha Karun and Sajini, 1996). Recently Rajanaidu *et al.* (1997) reviewed the current status of oil palm clonal production on commercial scale. According to them, not all embryoids formed will proliferate and germinate successfully in polyembryogenic tissues (PE). Besides, the performance of clones derived from selected high oil yielding ortets is not consistent for fresh fruit bunches (FFB). Hence the immediate prospect of tissue culture techniques is to develop biclonal seeds. This involves the multiplication of elite *dura* and *pisifera* parents through tissue culture and then crossing these to produce D X P seeds. Simultaneously the various stages in tissue culture process must be improved to produce normal plantlets for final selection. In any event, it would be safer to plant polyclonal orchards of elite DxP combinations, in view of the risks involved in planting monoclonal plantation, losing the advantages of heterozygosity in the event of new strains of pathogens and pests appearing.

Molecular Markers

Jack and Mayes (1993) reported for the first time the use of molecular markers in oil palm. Further the same group studied the application of RFLP probes derived from organelles and nuclear DNA in a number of oil palm genotypes (Jack, Dimitrijevic and Mayes, 1995). Recently Mayes *et al.* (1996) reported the study of comparatively limited number of highly variable RFLP probes which were used to obtain fingerprint information for 111 elite breeding palms and considered their value for palm identification. It was the first attempt towards an assessment of genotypic identity in oil palm.

Rival *et al.* (1997) used the flow cytometric analysis on two different crosses of *dura* x *pisifera* oil palm to get an accurate estimation of nuclear DNA content. The genome size of *Elaeis guineensis* was found to be 2C=3.76+(-)0.09 pg and therefore ca.3.4x109. Embryogenic calli and plants showed the same ploidy level but the measured 2C DNA values differred significanly. Since fast growing callus (FGC) already identified as a source of 'mantled' phenotype variants did not show any difference in their ploidy level, this proved the hypothesis that this is an epigenetic origin of a somoclonal variant.

Genetic Transformation

Studies on genetic transformation in oil palm was reported only recently (Chowdhury *et al.* 1997). These workers have studied the efficiency of GUS (á-Glucuronidase) gene expression in embryogenic callus and young leaflets of mature and seedling palms. They studied the expression of the GUS gene driven by the Emu, Ubi1, Act1, 35S or Adh1 both histochemically and fluorometrically. The results indicated that either the Ubi1 or Emu promoter should facilitate the expression of desired genes in oil palm and aid in development of an efficient stable transformation system.

Cryo Preservation

The need to conserve oil palm in vitro arises because of the large area which otherwise would be needed for ex vitro field conservation. Very little work has been done on this aspect inspite of its importance. Engelmann *et al.* (1988) was the first to standardize the technique of cryopreservation. They were able to store the embryoids for 15 months in liquid nitrogen and then could regenerate plantlets from the frozen materials.

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Cocoa Germplasm – Characterization, Conservation and Utilization

Vivek R.Bhat

Introduction

Cocoa (*Theobroma cacao* Linn.) is a diploid species with a chromosome number of 2n=20 and has been subdivided into two subspecies by Cuatrecasas (1964):

i) Theobroma cacao cacao consists of *Criollo* populations of Central and South America.

ii) *Theobroma cacao sphaerocarpum* includes all the other populations viz., *Forastero* and *Trinitario*.

Theobroma cacao is the only species which is being cultivated widely among 22 species of the genus. *T. bicolor* and *T. grandiflorum* are the other better known species. *T. bicolor* is a typical of the genus as its inflorescence appear in the axils of the new leaves so that its large heavy pods are borne on the ends of the branches which are bent down when the pods reach maturity. Other species including *T. cacao* have cauliflorous inflorescence.

Centres of Diversity

The primary centre of diversity is generally accepted to be the upper Amazon basin. The tropical part of Central America qualifies as a secondary centre of diversity.

Incompatibility

This is a well-known phenomenon wherein, failure to set fruit with the pollen from the same plant (self-incompatibility) or with pollen from other plants (cross incompatibility)occurs in cross-fertilizing plants which was first reported in cocoa by Pound (1932). The incompatibility in cocoa is gametophytic i.e., the male gamete does not fuse with female gamete while mating. A genetic mechanism controlling the fusion of gametes has been proposed, consisting of a series of S factors. Five S - alleles controlling selfing and crossing between many cultivars are proposed (according to their dominance relationship):

Sa = Sb = Sc >Sd >Sf

The Amazon cultivars are self-incompatible but are generally cross-compatible, while the Amelonado populations are entirely self-compatible trees which will not cross with self-incompatible trees, but accept pollen from self-compatible trees.

To study the self incompatibility and cross-compatibility in cocoa, the rate of fruit setting was measured after self-pollination and related and unrelated cross pollination. Artificial pollination was carried out on mature, one and a half to two and a half year old trees. As compared with cross pollination, self pollination resulted in lower fruit setting and a higher 'Cherelle-wilt'. Self pollination of secondary clones in a poly clonal garden (144 clones) showed that nearly 10 percent of the clones were self-compatible. Ten primary clones of IMC, Pa, Pound and UF selections were self-compatible and cross-compatible with unrelated populations. Cross pollination in related parents resulted in low fruit setting or compatibility; some combinations were cross incompatible. Reciprocal crosses showed differences between clones used as male or as female parents – for fruit setting. The lower fruit setting in related parent crosses, suggested that a mixture of hybrid varieties would produce higher setting and pod-production than a monohybrid (Capitupulu, 1984).

Fruit Development

Cocoa pod is an indehiscent drupe with 30-40 beans attached to central placenta. The stages of the fruit growth is shown in Fig.1

Between 40th and 50th day after pollination, zygote (a single cell) starts its first division to become embryo. Eighty five days after pollination, the second growth period starts when embryo starts growing and pod and ovule growth slow down. Fat accumulation occurs at 140 Days After Pollination (DAP) when embryo growth ceases and ripening sets in. Fruit thinning occurs in cocoa by shedding of young fruits called cherelles. Cherelle wilt occurs up to 50 DAP (peak period) at increased rate and then at reduced rate. Second peak is noticed at 70 DAP. Beyond 95-100 DAP, wilting does not occur.

Bean Characters

The dry weight of beans is mainly determined by the tree that produces it and to some extent by the pollen parent. Among climatic factors, rainfall is the main decider of bean dry weight. The fat content of dry bean ranges from 45-65 per cent and it has positive correlation with bean weight. The shell is the product of testa and remnants of mucilage

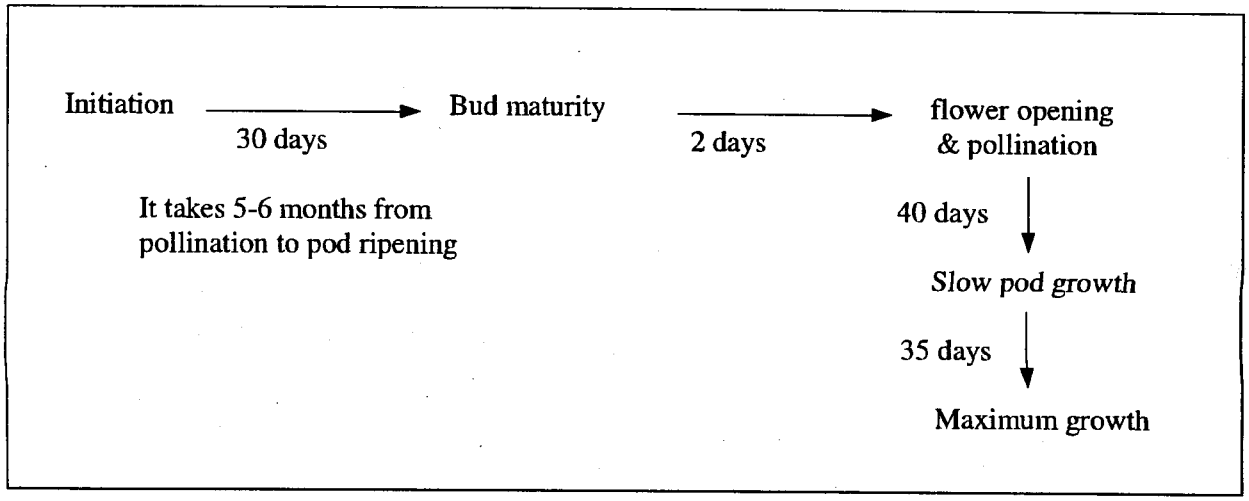


Fig. 1. Stages of fruit growth in cocoa

after fermentation and drying. Shell content is the proportion of shell weight over total bean weight expressed in terms of percentage. It is lower in wet season than in dry season.

Variation is a thumb rule in cocoa due to the fact of naturally occurring self-incompatibility among the most of the types/ varieties with the exception of Amelonado that breeds true. Phenotypical characters, that too mainly pod morphological variations have been the major criteria for classification of cocoa lines.

Pod Morphology

The morphology of the pod is determined by a combination of characters of independent inheritance.
Surface - usually 10 ridges (alternate ones are more pronounced); it may be deep to shallow furrowed or smooth to warty.

Bottle neck - a basal constriction may be present or absent and if present, it may be conspicuous or inconspicuous; shoulder may be narrow to broad.

Colour - developing pod will be green or red; ripe pod is yellow to orange.

Point/apex - may be present or absent; if present varies from long acute to blunt and indented.

Varieties

Though the Criollo type was in great demand in the early parts of chocolate industry due to best quality beans they provide, the present day cocoa production is derived either from bulk Forastero or from mixed hybrids that make Trinitarios. The main reason for this selectivity has been the susceptibility of Criollo to major diseases like Witches' broom, Cocoa Swollen Shoot Virus etc..

Engels (1986) has proposed a new classification for grouping the cocoa varieties as majority of them are hybrids based on 10 characters. A scatter diagram of longitudinal and transverse fruit sections is presented so as to identify, the cultvars that are known. Cluster principal component analyses and simple statistical methods using around 39 characters were employed to group 294 cultivars (mainly clones). These distributions roughly corresponded to the traditional classification into Criollos, Forasteros and their sub divisions in Ethiopia.

Engels (1986) developed methods to measure and compare the discriminative values of both qualitative and quantitative characters to facilitate selection of the most useful

Table 1. Distinctive characters of cocoa types

Characters	Criollo	Forastero	Trinitario
Pod husk			
Texture	Soft	Hard	Mostly hard
Colour	Red	Green	Variable
Beans			
Av. no. per pod	20-30	30 or more	30 or more
Colour of cotyledons	White, ivory or very pale	Pale or deep purple	Variable, white beans rarely occur

characters for systematic description of a germplasm collections. Relationships between clones were studied to determine their influence on the value of the discriminatory power of a given character for a given group of clones. The inheritance of qualitative and quantitative characters were studied. Although such a relationship could not be established, there were strong indications that qualitative characters examined followed tetraploid rather than the diploid inheritance.

Collection and Conservation

In little more than two centuries, the commercial growing of cocoa has extended from its centre of origin in South America to West Africa, the far east and Oceania. Now, cocoa has become an important crop throughout the Humid Tropics. However, much of the material that has been used for commercial plantings in each of these areas has been derived from a very narrow genetic base. The increase in global cocoa production from 1.5 million tons in 1984 to 2.7 million tons in 1998 is almost entirely due to an increase in production, area where as productivity has remained low(about 400 kg per ha; ICCO, 1993). This contrasts with the often dramatic advances in yields of other tropical or temperate crops. As pressure on available land increases, gains in global productivity of cocoa has become urgent.

It has long been recognized that there is need to improve the genetic diversity of material available to cocoa breeders and this has led to the scientific expeditions to collect wild cocoa over the last 50 years (Soria, 1970 ; Allen & Lass). Much of the material collected in these expeditions is now maintained in national and international germplasm collections in Central and South America and in the Caribbean.

Collections at CATIE and ICG,T have been designated as primary collections by the IBPGR and the germplasm from these centres are freely available to all who request it (Table 2).

Meanwhile, genetic studies of the cocoa plant have revealed additive inheritance of economically important traits, including disease resistance and yield. Significant correlations between the performance of parental clones and their offsprings have been demonstrated. These findings open up new avenues for cocoa breeding that are as follows.

1. Germplasm enhancement – possibilities to improve specific traits, including resistance, through accumulation of genes in cross progenies.
2. Population improvement strategy – through recurrent selection – aiming at long- term improvement for all economically important traits.

Table 2. Cocoa Gene Banks

Station	Location	Country
Centro Agronomica Tropical de Investigacion & Ensenanza (CATIE)	Turialba	Costa Rica
Departmento Esapecial da Amazonia, CEPLAC	Belem	Brazil
Instituto Colombiano Agropecuaria	Palmira	Colombia
Estacion Experimental Tropical	Pichilingue	Ecuador
Intrenational Cocoa Genebank, Trinidad (ICG,T) at University of West Indies	St. Augustine	Trinidad
IRCC	Sinnamary	French Gayana
USDA Agricultural Research Station	Mayaguez	Puerto Rico

Advances have been made in developing more reliable early screening tests for resistance to diseases, especially for black pod and witches broom. Inoculation of young plants or leaves have provided good results. For example for PBD in Cameroon and Trinidad (Nyasse *et. al.*, 1995; Iwaro *et. al.*, 1997).

Many cocoa producing countries have been unable to maintain effective long-term breeding activities because of limited financial resources, especially during the recent period of depressed cocoa prices. In addition, many breeders operate in very isolated conditions. This is why in 1993 the INGENIC – (International Group for the Genetic Improvement of Cocoa) was created.

In India, cocoa germplasm collections have been conserved with further exploration at two main centres, viz., (1)CPCRI Regional Station Vittal (137 accessions) and (2) College of Horticulture, Velanikkara under Kerala Agricultural University (300 plus). Evaluation at these centres has been concentrated under different cropping systems like that of arecanut, coconut and rubber.

Cocoa breeders and curators have been creating collections, with wild or cultivated materials, which currently contain about 7,000 original accessions globally. There is a threat of loss of diversity in germplasm collections, not only due to natural calamities (fire, diseases), but also due to irregular funding. The existing international germplasm collections at CRU and CATIE, containing approximately 3,000 and 800 accessions respectively, have been officially recognized by IPGRI as International base collections. Large collections with original genotypes exist also in Brazil,

Colombia, Ecuador, French Guyana, Mexico and Venezuela. Collections have been built up also in West Africa and South East Asian cocoa producing countries, including local selections and accessions introduced from Latin America. Transfer of germplasm from International Germplasm Centres to user countries is done through intermediate quarantine, of two years, at facilities in the Reading University, UK and at CIRAD, Montpellier, France (Frison and Felin, 1989). However, the demand for new germplasm by user countries in recent years has been relatively limited, because the breeding value of this material is generally unknown and due to the restricted absorptive capacity of many institutes due to general decline in breeding activities.

More heritable economic traits are being evaluated at the International Cocoa germplasm collection site at CRU in Trinidad (ICG-T), especially resistance to black pod and Witches' broom diseases. Germplasm enhancement consists of identifying more resistant seedlings within the crosses between selected clones. This approach explores the large genetic diversity present in this collection to create improved populations.

Presently, germplasm accessions have been conserved in the field either in the form of seedlings or as clones. The standardized clonal multiplication at various centres has paved ways for multiplication and maintenance of accessions with greater degree of true breeding values. Moisture loss from bud sticks can be reduced or delayed by applying molten paraffin to the ends of bud sticks and to the petiole stubs if they remain attached. Petioles should be cut 10-15 days before removing bud sticks from donor trees. If patch or chip buds could not be used, the side veneer graft resulted in high survival of germplasm (Purdy, 1989).

In the course of breeding for improvements in the cocoa plants, desirable clones will be developed in the following way. Within one month after bending, buds along the top and side of the arched orthrotropic trunk produced multiple chupons. Flower cushions, when present on the top or sides of the orchard trunk, changed from the reproductive to the vegetative phase and also produced multiple orthrotropic shoots. Flower cushions remained vegetative throughout the course of our observations i.e. approx. one year. At CCRI, Papua New Guinea, an experiment was conducted on induction of chupons on different improved clones derived from hybrid progenies. Generally, chupons produce only chupons, and fan branches unusually give rise to new fan branches. Heavy pruning in all the clones induced a frequency of chupons.

Utilization

The major utilization of cocoa germplasm has been in selecting the best lines that are most adapted to the locality with desired traits like higher bean yield, tolerance to biotic and abiotic stresses, multiplying them for mass production, furthering them through breeding programmes (hybridization and evaluation for the desired traits) to gain heterosis and desired genes inherited.

About 40 percent of world cocoa production is from improved varieties (Paulin and Eskes, 1995). The majority are hybrids (mixtures of bi-parental crosses) but use of clonal cocoa is increasing. Practically all cultivated varieties, selected or unselected are highly susceptible to disease and pests of local importance. Exceptions are varieties with effective VSD resistance selected in Asia and with witches broom resistance in Trinidad.

Cocoa breeding started early this century mainly by clonal selection in heterogeneous Trinitario populations (ICS, DR clones). Expeditions were organized in the 1930's and 1940's to search for Witches' broom resistant cocoa trees in the Upper Amazon basin. Although, only few highly resistant trees could be identified, it was soon found that hybrid vigour was expressed in crosses between these Upper Amazon types and local clones. Hybrid varieties were subsequently created in many countries and provided better establishment capacity, vigour, precocity and yield potential than traditional local varieties (Amelonado, Trinitario).

Shortcomings of these varieties were identified later on such as heterogeneity of of hybrid mixutres, low resistance to diseases and pests, and sometimes, an early decline in production capacity with the aging of plantations. Further progress with traditional hybrid breeding depends on identifying or creating parental clones that combine several desirable traits (high quality, yield and disease resistance) (Kennedy *et. al.*, 1987).

The first step in breeding programme is selection from the local populations. In West Africa, local selections' were made in 1940 from most productive individual trees in local plantings. In small cocoa growing countries like Trinidad and Indonesia it was possible to go for vegetative cuttings/ budding for multiplication of selections but it was not so in W. Africa. Hence, seeds resulting from selfing/inter crossing were utilized for this purpose. Therefore, 'Monoclonal' blocks were planted for large scale production of selfed seeds from best selections from Ghana and Nigeria.

The next step is to cross the different selections from various sources. In Nigeria N 38 (local selection) was crossed with selections from ICS (Imperial College Selections) parents yielding progenies that were strikingly vigorous - an early example of heterosis.

The important parent materials for cocoa germplasm are given below:

(i) ICS - selections from Imperial College of Tropical Agriculture in Trinidad.
(ii) Upper Amazon parents- these include IMC, NA, PA and SCA.
(iii) Amelonado- originated in West Africa.

Modern hybrid varieties are the later developments and have the following plus points:

1. Grow much faster compared to old local varieties and are therefore, much easier to establish.
2. Start to flower in 3rd or 4th year after planting
3. Due to extra vigour there will be quicker canopy development leading to proportional reduction in the cost of establishment.
4. Due to vigour they have got quite a good regenerative power.
5. On an average yield 2000 kg per ha.

Development of hybrid varieties and production of seed in large quantities involves a large programme of research and development. Local selections and introductions are to be crossed. Resulting progenies are to be tested in various localities. Yield and other characters have to be recorded for 10 years from planting to final evaluation of progenies. These large seed gardens are of to specific design, and large scale seed production takes 4-6 years. In total, the whole programme needs 12 years.

Introduction needs further emphasis in breeding programme of new genetic material. Pound's Upper Amazon material forms one component of the breeding programme in nearly all cocoa growing countries and this is likely to continue for some time. Only eight of Pound's clones have been used in breeding work. These eight clones were chosen more or less at random from the vast collection in Trinidad, most of which still awaits full evaluation. Thus, cocoa breeding work which has had spectacular results has been based on a very narrow range of genetic material. There is a need to widen the genetic base not only by evaluation of available germplasm but also by collecting more germplasm from centres of diversity and to organize its distribution with appropriate phytosanitary precautions. This will help local breeding programs to assemble collections with a broad range of genetic material.

With this view, the cocoa improvement programme was started at CPCRI Regional Station Vittal for the first time in the country involving the following strategies of 1) germplasm collection, 2) selection for high yield and bean size, 3) multiplying them vegetatively, 4) hybridization, 5) laying out progeny trials to evaluate the different combinations, and 6) establishment of clonal orchards. The main objectives of breeding have been : (a) high yield, (b) bean size of more than 1.0 g , (c) drought tolerance, and (d) resistance to black pod diseases.

Over the years starting from 1970 onwards 137 accessions of cocoa have been collected from various places for enriching the cocoa germplasm at CPCRI Regional Station Vittal (Table 3.) Evaluation of germplasm was carried out for yield (No. of pods/tree/year), pod value, bean weight and number of beans per pod. The germplasm collection showed wide variations for all the characters. Seven trees with high yield and good bean size (>1.0 g) were selected from collections obtained from Malaysia and Nigeria (Table 3).

Table 3. Cocoa germplasm at Vittal

Origin	Place of collection	No. of acces-sions	Year of plant-ing	Planting material
Malaysia	Malaysia	11	1970	Seedlings
Nigeria	Nigeria	44	1975	Seedlings
Kew Garden England	Kew Garden England	5	1981	Clones
Kew Garden England	Lalbagh Bangalore	9	1983	Clones
Ghana	KAU, Trissur	12	1986	Clones
	Wynad	10	1988	Seedlings/
		13	1998	Clones
	Kallar	1	1988	Seedlings
	KAU, Trissur	12 20	1991 1996	Clones Clones

Systematic evaluation of germplasm has resulted in some drought tolerant lines like NC 42, NC 23 and NC 29, with favourable physiological parameters like better stomatal regulation , thicker epicuticular wax etc. Similarly, *in vitro* screening of majority of the available germplasm against the main disease, BPD using the prevailing three *Phytophthora* sp., viz., *P. palmivora, P. capsici, P. citropthora* has indicated a few good lines with certain degree of tolerance and one among them has been NC 51 (parentage being C44). This particular line has been utilized as pollen donor in inheritance study with the selected seven best lines. However, lack of pure lines is felt in this direction.

Based on the yield, bean size, self- and cross-compatibility reactions, the following 4 hybrids were recommended for cultivation in Kerala and Karnataka. All the 4 parents are self-incompatible and cross compatible.

Kerala
I-14 x I-56 ; I-14 x NC 42/94 ; I-56 x NC 42/94
Karnataka
III-105 x I-56

All these 4 parents are vegetatively propagated for the establishment of six biclonal seed gardens and one Polyclonal garden. These orchards have been planted at Seed Farm, Kidu for quality seed distribution among farmers (Table 4.).

Table 4. Selected parents for production of planting materials

Tree No.	Genotype	Bean wt. (g)	Yield dry bean wt.(kg)	SI/ SC
I-56	PA 7 x Na32	1.20	6.99	SI
I-14	Jarangau Red axil	1.17	7.51	SI
II-67	Landas 364	1.34	4.67	SI
III-35	Amel. x Na32	1.09	4.03	SI
III-105	Amel. x PA 7	1.06	3.98	SI
IV-20	Landas 357	1.06	4.27	SC
NC42/94	T 86/2	1.08	3.03	SI

SC= Self compatible; SI= Self incompatible

Field Evaluation

Field evaluation of cocoa germplasm led to selection of certain best bean yielders (Table 5.). These along with few more selected lines have been used in hybridization programmes with the objective of evolving high yielding cocoa lines. About 40 progenies of these cocoa lines have been tried under four sets of progeny row trial. First three trials have yielded nine best hybrid combinations while the fourth is indicating preliminary performance.

Two cocoa trials involving 25 progenies in trial I and 16 progenies in trial 2, were grown under inland conditions in Peninsular Malaysia. Pod production/tree and kg dry bean (kdb) production / ha showed significant differences among progenies for both the trials. However, seasonal influence seemed more pronounced than progeny effect for pod production for both the trials. The reverse was the case for the kdb production/ha. Progeny x season interaction was non-significant for both the trials and for both the yield experiences. A factorial analysis of the pod weight, bean weight and bean number were carried out for 5 random progenies from trial 1,5 from 2 where UF1 was the common female parent. For trial 1, it was significant for bean weight and number. while, for 2nd trial it wasn't. Bean weight was significantly influenced by season while pod weight wasn't. The bean and pod weight showed no significant interaction with season. Significant correlations for pod weight with bean weight and pod weight with bean number were obtained (Palaniappan and Shamsuddin, 1990).

Paulin (1990) studied the cocoa hybrids from crosses between Upper Amazon(UA) x Amelonado, UA x Trinitario in Ivory coast. Analysis of 4 trials with hybrids between 16 UA clones (female parents) and 4 locally selected Amelonado clones (male parents)was done. Individual tree yields between 1982 and 1987, vigour of young tree and size of adult trees, fruit damage due to black pod and rats and tree mortality were determined. Results on productivity show the superiority of most hybrids. The best female parents were Sca 6, Na 32, T60887, T 79/501, Pa7 and T 85/799.

Cocoa clones introduced into Indonesia from Kew Gardens, UK and Wageningen, Netherlands, resulted in best clones that yielded 20-40 percent more than the hybrid seedlings. IMC clones gave the greatest number of smaller beans. UF clones gave a few, large beans, while Pa clones gave a moderate number of medium-sized beans. Clones useful for further breeding were identified by Napitupulu (1990).

Table 5. Selected cocoa lines from progeny trials with bean yield potential.

Trial	Total progenies tried with parents(P) & checks (C)	Best lines/ hybrids	Dry bean yield (kg/plant)
Progeny I	5	Na 33 x ICS 89	1.005
Progeny II	17 +7 (P) + 1 (C)	I-56 x II-67 I-14 x II-67 I-56 x III-105 I-14 x NC 42/94	1.481 1.465 1.418 1.389
Progeny III	9 +4 *(F3 Amazons)*	Amel. X Na 33	1.082
Nigerian Clonal Trial	8+2 (C)	NC 45/53	1.328

Possibilities for developing F1 hybrids of cocoa of good productivity and uniformity were studied by Pinto *et al.* (1990) at CEPEC, Bahia, Brazil on the basis of literature search. Reducing the long juvenile period and the need for large areas for field trials by reducing the number of generations and the number of years per cycle of endogamous breeding has been emphasized. The breeding method consists of successive self fertilization or diploidization of haploids obtained from immature seeds.

Tan (1990) reported the combining ability analyses of yield and its components in cocoa from PNG, CCRI, Rabaul. Six Trinitario female plants derived from crosses between Criollo and Forastero were crossed with 9 Amazonian male parents in factorial crossing design. The 54 hybrid progenies were used to estimate genetic variability due to GCA and SCA for yield, pod production, pod weight, husk content, number of beans/pod, average bean weight and pod value. Results demonstrated that GCA was significant for all characteristics. The ratio of GCA to SCA ranged from 7.1 for beans per pod to 25.7 per pod weight suggesting that major portion of the genetic variability was additive. Among the 6 Trinitarios, KA2-106 was the best female parent contributing to high yield and all the desirable pod and bean characteristics of the hybrid progenies. Trinitario KA2-101 combined high pod production and yield, but tended to transmit below-average pod and bean characteristics to its progenies. Amazonians KEE 6 and KEE 12 were the 2 highest yielding male parents, but had below- average bean number per pod and average bean weight. KEE 42 and KEE 43 combined high yield and transmitted good pod and bean characteristics to their progenies. Based on the GCA effects and the mean performance of the hybrid progenies, a multi-line cultivar consisting of 20 high yielding crosses with good pod and bean characteristics is being produced in seed gardens for commercial planting.

Ojo *et. al.* (1991) prescribed use of about 50 percent of the progenies as composite variety from the progenies of 17 double crosses of Nanny and Parinary selected hybrids in Nigeria.

Inheritance

Bean number and bean size are strongly inherited. In the Pa 7 x Na 32 F1 progeny inherent bean sizes are low and probably relatively constant while inherent bean numbers vary widely; in consequence inherent bean numbers are well indicated by samples of pods taken from the trees, and inheritance of bean number in the F2 progenies is very clear while inheritance of bean size is not. In contrast, in the F2 of PA 35 x Na 32 there is a clear segregation in bean size while bean numbers are relatively high and constant; inheritance of bean size in the F2 progenies is clear while, the evidence of inheritance of bean number is weaker. The average pod weight of a progeny seems to be determined by the inherent bean size and the inherent bean number.

Bean breadth and bean thickness tend to be negatively correlated. It is suggested that where the number of ranks of beans in a pod is high relative to the length of the pod and the inherent bean size, the beans lacking room for expansion in thickness, tend to increase in breadth so as to attain the inherent size. Short fat pods may therefore, tend to contain broad, thin, plate-like beans (Glendinning, 1963). It is clear that bean size is controlled by Mendelian genes, bean number is under genetic control but it has not been possible to work out the situation in detail. Average pod size appears to be controlled by inherent size and bean number. It would seem therefore, that bean size can be bred and that large pods should be obtainable by breeding for high bean numbers and large beans.

Comparative trials involving hybrids from un-programmed crosses do not allow access to the genetic parameters like genetic variances (genotypic, additive and dominance variances) and heritability in narrow and broad sense, whereas schemes hierarchical, factorial and diallel crosses do. When numerous crosses need to be studied it is therefore preferable to adopt hierarchical or factorial breeding schemes. If, in contrast, the objective is to determine with accuracy the heritability of a given character, a diallel system is more suitable. Indexed multicharacter breeding may be envisaged if these genetic parameters and respective genetic correlations are known for several characters. More frequent application of quantitative genetic approach to cocoa would thus seem desirable to permit the preparation of a breeding index, the objective being simultaneous improvement of the different characters chosen as selection criteria (Cilas, 1991).

While investigating the influence of relative ratio of parent trees in a biclonal seed garden on quantity, quality and genetic origin of the seeds in Cote d'Ivoire, Lachenaud and Sounigo (1991) indicated no significant difference on varying the percentage of male trees (0.5 to 9.7%). Neither productivity (no. of pods and weight of beans) nor pod filling (no.of beans/pod and percentage of flat beans) were affected by varied density of male parents. Blocks with highest no. of male parents had the least percentage of beans by self-fertilization than did the other two.

Disease resistance

Cilas *et. al.* (1988) studied the resistance to swollen shoot of cocoa in a quasi complete 8 x 8 diall. in Togo. Beans of cocoa plants produced from diallel crosses were inoculated with larvae of *Ferrisia virgata*. No cytoplasmic heredity was found for resistance to CSSV, which is polygenic and partly

linked with plant vigour. The clone IMC seem to be the best parent for this character.

Hybrids resulting from crosses of clones BE5, CAS1, EEG 8, 9 and 65, EET 103,ICS 84 and 95, MA 15, SGU 3 and SPA 17 with the clone STC 802 having a common progenitor, were tested during seedling stage aiming at an early screening of resistance to *Phytophthora capsici, P. palmivora, P. citrophthora* agents of cocoa black pod diseases in Southern Bahia. *Phytophthora capsici* showed always the least average of lesioned area, followed by *P. palmivora* and *P. citrophthora*. The progenies of the clones of BE 5, EEG 8 and 9 and MA 15 showed the highest level of resistance; SPA 17, EEG 65, EET 103 and SGU 3 presented intermediate levels, while ICS 84 and 95 and CAS1 showed the highest susceptibility levels (Pinto *et. al.*, 1990).

Tan (1992) reported the breeding trials conducted at Cocoa and Coconut Research Institute, Rabaul, Papua New Guinea, aimed at finding lines of cocoa resistant to various pests and diseases.

Bong and Phua (1989) screened cocoa hybrid progenies at Agriculture Research Centre, Tuaran, Sabah, Malaysia against vascular streak die back (VSD) and reported seven highly resistant hybrid seedlings when screened in nursery and field. Pa 7 x Na 32 progenies were taken as check plants/standards for comparative evaluation.

The Principal threat comes from Witches' broom disease (caused by *Crinipellis perniciosa*) which occurs only in South and Central America. The risk of spread of this disease is well illustrated by its recent identification from cocoa plantings in the State of Bahia.

Authentic cocoa swollen shoot virus is only known to be present in West Africa and VSD caused by *Oncobasidium theobromae* – is only found in the Far East. In order to arrest the spread of these diseases it is compulsory that the plantings should pass through a period of intermediate quarantine in a non-cocoa producing country where the material can be safely screened for pests and diseases (Frison and Feliu, 1989).

Table 6. Composition of Bi-clonal and Poly-clonal orchards

Bi-clonal	Poly- clonal
NC 42/94 & I-56	I-14
SCA 6 & ICS 6	I-56
I-56 & III-105	III-105
NC 42/94 & I-14	NC 42/94
I-14 & I-56	
I-14 & IV-20	

In recent years, the major intermediate cocoa quarantine centre was at the USDA sub-tropical research station at Miami, Florida. However, over the last two and a half years a new quarantine facility has been established at the University of Reading, UK to increase the availability of cocoa germplasm. Collection of clones at Royal Botanical Gardens, Kew been transferred to Horticultural Department of University of Reading.

Future Thrust

Since the late seventies, systematic efforts have been initiated to characterize germplasm in collections, mainly by observing morphological traits. With the development of DNA marker technology, genetic diversity in these collections becomes better understood. There has been no systematic germplasm collection for agronomic traits and disease resistance. These traits often vary according to the environment and consequently, final evaluation should be done in user countries. However, centralized evaluation in base germplasm collections for heritable traits, such as quality and disease resistance, appears to be highly cost effective. It has been estimated that approximately five percent of the unique cocoa genotypes, globally available, have so far been evaluated and used as parents to select more productive varieties (Paulin and Eskes, 1995). The recent emphasis in cocoa breeding is to combine yield with other important traits, like quality and disease resistance. Most of the smaller national collections lack sufficient genetic variability for these traits and so international collaboration is essential to identify and disseminate interesting clones to be used in future breeding programs.

Quite a good number of clones/hybrids with desirable traits and bean yield have been evolved using the exotic germplasm collected and conserved at CPCRI Regional Station Vittal, and KAU Velanikkara campus. Much variability has been generated through selections and crossing the compatible lines. Though the major thrust has been in evolving high yielding clones equal emphasis is being paid for selecting varieties with certain degree of tolerance to major disease causing pathogens like *Phytophthora* (BPD) and *Oncobasidium theobromae* (VSD) since these two have been major threat to Indian cocoa industry. Drought tolerant lines will also have equally high value in the Indian Subcontinent due to the prolonged non-monsoon period occurring every year.

Though the germplasm has been maintained with clonal materials that are supposed to be true bred , there occurs certain amount of variation in the lines due to the stionic effect if they happen to be grafts/ buddlings. This can be minimized by adopting micro-propagation techniques or cuttings at macro level.

Top working in cocoa has been almost standardized by Kerala Agricultural University team and this may be very well adopted in conserving the vast numbers of cocoa germplasm by employing multi –varietal top working and thereby cutting down the requirement of vast land area.

It is always wise to plant multiple varieties in a place so as to check spread of and loss due to any devastating disease causing pathogens. Hence this multi-line / synthetic variety concept is highly acceptable in cocoa.

Improvement and conservation of cocoa gene pool have been the main tasks of international cocoa genetic projects. Quite a few international projects have been concentrating on improving the productivity, harnessing the desirable traits available in the already existing germplasm and also by widening the gene base by undertaking expeditions. Effort is being continued in recognizing the misnomers, and correctly labelling the germplasm throughout the world.

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Cashew Development - A Futuristic Approach

E. V.V. Bhaskara Rao

Introduction

Cashew ranks first among the horticultural commodities exported from India. During the past one decade the export earnings have been on the increase and during 1997-98 it is estimated that the export earnings will be around Rs.14,200 million with the export of 79,320 MTs of kernels. However, around Rs.8,180 million were spent by India for the import of 244,588 MTs of raw nuts from different countries. The primary mandate of the research programmes and the development support for the cashew crop should be to enhance the production and productivity to meet the domestic processing capacity of well over 700,000 MTs established in 771 processing factories in the country. India is probably the only cashew growing country which has got an excellent net work of research infrastructure covering almost all the cashew growing States. The establishment of the research infrastructure dates back to 1970 with the inception of Central Plantation Crops Research Institute and the All India Coordinated Spices and Cashewnut Improvement Project in 1971. Over the years, number of initiatives were taken to strengthen the research capability for developing viable technologies to increase the production and productivity of cashew in the country. Today, we have National Research Centre for Cashew as the nodal agency under the Indian Council of Agricultural Research with its headquarters at Puttur in Dakshina Kannada District of Karnataka and the All India Coordinated Research Project covers eight cashew growing States with nine Centres including the one in the non-traditional area at Jagadalpur in Bastar District of Madhya Pradesh. However, the north-eastern region which also has the potential for cashew cultivation is yet to be supported with research centres.

Cashew cultivation in India dates back to four centuries when it was originally introduced by the Portuguese sometime during the 16th Century. The concept that cashew was introduced for soil conservation led to the relegation of this crop to soil conservation, afforestation and waste land development programmes which has adversely affected the crop importance as a horticultural crop. Further the emphasis given in the development programmes for area expansion and implementation of this programme with a target achieving approach has led to the establishment of large plantations under the Forest Departments, Soil Conservation Department as well as in degraded lands in farmers' plots with seedling progenies of non-descript origin. These plantations also received very little or no input in the form of prod package and were grown under totally neglected co This has led to rapid decline in the yields after a period and by 1970 we had approximately an area of 2.81 l totally covered with the progenies of seed origin of variable production potential. The varietal concep introduced between 1970 and 1980 through testi progenies of elite lines under All India Coordinated Re Project. But, however, the benefits of yield could n translated immediately due to lack of commercially vi vegetative propagation method.

Current Status of Cashew Plantations

As mentioned before, by 1970 we had 2.81 lakh which is purely of non-descript seedling origin. Betw 1970s and 1980s there were efforts to identify superior m plants as seed sources. However, the propagation continued to be through open pollinated seeds. During period, under the area expansion programme supported Government sponsored development programmes as wel through independent farmers initiatives 1.68 lakh ha has b added to the cashew area in the country (Table-1). Du 1982 - 1986, the World Bank aided Multi State Cash Project was implemented in four States, namely, And Pradesh, Karnataka, Kerala and Orissa. However, even in t World Bank funded project, plantations raised were mainly seedling origin, but in many cases the seeds were collec from the progeny orchards established by the Rese Centres. One of the biggest benefits which the country co get in this programme was the standardization of vegeta propagation which later was refined and developed int commercially viable soft wood grafting method for producti of cashew varieties. During 1980s the research centres in t country also have identified a number of high yielding selections and also developed few hybrids. During 1990s th commercial viability of vegetative propagation was confirmed in cashew and a large number of nurseries were established for multiplication of cashew varieties. Some of these nurseries were established with the assistance of Government of India through the Directorate of Cashewnut Development under the Regional Nursery Programme. Between 1980 and 1990 an area of 0.83 lakh ha were added which is also of seedling origin but from the seeds collected mostly from the progeny orchards while large proportion of 1.29 lakh ha raised between 1990 and 1997 are of soft wood grafts. This status of cashew plantations calls for location oriented technological

approach in the development programmes, which are summarized below:

Replanting

The plantations existing as on 1970 accounting 2.81 lakh ha certainly needs to be replanted. These are the plantations of non-descript seedling origin grown under neglected conditions over the years and in many cases with low plant densities. Often it is contemplated to look into the possibility of top working and rejuvenating the old and unthrifty plantations as one of the strategies for these plantations. It may be mentioned that top working even in places where it has been reported to be successful, is confined to the age group of 10 to 15 years only. These plantations which are around 30 years and above are not amenable for top working. Hence replanting appears to be the most ideal programme to be implemented. Tamil Nadu and Kerala are the two States which should receive priority for this programme along with Goa which have sizable area under pre-1970 plantations.

One of the advantages which India has is the availability of planting material in large numbers at present. Replanting certainly is the better option and a priority programme than the expansion of the area. Currently the available vacant lands are much more degraded due to severe soil erosion. Even though these old plantations are not giving economical yields, they certainly have served the purpose of soil conservation. Further the leaf litter and root decay over the years have made these soils relatively more fertile than the vacant lands which are available for area expansion. Large planting material availability also supports high density plantings of more than 200 plants per ha which help us in realising the targeted production of 700,000 MTs of raw nuts in shorter period. However, caution is to be exercised in selecting the plant densities based on the crop growth pattern in different areas. The objective of high density planting should be to see the optimum use of area available is made by promoting the canopy coverage of the entire area in the shortest period. Judicious management of the canopy through training and removal of the criss-cross branches is also necessary to gain the benefits of this strategy.

Varietal Selection

It is also necessary to exercise the caution in selection of the variety for taking up the planting in the replanting programme. Today we have 34 varieties in the country (Table-2), of which 23 are selections and 11 are the hybrids. Not all the varieties are suitable for high density planting. Only those with compact canopy and intensive branching may suit this model. Further, the performance of these varieties and hybrids was found to be region specific and they are well suited only for the region for which they have recommended. While taking up replanting it is also necessary to select the varieties which have different flowering habits (early, middle and late) depending on the rainfall pattern, tea mosquito incidence and severe summer. For example, in places where early monsoon is expected only the varieties which can complete the total harvest before the onset of the monsoon, can be planted. While in places like Tamil Nadu, especially in

Table 1. Statewise growth under cashew in india (in lakh ha.)

State	1970	1980	1990	1997	Change between 1990 and 1997
Andhra Pradesh	0.26	0.44	0.71	1.21	0.50
Goa	0.34	0.41	0.44	0.51	0.07
Karnataka	0.19	0.53	0.74	0.85	0.11
Kerala	0.99	1.44	1.55	1.19	-0.36
Maharashtra	0.18	0.23	0.23	0.80	0.57
Orissa	0.03	0.39	0.60	1.05	0.45
Tamil Nadu	0.80	0.95	0.95	0.79	-0.16
West Bengal	0.02	0.07	0.07	0.09	0.02
Others	–	0.01	0.01	0.10	0.09
Total	2.81	4.47	5.30	6.59	1.29
Increase over previous period	–	1.66	0.83	1.29	

Vridhachalam of South-Arcot district where severe drought and high summer temperatures are noticed, varietal selection should be confined only to early and middle flowering varieties to realise profitable yields. One of the factors which was noticed during 1997-98 cropping season is the unusual rainfall which coincided with the flowering of some of the varieties in Karnataka has resulted in severe loss of crop in that region. However, late flowering varieties which have escaped the heavy rain are now (April 1998) in the fruiting stage. Therefore, consideration of the weather factors over a period of time and selection of the varieties will be necessary. Considering the cross-pollinated nature of the crop and also to avoid the monoculture, it is emphasized that more than one clonal progeny should be planted in each of the garden so that any adverse factors will not affect the total plantations.

Technology Selection

For enhancing the returns to the farmers the plantations which are contemplated to be raised at a regular plant density of 200 plants, it will be better to raise the plantations at 10 x 5m spacing for facilitating intercropping in the plots.

Identification of the production constraints in the region is an important factor which should guide the selection of technologies for that region. For example, in the undulating lands of the West-coast, soil conservation practices becomes mandatory while in the high rainfall areas like Kerala, both soil conservation as well as moisture conservation will benefit the crop. In the rain shadow areas in Tamil Nadu and Maidan

Table 2. Canopy type, branching habit, flowering period and fruiting period of released cashew varieties (Compiled from information furnished by respective research centres)

S. No.	Variety	Canopy type	Branching habit	Flowering		Fruiting	
				From	To	From	To
1.	BPP-1	Open	Extensive (Mostly)	Feb. (II Fortnight)	April (I Fortnight)	April	May
2.	BPP-2	Open	Extensive (Mostly)	Feb. (II Fortnight)	April (I Fortnight)	April	May
3.	BPP-3	Open	Extensive (Mostly)	March (I Fortnight)	May (I Fortnight)	April	June
4.	BPP-4	Open	Extensive (Mostly)	Feb. (I Fortnight)	April (I Fortnight)	April	May
5.	BPP-5	Compact	Intensive (Mostly)	Feb. (II Fortnight)	April (I Fortnight)	April	May
6.	BPP-6	Open	Extensive (Mostly)	Feb. (II Fortnight)	May (I Fortnight)	April	June
7.	BPP-8	Compact	Intensive (Mostly)	Feb. (I Fortnight)	April (I Fortnight)	April	May
8.	Bhubaneshwar-1	Compact	Intensive	Jan.	March	March	May
9.	Chintamani-1	Open (Intermrdiate)	Intensive	Jan.	April	Feb.	May
10.	Jhargram-1	Medium Compact	Intensive	Feb.	April	April	May
11.	Anakkayam-1 (BLA-139-1)	Compact	Intensive	Nov.	Dec.	Jan.	Feb.
12.	Madakkathara-1 (BLA-39-4)	Compact	Intensive	Nov.	Jan.	Jan.	March

Continued in next page

Table 2. (Continued from the previous page)

S.No	Variety	Canopy type	Branching habit	Flowering		Fruiting	
				From	To	From	To
13.	Madakkathara-2 (NDR-2-1)	Open	Intensive	Dec.	March	Feb.	May
14.	K-22-1	Compact	Intensive	Dec.	Jan.	Feb.	April
15.	Dhana (H-1608)	Compact	Intensive	Dec.	Feb.	Feb.	April
16.	Kanaka (H-1598)	Open	Intensive	Nov.	Jan.	Jan.	March
17.	Priyanka (H-1591)	Open	Intensive	Dec.	March	Feb.	May
18.	V-1	Compact	Intensive	Sept.	Nov.	Dec.	March
19.	V-3	Compact	Intensive	Oct.	Dec.	Jan.	April
20.	V-3	Compact	Intensive	Nov.	Dec.	Feb.	May
21.	V-4	Open	Extensive	Nov.	Dec.	Feb.	May
22.	V-5	Compact	Intensive	Oct.	Dec.	Jan.	April
23.	V-6	Compact	Intensive	Nov.	Dec.	Feb.	May
24.	V-7	Medium	Intensive	Dec.	Feb.	Feb.	April
25.	VRI-1	Compact	Intensive	Jan.	April	Feb.	May
26.	VRI-2	Compact	Intensive	Feb.	April	March	May
27.	VRI-3	Compact	Intensive	Jan.	April	Feb.	May
28.	NRCC Sel. 1	Medium Compact	Extensive	Dec.	Feb.	March	April
29.	NRCC Sel.2	Medium Compact	Extensive	Nov.	Jan.	Feb.	March
30.	Ullal-1	Medium Spreading	Intensive	Nov. (3rd week)	April (1st week)	Feb.	May
31.	Ullal-2	Medium Spreading	Intensive	Dec. (2nd week)	March (Last week)	Feb.	April
32.	Ullal-3	Open	Intensive	Nov. (1st week)	Jan. (Last week)	Jan.	March
33.	Ullal-4	Medium Spreading	Intensive	Nov. (2nd week)	Feb. (Last week)	Jan.	April
34.	UN-50	Open	Intensive (Last week)	Nov.	Feb. (Last week)	Feb.	May

parts of Karnataka, the supplementary irrigation during the summer months will be relevant. Therefore, technological package also should be made region-specific for which a programme on technology testing and refinement is required to be incorporated in the development strategy. Even though the research network which is available in the country covers all the cashew growing States, it does not cover all the production sites in each State. Even the varieties which are recommended today are based on the evaluation at the Research Centres which do not adequately represent the total

cashew growing areas within the State. For example, Bapatla Centre in Andhra Pradesh under APAU (now the NG Ranga Agricultural University) has only sandy soil while the major cashew growing areas of East & West Godavari and Vishakapatnam districts have different soil types. Such a situation holds true for most of the States, with respect to soil type, weather parameters, especially the temperature, humidity, rainfall and also the pest incidence.

Technology Refinement

There is a need to take up pilot testing of the varieties and a *demonstration cum technology refinement programme*, which can be included in the IX Plan Development strategy. This will enable the farmers' participation in technology refinement so that the technologies developed in this programme are more easily acceptable and profitable for the cashew farmers. With the growing competition in the international market and a number of South-East Asian countries taking up cashew cultivation, it will be necessary for us to redefine our development programmes and give a new approach. In this, the aim should not be only to support the crop development through subsidies but it should also help in farmers participation in the technology refinement as well as establishing sites for disseminating the production technologies. These plantations which are raised under the demonstration cum technology refinement programme can also be used as sites for farmers training programmes, thereby taking the technology to the farmers' sites than trying to propagate it through the field days, training programmes or Kisan Melas organised in the Research Centres.

Management of Existing Plantations:

As mentioned in the beginning, between 1990 and 1997 1.29 lakh ha has been added to cashew growing areas in the country which consists mostly of grafts of recommended varieties. With these plantations coming to production stage during the IX Plan period, it is logical for us to expect higher production during the next five years. One of the encouraging features is that the large area expansion has taken place in Maharashtra, Orissa and Andhra Pradesh which are traditional cashew growing States where the productivity is also reasonably high. The productivity in Maharashtra has already touched 1.5 tonnes, while in Andhra Pradesh it is 0.8 tonnes per ha (Table-3). In Orissa the average productivity is around 0.7 tonnes, which is mainly due to the large plantations of seedling origin which has been raised during the implementation of Multi State Cashew Project. However, these plantations which are raised between 1980 and 1990 can be rejuvenated through judicious application of production packages like fertilizer application, and soil and water conservation measures wherever necessary. Being the seedling progenies, these plantations also did not receive any kind of canopy management practices. Therefore removal of deadwood and criss-cross branches (pruning) should be favourable for increasing the productivity from these plantations.

Table 3. Area, production and productivity of cashew in india (1996-97)

State	Total area (lakh ha.)	Productive area (lakh ha.)	Production (lakh MT)	Av. Productivity (Kg/ha)
Andhra Pradesh	1.210	0.720	0.600	830
Goa	0.510	0.460	0.200	430
Karnataka	0.850	0.750	0.520	690
Kerala	1.190	1.180	1.340	1140
Maharashtra	0.800	0.510	0.800	1570
Orissa	1.050	0.600	0.400	670
Tamil Nadu	0.790	0.770	0.300	390
West Bengal	0.090	0.070	0.060	870
Others	0.100	0.090	0.080	–
Total	6.590	5.150	4.300	835

Yield Target

Review of the current cashew plantations in India and the production technologies available indicate that identifying location-specific technology package should help us in achieving the goal of self-sufficiency in the production of raw nuts in the country. It should be possible to boost the yields further in the new plantations by revising the yield target to 2 tonnes per ha instead of the current one ton per ha by insisting on multiplication of only such of those varieties which have 2 tonnes production potential. This is also possible because of the large network of regional nurseries which are established will support such transition. This calls for the review of available varieties and identification of varieties which are suitable for different States/regions in the States and replacing the existing scion banks with the varieties which have the production potential of 2 tonnes per ha, through top working. Top working technology for the scion banks is very relevant in this context. Therefore, with this method,,we will be able to start producing the desired planting material within the next 2-3 years in large numbers. Even with the present recommended varieties, if careful planning is made for identification of technologies relevant to different production sites, it should be possible for us to achieve a target of 10 lakh MTs of raw nuts within the next 5 –7 years.

Genetic Resources of Cashew and Their Utilization in Improvement

M. G. Bhat, E. V. V. Bhaskara Rao and K. R. N. Swamy

Introduction

Cashew (*Anacardium occidentale* L.) is a very important foreign exchange earning horticultural crop of our country. Cashew cultivation in India dates back to the 16th Century with the introduction of the crop in the West Coast region by the Portuguese. Cashew is a native of Brazil and Portuguese discovered it in Brazil and spread it to other parts of the world. As cashew is a hardy plant, which thrives, well in adverse soil and climatic conditions, it has been able to spread to various countries for soil conservation, afforestation and wasteland development. It belongs to the family Anacardiaceae and is commercially cultivated in the tropics for its edible kernels. In the global trade, cashew kernels are worth US $500 million at trading level, while at the consumer level the value is estimated at US $1000 million (Nomisma, 1994). India was the first country to exploit the international trade of cashew kernels in the early part of this Century and India is the largest exporter of cashew kernels. India was also the first country to initiate systematic research in the early fifties which was further strengthened with the establishment of Central Plantation Crops Research Institute (CPCRI) at Kasaragod (Kerala) in 1970, launching of All India Coordinated Spices and Cashewnut Improvement Project in 1971 and later in 1986 with the establishment of National Research Centre for Cashew (NRCC) at Puttur (Karnataka) and also All India Coordinated Research Project on Cashew with its headquarters at NRCC, Puttur. In the recent years, considerable research efforts are also being made in Australia, Vietnam, Brazil, Tanzania and China (Nomisma, 1994).

In India, cashew is grown in an area of 0.701 million hectares (with productive area of 0.512 million hectares) with a production of 0.360 million tons of raw cashewnut during 1997-98. India earned foreign exchange of Rs. 13,890 million in 1997-98 through the export of 76,323 metric tons of cashew kernels. The record production achieved in cashew was in 1996-97 with 0.430 million tons of raw cashewnuts with productivity of 835 kg/ha based on productive area. A total of 35 cashew varieties have been released for commercial cultivation in the country. Among them, 23 are selections and 12 are hybrids. The crop has now been elevated from the status of a wasteland crop to that of an important horticultural crop.

The extent of genetic improvement that could be achieved in a crop mainly depends on the richness and diversity of genetic resources existing in that crop and its accessibility to the researchers. In India, as all the cashew plantations were raised from the limited initial introductions, the genetic base available in the country is very narrow. One of the immediate priorities of the Indian Cashew germplasm programme is to enhance the genetic variability in the collections. Therefore it is essential to increase the efforts to introduce diverse cashew types from Central America and Brazil where considerable variability including the dwarf types suitable for high density planting is reported to exist.

Germplasm Collection/Introduction.

The objective of any germplasm collection programme is to increase the range of genetic variation available for use by breeders. The value of the germplasm resources will increase as they become more adequately described, evaluated and catalogued (Sprague, 1980). Even though no reliable records of the introduction of cashew are available, it is presumed that the initial introductions in the Malabar Coast of Kerala were from only few trees and due to the hardy nature of the crop it has spread to all the coastal regions of India naturally. The initial emphasis was only on the establishment of plantations of seedling origin. As cashew is primarily a cross pollinated crop, it is highly heterozygous. Considerable segregation has resulted in large variation in the populations (Bhaskara Rao and Bhat, 1996). Subsequent to the initiation of research under ICAR, the germplasm collection for collecting these variants/segregants has been undertaken at all the Research Centres.

The early attempts for germplasm collection in India were made during the early fifties (1952-1957) with the sanctioning of Ad-hoc schemes in five States. The research stations started under these Ad-hoc schemes in Kerala (Kottarakara), Karnataka (Ullal), Andhra Pradesh (Bapatla), Assam (Daregaon) and Maharashtra (Vengurla) took up the programme of collection of locally available elite plants for evaluation and further selection. These were the first attempts in collection of cashew germplasm in India. A cashew research station was established at Vridhachalam in Tamil Nadu by Tamil Nadu Agricultural University in the year 1963. Many of the other research centres which were established subsequently have collected the seeds of germplasm from the centres, namely, Bapatla, Kottarakara, Ullal, Vridhachalam and Vengurla. While making the initial collections of germplasm, these centers have confined their survey mainly to

respective States and hence they represent the local germplasm available in the States. Since the inception of All India Coordinated Spices and Cashewnut Improvement Project in 1971, Central Plantations Crops Research Institute (CPCRI), Regional Station, Vittal, also took up the programme of cashew germplasm collection which mainly consisted of the seedling progenies which were available at Bapatla, Vridhachalam, Vengurla, Anakkayam (Secondary collections) and a few collections made locally from Karnataka.

The National Cashew Gene Bank (NCGB) which has been established at NRCC, Puttur, is exclusively with the clonal accessions. In the current research efforts, the accessions to be collected are identified in the germplasm collection survey taken up during the fruiting season and the scions from the identified mother tree are collected during the propagation season (June to September) and the grafts are produced and the clonal accessions are planted in NCGB. Efforts are also under way to establish conservation blocks with clonal accessions in coordinating centres of All India Coordinated Research Project on Cashew.

Conservation of Cashew Germplasm

Subsequent to the establishment of NRCC at Puttur in 1986, the germplasm collection through seeds has been discontinued and only the vegetatively propagated material is being collected and conserved in the NCGB. In the NCGB so far 392 clonal accessions which were collected from different cashew growing States from 1986 to 1997 have been conserved (Table 1 and 2). Similarly, Regional Cashew Gene Banks (RCGBs) have been established at the All India Coordianted Research Project on Cashew centres such as Vengurla, Bhubaneswar, Madakkathara and Chintamani. A total of 1490 accessions have been conserved by different Cashew Research Stations in India (Table 3).

Germplasm Evaluation

Evaluation of the cashew germplasm accessions (Seedling progeny) planted during 1972 at CPCRI, Regional Station, Vittal has resulted in the identification of elite trees from the seedling progenies for different characters such as high yield, medium nut size, high shelling percentage, big sized apple, early maturity, cluster bearing habit and bushy-medium plant habit with compact-medium canopy. These were clonally multiplied and planted in the National Cashew Gene Bank for conservation purpose. Out of these, two elite clones, namely VTH 107/3I and VTH 40/1I were recommended for release in Karnataka as NRC Cashew Selection-1 and 2, respectively. These two selections are high yielding (9-10 kg/tree/year) with medium sized nuts (7.6-9.2g). They have a high shelling percentage (29%) with a low

Table 1. Distribution status of germplasm collection in NCGB

State	No. of Accessions
Andhra Pradesh	27
Goa	40
Karnataka	253*
Kerala	9
Maharashtra	21
Orissa	15
Pondicherry	3
Tamil Nadu	10
West Bengal	14
Total	392

* Including 13 clones produced from seedlings of Brazilian origin

Table 2. Germplasm holding at NCGB

Released varieties	34
Genetic stocks	348
Related Species *A. pumilium, A. orthonianum, A. micro-carpum*	4
Mutants (CNSL free types / purple plant type)	6
Total	392

kernel count of 210 wholes/lb. These also compare well with other cashew varieties with respect to chemical composition of kernels. When compared with other cashew varieties, the kernel protein content is one and a half to two times more in these selections (Swamy *et al.*, 1990). Wide variation within the accessions due to the cross pollinated nature of the crop was noticed in these germplasm accessions of seed origin. Variability recorded for some of the important characters in seedling germplasm accessions is given in Table 4 (Swamy and Thimmappaiah, 1991; Bhaskara Rao and Swamy, 1994).

Evaluation of seedling progenies of cashew germplasm at different Cashew Research Stations and NRCC has resulted in identifying superior genotypes for several

Table 3. Cashew germplasm holding in India (Bhaskara Rao and Swamy, 1994)

Research Station	No. of accessions conserved
National Research Centre for Cashew, Puttur, Karnataka	392
Agricultural Research Station (UAS), Ullal, Karnataka	20
Agricultural Research Station (UAS), Chintamani, Karnataka	134
Cashew Research Station (ANGRAU), Bapatla, Andhra Pradesh	135
Cashew Research Station (OUAT), Bhubaneswar, Orissa	96
Regional Research Station (BCKVV), Jhargram, West Bengal	116
Regional Research Station (TNAU), Vridhachalam, Tamil Nadu	258
Cashew Research Station (KAU), Madakkathara, Kerala	127
Regional Agricultural Research Station (KAU), Pilicode, Kerala	36
Regional Fruit Research Station (KKV), Vengurla, Maharashtra	166
Zonal Agricultural Research Station (IGKVV), Jagdalpur, Madhya Pradesh	10
Total	1490

Table 4. Variability in germplasm accessions (seedling progenies)

Character	Range
Flowering season	Oct. - Jan.
Flowering duration	40 - 127 days
Harvesting duration	30 - 105 days
Number of fruits / panicle	1 - 8
Apple weight	30 - 150 g
Nut weight	2.4 - 18.0 g
Apple : Nut ratio	4:1 - 12:1
Shelling percentage	19.0 - 35.0
Kernel weight	0.5 - 4.5 g
Kernel count / lb	100 - 900
Shell thickness	1.5 - 5.0 mm
Mean yield/plant/ year (10 year mean)	0.50 - 11.75 kg

characters. So far, a total number of 23 high yielding varieties have been released by different Cashew Research Stations in the country as a result of selections made from the germplasm materials (Ramadas and Veeraraghavanatham, 1982; Nagabhushanam, *et al.*, 1977, Sawke *et al.*, 1985, Aravindakshan *et al.*, 1986; Khan and Kumar, 1988; Krishna Murthy *et al.*, 1985; Bhaskara Rao, 1989; Ghosh, 1990 a and b; Swamy *et al.*, 1990, Veeraraghavan *et al.*, 1991, Sawke *et al.*, 1993; Kumar and Hegde, 1994; Bhaskara Rao *et al.*, 1998). The salient features of these varieties are presented in Table 5.

As initially the crop has been propagated from "plus trees" for soil conservation and afforestation, not much emphasis has been given on the varietal concept of cashew. The concept of the varieties in cashew is of recent origin. The initial identification of varieties was based on total yield realised per tree only. This has resulted in release of varieties even with a kernel grade of more than W 320. Important attributes like kernel weight, shelling percentage and recovery of whole kernels received little attention. In recent years, with the increasing concern for the quality, emphasis is given for identification of varieties with kernel weight of over 2g falling into the export grade of W 210 to W 240. In order to realise higher recovery of whole kernels, standards have been fixed for shelling percentage (not less than 30%). This calls for the identification of donor parents having these characters and which can transmit them to the progenies (Bhaskara Rao *et al.*, 1998).

Cataloguing of Germplasm

Of the 392 clonal accessions conserved in NCGB, 153 accessions (planted during 1986 to 1988) have already been characterized and catalogued. In order to catalogue the germplasm accessions in NCGB, preliminary evaluation and characterization were done after six annual harvests. Minimum IBPGR (presently IPGRI) descriptors were applied to 153 cashew accessions which were planted during 1986 to 1988. The catalogues have been published by NRCC, Puttur (Swamy *et al.*, 1997 and 1998).

An attempt has been made to group the 153 accessions which have already been characterized into 18 clusters based on three criteria, namely, category of

Table 5. Cashew varieties developed through selection from germplasm material at different Cashew Research Stations in India

Research Station	Name of variety	Source of germplasm	Yield Potential (Kg/tree)	Nut Wt. (g)	Kernel Wt. (g)	Shelling (%)	Kernel grade
National Research Centre for Cashew, Puttur, Karnataka.	Selection-1	VTH 107/3 I (3/8 Simhachalam)	10.0	7.6	2.2	28.8	W 210
	Selection-2	VTH 40/1 I (2/9 Dicherla)	9.0	9.2	2.5	28.6	W 210
Agricultural Research Station, Ullal, Mangalore, Karnataka.	Ullal-1	8/46 Taliparamba	16.0	6.7	2.1	30.7	W 210
	Ullal-2	3/67 Guntur	9.0	6.0	1.8	30.5	W 240
	Ullal-3	5/37 Manjeri	14.7	7.0	2.1	30.0	W 210
	Ullal-4	2/77 Tuni	9.5	7.2	2.2	31.0	W 210
	UN-50	2/27 Nileshwar	10.5	9.0	2.9	32.8	W 180
Agricultural Research Station, Chintamani, Karnataka.	Chintamani-1	8/46 Taliparamba	7.2	6.9	2.1	31.0	W 210
Cashew Research Station, Bapatla, Andhra Pradesh.	BPP-3	3/3 Simhachalam	11.0	4.8	1.3	28.1	W 400
	BPP-4	9/8 Epurupalem	10.5	6.0	1.3	23.0	W 400
	BPP-5	Tree No.1	11.0	5.2	1.2	24.0	W 400
	BPP-6	Tree No. 56	10.5	5.2	1.2	24.0	W 400
Cashew Research Station, Bhubaneshwar, Orissa.	Bhubaneswar-1	WBDC-V (Ven. 36/3)	10.5	4.6	1.4	32.0	W 320
Regional Research Station, Jhargram, West Bengal.	Jhargram-1	T. No. 16 of Bapatla	8.5	5.0	1.5	30.0	W 320
Cashew Research Station, Anakkayam, Kerala.	Anakkayam-1	BLA 139-1 (T.No. 139 of Bapatla)	12.0	6.0	1.7	28.0	W 280
Cashew Research Station, Madakkathara/Anakkayam, Kerala.	Madakkathara-1	BLA 39-4 (T. No. 39 of Bapatla)	13.8	6.2	1.6	26.8	W 280
	Madakkathara-2	NDR 2-1 (Neduvellur 2-1)	17.0	7.3	2.0	26.2	W 240
	K 22-1	Kottarakkara 22	13.2	6.2	1.6	26.5	W 280
Regional Fruit Research Station, Vengurla, Maharastra.	Vengurla-1	Ansur-1	19.0	6.2	1.9	31.0	W 240
	Vengurla-2	WBDC-VI (Ven.37/3)	24.0	4.3	1.4	32.0	W 320
Regional Research Station, Vridhachalam, Tamilnadu.	VRI-1	M 10/4 (Vazhisodhanaipalayam)	7.2	5.0	1.4	28.0	W 320
	VRI-2	M 44/3 (T.No.1668 of Kattupalli)	7.4	5.1	1.4	28.3	W 320
	VRI-3	M 26/2 (Edayanchavadi)	10.0	7.2	2.1	29.1	W 210

material/level of domestication, agro-ecological region and characterization and evaluation data (different character states for certain key characters of importance such as season of flowering, duration of flowering and colour of mature cashew apple). From each group a 10 per cent sample size was randomly selected as core entries (Table 6).

Utilization of Germplasm in Cashew Improvement

Of the 35 cashew varieties released in India, 12 are hybrids, which have been developed by utilizing 14 germplasm accessions as parents in hybridization (Table 7). The performance of the 35 cashew varieties showed that in the States where both selections and hybrids were released for

Table 6. Grouping of cashew accessions into clusters (core accessions are shown as bold)

Category of material	Agro-ecological region	Season of flowering	Duration of flowering	Colour of mature cashew apple	No.of accessions	Accession number (NRC)
Genetic stocks	Coastal ecosystem	Early	Medium	Yellow	4	**1**, 50, 56, 90
		Early	Long	Yellow	20	**3**, 6, 20, 21, 40, 46,, 47, 87, 92, 97, 102, 122, 126, 128, 129, 132, 135, 139, **140,** 144
		Early	Long	Red	11	**38**, 39, 73, 116, 120, 127, 130, 133, 134, 136, 148
		Mid	Medium	Yellow	16	5, **7**, 13, 17, 42, 53, 55, **80**, 85, 86, 89, 91, 98, 107, 118, 143
		Mid	Medium	Red	17	14, **27**, 29, 35, 36, 37, 41, **79**, 81, 83, **104**, 113, 119, 121, 123, 125, **141**
		Mid	Long	Yellow	39	2, **4**, 9, 10, 12, 15, 16, 22, 30, 31, 34, 43, 44, 45, 48, 49, 52, 54, 57, 60, 61, **63**, 64, 65, 70, 72, 74, 75, 76, 78, 82, 84, 103, 105, 106, **110**, 111, 112, **114**
		Mid	Long	Red	21	**8**, 11, 25, 28, 32, 51, 58, 59, 62, 66, 67, 68, 69, 71, 77, 88, 100, **108**, 109, 115, 117
		Late	Medium	Yellow	6	**26**, 146, 147, 149, 150, 151
		Late	Medium	Red	3	18, 33, **124**
		Late	Long	Yellow	2	23, **24**
		Late	Long	Red	1	**19**
Cultivars	Coastal ecosystem	Early	Medium	Yellow	1	**93**
		Early	Long	Yellow	5	94, 95, 96, **101**, 138
		Early	Long	Red	1	**131**
		Mid	Long	Red	2	**99**, 145
		Late	Medium	Yellow	1	**137**
Related spp.	Coastal ecosystem	Mid	Long	Red	1	**153**
		Late	Medium	Red	2	**142**, 152

cultivation, hybrids have performed better than the selections. Hybrid vigour could easily be commercially exploited in cashew through the softwood grafting technique, which has been standardized for commercial multiplication of cashew varieties.

Hybridization in cashew was started in Kerala at Kottarakkara in 1963 and later continued at Anakkayam and then shifted to Madakkathara. At Anakkayam, three prolific bearing parents and three boldnut parents were used in hybridization in the initial breeding programme (Damodaran, 1977). It was reported that wherever Brazil-18, an exotic bold nut accession, was used in the hybridization, the percentage of progenies with high yield (above 8 kg of rawnuts/tree) was higher (35%) than those involving the accessions which are collected within the country (9.1%). Results reported from different research stations which have undertaken the hybridization indicated that whenever prolific bearer was crossed with bold nut type, the chances of realising the hybrid with better nut weight were more (Nagabhushanam *et al.*, 1977 and Salvi, 1979). Based on these results, varieties with smaller nut size but with high nut yield were crossed with bold nut types such as Vetore-56 in Cashew Research Stations in Maharashtra, Andhra Pradesh and Kerala. Nawale and Salvi (1990) studied the inheritance of bold nut character in the progenies of the crosses between small nut types and bold nut types and found that Vetore-56 exhibited higher ability of transmitting bold nut character to the progenies. The four hybrids recently released from Kerala Agricultural University, namely, Dhana, Kanaka, Priyanka and Amrutha have at least one parent with bold nut character (Table 7). Dhana is derived from the cross ALGD-1 x K 30/1 while Priyanka is a cross between BLA 139-1 and K 30/1 where K 30/1 has good nut weight (over 8g). Both Kanaka and Amrutha have the same parentage of BLA 139-1 x H 3-13. The parent H 3-13 is itself a hybrid having one of its parents with bold nut size, namely, Brazil-18 (Bhaskara Rao, *et al.*, 1998).

Breeding Perspectives

Till recently, the emphasis has been on selecting or producing a hybrid having high yield only and size of the nut was not given required attention till 1980s. Currently efforts are being made at different Cashew Research Stations in the country to identify few accessions with bold nuts for improving the nut size in the prolific bearing varieties. Among the 12 cashew hybrids released in India (Table 7), three hybrids, namely, BPP-1, BPP-2 and Vengurla-5 have small

Table 7. Cashew germplasm accessions utilised as parents and hybrids developed by different Cashew Research Stations in India

Research Station	Name of hybrid	Parentage	Yield Potential (Kg/tree)	Nut Wt. (g)	Kernel Wt. (g)	Shelling %	Kernel grade
Cashew Research Station, Bapatla, Andhra Pradesh	BPP-1 (H 2/11)	T.No.1 x T.No.273	10.0	5.0	1.3	27.5	W 400
	BPP-2 (H 2/12)	T.No.1 x T.No.273	11.0	4.0	1.0	25.7	W 450
	BPP-8 (H 2/16)	T.No.1 x T.No.39	14.5	8.2	2.3	29.0	W 210
Cashew Research Station, Madakkathara, Kerala	Dhana (H 1608)	ALGD-1 x K 30-1	17.5	9.5	2.2	28.0	W 210
	Kanaka (H 1598)	BLA-139-1 x H 3-13	19.0	6.8	2.1	31.0	W 210
	Priyanka (H 1591)	BLA-139-1 x K 30-1	16.9	10.8	2.8	26.5	W 180
	Amrutha (H 1597)	BLA-139-1 x H 3-13	18.4	7.2	2.2	31.6	W 210
Regional Fruit Research Station, Vengurla, Maharashtra	Vengurla-3	Ansur-1 x Vetore-56	14.4	9.1	2.4	27.0	W 210
	Vengurla-4	Midnapore Red x Vetore-56	17.2	7.7	2.4	31.0	W 210
	Vengurla-5	Ansur Early x Mysore Kotekar 1/61	16.6	4.5	1.3	30.0	W 400
	Vengurla-6	Vetore-56 x Ansur-1	13.8	8.0	2.2	28.0	W 210
	Vengurla-7 (H 255)	Vengurla-3 x M 10/4	18.5	10.0	2.9	30.5	W 180

sized nuts (4.0 to 5.0 g) with kernel grade of W 400 to W 450, while remaining nine hybrids have kernel grade of W 180 to W 210. These nine hybrids have at least one of the parents with bold nut character and thus prove the usefulness of selecting the parent with bold nut type for transmitting the bold nut/bold kernel character to the resultant hybrid. Coupled with this, it is advisable to select at least one of the parents of the hybrid having better shelling percentage so that the actual kernel output will be higher (Bhaskara Rao, 1996 and Bhaskara Rao *et al.*, 1998).

High nutritive value of kernels will surely receive greater attention in future cashew research programmes. The short duration of flowering in the hybrids is also an important character which should be looked into in the parents selected for hybridization so that the cost of nut collection will also be reduced (Bhaskara Rao and Bhat, 1996). In the hybrids, Kanaka, Priyanka and Amrutha, one of the parents used was BLA 139-1 which has a short duration of flowering. Cashew is a andromonoecious plant bearing large number of hermaphrodite and staminate flowers in the same panicle (Rao and Hassan, 1957). It was reported that large anther of male flower produces the pollen which is more efficient in germination, penetration and fertilizing ovules than the other three anther types (Wunnachit *et al.*, 1992a). Therefore, the varieties with longer mixed phase and also high sex ratio are to be preferred as parents over types which have distinct male phase or over varieties with very high proportion of hermaphrodite flowers only (Bhaskara Rao and Bhat, 1996). Post-zygotic mechanism responsible for self-sterility in tree crops was reported by Sedgley and Griffin (1989) and in cashew by Wunnachit *et al.*, (1992b). Premature preferential shed of selfed fruits also occurs in avocado (Degani *et al.*, 1989). Better understanding of compatibility relationships of cashew genotypes is required since one of the major problems in cashew production is premature fruit drop (Bhaskara Rao, 1996). Effective designs of interplanting genotypes are to be developed to ensure highest cross compatibility between the clones for realising higher yields (Bhaskara Rao, 1996). Cluster bearing types, which do not have primigenic dominance (i.e., dominance hierarchy), may be selected as parents in the hybridization programme in order to get high yielding hybrid progenies. Breeding genotypes having compact canopy and dwarf stature with intensive branching with high proportion of flowering laterals per unit area will be prerequisite for using them in high density planting system in order to increase productivity of cashew per unit area.

One of the major production constraints in cashew growing countries is the incidence of Tea Mosquito Bug (TMB). Phenomenon of phenological evasion shown by some genotypes such as Goa 11/6 may be taken advantage in breeding programmes to escape severe infestation by TMB.

The current breeding strategy is to plant large number of hybrid progenies at closer spacing for preliminary evaluation and then to multiply the identified hybrids with the desirable characters through softwood grafting for final testing, preferably multiplication testing. There is a time lag of 6-7 years between the production of hybrids and multilocation testing in this method. As is being followed in Australia, hybrid plants can be detopped during the first year itself so that adequate number of scions are obtained for producing grafts required for field testing (Chacko, 1993). However, this modified method needs large area and huge experimentation cost as the initial evaluation is not done and all the hybrids are field tested.

As yield in cashew is a complex character, it is essential to identify yield contributing component characters having high heritability through appropriate statistical means for making quick progress in yield improvement (Bhaskara Rao *et al.*, 1998). A total of 52 accessions from NCGB were supplied so far for utilization in breeding programmes of NRCC and other Cashew Research Stations of State Agril. Universities.

Summary and Future Thrust

Cashew plays an important role in the Indian economy and it is the third largest foreign exchange earner after rice and coffee and share of cashew comes to about 40% of the total earnings by export of horticultural commodities. Soon after the independence, cashew research was initiated in 1950s. Cashew research got a fillip with the establishment of Central Plantation Crops Research Institute in 1970. A total of 35 cashew varieties have been released so far for commercial cultivation in India.

Cashew germplasm collection was started in India during fifties with the sanctioning of ad-hoc schemes in five states. National Cashew Gene Bank has been established at National Research Centre for Cashew (NRCC), Puttur with clonally propagated material and till date 392 clonal accessions have been collected and conserved. A total of 1490 accessions have been conserved by different Cashew Research Stations in India. Two germplasm catalogues (for 153 accessions) have already been brought out by NRCC.

Of the 35 cashew varieties released in the country, 23 are selections made from the gerplasm materials and 12 are hybrids, which have been developed through hybridizing 14 germplasm accessions as parents. Hybrids have been found to perform better than the selections. Softwood grafting technique has enabled us to exploit hybrid vigour commercially in cashew. Currently efforts are under way in all the research stations to develop hybrids having high yield, bold kernels, high shelling percentage and kernels with better nutritive value.

As the cashew plantations in India were raised from the limited introductions made in 16th Century by Portuguese, the genetic diversity is limited. So immediate priority of the Indian Cashew germplasm programme is to enhance genetic variability through introductions from abroad, particularly, from Brazil which is the original home of cashew. It is also essential to develop compact and dwarf cashew types with high yield which are suitable for planting under high density planting system in order to achieve higher productivity per unit area.

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An Overview of Spices Development in India

K. Sivaraman and K.V. Peter

Introduction

Consumption of spices varies from one country to another and is influenced to a large extent by the size of the population and the rate at which it grows. It is also influenced by the disposable income, which in the case of developing countries is a major factor. In the developed countries, spices are used in the industrial sector, principally in food processing whereas in developing countries, spices are mainly consumed in individual households. However, the social habits, particularly those of cooking and eating, determine the overall per capita consumption of spices in both the industrialised and developing countries. These are among the factors to be considered for the long-term development for spices in the country.

Production Trends of Spices in India

The present annual production of spices in the country is around 25 lakh tonnes valued at about Rs. 7000 crores. Our strong domestic market absorbs over 90 % of the production and the rest exported. During 1997 -98 the country earned a foreign exchange worth Rs. 1352.10 crores by the export of 2,18,750 tonnes of spices in raw as well as value added forms.

Organizations Engaged in Research, Development and Export Promotion of Spices

There are three organizations at the national level to undertake the promotion of their respective activities.

Indian Institute of Spices Research (IISR), Calicut in Kerala under Indian Council of Agricultural Research is the apex Institute responsible for research coordination in spices in India in collaboration with State Agricultural Universities. The research efforts showed impact on the spices farming community and the farmers are coming forward to test and adapt various technologies formulated by the Institute for increasing production and also management schedules for protection from diseases and pests. There is an ever increasing demand for the planting materials of new crop varieties developed by the Institute and also for biocontrol agents for the suppression of diseases and pests, particularly for management of *Phytophthora* foot rot of black pepper, soft rot of ginger and rhizome rot in cardamom.

Directorate of Arecanut and Spices Development under the Ministry of Agriculture, Government of India is the nodal agency at the national level for formulating crop development programmes in association with various developmental agencies of the states. This directorate monitors implementation of Centrally sponsored scheme in Integrated programme for Development of Spices at an annual average expenditure of about Rs.25 crores for the last seven years in spices growing states of India.

The Spices Board, an autonomous body under the Spices Board Act 1986 under the Ministry of Commerce was created by the Government of India as the agency to promote export of spices in the world. The governing body of the Spices Board consists of exporters, growers, research scientists and officials of the Central and State Governments and the Planning Commission. The Board is primarily entrusted with the responsibility of export promotion. It also acts as a window for importers to get in touch with exporters, as a contact point for farmers and agricultural development organizations to know the latest trends in market demands and as a coordinating agency between various departments and interests.

Technology Development Directly Useful to the Farming Community

Research work carried both at IISR and agricultural universities under All India Coordinated Spices improvement Project resulted in formulation of following technologies useful to the farmers.

Considerable increase in productivity has been reported in research stations especially in pepper, ginger, turmeric and coriander (Table 1). The need is effective transfer of technology. Attempts are made to identify main production constraints and workout appropriate and economic strategies (Table 2).

So far, 10 high yielding varieties/hybrids in black pepper, 6 in small cardamom, 3 in ginger, 14 in turmeric, 13 in coriander, 5 in cumin, 4 each in fennel and fenugreek are released (Table 3.). Two cinnamon varieties have also been released recently.

An exclusive nucleus seed multiplication programme

Table 1. Potential for productivity increase at the national level (kg/ha)

Crop	National	Progressive farmer	Research station	Abroad
Pepper	290	2000	2445	2925 (Malaysia)
Cardamom	128	1625	450	200 (Guatemala)
Ginger	2421	5500	8250	-
Turmeric	2738	6200	10700	-
Coriander	476	-	1900	515 (Morocco)
Cumin	578	-	2000	-

Table 2. Main production constraints in spices

Spices	Constraints	Research attainments
Black pepper	*Phytophthora* foot rot	Management of the disease through a package of practices is standardised. Tolerant lines to the disease are developed. Biocontrol is being tried.
	Stunt disease	No effective control measures except uprooting of diseased plants. Causative organism is virus/insect/micronutrient deficiency.
	Slow decline	Effective management method (s) are available except no source of resistance to *Radopholus similis* nematode.
Small Cardamom	Low productivity	High Production Technology is demonstrated.
	'Katte' disease 'Vein clearing virus disease' or 'Kokke kanthu'	Virus etiology is established. 'Katte' escapes are identified. 'Katte' tolerant lines are multiplied.
Ginger and Turmeric	Low productivity	Removal of diseased plants is advocated. No effective management measures are available. Spread has been checked by social action.
	Rhizome rot	High Production Technology (HPT) is demonstrated.
	Bacterial wilt	Causative organisms are identified. Solarization of soil prior to planting is effective. Bio control is tried successfully. *R`alstonia solanacearum* is the causal organism. No resistant variety available.

Table 3. High yielding spices varieties released

Spices	Hybrids / varieties released
Black pepper	Panniyur 1 (H), Panniyur 2 (V), Panniyur 3 (H), Panniyur 4 (V), Panniyur 5 (V), Subhakara (V), Palode 2 (V), Sreekara (V), Panchami (V), Pournami (V).
Cardamom	Mudigere-I (V), PV. 1(V), CCS-1 (V), ICRI. I (V), ICRI. 2 (V), ICRI – 3 (SKP – 14) (V)
Cinnamon	IISR Navasree (V), IISR Nithya Sree (V)
Ginger	Suprabha (V), Suruchi (V), Suravi (V). Varada (V)
Turmeric	Col. 1 (m), Krishna (V), Sugandham (V), BSR. 1 (V), Suvarna (V), Roma (V), Suroma (V), Rajendra Sonia (V), Suguna (V), Sudarshana (V), Ranga (V), Rasmi (V), IISR Prabha (V), IISR Prathibha (V).
Coriander	Gujarat Coriander – 1 (V), Co. 1 (V), Co.2 (V), Gujarat Coriander 2 (V), Rajendra Swati (V), RCr. 4 (V), Sadhana (V), Swathi (V), Co. 3 (V), CS. 287 (V), Sindhu (V), UD 20 (V), DH-5 (V).
Cumin	S-404 (V), MC-43 (V), Gujarat Cumin. 2 (V), Gujarat Cumin. 1(V), RZ-19 (V).
Fennel	S-7-9 (V), PF. 35 (V), Gujarat Fennel. 1 (V), Co. 1 (V).
Fenugreek	Co.1 (V), Rajendra Kanti (V), RMt. 1 (V), Lam Selection. 1 (V)

H = Hybrid, V = Variety, m = Mutant.

to supply quality planting materials to farmers is under implementation. Research results are available on rapid multiplication through tissue culture of black pepper, cardamom, clove, nutmeg, cinnamon, ginger and turmeric (Table 4). Biotechnological research has great potential in spices and the salient achievements are given in Table.5.

In vitro selection for resistance to biotic and abiotic stresses especially rhizome rot in ginger is in progress. Protocols are also available for direct regeneration through tissue culture in long pepper, chaba pepper, kaempferia, curry leaf, tamarind, coriander, fennel, cumin, dill, lavender, aniseed, thyme and large cardamom. Synseed technology(s) are also available in cardamom, ginger, turmeric and pepper.

Quality Maintenance in Indian Spices

India has global monopoly in spices oils and oleoresins. During 1997-98, India exported 2270 tonnes of oils and oleoresins valued Rs 226.48 crores against 2358 tonnes valued Rs. 159.01 crores during 1996-97. There are AGMARK specifications for various Indian spices and their value added products. The Bureau of Indian Standards has published a series of specifications to maintain and improve quality of Indian spices. High curcumin lines in turmeric, high piperine lines in black pepper, high essential oil lines in clove, cinnamon and nutmeg etc. are in the pipeline at Indian Institute of Spices Research, Calicut.

Table 4 . Methods of plant propagation in spices

Spices	Method of propagation	Advantages
Black Pepper	Single nodded rooted cuttings using bamboo method	Multiplication rate of 1:40 per year. Good anchorage due to presence of two root systems.
Cardamom	Trench method of sucker production	Multiplication rate of 1:20 per year
Clove	Inarching on clove seedlings.	Earliness, dwarfness and high productivity
Nutmeg	Epicotyl grafting Top working Cuttage.	Female plants are propagated Conversion of male plants to female plants.
Cinnamon-Cassia	Air layering	Rapid multiplication of elite plants.
Ginger and Turmeric	Crop rotation, solarisation and disease free rhizomes	Earliness, more plants per unit area Management of rhizome rot.

Table 5. Salient achievements in biotechnology in spices

Spices	Achievements
Cardamom	Clonal multiplication, Field evaluation of tissue cultured plants, Inflorescence culture, Regeneration of plantlets from callus, somaclones are evaluated.
Black Pepper	Clonal multiplication, Callus culture and regeneration of plantlets, Micropropagation of related species of *Piper. Piper longum, P. betle, P. colubrinum* and *P. chaba.*
Ginger	Clonal multiplication, Field evaluation of TC plants, *In vitro* rhizome formation, Regeneration of plantlets from callus, *In vitro* selection, *In vitro* polyploidy, Inflorescence culture and *In vitro* development of fruit.
Paprika	Plants regenerated from shoot and leaf explants. Protoplasts were isolated
Curry leaf	Micropropagation protocols are standardised.
Turmeric	Micropropagation, Plant regeneration from callus, Micropropagation of related species and genera.
Tree spices	Micropropagation, *In vitro* proliferation of mace and synthesis of flavour components in culture.
Vanilla	Seed and embryo culture.

Environmentally Friendly Spices Culture

Use of plant protection chemicals leads to residual toxicity in spices products. Bio control of pests and diseases is another area where useful information are generated (Table 6). A fungus *Trichoderma* sp. in combination with VAM suppresses *Phytophthora capsici,* causative organism of foot rot in black pepper. Biopesticides to manage pests of spices are also developed. There is break through in generation of technologies (Table 7).

Table. 6 Bio-control of pests and diseases in spices

Pests/disease	Biocontrol agent tried
Black pepper	
Phytophthora capsici	*Trichoderma* sp. in ombination with VAM
Scale insects	Natural enemies viz. *Encarsia lounsburyi.*
Top shoot borer	*Apanteles cypris,* an important parasite.
Pollu beetle	An entomophagous mite and nematode
Cardamom	
Rhizome rot and damping off	*Trichoderma* sp. and *Paecilomyces Lilacinus*
Root – knot nematode	*Paecilomyces lilacinus*

The targeted export during 1998-99 is 2.48 lakh tonnes valued Rs. 1780 crores. Research and development activities are well tuned to achieve the above targets (Table 8). Unreliable and unsustained availability of spices for export continues to bother Indian exporters. The targeted production and export of spices during 1998-99 would be achieved subject to the stability in remunerative prices and the extent to which above negative trends are reversed.

Development Programmes

A "Centrally Sponsored Scheme on Integrated Programme for Development of Spices" mainly on black pepper and to a lesser extent on ginger, turmeric and chillies was drawn up and implemented in the last 3 years of the VII Plan (1987-90) at an overall outlay of Rs. 435 lakhs (Rs 240 lakhs central share and the rest to be borne by the implementing State Governments). The development measures taken up were production and distribution of black pepper rooted cuttings of high yielding varieties, establishment of model pepper gardens, distribution of input kits, laying out pepper demonstration plots, rehabilitation of old pepper gardens, seedling production and laying out demonstration plots of tree spices and popularisation of scientific methods of on-farm processing of spices.

In the Annual Plans (1990-91 and 1991-92) the Centrally Sponsored Integrated Programme for Development of Spices was expanded by increasing the financial outlay to the tune of Rs 244 lakhs and Rs 574 lakhs respectively, providing cent per cent central assistance. In addition to programmes taken up during the VIIth Plan, planting material multiplication programme of ginger, turmeric, chillies, seed spices and paprika, special programme for spices development in the North Eastern Region etc. were also taken up. The programmes were mostly implemented through the State Horticulture/Agriculture Departments who have a well distributed extension network through out the nook and corners of the country with adequate technical support. The nucleus planting material production programme was mostly assigned to Research farms under State Agricultural Universities and ICAR Institutes.

The Integrated Programme for Development of Spices was further expanded with a financial outlay of Rs 125 crores in the VIII Plan (1992-97) to increase the overall production of spices both by area expansion and stepping up productivity, bringing down the cost of production and improving the quality of the produce of about 27 commercially important spices grown in the country. The strategies adopted were:

1. Identifying spices varieties having high production potential and exports quality characteristics and undertakes their development.
2. Large scale production of quality planting material adopting the latest technology(s).
3. Rejuvenation of the existing unproductive spices gardens.
4. Motivating the farmers to undertake scientific farming through field demonstrations, input subsidy, extension support etc.
5. Encouraging farmers to take up mono cropping using the accredited varieties with an eye on export.
6. Developing water sources to improve irrigation facilities.
7. Encouraging the production of clean spices.
8. Developing common facilities for quality

upgradation, product diversification, storage and marketing.

9. Improving the database on area, production, market arrivals, prices etc.
10. Rendering extension support.

An overall average annual growth in production to the tune of 8% was achieved in the VIIIth Plan as against 4% in the VIIth Plan. The programmes undertaken are broadly classified as follows:-

1. Production of planting materials – Nucleus planting material production at the research stations of State Agriculture Universities, and ICAR Institutes and their further multiplication for distribution to the farmers.
2. Laying out demonstration plots in the farmers' fields to convince and motivate the farmers to take up the cultivation of new varieties adopting improved agro-techniques.
3. Rehabilitation of old pepper gardens by replacing the uneconomically yielding or disease affected vines with high yielding varieties and adopting proper management practices in the entire garden.
4. Area expansion programme to encourage large scale cultivation of improved and exports oriented varieties and facilities for community level on-farm processing and marketing.
5. Distribution of mini kits for rapid spread of improved varieties and promotes homestead cultivation.
6. Adoption of integrated plant protection measures

Table 7. Technologies developed at Indian Institute of Spices Research

	Major constraints	Technology (s)
1.	*Phytophthora* foot rot in black pepper	Two pre-monsoon sprays with Bordeaux mixture (1%), one drenching with copper oxychloride (1%) and phytosanitary measures can manage the disease.
2.	'Kokke kandu' viral disease in cardamom	Roughing out diseased plants as and when appear can reduce the incidence.
3.	Seedling diseases in pepper and cardamom	Incorporation of VAM in the nursery stages reduces disease incidence.
4.	Stunted disease of black pepper	Viral etiology is established. Removal of infected vines is recommended.
5.	Rhizome rot of ginger	Biological control of *Trichoderma* sp. is effective
6.	Nematodes, thrips and root grubs in cardamom	Spot application of phorate @ 2.5 kg a.i. per clump, twice a year during April-May and October-November is advocated.
7.	Nematodes and soil borne diseases in cardamom nurseries	Soil solarization by mulching with polythene sheets for 40-45 days as a pre-sowing treatment.
8.	Diseases in planting materials of black pepper	The nursery mixture may be sterilised by soil solarization and fortified with VAM and *Trichoderma* at the time of raising cuttings.
9.	Pollu beetle on black pepper	Spraying Endosulfan (0.05%) during July (21-30 days after setting berries) followed by three sprays of Neemgold (0.6%) during August, September and October or four sprays of Neemgold (0.6%) during July, August, September and October is effective.
10.	Shoot borer in ginger and turmeric	Four sprays of Dipel (0.3%) *(Bacillus thuringiensis)* during July–October at 21 days interval commencing from the first symptom of pest infestation are effective.

Table 8. Research innovations in pipeline

Crop	Innovations
Black pepper	Hybrids HP 813, 34 and 105 are promising at Valparai Soil application of *Azospirillum*, phosphobacteria and VAM alone and in combination increased biomass, dry matter production and nutrient uptake of black pepper. Application of Zn, B and Mo @ 5, 2 and 1 kg/ha along with 150, 60, and 270 kg/ha of N, P and K increased the yield by 134%/ Technologies for protected cultivation of busk black pepper with high density (350 pots per 140 sq.m) are standardised. Spraying ethrel on the harvested berries hastened the retting period for preparing white pepper. Black pepper OP lines 24 continued to show field resistance against *Phytophthora* foot rot in large demonstration trials. Integrated disease management involving potassium phosphonate spraying, application of neem cake at 1 kg per vine and bio control agents showed the lowest disease incidence.
Cardamom	F1 hybrids involving 'katte' resistant line NKE 10 x NKE 34, NKE 12 X NKE 19 and NKE 12 x RR 1 (rhizome rot tolerant) are promising.
Ginger	Accessions 15 and 27 performed better consistently with 25% dry recovery. Accession 15 had 2.5% volatile oil and 3.2% crude fibre. Colchiploids in ginger are under evaluation. Based on colour, appearance, flavour and texture, ginger accessions 35, 64, 71, 117 and 179 were found good to prepare salted ginger.
Turmeric	The Alleppey turmeric Acc. 585 was identified with 7% curcumin. Treatment of rhizomes with Ridomil mancozeb and soil application with *Trichoderma harzianum* reduced rhizome rot of ginger and turmeric.
Tree spices	Clove line B-95 is promising Allspice cuttings treated with IBA (2500 ppm) + NAA (2500 ppm) in charcoal gave 63% rooting. Cassia lines with high leaf oil, bark oil and bark oleoresin are identified.

against major diseases like phytophthora foot rot and stunt disease of pepper, soft rot of ginger, fruit rot and die back of chillies etc. on compact area basis to ward off the menace within the shortest period.

7. Establishment and maintenance of demonstration-cum-progeny gardens in the North Eastern Region to serve as centres of excellence in education and training on spices cultivation and make available quality planting materials.
8. Comprehensive programme for spices development in Andaman & Nicobar Islands.

In all about 27 commodities were included in the scheme, which was implemented through Horticulture/Agriculture Departments in 25 States, 2 Union Territories, 20 Agricultural Universities, 5 ICAR Institutes and 2 other Government organizations.

Impact of the Programme Implemented

In the post independence era, commencing from 1951 from which official data on area & production are available. There was increase in area and production in respect of all the spice crops grown in the country. The increase is also indicative of the efforts put into for the development of the crop. As regards pepper increase was over 125% in respect of area and production 110% indicating an average annual growth in area & production to the tune of 5%. As regards ginger, the area has gone up from 19,000 ha in 1956 to 61000 ha. In 1995 and the production 17,000 tonnes to 1,89,000 tonnes indicating a commendable achievement over the period. The performance of turmeric & chillies are also encouraging. Impact of the development scheme on other spices particularly seed spices and tree spices could not be exposed for want of realistic estimates on area and production.

It is gratifying to note that due attention has been given for the development of almost all spices crops grown in the country since VIII Five Year Plan and the momentum is being maintained during the IX Plan with a substantial financial allocation from Central Sector for spices development.

Market Overview

Spices are mostly grown and exported by developing and least developed countries. However, the global spice trade has undergone major changes in the past few years. The food industry (mainly the meat processing sector) and food-service sectors now account for nearly 60% of the spice trade in developed countries and the household sector has been relegated to second place. Certain spices are used in confectionery as well, however, quantities used are relatively small.

Pepper outranks all other spices in household consumption, although nutmeg, cinnamon (cassia), paprika and vanilla are also widely used and are sold through retail outlets. However, retail sales seem to be diminishing and this may be due to the increasing sales of ready-to-eat foods, fast foods and restaurant food. Eating habits have become more adventurous, with consumers turning more towards ethnic cuisine and spicy foods. What has been termed the "hot trend" in spices is increasing per capita consumption of spices like pepper, chilli, ginger and mustard.

Food companies (including snack-food companies) are growing not only in the traditional industrialized markets but also in new developing country markets. The cuisine in some of these promising new markets (e.g. India and China) is complex and uses a variety of spices. Food companies need to recreate the same taste and flavour profiles to capture such markets. The option open to them lies in the spices they use and how they are used.

In case of spice oils and oleoresins, after an initial growth in the 1970s, usage stabilized. However, due to bacteriological problems, oleoresins have assumed greater significance more recently. Spices in other forms, such as encapsulated spices, are entering the market, which could not only influence the usage pattern but also affect the actual amount of spices used, particularly in the industrial sector.

Spices are available, other than the 100% natural spice, in the following forms:

- Encapsulated spice extractives extend on a salt or dextrose carrier;
- Encapsulated spice oils and oleoresins;
- Homogenous, free flowing oleoresin with the complete profile of the spice;
- Solvent extracts containing a complete flavour profile of spice.

Food technologists of leading spice companies state that they can apply spice alternatives singly or in blends to meet any taste. The advantages of these alternatives are reliable service, consistent quality and no bacterial contamination. Although the amounts of these new forms are relatively small, they are likely to gain ground with industrial users.

Production of Organic Spices

"Organic agriculture is a holistic production management system which promotes and enhances agro-ecosystem health, including biodiversity, biological cycles, and soil biological activity. It emphasises the use of management practices in preference to the use of off-farm inputs, taking into account that regional conditions require locally adapted systems. This is accomplished by using, where possible, agronomic, biological, and mechanical methods, as opposed to using synthetic materials, to fulfil any specific function within the system". The basic rules of organic production are that natural inputs are approved and synthetic inputs are prohibited. But there are exceptions in both cases. Certain natural inputs determined by the various certification programmes to be harmful to human health or the environment are prohibited (e.g. arsenic). As well, certain synthetic inputs determined to be essential and consistent with organic farming philosophy are allowed (e.g. insect pheromones). Lists of specific approved synthetic inputs and prohibited natural inputs are maintained by all certification programmes and such a list is under negotiation in Codex. Many certification programmes require additional environmental protection measures in addition to these two requirements. While many farmers in the developing world do not use synthetic inputs, this alone is not sufficient to classify their operations as organic.

Organic foods could jump from 1% to 5 - 10% of food sales in major markets in the next few years. Coffee, tea, fresh fruits and vegetables, rice, spices, sugar and hundreds of other organically grown products found in grocery stores are part of the broadened growing market for developing countries like India to export organic foods. To meet the fast-paced demand, Indian exporters need to adapt farming, processing and marketing techniques, and build good connections with importers and distributors in Europe, the United States and Japan.

Typically, organic exports are sold at impressive

premiums, often at prices 20 percent higher than identical products produced on non-organic farms. Over 100 countries produce organic food and beverages in commercial quantities: 65 are developing countries, and about 15 are less developed countries.

In order to ensure that products claimed to be organic are actually produced according to organic farming principles, they must be certified "organic". By certification, a third party gives written assurance that a product labelled organic is produced according to standards for organic farming.

International Federation of Organic Agriculture Movement (IFOAM) is playing a key role in promoting organic agriculture in different countries especially India. A publication by Spices Board not only deals with the principles and basic standards organic agriculture, but also gives production guidelines for important spices, documentation by farmers and inspection and certification procedures to be followed by the inspectors.

Development Programmes Envisaged for the Future

The following programmes are envisaged during next 10 years to improve the production efficiency and withstand global competition in the field cost competitiveness and export.

1. Standardization of nursery techniques involving biocontrol agents and mycorrhiza for prevention against possible infestation of *Phytophthora* foot rot of pepper in the initial stages. Popularization of this technology among the nursery agencies is to be done.

2. Popularization of integrated crop management technologies among spices growing community without jeopararadizing the existing farming systems.

3. Identification of suitable areas for organic production of spices to meet the increasing specific exports market demand abroad. Necessary arrangements are to be made for certification at each stage as per the international norms.

Genetic Resources, Conservation and Improvement of Major Spices Through Selection and Hybridisation

B. Sasikumar and P.N Ravindran

Introduction

Black pepper (*Piper nigrum* L., *Piperaceae*); cardamom (*Elettaria cardamomum* Maton, *Zingiberaceae*); ginger (*Zingiber officinale* Rosc., *Zingiberaceae*); turmeric (*Curcuma longa* L.) and tree spices such as nutmeg (*Myristica fragrans* Houitt, *Myristicaceae*); clove (*Syzygium aromaticum* (L.) Merr & Perry, *Myrtaceae*), cinnamon (*Cinnamomum verum* Brecht & Presl; *Cinnamomum aromaticum* Nees, *Lauraceae*) and allspice (*Pimenta dioica* (L.) Merr., *Myrtaceae*) are the important major spices grown in India. Vanilla (*Vanilla planifolia* Andr., *Orchidaceae*) is also regaining importance as a spice.

Black pepper of commerce is the dried berries of black pepper. In addition to black pepper, the commodity is traded as white pepper, canned green pepper and pepper powder. Conventionally, dried capsules of small cardamom are marketed. Ginger is traded as dry ginger, raw ginger, ginger flakes, ginger in brine, ginger powder, bleached dry ginger etc., whereas dried and polished rhizomes of turmeric and turmeric powder are the major items of trade in turmeric. Nutmeg produces nut (kernel) and mace and both are of commercial significance. Cinnamon is marketed, as processed barks (quills) whereas immature dried buds of clove are the traditional clove of commerce. Processed beans (pods) of vanilla are the item of trade in vanilla.

Black Pepper

Genetic resources of black pepper

Over 1000 species are reported in the genus *Piper* (Hooker, 1886). Of these, about 100 species occur in India. *P. nigrum* (2n=52) is the cultivated species. In the hot and humid tropical evergreen forests of Western Ghats of South India, *Piper nigrum*, still occurs in wild. It is believed that domestication of black pepper started long ago in the uplands and the coastal areas of Kerala and Karnataka presently about 100 cultivars are prevalent in India. Systematic collection of cultivated and wild germplasm of *P. nigrum* has been one of the thrust areas of research undertaken by IISR, Calicut which maintains over 2802 accessions of germplasm.

Land races in black pepper: Over a hundred traditional black pepper cultivars are prevalent in Kerala and Karnataka. Many of these cultivars are very popular in their respective tracts.

Exotic varieties: 'Kuching', 'Jamby', Ldk etc. are some of the popular high yielding varieties of Malaysia and Indonesia, maintained at IISR. However, these varieties are not significantly superior in yield or quality as compared to the common indigenous cultivars.

Breeding behaviour and breeding strategies

Clonal selection, hybridisation and open pollinated progeny selection have been used for evolving new varieties of black pepper (Sukumara Pillai *et al* 1994, Ravindran and Sasikumar, 1993).Black pepper is a predominantly self pollinated (geitonogamy) perennial vine propagated by cuttings. (Sasikumar *et al*, 1992). Pepper Research Station (KAU), Panniyur, Kannur District as well as IISR are the pioneers in black pepper breeding in the country.

Selection : Wide variability for yield and quality characters even within a particular cultivar is common in black pepper. Clonal selection in highly popular cultivars like 'Karimunda' and 'Kottanadan' has resulted in identifying superior varieties.

Hybridization: Hybridisation procedure involves the removal of the anther lobes of the female spike (female parent) before the emergence of the stigma with a fine needle. Usually only the upper 2/3 part of the spike is retained and the rest is removed. Emasculated spikes are covered with butter paper bag or finely perforated polythene cover. Undehisced anthers from the spikes of male parent are collected on the previous day evening prior to pollination and kept in a vial in a desicator. Next day morning, the vials are taken out, the anther lobes are gently crushed, and the dehisced pollen grains are mixed with a drop of water and the pollen suspension is applied on the stigmas of the emasculated spike with a small camel hair brush, after removing the bag from the spike. The spikes are again covered after pollination. Pollination is repeated for 3-4 days. The cover is retained till the development of the berries. In some varieties, where the female phase matures much earlier to the male phase (protogyny), emasculation may not be necessary and direct repeated pollinations will be sufficient to produce hybrids. The two hybrids Panniyur-1 and Panniyur-3 with high yield and high quality have been released.

Open pollinated progeny selection: Two black pepper varieties, Panniyur 2 and Panniyur 5 are released, so far, through open pollinated progeny selection.

Polyploidy breeding: An induced tetraploid of the black pepper variety Panniyur-1 has been evolved at IISR, by treating fresh seeds with 0.05% colchicine. A natural triploid (2n=78) cultivar of black pepper was also identified at IISR, Calicut (Nair *et al.*, 1993, Nair and Ravindran 1992). The varieties developed / released through the above strategies and their salient features are given in Table 1.

Breeding for nematode, disease and insect resistance:

Root knot nematode (*Meloidogyne incognita*) is a serious problem in some black pepper tracts and a a nematode tolerant cultivar "Pournami" through selection has been developed at IISR. *Phytophthora* foot rot (quick wilt) is another very serious disease of black pepper. Coll. 1041, a clone of 'Neelamundi', is found to be highly tolerant to foot rot disease at Valparai (Tata Tea Ltd.), a highly disease affected area. This cultivar is having a mean yield of 4.25 kg/ fresh berries vine in the 3rd year. Four accessions of cultivated black pepper viz., Acc. No.816, 841, 1084 and 1114 are found to be relatively resistant to *'pollu'* beetle. Incorporation of *'pollu'* beetle resistance through interspecific hybridization is involving *P. attenuatum* and *P. barberi* with *P. nigrum* has been tried (Sasikumar *et al.*, 1999).

Breeding for drought tolerance: Screening of germplasm against moisture stress has resulted in identifying few promising Karimunda lines viz. KS 69, KS 51 and KS 114. These drought tolerant lines are undergoing yield evaluation.

Breeding for high altitude: Most of the black pepper varieties are not specifically bred for high altitudes, where it can be grown either as a monocrop or as an intercrop on the shade trees of tea or coffee or cardamom estates. Evaluation of 100 hybrids at Valparai (Tata Tea Ltd.) is in progress and HP 34, HP 105, HP 813 etc. perform well.

Table 1. Improved varieties of black pepper and their salient features

N ame	Details	Pedigree	Released from	Average yield. Dry (kg/ha)	Oleo-resin (%)	Piper-ine (%)	E. Oil (%)
Panniyur 1	Suited to all pepper growing regions. Not suited to heavily shaded areas	F1 of Uthirankotta x Cheriyakaniyakadan	Pepper Research Station, Panni-yur (KAU)	1242.0	11.8	5.3	3.5
Panniyur 2	Reported to be shade tolerant	Open pollinated prog-eny of Balankotta	-do-	2570.0	10.9	6.6	3.4
Panniyur 3	Late maturing. Suited to all pepper growing regions	F1 of Uthirankotta x Cheriyakaniyakadan	-do-	1953.0	12.7	5.2	3.1
Panniyur 4	Reported to perform well under a variety of conditions. Stable yielder	Clonal selection from Kuthiravally	-do-	1277.0	9.2	4.4	2.1
Panniyur 5	Tolerant to nursery diseases and shade	Open pollinated prog-eny of Perumkodi	-do-	1098.0	12.3	5.5	3.8
Subhakara	Suited to all pepper growing regions	Clonal selection from Karimunda	IISR, Calicut	2352.0	12.4	3.4	6.0
Sreekara	Suited to all pepper growing regions	Clonal selection from karimunda	-do-	2677.0	13.0	5.1	7.0
Panchami	Late maturing type suited to all pepper growing areas	Clonal selection of Aim-piriyan	-do-	2828.0	12.5	4.7	3.4
Pournami	Tolerant to root knot nematode	Clonal selection of Ottaplackal	-do-	2333.0	13.8	4.1	3.4
PLD-2	Suited to Trivandrum and Quilon districts of Kerala	Clonal selection from Kottanadan	-do-	2475.0	15.5	3.3	3.5

Breeding for high quality: Black pepper cultivars rich in piperine, oleoresin and essential oil are in great demand. Screening of the germplasm collections has resulted in identifying some types with high piperine, oleoresin and oil contents. The cultivars Kottanadan, Kumbakodi, Kuthiravally and Nilgiri are rich in piperine and oleoresin whereas Balankotta, Kaniyakadan and Kumbakody are high in essential oil. These lines will be used in hybridisation programme to evolve high quality, high yielding cultivars.

Cardamom

Genetic resources of cardamom

Genetic resources of cardamom maintained at various research institutes are given in Table 2.

Table 2. Genetic resources of cardamom conserved in India

Conservatory	Germplasm holding		
	Cultivated	Wild & related taxa	Total
IISR Cardamom Research Station, Appangala	252	13	265
ICRI, Myladumpara	600	--	600
Cardamom Research Station, Pampadumpara	72	15	87
Regional Research Station, Mudigere	236	7	243
UPASI, Valparai	45	--	45
Horticultural Research Station, Yercaud	35	--	35

Crop improvement

Selection: Clonal selection is generally practiced in cardamom and it is based on both qualitative and quantitative

Table 3. Improved varieties of cardamom

Variety	Source	Yield Kg/ha (3rd year)	Essential Oil (%)	1,8-cineole (%)	Terpe-nyl acetate (%)	Capsule shape	Area(s) recommended
PV-1	KAU, Pampadumpara	260	6.8	33	46	Long	All cardamom tracts of Kerala & Karnataka
Mudigere-1	University of Agricultural Sciences (B), Mudigere	275	8.0	36	42	Oval	Malad region of Karnataka
Mudigere-2	University of Agricultural Sciences (B), Mudigere	476	8.0	45	38	Round	Traditional cardamom gro-wing tracts of hill zones of Kerala
ICRI-1	Indian Cardamom Research Institute, Myladumpara	375	8.3	29	38	Round	South Idukki Zone of Kerala
ICRI-2	Indian Cardamom Research Institute, Myladumpara	375	9.0	29	36	Oblong	Vandanmetu & Nelliampathi zone of Kerala & Anamalai & Meghamalai hills of Tamil Nadu
ICRI-3	Indian Cardamom Research Institute, Myladumpara	439	6.6	54	24	Oblong	Hill zones of Karnataka
CCS-1	Cardamom Research Centre, Appangala	409	8.7	42	37	Oblong	Kodagu & Hassan districts of Karnataka
ICRI-4	Indian Cardamom Research Institute, Thadiyankudisai	455	6.4	--	--	Globose	Lower Pulneys in Tamil Nadu

characters. The qualitative character refers to colour, shape, size and oil content of the capsule, nature of the panicle etc., where as the quantitative character denotes the litre weight of the capsule and yield. Initial selection in cardamom for desirable traits is made from the planters' field and wild habitats. The selection is made based on some passport characters identified in the descriptor for the crop. In order to isolate promising clones, germplasm collections and open pollinated progenies are subjected to initial evaluation studies.

Only after studies have been taken up for selection of seedlings having precocity in bearing. At present, thrust is given to isolate early as well as late bearing clones and work in this line is in progress (Madhusoodanan and Radhakrishnan 1996).

Systematic evaluation of germplasm accessions during the 1980's resulted in the identification and release of a few elite clones having high yield potential and good quality capsules such as ICRI-1, ICRI-2 and PV-1. Another important selection is the 'Green gold' developed by a farmer of Idukki District. The selections in cardamom are highly specific in its agro-ecological requirements.

Hybridisation: The most popular cardamom cultivar namely 'Vazhukka' is presumed to be evolved as a result of natural cross between cv. Malabar and cv. Mysore. Breeding in cardamom is aimed at evolving recombinants which are superior with regard to yield and quality of capsules. Intervarietal hybrids of cardamom are at various stages of cultivation.

Improved varieties:

The improved varieties of cardamom are given in Table 3. These are mostly selections. RR-1 is a rhizome rot resistant cardamom variety in pipeline (Anon., 1997).

Ginger

Genetic resources

The Indian Institute of Spices Research maintains a total of 530 accessions of ginger (indigenous and exotic) including wild types and related species. NBPGR centre at Trissur also maintains a good collection of ginger germplasm. *Zingiber* sp. found in South India is Z. *officinale* Rosc. Z. *roseum* Rosc; Z. *nimmoni* Dalz; Z. *cernum* Dalz; Z. *purpureum* Rosc., Z. *wightianum* Thev; Z. *zerumpet* (L) Smith and Z. *neesanum* (Ghaham) Ramamoorthy. (Ravindran *et al.*, 1994).

Crop improvement in ginger

Improvement of ginger through recombination breeding is handicapped by the absence of viable seed set. Eventhough good flowering and 18-45% pollen fertility, as estimated through staining, are observed in ginger (Ratnambal 1979), lack of viable seed set under Indian condition is a major barrier in breeding of ginger.

Genetic variability studies in ginger germplasm revealed moderate to good genetic variability of rhizome yield / plant and other yield attributes. Plant height followed by leaf length had maximum direct effect on rhizome yield/ plant. The study indicated the effectiveness of selection in improving ginger. (Sasikumar *et al* 1992b; Ratnambal *et al.* 1980).

The chromosome number of cultivated ginger is 2n=22. Omanakumari and Mathew (1985) reported intraspecific karyotype variability in the genus. One tetraploid line cv. 'Maran' is now under field evaluation at two locations and another tetraploid line of cv. Manathodi' obtained from Botany department, University of Kerala, is under initial evaluation at IISR.

Cultivars

About 50 commercial types of ginger are cultivated. Barring five improved cultivars, all other cultivars are land races or indigenous lines. The most important indigenous cultivars of ginger are Maran, Himachal, Wynad Local, Nadia, Bajpai, Kuruppampadi etc. Some of the popular exotic cultivars are Rio-de-Janeiro, Taffingiva, Jamaica and China. 'Varada' is the only ginger variety released from Kerala (Sasikumar *et al.*, 1996a). It is a selection from IISR. Other improved varieties of ginger are Suprabha, Suruchi, Suravi (released by OUAT, Pottangi, Orissa) and Himagiri (released by DYSPUHF, Solan, Himacal Pradesh)

High yielding and good quality ginger cultivars

Even though quality traits in ginger such as dry recovery, oleoresin, fibre content etc. are observed to vary with soil type, location, season, cultural condition, climate, genotype etc. there exists many local types which excel in yield and one or other quality traits (Table 4).

Turmeric

Genetic resources of turmeric

IISR maintains a total of 730 accessions of turmeric comprising cultivars, OP progenies, related species and taxa. NBPGR, Trissur also maintains a good collection of turmeric germplasm. Besides *C. longa*, the other economically important species of the genus are *C. anguistifolia, C. zedoaria, C. caulina, C. montana, C. pseudomontana, C. xanthorrhiza, C. leucorrhiza, C. malabarica, C. raktakanta, C. harita* etc. These species are used in arrowroot preparation (Velayudhan *et al.* 1994). *C. amada* (mango ginger) is also economically important. Kasturi turmeric (*Curcuma aromatica*) is another closely related economic species used

Table 4. High yielding and good quality ginger cultivars

Trait	Cultivars
High yield (fresh)	Rio-de-Janeiro, Suprabha, Suravi, Jugijan, Thing Pui, Wyanad Local, Himachal, Karakkal, Acc.64 (Varada).
Bold rhizome	China, Taffingiva, Sg - 35
High dry recovery	Zahirabad, Jorhat Local, Kuruppampadi, Eranad, Chernad, Suruchi, Maran, Assam, China, Mowshom, Thing Pui
Low fibre	Zahirabad, Kuruppampadi, Mizo. PGS-16, China, UP, Nadia Poona, Jamaica, Varada
High oleoresin	Wynad Kunnamangalam, Ambalavayalan Eranad Chernad, Sawthing Pui, Rio-de-Janeiro, Kuruppampadi, Himachal, China
High gingerol and shogaol	Wynad Kunnamangalam, Ambalavayalam, Eranad Chernad, Sawthing Pui, Rio-de-janeiro

mainly by the cosmetic industry. This species has got a characteristic aromatic flavour and is low in curcumin content. Cultivated turmeric, *C. longa,* is considered to be triploid and *C. aromatica* is tetraploid (2n=4x=84).

Crop improvement

For the past many years crop improvement in turmeric has been limited to selection and mutation breeding. Blossom biology and hybridization studies are carried out in turmeric at CPCRI, Kasaragod and KAU, Trissur. With the recent success of viable seed set in turmeric, recombination breeding programme is also in full swing in this clonally propagated crop. Two varieties of turmeric developed through open pollinated progeny selection by IISR, Calicut are recommended for release recently. (Sasikumar *et al.,* 1996b). The improved varieties of turmeric are given in Table 5.

Cultivars

About 50 commercial types of turmeric are cultivated in India. These land races, mostly from Andhra Pradesh or Orissa, are classified as short duration, medium duration, and long duration types. The cultivars G.L. Puram, Kasturi CA-69, Jabedi, Dughi, Dindigram, Katigia, Pakistan, Udayagiri and Amalapuram are the important short duration types. They have long, thick rhizomes with shiny skin and aroma. Yield potential is 8-20 t/ha with a dry recovery of 26-30% and takes about six months for maturity. They are low in curcumin content. (Rao and Rao, 1994).

ACC. 317, Kesari, Kothapeta, Gorakpur, Amrithapani, Panamalur, Rajapuri, Amalapuram etc. are medium duration varieties with a maturity range of 8 months. These types have rhizomes, which are medium long and thick with narrow constrictions. Its yield potential is 14-35 t/ha with a dry recovery of about 18-20%.

Armoor, Duggirala, CII.325, Mydukur, Tekurpet, Avanigadda, Sugandhan, Ethamukkale etc. are long duration types which take about nine months for maturity. These cultivars have long, stout, smooth and hard rhizomes with pale yellow colour. The yield ranges from 15 - 37 t/ha with a dry recovery of about 20%.

High curcumin cultivars

Even though curcumin content and dry recovery of turmeric varieties are reported to vary with location, season, soil type, cultural conditions, etc., there exists many land races which contain more than 6% curcumin. "Aieng" turmeric of Manipur; "Wyanad local", Edapalayam, Thodupuzha, Mananthody, Pulpally types of Kerala; Aizwal type of Mizoram and Sugantham of Gujarat are rich in curcumin content. Acc. 585, a selection of AFT (Alleppey Finger Turmeric) possesses 7% curcumin (Anony., 1997)

Tree Spices

Cinnamon (*Cinnamomum verum* Bercht. & Presl.), nutmeg (*Myristica fragrans* Houtt.), clove (*Syzygium aromaticum* (L.) Merr. & Perry and allspice (*Pimenta dioica* L.) are the important tree spices grown in India. The commercial products of these crops are whole spice, ground spice, spice oil, oleoresin etc.. In India, cinnamon is cultivated in Kerala, Karnataka and Tamil Nadu and is more prevalent in the hilly regions of the Western Ghats. Clove is mainly grown in Kanyakumari, Tirunelveli, Salem and the Nilgiris districts of Tamil Nadu and a few pockets in Kerala, Karnataka, Maharashtra and Andaman Islands. Nutmeg cultivation is more prevalent in the districts of Trichur, Ernakulam, Kottayam and Trivandrum of Kerala and also a few pockets in Tamil Nadu and Karnataka. A few allspice trees are available at Nagercoil, Kallar, Burliar, Peruvannamuzhi (Calicut) and Ratnagiri (Maharashtra).

Genetic resources

The Indian Institute of Spices Research has the world's largest germplasm assemblage of tree spices, accounting for more than 1000 accessions at its Experimental Farm, Peruvannamuzhi. The 275 accessions of cinnamon

Table 5. Improved varieties of turmeric and their salient feature

Name	Pedigree	Released from	Av. Yield (fresh) t/ha	Dura-tion (Days)	%Dry recovery	Cur-cumin (%)	Oleo-resin (%)	E. oil (%)	Suitable for
Co.1	Mutant of Erode local	TNAU, Coimbatore	30.5	285	19.5	3.2	6.7	3.7	TN. Drought tolerant.
BSR-1	Mutant of Erode Local	-do-	30.7	285	20.5	4.2	4.0	3.7	TN. (drought prone area & problem soil)
BSR-2	-do-	-do-							
Krishna	Clonal sel. from Tekur-	Maharashtra AU, Kasha	9.2	240	16.4	2.8	3.8	2.0	Maharashtra. Tolerant to major pests
Sugand-ham	Germplasm selection	Gujarat AU, Jagudan	15.0	210	23.3	3.1	11.0	2.7	Gujarat Tolerant to pests.
Suvarna (PCT-8)	Germplasm selection	IISR	17.4	200	20.0	4.3	13.5	7.0	Kerala, Karnataka & AP
Suguna (PCT-13)	-do-	-do-	29.3	190	12.0	7.3*	13.5	6.0	Kerala & AP Short duration
Sudarsana (PCT-14)	-do-	-do-	28.8	190	12.0	5.3*	15.0	7.0	-do-
IISR Prabha	Open polli-nated prog-	-do-	37.5	205	19.5	6.5	15.0	6.5	Kerala &TN . High curcumin type
IISR Pra-thiba	-do-	-do-	39.1	225	18.5	6.21	16.2	6.2	-do-
Roma (PTS-10)	Clonal se-lection	HARS (OUAT) Pot-	20.7	250	31.0	9.3 (*)	13.2	4.2	Orissa, TN, HP, AP & Kerala.
Suroma (PTS-24)	-do-	-do-	20.0	253.	26.0	9.3	13.1	4.4	Orissa, TN, & HP
Rasmi (PTS-9)	Germplasm selection		31.3	240	23.0	6.4	13.4	4.4	Orissa, TN, AP & Kerala.
Ranga	Clonal Sel. (Rajpuri	-do-	29.0	250	24.8	6.3	13.5		-do-
Rajendra Sonia (RH-10)	Germplasm selection	Rajendra AU, Dholi, Bihar	4.8	225	18.0	8.4		5.0	North Bihar
Kanti	Clonal Sel. (Mydukur)	KAU, Vel-lanikkara	7.9 (**)	240 to 270		7.2			
Sobha	Sel. from 'Methala Local'	-do-	5.74 (**)			7.2	15.9		
Mega Tur-meric	Sel. from "Lakadong' type	ICAR Res. Complex for NEH Re-gion, Shil-							

* Provisional ** dry yield

include high quality, high yielding lines and a few other economically important species like camphor (*Cinnamomum camphora* L.) cassia (*Cinnamomum aromaticum* Nees) and 'tejpat' (*Cinnamomum tamala* Nees), besides a few wild species and exotic collections. The 452 nutmeg accessions include high yielding lines, different wild species, some of which are rare and threatened related genera and special types such as one with 1 to 4 seeds per fruit. The clove collections numbering 217 include dwarf and bushy types, king clove, narrow leaves types and few exotic collections. There are 137 trees of allspice. (Krishnamoorthy *et al.* 1996).

Cinnamon and Cassia

Sri Lanka is considered to be the centre of origin of cinnamon. *Cinnamomum verum* (Bercht. and Presl.), is the true cinnamon of commerce while cassia is obtained from various sources like *C. cassia* (Bercht. and Presl.). (Syn *C. aromaticum* Nees), *C. burmannii* (C.G. and Th. Nees) B1. *C. loureirii* Nees and *C. tamala* Nees. The dried inner bark is the cinnamon of commerce. Cinnamon is cross pollinated and seed propagated. Based on quality and yield of the progenies of 189 Indian and 102 Sri Lankan Cinnamon lines, two high yielding and high quality lines, Navashree and Nithyashree have been released by IISR (Krishnamoorthy et al., 1996).

Few cassia lines rich in quality parameters are undergoing advanced yield trials at IISR. YCD-1 is released from open pollinated progeny selection of Cinnamon by the Horticultural Research Station, Yercaud, Tamil Nadu in 1996. 'Kokan Tej' is another cinnamon selection from Konkan Krishi Vidyapeeth, Maharashtra.

Nutmeg

Nutmeg (*Myristica fragrans* Houtt.) *Myristicaceae* is a tree spice, yielding two spices, namely the nutmeg, (dried kernel of the seed) and the mace (dried aril surrounding the seed). The tree is typically dioecious with male and female flowers on different trees. Occasionally male trees carrying a few female flowers or female trees carrying a few male flowers are observed. Very rarely bisexual types occur.

Nutmeg is indigenous to Moluccas islands of Indonesia. The oldest nutmeg populations in Kerala are in Kalady and Palai and are reported to be more than 150 years old.

Genetic variability in nutmeg population is low in the country as the present population evolved from a few mother trees introduced by Britishers (Krishinamoorthy et al., 1994). Crop improvement programme in nutmeg aims at selecting and breeding high yielding trees. Since nutmeg and mace are of economic importance, while breeding / selecting, emphasis is laid on both the products. High yielding elite trees have been identified from various nutmeg growing areas and their progenies are being evaluated for yield. A 94 is a superior nutmeg selection (Krishnamoorthy, 1997). 'Konkan sugandh' is a nutmeg selection from Konkan Krishi Vidyapeeth, Maharashtra. As a short term perspective, identification of elite mother trees, establishment of scion blocks and production and distribution of superior grafts are being carried out at IISR.

Clove

The clove of commerce is the dried, aromatic, fully grown but unopened flower buds of *Sygium aromaticum* (L.) Merr. and Perry (Syn. *Eugenia caryophyllus* (Sprengel) Bullock & Harrison) belonging to the family *Myrtaceae*. It is indigenous to the Moluccas islands, from where it has spread to many topical countries. Flowers are hermaphorodite, borne at the terminals in trichotomous panicles, with 3 to 20 flowers/ panicle. Floral biology of cloves favours self pollination.

Special efforts were made to identify and collect diverse types from Ashamboo hills, the southern most hills of India, where clove was first introduced. The genetic base of clove is narrow, due to the very few original introductions.. Differences have been observed in shape of trees, bearing habits, cropping season and variations occur in yield colour, shape and dimensions of clove. Surveys were conducted in major clove growing areas of Tamil Nadu and Kerala and a total of 35 elite trees had been identified. (Krishnamoorthy *et al.*, 1996a).

Accessions with extra bold clove buds (King clove), dwarf and bushy types, narrow leaved variants, two exotic collections (Sri Lanka and Zanzibar) are some of the important clove accessions being maintained at IISR (Krishnamoorthy *et al.*, 1996a).

Allspice

Allspice, *Pimenta dioica* (L.) Merr. is indigenous to West Indies and tropical America. Allspice of commerce is the dried immature fruits of the tree, *Pimenta dioica*. The flavour resembles a mixture of cinnamon, clove and nutmeg and hence the name. There are a few allspice trees available in Nagercoil, Kallar, Burliar and Horticultural Research Station, Ambalavayal. IISR has a collection of 137 trees.

Vanilla

Vanilla (*V. planifolia* Andr. Syn. *V. fragrans* Salisb.) is a climbing orchid native to tropical America and was introduced to India during the nineteenth century. Apart *from V. planifolia* other cultivated species are *V. pompona* sch. and *V. tahitensis*. T.W. Moore. All the three species are diploid (2n=32). *V. walkeriae* Wt. and *V. wightiana* Lndl. are two wild species of vanilla occurring in Western Ghats besides *V. vatsalae*. *V. pilifera* is reported from North East India. At IISR, 40 accessions of vanilla are conserved in addition to

seedling progenies and somaclones. The species conserved, include *V. planifolia, V. vatsalae, V. andamanica* and *V. pilifera.* There are no improved varieties of vanilla at present.

Future Thrust

Accurate documentation and characterisation of the germplasm including molecular marker based characterisation is the major area of future research.

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Germplasm in Tea: Its utilization and Improvement

V. S. Sharma and Ch. Sreedhar

Introduction

Geological history of eastern Yunan and distribution of Camellia species in that area indicate that the long narrow region of Wenshan and Honghe, located at 22° 40' to 24° 10' N and 103° 10' to 105° 20' E in the centre of genesis of tea plant (Yu, 1986; Yu and Lin, 1987). From the traditional centres of cultivation in south and south east Asia, tea has been introduced into many other domains of the world and is now grown in environments ranging from Mediterranean climate to hot humid tropics. However, controversy still persists as to the real place of origin of tea because of the non-availability of true wild populations that are exemplary of the form from which cultivated populations of diverse morphological characters originated.

Tea today is generally referred to as *Camellia sinensis* (L.) O. Kuntze, irrespective of species-specific differences. Botanists distinguished three distinct tea producing taxa, *Camellia sinensis* (L.) L. Kuntze ("China type"), C. assamica (Masters) Wight ("Assam type") and C. assamica spp. lasiocalyx (Plan. Ex. Watt) Wight ("Cambod type") which are responsible for commercial tea; the non-tea producing taxa such as, *C. irrawadiensis* Barua (Wilson's Camellia), C. reticulata, C. sasanqua Thunb., C. lutescens Dyer, *C. saluensis* and *C. taliensis* (W.W. Smith) Melchior and other closely allied species are known to have been involved in the evolution of the present string of genetic pool of commercial tea populations (Kingdonward, 1950; Roberts et al., 1958; Wood and Barua, 1958; Wight, 1962; Barua, 1963a; Barua, 1963b; Barua, 1965; Visser, 1969; Sharma and Venkataramani, 1974; Benzbaruah, 1975a). The present day commercial tea populations are, thus, polymorphic in origin, resulting in a wide genetic diversity.

Exploitation of the heterogeneity in seedling populations by clonal selection has played a vital role in tea improvement programme. This line of work has resulted in the development of several useful clones for commercial exploitation in different tea growing countries (Harada et al., 1961; Barua, 1963a; Visser, 1969; Arifin, 1978; Sharma, 1982; Singh, 1982; Nyirenda and Ridpath, 1984). Additionally, clonal material has been the source for evolving biclonal and polyclonal seed stocks of commercial significance.

Mutation, polyploidy, nursery grafting, biotechnology, and genetic engineering are some of the important lines that should contribute to the further improvement of tea germplasm.

Clonal Selection

Seedling populations in tea display considerable variations in growth habit, branching, size, shape, pose of the leaf, yield potential and quality (Wellensiek, 1934 a, b; Anonymous, 1962; Bezbaruah, 1975a). Such variability in commercial seedling populations offers an immense scope for selection of elite mother bushes to develop them into clones.

An important step in the development of clones is the selection of elite mother bushes. In a majority of the tea growing areas, mother bushes are selected on the basis of visual assessment of morphological characters, such as the nature of frame, branching habit, size orientation and colour of leaf, density of shoots, pubescence on the bud and abaxial surface of leaves (Barua, 1963a; Visser, 1969; Venkataramani, 1970; Arifin, 1978; Nyirenda and Ridpath, 1984). Although an element of subjectivity cannot be ruled out in such a method of selection, positive correlation between yields of selected bushes and their clonal derivatives suggest a strong genetic basis (Green, 1971). Positive association between pubescence of shoots and quality of black tea reinforces this view (Anon,, 1964 and Wu, 1964).

Subsequent processes in the development of clones involve the assessment of the rooting performance in the nursery, establishment in the field in the initial years after planting, yielding ability and tolerance to abiotic and biotic stresses. The whole process from the time of selection of mother bushes to the release of clones for commercial use takes about 10 to 12 years (Barua, 1963 b; Benzbaruah, 1968; Satyanarayana and Sharma, 1986).

Clonal selection has resulted in the development of several superior clones for commercial use in different tea growing regions (Harada et al., 1961; Visser, 1969; Venkataramani, 1970; Arifin, 1978; Singh, 1984). Besides, the clonal material has been the source for evolving biclonal and polyclonal seed stocks of commercial significance.

Criteria for clonal selection in tea are clearly laid out

(Venkataramani, 1970); but, criteria for early yield prediction of the clonal progenies are not well defined.

Currently, mother bushes are selected on the basis of visual examination of their exomorphic characters as well as certain biometric parameters (Venkataramani, 1970; Satyanarayana and Sharma, 1981). Comparison of the yield of selected bushes is made on the basis of yield potential. Bushes with high yield potential are multiplied through the conventional method of vegetative propagation of one leaf and internode cuttings. Performance of the vegetatively propagated progenies is evaluated in the nursery and field.

Per cent rooting of cuttings and vigour of growth of plants are evaluated in the nursery. Establishment of plants in the initial years of planting, survival of plants through successive drought seasons, yield over a period of two pruning cycles, quality and tolerance to pests and diseases are some of the more important characters that are evaluated in the field. Selections that are identified as promising after one cycle of testing in the field are planted in different districts to study their performance under varying agroclimatic conditions (Sharma and Satyanarayana, 1987). Based on a comprehensive assessment of the data generated from different trials, clones are released for commercial planting.

A positive and significant correlation was established between the progeny yields during the immature stages and the yield potential based on yield of seven years (Sebastiampillai and Sólomon, 1976). Significant correlations were also established between certain biometric parameters like leaf area, density of plucking points and pruning weights and the yields of selected bushes (Satyanarayana and Sharma, 1982). However, the efficiency of such correlations in early yield prediction of clonal progenies has to be evaluated on a large scale, over a period of time.

Canopy architecture, allocation of dry matter, rations between the dry matter accumulation in different organs and harvest index should attract more attention in evolving guidelines in future, for an early yield prediction of tea cultivars.

Computerization of initial selection of mother bushes based on yields recorded for six months was tried in Kenya; the computer selected bushes were not found to be superior to those selected by conventional methods (Njuguna, 1984).

Development of Seed Stock

The use of only a few clones is hazardous because of the possibility of the clonal populations becoming susceptible to pest or disease epidemics at a future date. Moreover, planting of only clonal material will narrow the genetic base. In order to maintain genetic diversity for future exploitation in plant improvement, development of seed stocks also should be given importance.

Initial attempts to produce improved seed were made as early as 1840 by mass selection of plants in the nursery. Although specific criteria had not been evolved to select parent plants, importance was given to size of the leaf and vigour of the plants (Wellensiek, 1934a). However, it was soon realised that such a method of plant improvement, being restricted to a particular 'jat' (equivalent to variety) would narrow the genetic base. This led to the adoption of line breeding technique by hybridization (Watt, 1907). The emphasis in line breeding is the development of improved seed stocks by combining the desirable attributes such as yield, quality and tolerance to pests, disease and drought found in different 'jats' (Harada *et al.*, 1961; Barua, 1963a).

Use of clones of proven performance, as parents have remained popular till date. Seed obtained from crosses involving more than two clones is referred to as polyclonal seed, while that resulting from hybridization between two clones is called bioclonal seed. In view of comparatively greater phenotypic uniformity in the progenies, biclonal seed is preferred to polyclonal seed in most of the tea growing countries (Bezbaruah, 1975b; Barua, 1989).

Tea breeding programme was initiated at the Tockali Experimental Station in 1939 (Bezbaruah, 1975b; Barua, 1989). A polyclonal seed variety involving seven clones was developed in the mid-fifties as an interim measure to meet the pressing demand of the tea industry for a hardy 'jat' of good quality and yield. Planting of this clonal seed stock was discontinued when biclonal seeds of superior merit became available to the growers. The biclonal seed stocks while maintaining genetic variation, retain certain amount of phenotypic uniformity. Such inherent variation is valuable for further development of clones, which in turn could be used for evolving seed stocks. Thus,. A clone-seed cycle is important for continued plant improvement and its appropriate commercial exploitation.

In view of self-sterility application of the line breeding technique in plant improvement programme of tea has been useful in developing improved seed stocks of commercial importance in different countries (Harada *et al.*, 1961; Visser, 1969; Bezbaruah, 1975a; Singh, 1984; Satyanarayana and Sharma, 1993). Improved seed stocks have also widened the choice of source material for the development of elite clones.

A successful hybridization between *C. sinensis* and *C. japonica*, a native of China and Japan, has been reported by

uah and Gogoi (1972). In general, introgression and ization with the species of *Camellia* other than those attributes to produce an acceptable quality of tea have en encouraging. However, there are exceptions; for le, F1 hybrids between *C. irrawadiensis* x *C. assamica* crossed with Assam-China hybrids (TV2) produced a productive clone (TV 24) (Bezbaruah, 1987).

The progenies of inter-specific and wide crosses en different races of tea are usually vigorous but lack ty and morphological uniformity.

At present, emphasis in Japan appears to be on the uction of vegetative clones. These have been selected hybrid progenies raised by crossing different types of high yield, good cup characters and a high degree of rance to low temperature are the major considerations in choice of clones. A procedure similar to that in Japan is g followed in Taiwan where a number of excellent clones e been developed from F1 progenies of crosses made ween and within the "Assam" and the "Choina" races of . Selection is made (Wu, 1981) separately for the oduction for Oolong, Poachong and black tea.

In the U.S.S.R., a large area was planted in the past th locally developed "China" jats of tea. With a view to place these 'jats' with high yielding and superior quality nting material, an intensive tea breeding programme was ken up some 40 years ago. Polycross breeding between hina' and 'Cambod' races of tea resulted in the development a number of seed varieties which yielded 50 to 60 per cent ore than the old 'jats', besides producing teas of superior cup-ality. All the newly bred varieties are frost resistant and e of them like Georgian hybrid No.8 are said to thrive at 22° C.

Breeding has been initiated in Sri Lanka using a few cted vegetative clones as the parents. However, the genies of these crosses were found to be highly rozygous and they fall far short of the parent clones in ld and quality (Richards, 1967).

In Kenya, priority has now shifted from the selection vegetative clones to the production of biclonal seed genies, primarily for want of reliable selection criteria for getative clones. However, clonal seed stocks have not yet en produced on a commercial scale (Barua, 1989).

rafting

Grafting as a method of propagation of tea plant was first tried in Java in the late twenties and then, in north - east dia from the mid thirties. In those early years, only patch budding technique was used. Later, another version of bud grafting known as shield budding or inverted "T" budding was also used successfully.

Other forms of grafting such as splice grafting, chip budding (Anyuka and Otheino, 1982; Nixon and Sanga, 1995; Sharma et al., 1995) and wedge grafting have also been tried successfully in tea (*Camellia* L. Spp.). Chip budding has been tried as a means of producing composite plants (Scarborough and Kayange, 1977; Kayange, 1985; Kayange 1988; Bore *et al.*, 1995). Rind grafting was found to be easier and successful as the cleft grafting method was used previously in conversion of seed baris (Singh *et al.*, 1985). Cleft grafting was introduced at a later stage which is now widely followed in commercial tea nurseries (Sharma and Satyanarayana, 1982; Anyuka and Othieno, 1982; Barua, 1989; Kayange, 1990; Sharma *et al.*, 1995).

Earlier, the object of grafting was rapid multiplication of clones by establishing nucleus plot of mother bushes and conversion of seedling bushes into clones for establishing biclonal/polyclonal seed baris (Barua, 1968; Bezbaruah, 1971). Scarborough (1964) suggested that grafting could be used to convert old bushes of seedling origin into new clones thereby avoiding the need to uproot and replant. This method was not successful on a large scale owing to the effort, expense and high population density in tea field involved. Katsuo (1969) used crown grafting on mature bushes for rapid production of vegetative material.

Raising composite plants by traditional grafting besides being cumbersome, takes longer time than the normal procedure of raising plants from clonal cuttings. The success of nursery grafting of fresh, clonal, single node cuttings (Sharma, 1972; 1976; Haridas, 1979; Satyanarayana, 1980) revolutionized the raising of composite plants combining the early rooting and drought tolerance of the rootstock with the yield/quality of the scion in the nursery; this technique facilities commercial planting with grafted composite plants.

The technique of grafting of fresh, unrooted tea clonal cuttings in nursery added a new dimension and shifted the emphasis to development of composite plants for commercial planting. The possibility of overcoming drought susceptibility of high yielding clones by grafting spurred interest in nursery grafting in other tea growing areas also (Nagarajah and Solomon, 1981; Harvey, 1989; Pallemulla et al., 1992; Nixon and Sanga, 1995).

In tea, as in other crops, grafting success depends on compatibility between scion and rootstock. The variation in yield, tolerance to drought and production of phytomass exhibited by grafted plants has been attributed to varying compatibility between graft partners (Satyanarayana et al., 1992).

Polyploidy and Mutation Breeding

The main taxa of tea are diploids (2n = 30) and their chromosome structures are also comparable;; even C. irrawadiensis conforms to 2n=30 (Bezbaruah, 1971). This constancy in diploid chromosome number suggests a monophylatic origin of all tea species. Deviations from normal chromosome number are known more in Japanese taxa than in tea taxa from other areas. *C. sasanqua* is a hexaploid (2n = 90), *C. rosaeflora*, which is a native of Sri Lanka, is also a triploid (Karasawa, 1932). Natural triploids have also been reported from India (Jayasurya and Govindarajulu, 1975) and China (Zhan *et al.*, 1987).

Naturally evolved polyploids in tea are very rare. Only a few natural triploids (2n=45)have so far been reported from Japan (Karasawa, 1932; 1935; Simura and Inabe, 1953; Simura, 1935); north-east India (Anonymous 1969-70), south India (Venkataramani and Sharma, 1974) and the U.S.S.R. (Kapanadze and Eliseev, 1975). Triploids in general are more vigorous and hardier than diploids. Simura (1956) found them to be cold tolerant under conditions prevailing in Japan. Bezbaruah (1971) reported that natural triploids found in north-east India produced very poor tea (Sarmah and Bezbaruah, 1984). However, tea of high quality has also been made from triploid clone 'Sundaram' in south India (Venkataramani and Sharma, 1974; Sharma and Ranganathan, 1985). Another natural triploid clone, UPASI - 20, a moderate yielder, has been found to be highly tolerant to drought. Genetic variation or mutation of diploid tea plants into polyploids can, therefore, be expected to improve vigour and hardiness.

Initial attempts at Tocklai Experimental station to induce mutation by treatment of tea shoots with colchine and ethyl methane sulphonate did not meet with success (Anonymous, 1068-69; 1969-70). However, by resorting to more drastic treatments, Goswami and Sarma (1979) succeeded in inducing mutation.

Natural triploids, pentaploids, tetraploids and aneuploids have been sampled in tea populations in Assam, but are reported to be present in very low frequency (Singh, 1984). Generally, rooting ability, leaf size and leaf dry weight of triploids and tetraploids are higher than those in diploids. But pentaploids and aneuploids are poor rooters and have smaller leaves than those of diploids, triploids and tetraploids. Pollen viability and fertility of triploids are usually poor;; tetraploids are more fertile than the triploids, but less.than the diploids (Visser, 1969).

The main advantage of the polyploids is their high vigour and resistance to environmental stresses, but they do not always contribute towards high yield. Polyploids, therefore, are of restrictive value in breeding. This divergence of growth and quality characteristics requires a selective approach in polyploidy breeding.

Considerable amount of work has been carried out in developing polyploid cultivars in tea (Simura and Inabe, 1953; Simura, 1956; Singh, 1984). In addition to natural triploids, crosses between tetraploid and diploid clones have resulted in the development of triploid (Sarmah and Bezbaruah, 1984; Singh, 1980, 1984). Tetraploids have been derived by treatment of apical bud of young tea plants with colchine (Visser, 1969). Tetraploids and aneuploids have been reported from progenies of natural triploids (Simura, 1956; Bezbaruah, 1968). Generally, polyploid cultivars have not found commercial acceptance, probably because of poor quality (Bezbaruah, 1968).

Naturally occurring mutants have not been identified in tea, so far. Attempts have been made to induce mutation by subjecting clonal cuttings, seed and pollen to physical and chemical mutagens (Singh, 1980; Amma, 1974; Katsuo, 1966; Sebastiampillai, 1976). Pollination with treated pollen is reported to have led to fruit drop, while treatment of propagation material resulted in plants with reduced vigour.

Biotechnology

Although the scope for tissue culture in tea improvement is identified, most investigations have focussed attention only on rapid multiplication. Tissue culture of tea is being carried out in Japan, China, Thailand, Sri Lanka, the former U.S.S.R. and India. Plantlet regeneration has been reported from nodal and stem segments (Nakamura, 1988; Arulpragasam, 1990; Kato, 1990), as well as through somatic embryogenesis from cotyledons (Nakamura, 1988; Kato, 1990). Polyploid plants through culture of somatic embryos treated with 0.1 per cent colchicine were also obtained. Somatic embryos have been reported from cotyledon segments of *C. sinensis, C. japonica, C. oleifera* and other species. Shoot tip and axillary bud cultures have been studied and the latter were found to be more suitable for shoot multiplication (Nakamura, 1988; Arulpragasam, 1990).

Regeneration of plants from callus tissues has also been reported (Nakamura, 1988; Kato, 1990). Some indications of somatic embryogenesis from stem and leaf callus cultures were also reported; however, these embryoids could not be regenerated into complete plants (Sarathchandra *et al.*, 1988). Only sporadic success with another culture of tea has been reported so far, and the work has been reviewed recently (Chen and Liao, 1990).

Embryo rescue techniques have been successfully used to obtain interspecific hybrids (Yamaguchi *et al.*, 1987);

preliminary reports of protoplast isolation have also appeared (Kuboi *et al.*, 1991). Development of pure lines through haploid technology will pave the way for much awaited programmes on tea breeding.

In India, the progress made so far, indicates that plantlets could be obtained from callus derived from cotyledonary and stem explants (Wu, 1976; Sood *et al.*, 1993). Induction of multiple shoots in apical and axillary bud explants and their subsequent rooting have also been achieved (Arulpragasam and Latiff, 1986; Rajasekaran and Mohan Kumar, 1992; Manivel, 1993). Despite these successful reports, rapid multiplication by tissue culture for routine use still remains to be standardized.

It has been reported that embryo cultures have been successfully employed in deriving interspecific hybrids in tea (Yamaguchi *et al.*, 1987). Another culture for developing haploid plants and protoplast fusion has not made much progress (Raina and Iyer, 1983; Nakamma, 1983).

Future Thrust

Genetic engineering aimed at conferring resistance to more important pests and diseases in elite and popular cultivars appears to have useful future. Induction of genetic and chromosomal changes in tissue and cell cultures will be useful in synthesizing variants. Development of haploid plants in microcultures and their diploidization will be useful in deriving isogenic cultivars. It will be useful to identify genetic markers linked to important agronomic traits for use in indirect selection of superior clones. It is necessary to study the mode of inheritance of components of important agronomic traits (example, quality and yield) as a model for understanding the polygenic nature of inheritance of such traits. It is useful to study and map out positions of genes controlling the complex quantitative traits loci (QTL) of yield and quality in tea.

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Coffee Germplasm-Conservation and Utilization in the Indian Context

C.S. Srinivasan and A. Santa Ram

Introduction

Genus *Coffea* consists of more than 80 species, of which the cultivated ones are mainly two namely *C. arabica* L. and *C. canephora* Pierre ex Froehner. Majority of the species are native of Africa. However, some species of the genus Psilanthus such as *bengalensis, khasiana, travancorensis* and *wightiana* which are closely related to Coffea are of Asian origin with little or no caffeine in their seeds. They have no economic importance so far as productivity is concerned. *Coffea arabica* is a native of the forests of Ethiopia while *Coffea canephora* is native of Central Africa (Congo and Zaire). Study of genetic diversity in a species is important for preserving and utilizing the same in breeding.

Early Collections (1925-1952)

A majority of these collections totaling 1462 were of indigenous origin with many putative hybrids such as Kents, Coorgs, S.26 and S.31 (both of *liberica* x *arabica* origin), Devamachy hybrid (*robusta* x *arabica* origin) etc. Many of these, such as Kents, S.26 were utilized in breeding for resistance to rust coupled with high productivity resulting successful varieties like S.288, S.795 and Sln.5 (Devamachy x Other *arabica*). Controlled crossing between Kents and robusta followed by back crossing resulting in development of Sln.6 was also obtained during this period.

World Collections (1953-1980)

Seeds of a number of varieties grown in Latin American countries were received in 1953 through the courtesy of Dr. W.H. Cowgill of Guatemala and also from Ethiopia, USDA, FAO, Brazil, Tanzania, Kenya, Puerto Rico, Costa Rica, Belgian Congo, Indonesia etc. Later on in 1963-64, an expedition to Ethiopia organized by the FAO to collect the germplasm of arabica and the then Botanist of the station Sri. R.L. Narasimha Swamy was also a member of the team. Seeds of as many as 80 *arabica* collections from Ethiopian forests were brought during this expedition and established at CCRI.

A number of arabica lines showing different levels of resistance to leaf rust races based on screening done at Coffee Rusts Research Centre, Portugal were also introduced during 1960s. Another important natural hybrid of *robusta* x *arabica* origin known as Hibrido de Timor showing high degree resistance to rust was introduced from CRRC, Portugal 1961. This hybrid has been extensively used in breeding improve the rust resistance of other arabica types through-o the world. Out of these collections, the San Ramon, mutant arabica was used in crossing with S.795, Agaro and HDT t evolve dwarf selection 7.3. It is having a high degree o tolerance to rust and drought. However, it is a late ripening variety. Hibrido de Timor was also released as Sln.8 and its cross with Tafarikela, an Ethiopian arabica variety was released as Sln.9. Another dwarf mutant of arabica known as Caturra has also been used in crossing with Cioccie, an Ethiopian variety and S.795 of Indian origin to evolve Sln.10. It is having moderate resistance to rust with bold fruits and seeds.

Recent Introductions (1980-1999)

Another dwarf hybrid between Caturra and Hibrido de Timor was carried forward up to F_6 generation under an international program of breeding coffee for resistance to rust and high yield co-ordinated by CRRC, Portugal. This hybrid is known as Catimor. Seeds of this hybrid were received in India in 1982 and based on its initial good performance it was released as Cauvery in 1985. From 1995 onwards, it started showing susceptibility to rust races as indicated evolution of 5 new races by rust pathogen. Thus, its popularity has started coming down in recent years.

Another dwarf mutant of arabica known as 'Villa Sarchi' was crossed with Hibrido de Timor and the seeds were received from CRRC, Portugal in 1975. The F_2 generation planted in 1981 has remained free from rust to this day. Seeds of this hybrid have been issued for multilocation trial. A cross between Catimor and Sarchimor is also under multilocational evaluation. Hybrids between Catimor and Catuai (Caturra x Mundo Novo) are also under multilocational evaluation. The future planting material will come from these hybrids.

Coffea canephora

Robusta coffee was introduced to India from Indonesia and Sri Lanka in the late 19th Century when arabica started showing severe incidence of leaf rust. Early selections were made from the estate plantings in order to improve the fruit size and bean size, which is generally small in robusta. A bold fruited selection S.274 was released for cultivation in 1950s. Another species, namely, *C. congensis* showing compact

bush size with better quality of seeds was introduced in 1930s. It was crossed with S.274 robusta in 1942 followed by back crossing F_1 to robusta. The resulting progenies were sib-mated to stabilize the compact bush character coupled with bold fruits and seeds and superior cup quality. Seeds from the sib-mated progenies are given for cultivation from 1988 onwards. Other robusta introductions from Costa Rica, Uganda, Madagascar, Ivory Coast etc. were made between 1950 and 1970 and these are found on par to the local selection S.274 but not superior.

Species Collections

CCRI has a collection of 18 species belonging to *Coffea* and the closely related genus Psilanthus. An amphidiploid vertical shoot resulting from the cross between *C. liberica* and *C. eugenioides* was found to resemble arabica in cup quality. It also possesses drought and rust tolerance. It has been found to perform well in marginal areas.

From the foregoing account, it may be inferred that in a perennial crop like coffee efforts at conservation of germplasm at moderate levels and its utilization in breeding has paid and will continue to pay rich dividends in India. Work on molecular characterization of the observed phenotypic variability is in progress.

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Germplasm Conservation, Utilization and Improvement in Rubber

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Introduction

The para rubber tree of commerce, *Hevea brasiliensis Mull. Arg.,* produces around 99 % of the world's natural rubber, an industrial raw material of strategic importance. The rubber plantations in the east, producing a major share of the total production, are reported to have originated from a narrow genetic base. From this small genetic foundation, substantial improvement in productivity has already been achieved. However, there has been a slow down in genetic advance in recent years, which is attributed mainly to the narrow genetic base. Hence action was initiated at the international level for enriching the original gene pool by introducing a large number of wild germplasm from the center of diversity, in Brazil. These are being conserved, catalogued, evaluated and documented in the different rubber producing countries with the objective of broadening the genetic base and thereby achieving further genetic improvement of the species.

The ten species reported in *Hevea* are *H.brasiliensis, H. benthamiana, H.guianensis, H.nitida, H.pauciflora, H.rigidifolia, H.camargoana, H.spruceana, H.microphylla* and *H.camporum* . The genus *Hevea* has its origin in the whole of the Amazon river basin in Brazil, covering parts of Brazil, Bolivia, Peru, Colombia, Ecuador, Venezuela, French Guyana, Surinam and Guyana, upto an altitude of about 800m. (Webster and Paardekooper, 1989). Since there is no cytological barrier among most of the species, natural hybrids and genetic variants are also found in this population. The different species exhibit wide variation in growth and morphological traits.

Origin and Distribution

Of the ten spices reported under *Hevea*, the commercially important species *Hevea brasiliensis* occupies about half the range of the genus, mainly in the region south of the Amazon, extending to Acre, Mato Grosso and Parana areas of Brazil, parts of Bolivia, Peru, north of the Amazon to the West of Manaus as far as the extreme south of Colombia. The species is now grown mainly in the tropical regions of Asia, Africa and America, in countries like Malaysia, Indonesia, India, Sri Lanka, Thailand, China, the Philippines, Vietnam, Kampuchea, Myanmar, Bangladesh, Singapore, Nigeria, Cameroon, Central Africa, the Ivory Coast, Ghana, Zaire, Liberia, Brazil and Mexico. However, the major share of the total production comes from tropical Asia.

The Genetic Base

The genetic base of *Hevea* in the east is reported to be very narrow, limited to a few seedlings originally collected by Sir Henry Wickham, referred to as the 'Wickham base'. (Simmonds, 1989).These few seedlings originate from a minuscule of the genetic range of the species in Boim, near the Tapajos river in Brazil (Wycherley, 1968). Thus, this collection lacked species diversity and also naturally occurring hybrids of the genus (Schultes, 1977).

Decrease in genetic diversity

The original gene pool was further narrowed down due to a number of factors, like a directional selection for yield, cyclical generation wise assortative breeding pattern and a wider adaptation of clonal propagation by budding. In all crop improvement programs till recently, the primary concern was productivity improvement. Such unidirectional selection for yield, over the years, ignoring the genetic variability with regard to secondary characters (Wycherley, 1969), has reduced the genetic variability in the population. Breeding in *Hevea* involves generation wise assortative mating (GAM), where the best clones in one cycle are used as parents for the next and so on (Simmonds, 1989). Hence ,the parentage of popular clones bred in various rubber growing countries can be traced back to just a handful of parent clones, like Tjir 1, Pil A 44, Pil B84, PB 24, PB 49, PB 56 and PB 86 (Tan,1987 and Varghese, 1992).

With the development of high yielding clones, extensive areas are being planted with a limited number of modern clones multiplied through vegetative propagation by budding, which also has had its share in decreasing the genetic base.

Broadening genetic base for biotic and abiotic stresses

Rubber plantations in the east are under the potential threat of *Microcyclus ulei*, prevalent in the American hemisphere, causing the devastating South American Leaf Blight (SALB) which is specific to *Hevea* species (Chee and Holliday,1986; Edathil, 1986). None of the Wickham clones have been reported to have resistance to SALB. There are also indications of erosion of genes controlling resistance to

Oidium and *Gloeosporium* in the original Wickham material (Wycherley, 1977). Besides, there is the threat of several minor diseases assuming epidemic proportions. The most serious problem reported is the severe incidence of *Corynespora* leaf spot disease, observed from 1985 onwards affecting the clones RRIC 103, KRS 21 and RRIM 725 in Sri Lanka. As a result, RRIC 103, one of the most popular high yielders planted extensively, had to be withdrawn from the planting recommendation necessitating replanting of vast areas under this clone (Liyanage *et al.*, 1991). In Malaysia, the popular clone GT1 was also severely affected by this disease (Tan, 1990). In India, the two major leaf diseases viz. abnormal leaf fall disease (*Phytophthora* sp.) and powdery mildew (*Oidium* sp.) cause considerable crop loss. Recent reports on the incidence of *Coryenespora* leaf spot observed in the popular clones RRII 105 and RRIM 600, in the rubber growing tracts of Karnataka and certain parts of North Kerala (Jacob, 1996), has caused serious concern over the possibility of the disease attaining epidemic proportions. In the case of the emergence of a virulent strain of a particular pathogen in favourable environmental conditions, the disease will spread and cause serious damage, if sufficient genetic variability is not available in the population.

Apart from the problem of disease susceptibility, variability for resistance/tolerance to various abiotic stress situations like drought, cold, high elevation, high velocity wind, low soil fertility etc. assumes much significance in the present day context of rubber cultivation extended to marginal and non-traditional areas due to non availability of land in the traditional rubber growing tracts. In order to develop/ select clones suitable for specific locations, the base material should contain ample genetic variability.

Considering all these factors which are essential for further genetic improvement of the crop, the breeders realized the need for broadening the genetic base of the crop by the introduction of fresh germplasm into the breeding cycle.

Germplasm Resources

The spectrum of *Hevea* germplasm can be broadly classified into (a) those existing in the primary centre of diversity in Brazil and (b) those developed in the centres of secondary diversity. The primary centre of diversity accommodates the wild genotype of the genus, along with naturally occurring hybrids, morphotypes and variants, while commercial cultivars, obsolete clones, cytotypes and genetic variants selected over the years are available in the secondary centres. All the available germplasm need to be conserved in a genepool, which can be utilized in breeding programmes as and when, required.

The genetic resources developed in the secondary centers also contribute to the broadening of the genetic base to a limited extent. Regular exchange of desirable genotypes between different countries, makes available potential clones developed elsewhere for adaptability studies besides broadening the genetic base for further utilization.

Early introductions

After the Wickham collection of 1876, there were a few attempts to introduce new germplasm to the centres of secondary diversity. These include introductions made in 1890s and 1910s from Brazil and Surinam to Java (Dijkman, 1951); five spp. and some of their hybrids from Brazil to Malaysia in 1951-52 (Brookson, 1956); 106 IAN clones, from Brazil via Sri Lanka to Malaysia, in 1952 (Baptiste, 1961) of which IAN 873 and IAN 717 were good yielders with tolerance to *Colletotrichum* sp. and *Microcyclus* sp.(Ong *et al.*, 1986; Ong and Tan, 1987) and the famous Schultes collection in 1943-46 in the Colombian forests (IRRDB, 1978). In Brazil, seed collections were made in 1945, 1952, and 1962 (IRRDB, 1982) and budwood of different species from the Amazonas, Acre, Para and Rondonia during 1972-82 (IRRDB, 1978; Goncalves *et al.*, 1983).

A Franco-Brazilian prospection in 1974 to the forests of Acre and Rondonia collected budwood from 60 high yielding trees 41 of which were later introduced into Ivory Coast (IRRDB, 1978). In general, all these introductions were of relatively small sample size and had low yield potential, when compared to the original Wickham collection and hence have contributed little to the plantation industry. (Simmonds, 1989).

1981 BIRRD (International Rubber Research and Development Board) Collection

Hevea breeders across the world stressed the need for broadening the narrow genetic base through introduction of wild germplasm into the breeding pool. There were also reports of constant threat to the survival of the species in the wild habitat due to urbanization of the region. The IRRDB organized a major collection expedition to the Amazon rain forests in 1981. This effort can be considered as one of the most significant events in the history of rubber germplasm collection, made with a view to ensuring a healthy future for the plantation industry (Varghese, 1992). This expedition organized jointly with the Brazilian Government, collected a total of 64736 seeds (Ong *et al.*, 1983; Mohd.Noor and Ibrahim, 1986) from the Brazilian states of Acre and Mato Grosso and the territory of Rondonia and budwood from 194 presumably high yielding seedling trees (ortets) which were not affected by *Microcyclus* and *Phytophthora* (Ong *et al.*, 1983).

The seeds and budwoods collected were despatched to the primary nursery at Manaus in Brazil, where 50% of the

entire seed collection was retained, as per the agreement with Brazil. Of the remaining seeds, 75% was sent to the Asian multiplication and distribution center in Malaysia, and 25% to the African Center in Ivory Coast. From the seedlings raised at these centers, budwood were distributed to member countries. The entire budwood collection was raised in the primary center at Manaus, of which 150 clones were despatched to the secondary nursery at Guadeloupe from where it was distributed to the Malaysian and African centers. In Malaysia, 131 ortets survived (Ong and Ghani, 1990). Varying proportions of this fresh germplasm were distributed as per the requests from the IRRDB member countries.

In India, this new germplasm was imported from Malaysia during the period 1984 to 1990, was established at the RRII Central Experimental Station in South Kerala and in the North East. The total number of accessions established in the traditional and non-traditional areas in the country is 4967, the number in each location being 3617 and 1350 respectively.

Conservation of Germplasm

Both *in situ* conservation of genotypes in their original habitats and *ex situ* conservation in special nurseries or fields are feasible in *Hevea*, of which the latter is widely adopted due to practical considerations.

Conservation of genetic resources of *Hevea* is indeed elaborate, expensive and difficult. The germplasm collection, maintained in the field as 'active collection' for regeneration, multiplication, distribution and characterization, are exposed to natural calamities as well as pest and disease outbreaks. From this a 'core collection' or a condensed assembly of germplasm should be identified and established for efficient conservation as well as for elimination of redundancy in large collections. Finally a 'working population' to suit short term needs of individual breeders and breeding programs can be established for current use. (Varghese, 1992). Clement-Demange *et al.*, 1997 proposed a conservation scheme with two levels viz. (1) basic conservation of the whole germplasm in the existing budwood garden, with pruning reduced to a minimum frequency, and (2) conservation of a core collection in two replications at two different sites, and with regular cutting back of the two replicates on an alternate basis.

In India, the germplasm materials are established and maintained in conservation nurseries in the traditional and /or non-traditional areas with a spacing of 1m between plants. In source bush nurseries, each genotype is represented by 5-10 plants which are inter planted with the selected control clones, ensuring proper identity of the accessions. Selected genotypes are also being conserved and evaluated in a phased manner in field conservation gardens.

In the conservation nurseries at RRII, one plant per genotype is allowed to grow without regular pruning in order to gather early information on tree habit, flowering pattern, floral characteristics and seed morphology. Madhavan *et al.*, (1997) identified two off types exhibiting variations in flower colour, presence of a prominent disc at the base of the staminal column, shape of fruits and seeds.

Though cryopreservation protocols for the long-term storage of germplasm have been developed for various field crops, attempts in this direction are rather scanty in *Hevea*. IPGRI (International Plant Genetic Resources Institute) has recently reported the establishment of two efficient cryopreservation protocols for the embryogenic calli of *Hevea*. Under optimal conditions, high survival rate and rapid regrowth of cryopreserved somatic embryos, compared to the control was observed (Englemann *et al.*, 1997). Feasibility of this *in vitro* technique as a convenient and secure alternative to the present *ex situ* method of conservation of the large collection of *Hevea* germplasm, needs to be established.

Characterization and Evaluation of Germplasm

Studies on the 1981 collections established in conservation nurseries and/or field evaluation gardens, are underway in the different Institutes across the world, where they have been introduced and established. The genotypes are subjected to preliminary characterization and evaluation in source bush nurseries laid out employing augmented design. Selections for specific characters are then planted in field trials employing suitable statistical designs.

With the objective of characterization of the wild germplasm, a *Hevea* descriptor has been prepared for the first time in India. The descriptor includes passport data, plant type description at juvenile phase and data on relevant quantitative and qualitative characters expressed in subsequent phases of growth. Abraham *et al.*(1994) reported morphological characterization of the wild germplasm at the juvenile phase.

Based on D^2 analysis for yield and various yield components a set of 40 and 35 mature Wickham clones were grouped into eight (Mydin *et al.*, 1992) and nine (Abraham *et al.*, 1997) genetically divergent clusters. Data on early growth, dry rubber yield and important bark structural parameters of the five IRCA (Institute de Recherches Sur la Caoutchouc) clones from Ivory Coast indicate their superiority over the popular clone RRII 105, with IRCA 130 being the best among the five (Reghu *et al.*, 1997).

Preliminary studies at RRII, revealed wide variability in the wild germpalsm with respect to a set of morphological and structural parameters as well as juvenile yield (Annamma *et al.*, 1988;1989; Abraham *et al.*, 1992; Madhavan *et al.*,

1993; Mercy *et al.*, 1993). Genotype MT 999 has been identified as a superior one, with respect to the number of latex vessel rows and diameter and cross sectional area of laticifers (Abraham *et al.*, 1992; Reghu *et al.*, 1996) and the genotypes MT 1650, RO 1269, AC 2016 were more vigorous than the control clone RRII 105 (Mercy *et al.*, 1993). The data generated so far has also been analyzed to study the degree of association between different characters, and their direct and indirect effects on yield (Madhavan *et al.*, 1996). In general, the wild genotypes recorded poor yield, as compared to the domesticated control clones. Similar results have also been reported from Malaysia, (IRRDB 1996), Ivory Coast (Clement-Demange *et al.*, 1997) and Vietnam (Lam *et al.*, 1997).

Evaluation of provenance wise performance of the wild accessions for various morphological and anatomical traits and juvenile yield revealed that the genotypes from the provenance of Mato Grosso, were found to be superior in performance, compared to those from Acre and Rondonia (Reghu *et al.*, 1996; Mercy *et al.*, 1993). Similarly, in a source bush nursery, genotypes from Mato Grosso exhibited superior field tolerance against shoot rot disease caused by *Phytophthora* sp. compared to Acre and Rondonian genotypes (Mercy *et al.*, 1995). Lam *et al.*, 1997, also reported superiority of Mato Grosso genotypes over those from Acre and Rondonia, in Vietnam. In Malaysia, however, Rondonian genotypes recorded superior yield compared to the other two provenance (IRRDB, 1996).

A set of 175 wild genotypes were grouped into 3 distinct classes of low, medium and high performers using index-score method and metroglyph analysis based on certain growth characters. (Mercy *et al.*, 1993). Another set of 100 genotypes grouped into five clusters using D^2 analysis revealed that the genetic diversity is independent of the geographic origin. Acre genotypes had a wider distribution in the clusters compared to the other two provenance, indicating the existence of greater genetic diversity among the Acre genotypes (Abraham *et al.*, 1995)

Identification of desirable genotypes for qualitative and quantitative timber traits from the wild germplasm has been recognized as a priority area since rubber wood has been accepted as an alternate source of commercial hardwood. The search for vigorous genotypes, which have potential for timber and productivity, has been initiated in various countries (Clement-Demange *et al.*, 1997; Lam *et al.*, 1997; IRRDB, 1996). Screening of the wild genotypes for timber-latex traits has also been envisaged at the RRII In India, Acre and Rondonia genotypes were observed to be more vigorous with the main trunk growing straight with very little branching, which is a desirable feature for timber-latex clones whereas, the growth habit of genotypes from Mato Grosso resembled more to Wickham clones, with more intense branching and comparatively less vigorous growth. Similar observations were reported from Ivory-Coast also. (Clement-Demange *et al.*, 1997).

Selected accessions from the preliminary studies are being subjected to field evaluation, in a phased manner, for their performance in terms of growth characters, structural parameters, rubber yield, incidence of major diseases and other desired secondary parameters. The micromorphological and histological parameters also supplement the selection of potential genotypes for hot spot screening for resistance to various abiotic factors.

Documentation of Germplasm

Being the national agency dealing exclusively with all the research activities related to *Hevea* germplasm, RRII maintains a National Accession Register, with all the relevant basic data like accession number, genotype code, donor identification number and date of introduction. In order to store, use and retrieve information on the large volume of data being generated in the course of the elaborate evaluation process of *Hevea* germplasm, RRII has initiated steps to prepare an extensive and user friendly data base of *Hevea* germplasm.

Genetic Improvement

Heave breeding is aimed at synthesis of ideal clones with high production potential combined with desirable secondary attributes like initial vigour, smooth thick bark with a good latex vessel system, good bark renewal, high growth rate after opening, tolerance to major diseases, wind, tapping panel dryness(TPD), good response to stimulation and low frequency tapping (Varghese, 1992.). Since rubber is predominantly a small holder oriented crop, the breeding objectives should take care of their specific requirements too.

Utilization of Wickham germplasm

The conventional methods of genetic improvement viz., introduction, selection and hybridization are followed in *Hevea*.

Introduction of exotic clones

Clones introduced from other rubber producing countries form the base material for genetic improvement programmes so far in different Rubber Research Institutes.. Recent introductions under bilateral and multilateral clone exchange programmes organized by IRRDB (International Rubber Research and Development Board) and ANRPC (Association of Natural Rubber Producing Countries) are confined to potential clones of good performance. Popular clones of exotic origin are evaluated under the local agro-

climatic conditions and promising selections are recommended for large scale planting. In India, a total of 127 domesticated clones, originating from eight different countries, form the exotic component of the original gene pool.

Ortet selection

Ortet selection or mother tree or plus tree selection is the oldest breeding method aimed at systematically screening for outstanding seedling genotypes resultant of natural genetic recombination. Screening of extensive plantations in Indonesia, Malaysia and Sri Lanka resulted in a good number of primary clones of importance like Tjir 1, PR 107, GT 1, BD 10, AVROS 255, Gl 1, PB 28/59, Mil 3/2, Hil 28, PB 23, PB 25, PB 86 etc. of which clones GT 1, PB 28/59 are still planted widely. In India, ortet selection resulted in the identification of 46 primary clones of RRII 1 series. Among these RRII 1, RRII 2, RRII 3, RRII 4, RRII 5, RRII 6, RRII 43, RRII 44 are the selections for high yield (Marattukalam *et al.,* 1980). RRII 33 is a clone, resistant to abnormal leaf fall caused by *Phytophthora* sp. Further, a total number of 195 selections from different estates have been established in the small-scale trials for preliminary evaluation (Mydin *et al.,* 1990). Since seedling orchards are increasingly being replaced with modern clones, further extensive screening for yield, resistance to disease and drought in traditional and non-traditional areas is given priority.

Hybridization and clonal selection

Controlled pollination was started in Malaysia (1918), Sumatra (1920), Brazil (1937), Sri Lanka (1939) and Indo China (1947) (Panikkar *et al.,* 1980). In India hybridization programmes were initiated in 1954 and the early hybrid clones developed include RRII 100, RRII 200 and RRII 300 series.(Annamma *et al.,* 1990). Among the RRII 100 series, RRII 105 is a very promising selection.(Nair and George, 1969; George *et al.,* 1980; Nazeer *et al.*, 1986), with wide popularity in the rubber planting sectors. Clones RRII 203 and RRII 208 are the best selections in RRII 200 series (Saraswathy Amma *et al.,* 1980) and RRII 300 and RRII 308 in the 300 series (Premakumari *et al.,* 1984). Among another recent hybrid series under evaluation trial, nine clones revealed comparable/marked heterotic improvement during the mature phase with a yield increase ranging from 4 – 50% over the high yielding standard clone RRII 105 (Licy *et al.,* 1996). In a recent report on 24 hybrid clones, evaluated at 44 months age, 12 clones exhibited a heterotic increase of over 20% for yield, which offers much scope for exploitation of hybrid vigour (Varghese *et al.,* 1997).

The Rubber Research Institute of Malaysia developed clones RRIM 500 to RRIM 1000 series, while Prang Basar Institute in the private sector selected certain PB clones of commercial significance. The Indonesian Research Institute for Estate Crops in Java and Sumatra (BPM) evolved PR, AVROS, BPM, LCB, PPN and RR clones.

Apart from the conventional breeding methods, special techniques in breeding like polyploidy, mutation and *in vitro* culture has also been attempted in *Hevea.* Induction of polyploidy and mutation has been attempted on a limited scale (Saraswathy Amma *et al.,* 1984). By crossing diploids and tetraploids, a triploid has been synthesized from the clone RRII 105 (Saraswathy Amma *et al.,* 1980) and a spontaneous triploid also has been identified (Nazeer and Saraswathy Amma, 1987). The progenies of a genetic variant with compact crown (John *et al.,* 1995) is being incorporated in breeding programmes for altering the tree architecture with the objective of combining yield and compact canopy for high density planting.

Prepotency

As prepotency is comparable to General Combining Ability, identification of prepotent clones has been given due importance in *Hevea* breeding., as these can produce superior seedling progeny under open pollination. Specially designed polyclonal seed gardens, with prepotent component clones, yield superior polycross progenies for use as planting material and also as base material for ortet selection. On the basis of these studies, nine prepotent clones viz. AVT 73, RRII 105, PB 28/83, Ch 32, PB 215, PB 242, BD 5 and PB 252 have been identified.(Mydin *et al.*, 1990)

Clonal composites

In India, in the past two decades, the outstanding high yielder RRII 105 was planted extensively in traditional rubber growing belts, leading to a tendency towards monoculture. Considering the serious consequences of monoculture, a strategy for multiclone planting with suitable clonal composites is being propagated. Rubber Board of India is now recommending to restrict the planting of RRII 105 to 50% of the total area and to plant the remaining area with promising clones in Category II (upto 35%) and Category III (upto 15%). Several experiments have been laid out with different clonal combinations in traditional and non-traditional rubber growing areas to identify suitable clonal composites. There is no doubt that development of clone blends of diverse genetic materials will offer better protection to the plantation industry from the possible disasters due to monoculture in future.

Utilisation of wild germplasm

Characterization and evaluation of the large number of wild germplasm resultant of the 1981 IRRDB (International Rubber Research Board) prospection is in progress in different countries. Due importance has been given for the best utilization of the wild genotypes identified for various desirable characters. Among 12 cross combinations involving

wild genotypes and popular cultivars, juvenile yield at two years growth was highest in a hybrid from the cross RRII 105 X RO/87 (RRII, 1994). Nine wild genotypes identified for their superiority in growth/ anatomical characters and resistance to *Phytophthora* sp. have been used as male parents in a hand pollination programme incorporating Wickham and Amazonian clones. In Malaysia, progenies derived from crosses between oriental clones (RRIM 600, RRIM 701 and PB 5/51) and selected 1981 germplasm tapped for five cycles in the nursery, produced quite encouraging results for girth and yield. (IRRDB, 1996).

Resistance to biotic and abiotic stresses.

Scarcity of ideal land in the traditional rubber growing tracts has necessitated expansion of rubber cultivation to non-traditional and marginal lands, exposed to various biotic and abiotic stresses. Hence development or selection of location specific genotypes is of international importance.

The genetic potential of the wild germplasm for specific desirable traits has already been realized from the preliminary studies in India and other countries. Various fungal diseases limiting plant growth and yield in South East Asia, include those caused by *Phytophthora* sp., *Oidium* sp., *Corynespora* sp.and *Colletotrichum* sp. Identification of sources of resistance to all these diseases is the immediate priority. In India, screening of wild genotypes for resistance to major diseases caused by *Phytophthora* sp. and *Oidium heveae* are progressing. Due attention is being given to search for resistant sources for the *Corynespora* leaf spot disease, in the backdrop of the recent reports on the severity of the disease in certain parts of traditional rubber growing tracts. Laboratory screening of a population of 495 wild genotypes for resistance to *Phytophthora* sp. showed interesting results, with 53 genotypes showing high levels of resistance (RRII, 1997). Studies carried out in Indonesia on the wild germplasm have identified genotypes with resistance to *Colletotrichum* leaf diseases (Alwi and Suhendry, 1992).

Although SALB, the most disastrous disease of *Hevea* is presently confined to South America, the possibility of the disease entering the eastern hemisphere cannot be ruled out. Hence attempts are essential for identification of an array of genotypes having resistance to the various physiological races of the fungus. The existence of a general resistance to SALB in the Amazonian clones, compared to the total susceptibility of Wickham clones has been reported from French Guyana. In Ivory Coast, the hybrid population of Wickham X Amazonian crosses is reported to show continous variability for resistance to SALB (Clement-Demange *et al.*, 1997).

Abiotic stress conditions like drought, cold, high velocity wind etc. prevalent in the nor traditional and marginal areas warrants the necessity of developing clones capable of withstanding such extreme situations. In India, hot spot screening of preliminary selections of wild germplasm for drought tolerance is in progress. Screening of wild genotypes for membrane thermostability has indicated positive results with certain genotypes showing remarkable tolerance to water and temperature stresses.

Screening of the wild germplasm for cold tolerance revealed that 38 genotypes recorded higher tolerance than the Chinese cold tolerant line SLATC 93-114 . Similar evaluation of 5164 wild accessions revealed that 50 of them were more cold tolerant than SCATC 93-114 of which 10 survived a cold treatment even upto -2^0 C.(Lin *et al.* 1994)

Application of Molecular Techniques

Recent advances in molecular techniques like Restriction Fragment Length Polymorphism (RFLP), Random Amplified Polymorphic DNA (RAPD), and Simple sequence Repeats (SSR) or microsatellites offer reliable, fast and attractive adjuncts to the elaborate conventional procedures. This is especially significant in vegetatively propagated perennial spp. like *Hevea* where conventional genetic analysis is difficult due to the long breeding and selection cycle and difficulties in raising the F2 progeny. Molecular genetics has an important role to play in many aspects of conservation such as the detection, characterization and evaluation of plant genetic diversity for purposes of improved acquisition, maintenance and utilization (Kresovich *et al.*, 1992; Karp *et al.*, 1997). These DNA based diagnostics are now well established as a means to assay diversity at the locus, chromosome and whole genome levels for screening nucleotide sequence based polymorphism.

In *Hevea*, studies on the application of molecular markers, have been initiated and a few reports on the potential use of this powerful technique are available. Genetic diversity among wild and cultivated populations of *Hevea* was assessed using izozymes, (Chevallier et al., 1988) RFLP analysis (Besse *et al.*, 1994) and mitochondrial DNA analysis (Luo *et al.*, 1995). Significant genetic distance, between the 1981 germplasm and the Wickham group using Isozyme or RFLP/ RAPD had also been reported. (Clement-Demange and Nicolas, 1987). Wild populations appeared to be more polymorphic than the cultivated ones, the Rondonia and Mato Grosso genotypes being the most variable with RFLP (Besse *et al.*, 1994). RFLP analysis on wild genotypes and cultivated clones indicated that the wild ones have led to the enrichment of genetic resources and that the cultivated clones have conserved a relatively high level of polymorphism despite its narrow genetic base and high level of inbreeding. Variation in RAPD profile between TPD affected and normal plants

(Thulaseedharan *et al.*, 1994), *Oidium* resistant and susceptible genotypes (Shoucai *et al.*, 1994) and for *Phytophthora* leaf fall (Jacob, 1996) were observed.

In a recent study, the applicability of RAPD markers for genetic analysis in *Hevea* was evaluated using 42 informative primers in a set of 24 clones from the breeding pool of RRII (Varghese *et al.*, 1997). Estimation of genetic distance among the tested clones facilitated identification of genetically divergent clusters. Among the different clones tested, RRIC 100 displayed the highest mean genetic distance of 0.616. Use of this clone as a parent in hybridization programs has resulted in highly heterotic hybrids (Licy *et al.*, 1996). Regular use of such techniques will be of great help in the management of large number of germplasm for assessment of genetic identity, structure and variability among accessions. Work on these lines has been initiated at Rubber Research Institute of India.

Future prospects

Recognizing the urgent need for broadening the original narrow base, in *Hevea*, a major expedition to the centre of diversity made in 1981, collected a large number of wild germplasm which is under conservation and evaluation in the different rubber producing countries. Presently these accessions are conserved *ex situ*, which, however, is prone to natural calamities. Hence feasibility studies on alternate *in vitro* methods viz. Cryo-preservation are envisaged. Similarly, for characterization and evaluation, an optimum number of descriptors, which are highly heritable should be utilized. A set of descriptors for *Hevea* has been suggested for the first time in India, which has to be updated/ modified from time to time so as to accommodate all relevant traits of importance. Attempts are underway to develop a computerized database of *Hevea* germplasm, which will be of much help in supplementing the elaborate manual documentation system.

In *Hevea*, hybridization between widely divergent genotypes has resulted in greater range of variability especially in view of the highly heterozygous nature of the crop. Early performance of the progenies of such crosses has indicated promise. However, further systematic studies are required for the identification of wild genotypes with desired traits for introgression into cultivated clones.

It is all the more significant for development of location specific clones capable of withstanding different constraints prevalent in non traditional areas, like extremes of temperature in winter and summer, prolonged drought, high velocity winds and occasional hailstorms, high altitudes, depleted and soils. In India, the non-traditional areas include the northeastern states like Tripura, Assam and Meghalaya, Jalpaiguri District of W.Bengal. Konkan region of Maharashtra , Goa and selected areas in the states of Orissa and Andhra Pradesh. Regional Research Stations have been established in most of these states, to give research back up for scientific rubber cultivation. Wild germplasm is definitely a source of many valuable genes capable of withstanding the above mentioned stresses. The challenge before the breeder lies in evolving strategies for identifying these genes and incorporating them into high yielding clones. Studies have been initiated in this direction.

In spite of the creditable improvement of productivity within a short span of time utilizing the Wickham base, theoretical conclusions indicate more potential in terms of yield. (Sethuraj *et al.*, 1981). Various factors responsible for this gap need to be identified and steps taken to overcome the constraints. Due to the occurrence of significant G X E interaction, trials should be conducted in diverse environments for proper evaluation of genotypes. In addition to utilization of wild germplasm, multidisciplinary investigations assume importance in order to bridge the gap between the theoretical maximum and the present day yield. The prepotency concept and the principle of clonal composites still hold much importance for the future rubber crop improvement in the country.

Molecular techniques like RFLP, RAPD and microsatellites have already been deployed for the analysis of the extent and distribution of genetic diversity among Wickham and wild germplasm. These markers provide reliable genetic information for molecular characterization, evaluation and utilization of germplasm resources. Data on genetic distance is required for identification of diverse sub-populations.

Application of molecular markers can be a valuable adjunct to conventional breeding for better exploitation of the available genetic variability in the Wickham gene pool and the wild germplasm to bring about further significant genetic improvement.

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Biotechnology of Plantation Crops

R.D. Iyer

Introduction

The plantation crops being perennial in nature with a long prebearing age, generally outcrossing heterozygous populations, large experimental area and labour requirement throughout the year, present certain unique problems and challenges to the plant breeder engaged in crop improvement. Some like tea and cocoa which are self-incompatible, pose difficulties in developing inbred lines and early fixation of hybrids. The areas where we can use biotechnology are (Iyer, 1995):

- Use of cell, tissue and organ cultures for rapid clonal multiplication of elite, disease-free selections, *via* somatic embryogenesis and to screen for resistance / tolerance *in vitro*.
- Use of in vitro gene banks for conservation of native and exotic genetic resources and safe transfer of germplasm free from quarantine risks.
- Use of molecular markers to characterize cultivars, hybrids and elite disease resistant/tolerant selections from hot spots, for effective marker-assisted selections, subsequent gene cloning and transfer and to construct linkage maps to identify genomic regions controlling desirable traits.
- Use of haploids obtained through anther/pollen culture to develop isogenic inbreds for use in heterosis breeding and linkage analysis, especially in self-incompatible crops.

Palms

The palms, belonging to the order Palmae include commercially important coconut (*Cocos nucifera* L.), arecanut or betel nut (*Areca catechu* L), oil palm (*Elaeis guineensis* Jacq.) and palmyrah or toddy palm (*Borassus flabellifer* L.) and other ornamental palms. However biotechnological work on palms is mainly confined to coconut and oil palm.

The protocols for oilplam and coconut have been worked out. Oil palm clones derived from leaf/inflorescence culture have been commercialized by CIRAD (France). Success in coconut has been reported from seedling leaf tissues (Raju *et al.*, 1984), and inflorescence tissue (Blake, 1991; Hornung and Verdeil, 1997). Verdeil *et al.* (1989, 1992, 1993, 1994) and Rillo and Ebert (1993) have been successful in achieving regeneration in coconut. Plumular explants have given higher rates of reproducible somatic embryogenesis and regeneration (Oropeza *et al.*, 1997). Discussing the possible applications of coconut micropropagation, Verdeil *et al.* (1998) enumerate current limitations of protocol as poor embryo germination (7%), slow plantlet development making acclimation difficult, low recovery of *in vitro* plants (max. 20 from initial explants) and high cost involved.

Protocols for storage (Anitha Karun & Sajini, 1994, Batugal and Engelmann 1998, Anitha Karun *et al.*, 1998) and retrieval of coconut (Assy-Bah *et al.*, 1989, 1991) embryos have been standardised. Success has been achieved on the routine use of embryo culture for field collection. Koshy and Kumaran (1997; Anonymous, 1998) successfully collected 1342 embryos of Tall and Dwarf accessions from Indian Ocean Islands, in sterile distilled water and nearly 90% of these could be retrieved. The future priority should be to standardize cryo-storage methods using liquid nitrogen, so that *in vitro* gene banks will become a distinct possibility (Engelmann, 1997).

Our future research on *in vitro* culture of palms should be directed towards finding answers for: (1) reduced response of adult palms vs. juvenile seedling tissues, (2) trigger for callus-mediated vs. direct somatic embryogenesis, from leaf/inflorescence tissues, (3) role of antioxidants and activated charcoal (AC), in prevention of browning vs. absorption of growth factors and inhibitory chemicals like ethylene, or 5-hydroxymethyl furfural produced by sucrose dehydration, and of growth promoting auxins like 2,4-D. There is evidence that AC adsorbs 99.5% of the ^{14}C labeled 2,4-D by 4th day, leaving only 0.5% available for uptake by the explant (Ebert & Taylor, 1990), especially in liquid as against semi-solid media. Higher temperatures (20-30°C) and low pH of medium accelerated adsorption of 2,4-D by AC. Similar studies are needed to track the fate of other growth factors like cytokinins and vitamins to ascertain if they become growth limiting due to adsorption by AC (Ebert *et al.*, 1993).

Another aspect of *in vitro* culture that deserves our intensive attention is the production of haploids through anther/pollen culture, where preliminary success has been reported in India (Iyer, 1982), Philippines (Thanh Tuyen &

Guzman, 1983; Thanh-Tuyen, 1985), and France (Monfort, 1985), upto the pollen embryoid stage. The production of haploids and isogenic diploids in coconut and other palms will greatly accelerate the pace of our heterosis breeding and genetic engineering programmes to evolve rare recombinants.

Oil quality is another aspect, which needs attention in near future. In *tenera* oil palm hybrids, variation has been recorded in the ratio of saturated vs unsaturated fatty acids. In the annual oilseeds like rape (*Brassica rapa)* and *Arabidopsis,* possibilities are indicated, of evolving "designer oilseed crops" through the induction of useful oil-quality mutations in *Arabidopsis thaliana* and their subsequent transfer into rape species by a process known as 'shuttle mutagenesis' (Robbelen, 1991; Murphy, 1991; Ashri, 1992, 1993). Mutants for fatty acid composition have already been induced in *Arabidopsis* (Browse, 1989). Another possible way of integrating mutation breeding and genetic engineering is being considered in *Sesamum,* whose oil contains a natural phenolic anti-oxidant, 'sesamol' derived from sesamolin, which is being considered for reducing oil oxidation and prolonging shelf life of all vegetable oils. If genes controlling sesamol biosynthesis in *Sesamum* could be identified isolated and transferred to other oil plants and expressed, their oil stability can be greatly improved.

Similar attempts are being made in oil palm to study the lipid metabolism. Callus cultures of oil palm have been used to study the formation of a storage lipid whose biosynthesis was monitored by incubating the cells with ^{14}C - acetate and determining radioactivity in the triacyl glycerol fraction of labeled lipids formed (Turnham & Northcote, 1984).

Success in these efforts will possibly lead to development of genotypes that will produce 'tailor made' oils of specific fatty acid ratios to meet the needs of the edible oil (for human consumption), and of the industrial consumers for soap manufacture and other chemical industries and we may witness a shift from "petrochemistry" to "botanochemistry" as predicted by Pryde and Rothfus (1989), so that both developed and developing countries will stand to benefit from such a shift.

Breeding for tolerance to biotic and abiotic stress is anothjer area where biotechnology can contribute significantly. Among the biotic stress factors, phytoplasma incited diseases of palms, such as lethal yellowing (LY) of coconut in Jamaica, coconut root (wilt) disease (RWD) in Kerala, spear rot of oil palm, yellow leaf disease of arecanut (YLD), and Tatipaka disease of coconut in Andhra Pradesh, are the major diseases.

The disturbing factor is the wide host range of phytoplasma which not only affects coconut but several other palm genera. In a study conducted in Mexico, phytoplasma were detected in coconut palms of Yucatan Province, using radiolabelled cloned DNA probes (Harries, 1991). They found that two probes LYI-43 and LYD-9 containing DNA segments from a Florida LY phytoplasma, hybridized at moderate frequency with DNA extracted from 6 Yucatan LY-diseased but not healthy palms, thus suggesting similarities between LY phytoplasma from Yucatan, Mexico, and LY phytoplasma from Florida, USA.

In India also, the phytoplasma of coconut RWD, arecanut YLD and oil palm spearrot appear to be similar as they can cross-infect all the three hosts (Anon., 1995). This makes it all the more difficult to keep constant vigil of mixed plantations, or contiguous plantations of coconut, arecanut and oil palm, to detect any possible disease appearing. Only through molecular analyses one can unravel the real identity of the three phytoplasma and the nature of homology/ dissimilarities among them.

Harrison *et al.* (1992) cloned and identified 5 Eco RI restriction fragments comprising chromosomal DNA of phytoplasma associated with lethal yellow (LY) disease of Manila palm *(Veitchia merrillii)* occurring in Florida. When used individually as (^{32}P)d ATP - labeled probes in dot and Southern hybridizations at high stringence, four or five probes consistently hybridized to DNA extracted from LY-affected palms only. However, at moderate stringency, all probes hybridized with DNA of other phytoplasma that occur in Florida, and 3 probes also hybridized to DNA of several *Acholeplasmas* and/or *Spiroplasma* species. In addition to Manila palms, the probes also detected the presence of LY phytoplasma DNA in DNA samples extracted from heart tissues of LY affected true date *(Phoenix dactylifera),* cliff date *(P. nupicola),* chinese fan palm *(Livistona chinensis),* and five coconut palm cultivars. Probes also hybridized to DNA from symptomatic *Caryota rumphiana* and *Livistona rotundifolia,* two palm species previously not known to be affected by LY mycoplasma. This extends the known host range of LY phytoplasma and increases our understanding of epidemiology of the disease. These probes may be useful in identification of primary and alternate plant hosts and insect vector(s) as both the probes and the diseases are further characterized.

Similarly, molecular diagnosis has been developed for the viroid agent of Cadang-Cadang disease (CCCVD) of coconut in southern Luzon of Philippines (Hanold & Randles, 1991a,b; Maromorosch, 1993). Several other herbaceous monocots growing near coconut also contained viroid-like molecules with similar DNA sequence as CCCVD. These authors have cautioned against unrestricted movement of germplasm following their recent identification of CCCVD-

like sequence in the Pacific region, far away from Cadang Cadang area. Even embryo/tissue cultures of coconut and oil palm should be derived only from material tested for freedom from viroid. Rillo *et al.* (1988) have used *in vitro* cultured embryos to screen coconut populations for resistance to cadang-cadang.

Cashew

Cashew (*Anacardium occidentale* L.), a native of Brazil, has acclimatized well in India and it is one of the important plantation crops of Kerala. Biotechnological approaches in cashew have not advanced much. The areas where biotechnology would be of importance in cashew are: (1) intensification of research on somatic embryogenesis and plantlet regeneration which could subsequently be useful for genetic transformation to introduce genes for resistance to (a) tea mosquito, and (b) cashew stem and root borers, (2) standardization of micrografting techniques for building mother blocks of elite orchards for supply of scion materials and (3) molecular characterization of existing genetic diversity.

One of the major objectives in cashew improvement is to achieve stability of performance in diverse environments. However, it is not possible to pinpoint the specific gene combination or complex, which has contributed to the consistently stable performance of this variety over diverse locations. The use of modern tools of biotechnology such as RFLP/RAPD/AFLP markers can certainly help in identifying specific Quantitative Trait Loci (QTLs) which determine the high performance of varieties. The work in this direction has been initiated for characterising Tanzanian Cashew germplasm using RAPDs. The molecular markers available at present are many and suitable markers have to be identified for characterizing and tagging genes controlling kernel quality, and resistance to pests and diseases.

Micropropagation of cashew using shoot tips of seedlings has been reported recently by Hegde *et al.* (1998). Thimmappaiah and Shirly (1998) have reported limited success with mature-tree explants.

Use of tissue, cell and anther culture in cashew, should not be looked upon merely for generating clones of elite trees, both as rootstock as well as scion material. Efforts should also be directed towards developing a cell-suspension system, for induction and multiplication of somatic-embryos. The problem of browning particularly of adult tree tissues can be overcome to a great extent, by the use of liquid cultures under dark incubation, and use of chemicals like phenyl-3 methyl-5 pyrazolone, ammonium chloride, urea and sugar to remove inhibitors secreted by explants, which on reaching a certain threshold value inhibit the growth of tissues, bud-break and elongation. Successful *in vitro* micrografting a subsequent transfer of grafts to soil has been reported Kesavachandran *et al.* (1998).

Bud culture in cashew has given only a limit number of shoots, and increase in dose of cytokinin oft resulted in fasciated micro-shoots. However, lowering B levels and increase of sucrose, has induced elongation microshoots (D'Souza *et al.*, 1994). Recently, Cardoza a D'Souza (1998) have studied salt tolerance of multiple shoot

Immature cotyledon segments have given dire somatic embryogenesis without any intervening callus, or ver incipient callusing. This system if augmented and mad regular can be used for basic studies on somati embryogenesis, as also in encapsulation studies for developin protocols for germplasm storage both under limited growth conditions as well as cryostorage. Thimmappaiah and Shirly (1998) have reported 2-6 buds/explant of nodal segment excised from mature trees, on media containing Thidiazuron or BAP + GA + IBA.

There is a long standing need in cashew for developing haploids and isogenic lines to facilitate heterosis breeding as well as for gene transfer experiments. The major limitation in achieving *in vitro* androgenesis is the availability of only a single fertile anther whose size is quite small at the uninucleate microspore stage of the buds. Tea mosquito infestation compounds the problem further resulting in severe browning and contamination. Screening of cultivars and hybrids against tea mosquito-incited toxin, and further multiplication of the resistant selections is a priority area where tissue and cell culture combined with molecular techniques will pay dividends. The greatest advantage is the natural propensity for obtaining cashew grafts in large numbers, for which bio-technology approaches would help to supplement the additional requirement of scion shoots as well as root stock materials generated *in vitro* (Thimmappaiah *et al.*, 1999).

Beverage Crops

Tea, coffee and cocoa as a group form ideal model systems for combining conventional breeding with modern tools of biotechnology and genetic engineering for crop improvement, since the protocols for *in vitro* multiplication of elite materials have been perfected.

Tea

Tea (*Camellia sinensis (L)* O. Kuntze) is an important plantation crop. The major areas where biotechnology would be useful in tea improvement are: (i) micropropagation for mass multiplication of elite tea clones, (ii) application of molecular markers for characterizing tea

clones as well as QTL, (iii) genetic engineering for developing resistance to tea blister blight (*Exobasidium vexans)* and (iv) identification, characterization and gene transfer for low caffeine tea.

Protocols have been developed for micropropagation, somatic embryogenesis and their encapsulation to produce synthetic artificial 'seeds' of tea (Sood *et al.*, 1993; Manivel, 1993; Rajasekharan and Mohankumar, 1992; Rajkumar and Ayyappan, 1992; Rajkumar and Marimuthu, 1998; Haridas *et al.*, 1998). Tea plantlets have been successfully induced from cotyledon callus (Wu, 1976; Wu *et al.*, 1982) and from stem callus (Kato, 1985). Production of shoots and buds has been achieved using nodal explants (Phukan & Mitra, 1984). Tea being self-incompatible, it would be worthwhile producing haploids and homozygous diploids using anther/pollen culture technique, and preliminary success was reported up to the multicelled pollen stage and haploid callus formation (Raina & Iyer, 1974, 1983; Chen & Liao, 1987).

Evolving low caffeine tea with improved solubility, which involves the application of both conventional breeding as well as molecular tools, to unravel the molecular biology of cell wall polymers and architecture. Possibility of transferring low caffeine genes from other *Camellia* sp. should be explored both through conventional hybridization and transgenic approaches to modify the biosynthetic pathway for caffeine synthesis by using antigens RNA technology.

In vitro approaches for evolving drought tolerant teas are being followed at the UPASI Tea Research Institute, where, protocols for rapid clonal multiplication have been developed in four cultivars (Manivel, 1993). Induction of variation for selecting drought tolerant somaclones through irradiation or chemical mutagens, has been attempted using UPASI-3 clone. Omatic cell hybridization using protoplast fusion has been tried to transfer the Darjeeling tea flavour of 'China' clones to the Assam cultivars possessing strong and brisk liquors, (Banerjee, 1986; Balasubramanian *et al.*, 1998). Tea being a dicot species, it would be worthwhile pursuing *Agrobacterium* mediated transformation as the choice gene delivery system. Tea regeneration from both shoot tips and cotyledonary callus-derived somatic embryos has been reported from Japan (Nakamura, 1986). Recently Haridas *et al.* (1998) have reported 14% frequency of somatic embryogenesis produced directly or *via* callus on a nutrient medium containing BAP and NAA. Breeding for resistance/ tolerance to blister blight fungus *(Exobasidium vexans)* would be facilitated if the *in vitro* system is employed for evaluating and screening fungicides, as also the resistance of the tissues to various races of the pathogen (Agnihothrudu & Chandra Mouli, 1991). Raj Kumar and Marimuthu (1998) have reported that tissue culture clones were more vigorous than vegetatively propagated tea plants, and produced higher number of laterals in response to centering and tipping.

Coffee

The major constraints to coffee production and quality where biotechnological tools can offer solutions are: (1) development of resistance through genetic engineering techniques for fungal diseases particularly *Hemileia vastatrix* (leaf rust), (2) introduction of *Bt* genes for control of coffee berry borer *Hypothenemes hampei* Ferrari, and stem borer *Xylotrechus quadripes,* (3) use of embryo rescue techniques for interspecific crosses from resistant species like *C. stenophylla* for leaf miner and some species resistant to nematodes (Medina *et al.,* 1984) and (4) development of tools for quality improvement for uniform maturity, short-maturation cycles, high soluble solids, large bean size and increased bean density and texture (Sondahl and Loh, 1988), better aroma and low caffeine content.

Biotechnological research carried out in coffee has resulted in development of protocols for somatic embryogenesis, micropropagation, molecular markers and genetic transformation. Sondahl and Lauritis (1992) have presented a comprehensive review on coffee biotechnology. Since the successful induction of somatic embryogenesis in *C. canephora* by Staritsky (1970), numerous reports have appeared on the successful regeneration of plantlets from somatic embryos. Sondahl and Sharp (1977) developed a two step method for somatic embryogenesis from leaf explants. Later it was modified by Neuenschwander and Baumann (1992) as Self Controlled Somatic Embryogenesis (SCSE). In India, Sreenath and his group (Sreenath *et al.,* 1995) obtained somatic embryogenesis from integument tissue of *C. canephora.* Staritsky and van Hasselt (1980) suggested a modified process for conversion of somatic embryos in liquid cultures. A later development was that of temporary immersion which is suggested for improvement of micropropagation through microcuttings as well as somatic embryoids (Berthouly *et al.,* 1995). The successful recovery of plants via somatic embryogenesis in several wild coffee species, five *C. arabica* cultivars and two interspecific hybrids demonstrates the potential of using *in vitro* methods for coffee improvement (Sondahl and Lauritis, 1992). Muniswamy *et al.* (1998) have reported high frequency somatic embryogenesis in Cauvery on 1/2 MS medium with 4% sucrose.

For micropropagation nodal orthotropic explants of *C. arabica* (Custers *et al.,* 1980) and apical meristems (Zok, 1985) have been used. Berthouly *et al.* (1987) developed a long term programme for nodal culture of coffee. Use of haploidy has also been exploited in coffee breeding (Neuenschwander *et al.*, 1993). Synthetic seed technology for encapsulating embryos in sodium alginate has been

developed. Anther culture technique has been successfully employed for callus induction and plantlet regeneration in C x R inter-specific hybrid between *C. congensis* and *C. canephora*, for rapid fixation of heterosis. Since the first attempt by Ocampo *et al.* (1991) a few others have indicated success in genetic transformation studies (Spiral and Petiard, 1991; Barton *et al.* 1991; Sugiyama *et al.* 1995). Work is on to develop the *Agrobacterium*-mediated transformation system using a leaf-disc procedure, and on protoplast isolation and culture from embryogenic calli of *C. arabica* and C x R hybrid (Mamatha and Sreenath, 1998). Transient transformation was demonstrated in callus derived from *Arabica* coffee protoplasts co-cultivated with *Agrobacterium* carrying NPT II and -glucuronidase marker genes under control of CaMV 35S promoter.

Protoplast culture and subsequent plant regeneration has great potentialities in coffee improvement. Sondahl *et al.* (1980) isolated protoplasts from leaf derived friable callus and recovered microcolonies. Yasuda *et al.* (1986) first reported plantlet development from protoplasts. Recently, Mamatha and Sreenath (1998) have isolated and cultured protoplasts from embryogenic calli of Cauvery and C x R cultivars. Considering the repeatability of protoplast regeneration systems, the utilization of useful genes for coffee improvement is now a near to mid-term possibility with a high degree of success.

Another area where biotechnology is used is cryopreservation. Subsequent to the initial attempt by Kartha *et al.* (1981), Jouve *et al.* (1991) reported low temperature preservation of *C. arabica* and cryopreservation of zygotic and somatic embryos of coffee was reported by Abdelnour *et al* (1993). Subsequently, a few more reports have appeared on cryopreservation (Florin *et al.*, 1995). Use of molecular markers in identification of diversity has been attempted only recently in coffee. Lashermes *et al* (1993, 1996, 1997) applied various markers like RAPDs, RFLP, ITS etc., for identifying genetic diversity. Santa Ram and Sreenath (1998) have initiated DNA fingerprinting studies to identify DNA markers which would distinguish each of the 13 different coffee-rust differential hosts available in the gene-bank of CCRI.

Cocoa

Cocoa (*Theobroma cacao* L.) a native of South America is grown for its delicious seeds used in chocolate and beverage industry. Its self-incompatible nature has resulted in a highly heterozygous population. This necessitates the standardization of clonal propagation for perpetuation of the high yielding materials. The genetic base of cocoa is narrow, necessitating introduction of genes from other species or even genera for various traits, particularly for disease and insect resistance. Some of the areas where biotechnology can be used for cacao improvement are: (1) micropropagation for mass-multiplication of elite materials, (2) application of molecular markers for genetic diversity and character tagging, (3) *In vitro* conservation technique for germplasm conservation transfer and retrieval, (4) application of anther culture techniques to produce pure homozygous lines and (5) genetic transformation for introduction of genes of interest.

Although conventional methods of clonal propagation such as budding, side grafting and rooting of cuttings and air-layers are possible in cocoa, they are relatively expensive and provide only a limited number of propagules. Hence, there is good scope for exploitation of tissue culture for rapid clonal propagation and crop improvement in cocoa, as a supplement to conventional propagation techniques. The recalcitrant nature of cocoa has been attributed to the nutritional factors and the presence of gum at the cut surface (Figueira *et al* (1991, 1992) while Dufour and Dublin (1985) attributed the recalcitrance to the production of ethylene. Figueira et al. (1991) found that a high CO_2 environment promoted shoot and root development in cotyledon-derived somatic embryos. Depletion of CO_2 level in tissue cultures during the day, was limiting photosynthesis. Shoot elongation and leaf development increased asymptomatically after 30 days, with CO_2 levels from ambient (470 ppm) to 28,000 ppm.

A large number of reports are available on micropropagation and somatic embryogenesis in cocoa (Esan, 1985; Flynn *et al.*, 1990; Mallika *et al.*, 1992). MS medium was found to be the best basal medium with silver nitrate and cobalt chloride supplementation for improved shoot regeneration with little callus at the cut ends (Mallika *et al.*, 1992). Cotyledonary nodes cultured on MS medium supplemented with casein hydrolysate along with BAP was also found to enhance proliferation (Janick and Whipkey, 1985). Mallika *et al.*, (1996) developed protocols for micropropagation of cocoa. Somatic embryogenesis from immature zygotic embryos has been reported by many workers (Pence *et al.*, 1979; Elhag *et al.*, 1987; Adu Ampomah *et al.*, 1988 and Kononowicz and Janick 1984). Other tissues wherein success have been obtained are embryonic axes (Esan, 1974), Cotyledons (Novak *et al.*, 1986 Mallika *et al.*, 1992), hypocotyl (Elhag and Elhag, 1986) nucellus (Sondahl, 1991), petals and flower buds (Lopez-Baez *et al.*, 1993). Abraham *et al.* (1992) standardized *in vitro* induction and growth of somatic embryoids from immature cotyledon segments cultured on Murashige & Skoog's (1962) medium supplemented with NAA and BAP (0.5 mg/l each) and coconut water (15%). Indulekha & Iyer (1993) observed direct somatic embryogenesis from immature cotyledon explants, at a 20% frequency, on MS medium containing NAA and BAP (0.5 mg/l each). These somatic embryoids on subsequent transfer to MS medium containing abscisic acid (0.026 mg/l), underwent maturation and greening process. Plantlet formation occurred on transfer to BAP (0.5 mg/l)

containing MS medium. In spite of large amount of work done on somatic embryogenesis, successful production of large number of plants using this method is yet to be reported. Similarly, attempts are being made since 1989 to effectively develop methods for genetic engineering of cocoa (Mirazon *et al.*, 1989; Sain *et al.*,1994; Guiltinan *et al.*, 1997). But as in case of somatic embryogenesis, the success is yet to be achieved on its commercial use.

Drought tolerance is a vital character to be desired in our cocoa breeding programmes, and screening has been done for drought tolerance using physiological parameters (Balasimha and Anil Kumar, 1998). The productivity of present cocoa gardens is only about 400 Kg/ha whereas the potential is more than 800 Kg/ha. Drought, disease and pest losses are the chief depressants of yield. Hence, there is good scope for selection of cultivars and hybrids possessing higher yields and tolerance to biotic and abiotic stresses (Balasimha and Anil Kumar, 1998). These studies will be greatly helped by the use of molecular markers for DNA finger printing of cocoa clones to select desirable cultivars. The use of molecular markers such as RAPD and RFLP has resulted in characterizing the cocoa germplasm. Lanaud *et al.*, (1995) constructed a genetic linkage map which has 193 loci while Crouzillat *et al.*, (1996) used back cross progenies to construct a map with 138 loci. The application of RAPD has also been well documented (Lerceteaue *et al.*, 1992; Ronning *et al.*, 1995). Another area of interest is the production of cocoa butter and flavours *in vitro*.

Rubber

Rubber *(Hevea brasiliensis)* is a perennial open-pollinated tree and is highly heterozygous in nature. As a perennial tree crop with a long breeding cycle, the conventional breeding employed is both time consuming and labour intensive. The isolation and fixation of any particular gene requires several generations of crosses and field trials carried out over many years. However, plant genetic transformation offers a viable alternative approach that will usefully complement the efforts of the plant breeder.

Research on somatic embryogenesis of *Hevea* was undertaken in seventies (Carron *et al.*, 1998). They were able to produce several thousand *in vitro* plantlets on an experimental level. Similarly, El Hadrami *et al.* (1991) produced several embryos and plantlets from mature tissue of trees and integuments of immature seeds. They found that excess of auxin and cytokinin in the medium, even of a weak auxin like 2,4-D, and prolonged exposure to these hormones suppressed embryogenic potential of the callus. Thus, instead of 9 M each of 2, 4-D and BAP in the control medium they used only 4.5, 2.25 or 0.45M each of 2, 4-D and BAP. After 40 days they were subcultured on a medium containing 0.45 M each of NOA and BAP. Germination of somatic embryos was obtained on Woody Plant Medium of Lloyd and McCown (1980) supplemented with GA_3 (2.9 M). High hormonal level present during induction of callus, previously thought necessary, was thus shown to be responsible for arresting somatic embryogenesis in recently divided cells. This effect may explain the reputation of rubber as a recalcitrant embryogenic species. Genotypic differences were also seen between the two clones in the accumulation and degradation of these hormones, which in turn explains the genotype variation in embryogenic potential. Asokan *et al.* (1988) have reported successful *in vitro* multiplication and field planting of Clone-1 in media supplemented with 1.5 -3 mg/l IAA and 0.5-1.5 mg/l kinetin.

If haploids could be generated in rubber through anther culture or unpollinated ovule culture, it would prove a valuable tool for improving rubber through biotech-breeding, resulting in superior genotypes and new recombinants stabilized through diploidized haploids (Zhenghua, 1990). Pollen derived plants from 13 different clones have been transplanted and established in the field (Shijie *et al.*, 1990). The pure lines (isogenic lines) thus obtained can be used in heterosis breeding by propagating self-rooting plants, or artificial 'seeds' from trees of good combinations by tissue culture propagation, which could replace budding with bench grafting (Marattukulam and Varghese, 1998). Kumari Jayasree *et al.* (1999) have reported high frequency somatic embryogenesis and plant regeneration from immature anthers (at diploid stage) of RRII-105 clone cultured on a modified MS medium containing 1 gm/l NH_4NO_3, B5 Vitamins plus 5% sucrose 2,4-D (0-3 mg/l), kinetin (0.5 mg/l). Calli were subcultured on an embryo-induction medium containing 7% sucrose, 0.2% activated charcoal and various auxins in combination with kinetin (0.5 to 1.0 mg/l). After maturation, embryos were transferred to hormone-free medium containing 3% sucrose with 0.21% gelrite at pH 5.6. Cultures at induction phase were incubated in dark and later in light (16 hr.) at 25 ± 2°C for plant regeneration (27%). Cytological analysis of the plantlets showed diploid status.

Several methods have been developed for the introduction of foreign genes into various crop plant species. Arokiaraj and Wan Abdul Rahman (1991) reported the initial results of *Agrobacterium* mediated transformation of *Hevea* cells derived from seedling cultures. Subsequently Arokiaraj *et al.*, (1996) reported a gene transfer system on anther derived calli using *Agrobacterium* vectors harbouring *-glucuronidase (*GUS) gene and the *NPT II* gene. Two protocols for transformation, one *Agrobacterium*-mediated and the other by using a gene-gun was perfected by Sethuraj (1998). Developments in molecular genetics and the success in genetic transformation will lead to improvement of rubber through biotechnological tools.

The use of molecular markers has revealed high genetic polymorphism in *Hevea*, greater than that might have been suspected from its morphological variability (Chevallier *et al.*, 1988; Low and Gale, 1991; Seguin, 1993). This was first revealed through the development of isozyme markers (Chevallier *et al.*, 1988; Seguin *et al.*, 1996). Genetic diversity within selected material (the Wickham population) appeared to be high enough to be able to distinguish between cultivated clones according to their isoenzymatic banding patterns (Seguin, 1993; Leconte *et al.*, 1994). Genetic analyses using isozymes were followed by nucleic acid markers (RFLP, RAPD, microsatellites) offering a wide range of tools for use in characterizing diversity and analysing the *Hevea* genome (Seguin, 1993). Attanayaka *et al.* (1995) reported the genomic organization of the *ref* gene through nucleotide sequence analysis and Southern blots.

Spices and Medicinal Plants

Among the biotechnological tools, tissue and organ culture can be successfully exploited in a number of spice crops for (a) rapid clonal multiplication of elite, disease free planting material, (b) embryorescue, (c) generation of somaclonal variation, (d) *in vitro* screening for resistance/ tolerance to pathogens, (e) germplasm conservation and exchange *in vitro*, and (f) *in vitro* production of active components of metabolites, flavours and essences. Protocols for micropropagation are now available for a number of spice crops and in some it has been even commercialized, as in cardamom and vanilla. Cardamom clones have been produced both from vegetative buds (Nadgauda *et al.*, 1983) as well as immature panicles (Kumar *et al.*, 1985). Today a number of commercial Biotech Companies like A.V. Thomas Co., Hindustan Lever, Indo-American Hybrid Seeds etc. are producing and selling lakhs of cardamom clones using the above methods. Vanilla tissue culture technology has been standardized by using both shoot (Philip & Nainar, 1986), and root meristems (Philip and Nainar, 1988). Field evaluation of micropropagated cardamom has demonstrated their superiority in yield and better tiller production (Lukose *et al.*, 1993). Plant regeneration from callus of seedling, vegetative bud or rhizome explants gave 20-50 plantlets per culture. This technology is now being used for large scale production of somaclones and their field evaluation.

Both ginger (*Zingiber officinale* Rosc.) and turmeric (*Curcuma domestica* L.) have been successfully multiplied by tissue culture for raising disease-free planting material of ginger as also to multiply high curcumin types of turmeric (Nadgauda *et al.*, 1980; Kuruvinashetti and Iyer, 1980, 1982). In ginger, Nirmal Babu *et al.*(1993) have developed a technology of producing somatic embryoids and their encapsulation in sodium alginate to make artificial seeds, which will be useful in germplasm exchange and conservation. Nirmal Babu *et al.* (1992a) have also obtained direct regeneration of ginger plantlets from immature inflorescences. Kulkarni *et al.* (1987) have attempted to screen ginger calli for resistance to culture filtrates of *Pythium* sp. This requires to be reconfirmed by field testing the plants raised from resistant/tolerant calli (Rao *et al.*, 1998).

In vitro clonal propagation has also been achieved in Black Pepper using mature shoot tip explants (Nirmal Babu *et al.*, 1993; Nazeem *et al.*, 1992; Philip *et al.*, 1992), from seedling tissue (Mathews & Rao, 1984), and from stem and leaf callus (Nazeem *et al.*, 1993). These regeneration systems have been used to study *Agrobacterium* mediated transformation for transfer of resistance (to *Phytophthora capsici* causing foot-rot and *Radopholus similis* nematode causing slow wilt) from *Piper colubrinum* of S. America to *P. barberi* (Nirmal Babu *et al.*, 1993, 1994). Parani *et al.* (1997) employed RAPD fingerprinting to select micropropagated *Piper longum* plants for conservation of elite genotypes. Kelkar *et al.* (1996) obtained callus-mediated shoot regeneration from leaf explants of *Piper colubrinum* Link, a wild relative of black pepper, which is resistant to *Phytophthora* attack. Kelkar and Krishnamurthy (1998) have further reported shoot regeneration from root internode, petiole and leaf explants of *P. colubrinum*. Shaji Philip *et al.* (1998) have observed a faster regeneration efficiency of protoplasts in *P.colubrinum* as compared to that in *P.nigrum*.

Tree spices have proved to be more recalcitrant in tissue cultures, particularly explants from mature trees. Micropropagation of *clove* from seedling explants has been achieved (Jagadish Chandra and Rai, 1986; Superman and Blake, 1990; Mathew and Hariharan, 1990; 1992; Thara *et al.*, 1998; Mathew *et al.* 1998). However, Nirmal Babu *et al.* (1992b), have successfully multiplied the mace tissue of Nutmeg, obtaining a 10-fold increase in fresh weight in 2 weeks, and retaining the deep red colour and its characteristic flavour intact. If scaled up, this can be a commercial proposition for *in vitro* production of myristicin and myristic acid. Cinnamon has also been propagated by culturing nodal segments (Sheeja *et al.*, 1998).

With the ever-increasing demand for medicinal plant sources and their overexploitation, we are witnessing their depletion, gene erosion and possible extinction. Hence, there is urgent need to collect, multiply and conserve these valuable germplasm both *in situ*, *ex situ* and *in vitro* (Swaminathan, 1997; Iyer, 1998). Micropropagation protocols have been developed for a number of medicinal plants at various laboratories. Thus, the future stragegy on Biotechology of Spice crops will have to focus attention on the following:

1. Extensive screening of somaclones and induced mutations may be done for resistance/tolerance to *Phytophthora capsici* in black pepper (Shylaja *et al.*, 1994), *Phythium-*

incited rhizome rot and *Pseudomonas* - incited bacterial wilt in ginger, besides higher yield, quality and drought tolerance and for heat-tolerant cardamom clones for the South Indian plains.

2. Production of haploids through anther/pollen culture, and homozygous diploids in cardamom, pepper and ginger and their utilization in crop improvement.
3. Bio-reactor technology for large-scale production of biochemicals, essential oils, alkaloids, and flavours.
4. Use of artificial seeds in germplasm conservation and retrieval, after short-term as well as long-term storage (Ramanatha Rao and Riley, 1994).
5. Use of cell and protoplast culture and regeneration for genetic transormation through electro-fusion, and microprojectile bombardment for direct incorporation of DNA.
6. Use of RFLP/RAPD/AFLP to determine clonal fidelity, and to identify the transformants for the major spice crops.

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Micropropagation In Plantation Crops

CR Raju and R Kavitha

Introduction

The micropropagation of any species has two distinct stages. First is the research leading to developing the technology that can be carried out only by experienced persons, and the second stage of blindly following the technology for achieving the goal of production of plants. The research part is time consuming and at the same time quite expensive both in terms of capital investment as well as the recurring cost. The outcome is just a series of steps that one has to meticulously follow for producing sufficient number of plants .

The nutrient medium is the most important aspect which determines the success of the tissue culture process. As per our general concept the plants are autotrophic in the sense that if they get the basic nutrients they can synthesize the various complex chemicals needed for their growth (photosynthesis and the subsequent biosynthetic pathways). However, the tissues taken for the *in vitro* studies are too small and may not have the requisite maturity to carry out the photosynthetic processes fully. Hence, we may have to provide the limiting factors like source of energy, critical vitamins and growth regulating substances along with the usual mineral nutrients.

The process of micropropagation in all crops involves the basic procedures of producing sterile cultures on defined media of known chemical composition, transferring the cultured tissues or the new growths into new media with the same or altered chemical compositions to elicit the required patterns of development leading to the formation of propagules..

Coconut

Efforts are on since the 50's to standardize a commercially feasible micropropagation technique at several laboratories around the world. Almost every part of the tree has been tried for the culture initiation and the subsequent work. However, the tissues of coconut have always proved to be highly recalcitrant. It has always remained as a challenging work for all coconut tissue culturists all over the world to develop a repeatable and commercially viable technology. The successes have been limited so far. The high commercial potential itself has been pulling the researchers back as all information have always been veiled in a shroud of secrecy.

Young embryos

Considering the regeneration potential, immature embryos of 1.5 to 3mm size from tender nuts were used for standardizing a propagation protocol. The basal medium for this was developed through a broad spectrum experiment similar to the one described by De Fossard (1976). The tiny embryos swelled up after two weeks in culture and eventually formed white transparent convoluted callus mass. They observed the formation of embryogenic callus from the region very close to the cotyledon in media with 12-20 µM, 2, 4-D. All other auxins tried were ineffective. Along with the callus formation at the cotyledonary region the shoot apex also developed a few plumular leaves but the development was never complete. The early removal of the embryogenic callus from the rest of the developing embryo was crucial for the further developments. The fast growing callus on transfer to media containing low 2, 4-D (8 and 2 µM) in combination with 10 µM each of kinetin and BAP produced numerous white globular somatic embryos when incubated in the light. Their origin was traced to the sub-epidermal layers but later they emerged to the surface as globules. The presence of 2, 4-D was essential at all the stages of the embryogenesis. Repeated transfer of the embryoids to the high cytokinin medium and incubation in the light induced formation of pale greenish shoots. They however did not grow further.

Trials at CPCRI in the mid 80`s showed that the haustorial portion of these immature embryos developed into haustoria like structure with a highly undulating surface on similar media. They also had a very distinct outer layer of cells, which was peculiar to the haustorium alone. They have developed finger like structures on media containing 2iP or BAP and also showed slight greening on prolonged incubation in the light. They had leaf-like structures giving the appearance of shoots but the anatomical study showed that they lacked a meristem. Further study in this direction is worth pursuing, as a viable method to obtain multiple plants from the embryos of the prepotent palms which can produce uniform high yielding populations.

Very rarely was callus formed from the embryos.

The callus in coconut as such cannot be compared to the callus obtained from other plant species in terms of the structure and texture with the exception of the endosperm derived callus. The young embryos produced swollen masses with a glossy surface (a clear distinction from the usual callus) which has an even or lobed appearance on media containing higher concentration of 2,4-D. Further transfer of this callus, now termed calloid, to media with reduced auxin resulted in the localization of meristematic activity. These areas of meristematic activity were found to develop and protrude out of the callus mass. Occasionally these structures developed into club shaped structures that were often misconstrued as shoots. However, the original shoot pole in the embryo may grew into a shoot depending on the medium used. The rest of the structures lacked a proper meristematic tip and hence these emerging structures could not be interpreted as shoots. The white structures with varying shapes would not turn green even on incubation in the light. Similar structures were reported earlier (CPCRI, 1994).

Maturing/mature embryos

The embryo has a shoot – root axis and a massive cotyledon that almost covers the former. As such the technique of culturing the embryos appears rather simple as they tend to grow on a variety of media and to tolerate lot of variations in the hormonal and other supplements. Several studies have been carried out to derive multiple shoots but the results are not so encouraging. Shivashankar (CPCRI, 1994) has reported the formation of multiple shoots from embryos. Embryos excised from 7-8 month old nuts were cultured on MS medium with 100mgl^{-1}, 2,4-D to get high frequency callus induction. The callus on repeated transfer to fresh medium, containing gradually decreasing levels of 2, 4-D (100 mgl^{-1} to 5 mgl^{-1}) gave rise to organized multiple shoots. These turned green on exposure to light and roots could be induced in a medium supplemented with NAA and IBA (2 mgl^{-1} each). But there have been no reports of these structures developing into viable plantlets.

In another set of trials, embryos were cut into slices vertically and horizontally into several pieces and cultured on to different media. When the embryos were cut horizontally into 2mm thick pieces, the uppermost piece showed the development of the shoot from the shoot pole present in it. The lower slices developed calloid or spongy haustorium like tissue only. Up to a maximum of two shoots could be developed from one embryo by vertically cutting the embryo exactly through the shoot root axis into two halves. They also rooted on transfer to the usual embryo culture medium containing 60gl^{-1} sucrose and 1-5 mgl^{-1} IBA. The addition of sucrose at 60gl in the medium was found to improve the rooting in excised shoots from embryo derived plants *in vitro* (Fernando and Gamage, 1995). The shoots so developed from the split embryos did not produce more plants by further splitting through the shoot meristem. This invariably showed that the splitting of the shoots beyond a certain stage of development would not develop normally.

Several workers have succeeded in germinating embryos *in vitro* and transferring them into the field. The plants produced from the embryos during 80`s here at CPCRI and planted in the field have fruited with no abnormal behaviours. This procedure can be used for the safe exchange of coconut germplasm (Raju and Bavappa 1987).

Plumule

The plumule from the embryos of mature nuts 12-14 months after the pollination were used for induction of somatic embryogenesis (Chan *et al.*, 1998). The explants developed callus in about three months on Y3 medium which optimally contained 2,4-D at 0.1mM. The cytokinin was not necessary at this stage. Eventually the calli developed meristematic points indicative of embryogenic capacity and of multicellular pathway for embryo formation as suggested by Verdeil and Morel (1995). In addition, there was also individualisation of embryogenic cells indicative of the unicellular pathway of embryogenesis. The formation of the embryogenic structures was favoured by the undisturbed incubation of the cultures at the same level of auxin without subculturing. These embryogenic calli produced somatic embryos when transferred to media with auxin reduced to hundred fold and supplemented with BAP at 50 µM and incubated in the light at 12 hour photoperiod. The periodic subculturing of the cultures every 3 months allowed embryoids to germinate into plantlets.

All other systems of regeneration are time consuming and every stage takes several months. Thus the total time for realising plants runs to over a year from starting the culture. On the other hand, the plumule culture is promising in that the somatic embryos can be realized in just three months. More efforts are needed to make it a commercially viable technology for the propagation of coconut.

Endosperm

The endosperm is a triploid tissue. Coconut endosperm shows extensive variation in the chromosome number. Various levels of ploidy level have been reported in the past. Abraham *et al.* (1966) and Fisher and Tsai (1978) have demonstrated the formation of callus from the tender endosperm tissue. However, the results could not be repeated. Prakash *et al.* (1985) produced very soft friable callus from endosperm tissue. In our trials to know more details on the requirements of the coconut tissues in culture the endosperm from 5-6 month old nuts were cultured. The soft eye region of

the tender nuts of 6-7 months were excised aseptically. They contained the embryo and the surrounding mucilaginous endosperm. Cultures made on Y_3 medium (Eeuwens,1976) supplemented with 50 mgl^{-1}, 2, 4-D, 2 mgl^{-1}, kinetin and 1 gl^{-1} activated charcoal and incubated in the dark formed yellowish callus. This yellowish primary callus on subculture on to media containing reduced 2, 4-D and kinetin resulted in snow-white fast growing callus, which could be maintained by serial subcultures on to same media. Though the trials to induce regeneration was not successful to some extent the meristematic activity could be restricted to some areas. Xylogenesis or other types of regeneration could be observed on a variety of media tried.

Tender leaves

Tender leaves have proved to be another suitable explant for the *in vitro* studies (Raju *et al.*, 1984). After studying the responses of various tissues of coconut, initial trials were made for the induction of callus and for subsequent regeneration. However, the callus induction in leaf tissues was rather difficult. The browning of the coconut tissues in culture is a major problem that is yet to be solved. Of the several methods tried for overcoming browning, the addition of activated charcoal was found to be the best. However, the non specific adsorption of nutrients and hormones renders the techniques based on charcoal unreliable. In all the cases of callus induction, new cell divisions could be observed at the cut edges of the explant and they formed filaments rather than a true callus mass. These filamentous structures did not survive subculturing. The studies on the callus pathway for regeneration of plants were not very promising.

Later, in line with the broad spectrum experiment of De Fossard (1976) an experiment involving over 2300 combinations of media were tried at a stretch with tender leaf explants of unselected West Coat Tall seedlings and at the end in just one culture there was formation of globular structures at the cut edges of the veins. They eventually developed into tripolar structures. This needed incubation of cultures undisturbed for at least 16 weeks at 16 hr light photoperiod. By further adjusting the medium composition in terms of Mg: K ratio and level of hormones, it was possible to increase the percentage of responding cultures and reduce the time required for embryogenesis. A maximum of 48 embryoids were found to develop from a single leaf bit. It was interesting to note that all the responding explants had at least portions of 4 leaflets joined side by side indicative of a minimal size of the explant to elicit somatic embryogenesis.

The embryoids were found to originate from the phloem region of the veins. There was no intervening callus phase in the development of embryoids. Two types of embryoids were found to develop in the leaf explants. Most of the embryoids were thin with the shoot pole development inhibited at a very early stage. Some were thick and swollen and had the shoot pole visible. As such it was an ideal system to be pursued to develop a viable propagation method.

The somatic embryos produced on the leaf explants had well defined shoot pole, root pole and a small haustorial knob. The transfer of the embryoids to several combinations of media did not induce germination. In all cases, the root pole started growing fast and in this process the growth of the shoot was getting completely suppressed. The thick embryos alone were used for further studies. As the chemical manipulation of the medium was not giving positive results, mechanical manipulation was the only alternative. Careful removal of the entire root pole and part of the haustorial region resulted in sprouting in several embryoids. The over grown root pole of the embryoids were found to suppress the development of the shoot. The developing shoots appeared quite similar to the sprouting zygotic embryos. They could be rooted later in media containing IBA. Charcoal and higher concentration of sucrose were found to favour the balanced rooting. The plantlets with balanced shoot and root growth were transferred to potting medium, hardened and maintained in green house conditions.

Four such plants were planted in the field at Kasaragod along with two embryo derived plants during 1990. The growth was observed to be normal. They have fruited and none of the plants have shown any abnormal behaviour in the vegetative growth, flowering or in the fruits. These developments occurred during the period from 1982 to 1995. Later the tissues from similar o.p. seedlings cultured on to same medium did not respond in the same manner. Basically most of the morphogenetic activities are triggered by the light. The only reason that could be attributed to this differential behaviour was the erratic power supply leading to the disruption of the photoperiod, humidity and temperature conditions.

A non-destructive method for extraction of tender leaves from mature palms was later developed (Raju *et. al.*, 1988). Two whorls of leaves around the central column of spindle leaves are removed and the portion of the spindle beyond the sheathing leaf base was removed. Leaf column was cut off from the crown above the stem portion about 30 cm above the meristematic point. The tree was then treated with bavistin and monocrotophos and properly covered. The tree recouped later.

The tender leaf column was surface sterilised by wiping with alcohol. Over 2500 cultures could be produced form a single plant. The response of the explants from the mature palm was quite different from that of the seedling. In mature trees the leaflets are free from one another except at the tips. These explants from the tip region showed swelling

in less than 1% of the explants and later developed into embryo like structures.

At Hindustan Lever Ltd., Bombay, the leaf cultures have been in progress since 1977. Bhaskaran (1985) reported direct embryogenesis and the formation of callus followed by somatic embryogenesis. He has obtained 10 to 40 embryoids from the mid-rib of 10mm sized explant. The direct embryogenesis as well the callus mediated embryogenesis were obtained in similar culture conditions. The embryoids arising from the callus alone showed structural similarity to zygotic embryos. The embryos on high cytokinin medium germinated to yield plantlets. At National Chemical Laboratory, Poona, callus could be produced from the leaf, rachilla and stem regions on Y_3 medium supplemented with 2, 4-D, Ca panthothenate, biotin and activated charcoal (Mascarenhas *et al.*, 1988).

Root cultures

The work on root for the purpose of micro propagation was initiated only recently. The secondary roots were extracted and cultured to induce callus. A variety of media were tried and there is callus formation in several of the cultures from the tip region of the tertiary roots formed in culture under the influence of the added 2,4-D. Further efforts are on to multiply the callus and for the induction of regeneration.

Inflorescence

The flowers are considered modified shoots. In the course of development the vegetative meristem gets transformed into the flower bud. If a vegetative bud can develop into the flower bud it should be possible to get a flower bud revert the course of development to the vegetative phase. Several workers have tried the *in vitro* culture of inflorescence tissue (Schwabe 1973, 1983, Kuruvinashetti and Iyer 1982, Iyer, 1982). The rachilla explants from the inflorescence primordia in the axils of the first, second and third opened leaves were used. The response varies with the maturity of the inflorescence. The rachilla explants beyond the third leaf axil developed into flowers while the younger ones tended to show varying types of development. The very young ones responded with callus formation on media containing high levels of auxin. There were basically four types of development noticed: 1) callus formation, 2)indefinite growth of the floral primordia with several scaly structures, 3)determinate type of development wherein the primordium elongated to give rise to a few scaly leaf structures and ceased to grow further and 4) club shaped formation from the central portion of the floral primordia (Kuruvinashetti and Iyer 1982).

Immature inflorescence explants formed calloid on Y3 medium with $1g^{-1}$ 2, 4-D in presence of 0.25 gl^{-1} activated charcoal. Calloids showed a variety of responses and the behaviour was quite erratic (Blake, 1993). Vidhana Arachchi and Weerakoon (1997) reported the formation of callus and shoots from the rachilla explants of 8-10 cm sized spathes on modified Y3 medium supplemented with 24 µM 2, 4-D and 0.25% charcoal while 200 µM 2, 4-D and 0.2 % charcoal in the same basal medium was found to promote direct shoot formation in a few cultures.

The intensified work on the inflorescence tissues yielded calloid formation from the floral primordia (Verdeil *et. al.*, 1989) after prolonged incubation of the explants on high auxin medium containing charcoal. This is influenced by the maturity stage of the inflorescence. Explants from the inflorescences having 15 to 30 cm long external spathe were described to be the best for callus induction. The isolated cal were maintained for several months on similar medium a then the concentration of 2, 4-D was reduced and cytokinin 2iP or thidiazuron was incorporated for formation of embryogenic calli. The embryogenic poten was also influenced by the genotype. Around 23 % of calli yielded embryogenic structures in 4-6 months incubation. The germination of the embryos was favoured 2, 4-D and BAP along with charcoal in the medium process took around 10-12 months. They reported germination in 7% of the embryoids. Similar results h been reported by Rognon (1998).

The rachilla explants from both the 6th leaf axi 9th leaf axil in culture has shown the formation of c shooting and floral development depending on the c conditions (Thankamany and Kavitha unpublished). rachilla were cultured without cutting into smaller e They have observed the advantage of less browning an development in the intact rachilla as compared to the explants of 2-10 mm size. The charcoal that was usuall into the medium to reduce the browning could be re using entire rachilla. Transfer of explants every three a series of media with varying hormones has result induction of shooting. They are yet to develop a fully plant with a balanced shoot root system. However, th explants appear to be better than the leaf explan clonal propagation in coconut. More efforts are develop a commercially feasible *in vitro* prod coconut.

With successes obtained so far from leaf, r plumule cultures, let us hope that tissue culturists w to develop a commercially viable procedure for co near future.

Oil Palm

This is a major oil-producing crop of great economic value. As in the case of coconut, the propagation is exclusively through nuts. Here the production of propagules is more complicated as hybrids alone are used for the commercial planting. The absence of homozygous parental lines in the parental types *duras* and *pisiferas* render the production of uniform hybrids too difficult. Thus, there is a felt need to go in for alternative method for production of planting material. The *in vitro* technique would prove useful in the large-scale propagation of the elite palms.

The success in the *in vitro* propagation of oil palm was reported way back in 1974 by Jones. Since then, lot of work has been carried out on the various aspects of micropropagation of this crop (Corley *et.al.* 1977, Jones,1974; Rabechault and Martin, 1976, Durand Gasselin *et. al.* 1990). As in other commercial crops, the literature contains mainly the results obtained rather than the precise technology involved. What we could understand is that the tender leaf tissues produced a fast growing type of callus on media fortified with high levels of 2,4-D. This slow growing type of calli on repeated subculture produced fast growing callus. The fast growing callus on transfer to media with reduced levels of auxins turned embryogenic and the somatic embryos thus formed were germinated in the germination medium to produce the plantlets.

The non-availability of the entire procedure tempted us to attempt the tissue culture of oil palm. Tender leaf tissues of three year old seedlings were used for callus initiation. In our studies the tender leaf tissues from two to three year old seedlings were used. The outer old leaves were removed and the tender leaf column along with the sheathing leaf bases of the older leaves were dipped in 70% ethanol and flamed. The basal stem portion was then removed, as there was possibility of contamination. The sheathing base was removed to expose the inner white tender leaf tissue. Only the basal 5-cm portion was used. It was cut into approx. 5mm long bits each with a few leaf folds. The response of the single leaflet bits was too poor as compared with those of multiple folds.

Two distinct methods were developed for the realization of plants from oil palm tissues: through somatic embryogenesis and through a callus based regeneration pathway. A minimal callus phase followed by somatic embryogenesis and multiplication of the embryoids through budding and secondly, callus multiplication followed by regeneration of shoots.

The leaf explants could be cultured on medium containing 20 mgl^{-1} 2, 4-D and 1mgl^{-1} BAP, or a medium devoid of cytokinins to induce callus. The callus formation was a slow process taking several weeks. The callus was often found developing from the morphologically lower cut edges. Callus formed in media with cytokinin was more compact and hard as compared with that on media with 2, 4-D alone. In our trials more emphasis was given on reducing the total callus phase so as to reduce the risk of somaclonal variation (Raju *et. al.* 1989).

It was found that the embryoids on transfer to the same medium for embryogenesis produced more embryoids by budding. Over 200 embryoids developed from a single embryoid in 8 weeks. This could be a better method for the production of more embryoids than going for an extensive callus phase and then inducing embryogenesis. The callusing explants were transferred through a series of media wherein the 2, 4-D is replaced by NAA gradually. In about 8-20 weeks time small white club-shaped structures appeared at the callus lining. These were the somatic embryos. The number of embryoids produced per explant was few but they grew to about 3-5 mm size in 6-8 weeks. These embryoids had a tripolar appearance in which each of them had a shoot pole, a root pole and a haustorial part. These embryoids were distinct structures unconnected with the callus or the explant *per se*. The embryoids of 4mm size or bigger on transfer to fresh medium containing IAA and BAP showed three patterns of growth. About 50 % of the embryoids developed shoot first followed by rooting, 30% had simultaneous development of both the shoot and root, 15 % of them had first root initiation followed by shooting but the rest did not develop at all.

When the callus was allowed to multiply for several subcultures on the same medium with high auxin and in the process of subcultures the 2, 4-D content was reduced, they showed the formation of several meristematic points on the callus which turned green in light. Shoots emerged from these meristemoids later. Up to 18 such shoots were observed to form on a single culture. These shoots were interconnected through the callus and had vascular connections. They were individually separated and transferred for rooting in medium containing IBA. We could get rooting only in less than 20 % of the shoots. Such plants were then hardened in the green house condition and later planted in the field.

It was interesting to note that in a set of cultures kept on the callus stage for over an year on high auxin medium and then transferred to medium for somatic embryogenesis, initiation of inflorescence occurred. In one culture the male flower with well formed perianth and anthers was also observed.

In the earlier reports the embryogenesis occurred in the fast growing calli which emerged from the slowing callus on prolonged incubation. The plants derived from such cultures were tested in the field. Corley *et. al.* (1986) reported

gynomorphic male inflorescences and development of small fruits on them in the first batch of ramets. Mantled fruits and parthenocarpic fruits were also observed in them. A recent evaluation of the field planted ramets in Ivory Coast in 180 ha plantation is encouraging (Durand-Gasselin *et. al.* 1990). The flowering in the clones was well synchronized and the plants with abnormalities were only around 3%. Considering the other advantages, they claim that the level of abnormalities among the clones is not significant.

Tea (*Camellia sinensis* (L) O.Kuntze)

Crop improvement in tea is also difficult and time consuming due to the highly heterozygous nature, open pollination and long duration of the crop. The micropropagation is an alternative to the usual vegetative means of propagation especially when too large a number of plants required. George and Sherrington (1988) have detailed the earlier works on tea. The extensive variability between the cultivars necessitates the need to develop individualized protocol for each cultivar (Rajasekharan and Mohan Kumar, 1992). Murali et *.al.* (1996) has studied the variation in the culture media for the multiplication of several cultivars. The cytokinin and auxin requirement for the shoot proliferation and the rooting differ between the different varieties.

Different approaches have been made by different workers to achieve the micropropagation of tea. The usual tissues preferred were the shoot tips, axillary buds and cotyledons. Formation of multiple shoots were reported from the nodal and shoot tip explants by Wu *et al.* (1982), Phukan and Mitra (1984), Kato (1985), and Arulpragasam and Latiff (1986) while Abraham and Rajan (1986) and Ayyappan and Raj Kumar (1989) Abraham and Rahman (1986), Bano *et.al.* (1991) and Sood *et.al.* (1993) reported somatic embryogenesis from the cotyledonary tissues. Arulpragasam *et. al.* (1988) obtained plantlets through regeneration from the callus on cotyledonary explants. Rajkumar and Ayyappan (1992) have successfully regenerated plants from the aperiodic shoots formed subsequent to pruning.

Basically there are two approaches in the micropropagation of tea. First the regeneration of plants from the cotyledonary tissue which has very good regeneration potential due to the embryonic nature and less of phenolics. The cotyledons of selected hybrid combinations, either at the developing stage or at maturity were used for the culture initiation. The seeds were surface sterilized appropriately in calcium hypochlorite solution and inoculated onto MS medium (Murashige and Skoog 1962)with different hormonal combinations. Shoot buds were produced on medium with 2.5 mgl^{-1} kinetin and 1.0 mgl^{-1} IBA or 5.0 mgl^{-1} BAP alone. The shoot proliferation was enhanced by adjusting the concentrations of BAP, IAA and GA_3. Rooting of the shoots were in half strength MS medium with NAA at 0.5 to 2.5 mgl^{-1} after treating them with antioxidants like L-cysteine, PVP or ascorbic acid at 50 mgl^{-1} for 10 min.

Cotyledonary segments on media with NAA 1 mgl^{-1} and kinetin (0.5 to 10.0 mgl^{-1}) or BAP (0.5 to 5.0 mgl^{-1}) showed formation of somatic embryos and callusing. Somatic embryogenesis was profuse in half strength MS with 2% sucrose, 2.0 mgl^{-1} BAP and 0.2 mgl^{-1} IAA. Germination was achieved by adding 0.2 mgl^{-1} GA3. The embryoids thus produced had either a unicellular or a multicellular origin. They passed through globular, heart and torpedo stages and had no vascular connection with the underlying cotyledonary stages. After detachment, they germinated to produce rooted plants.

The separated somatic embryos were encapsulated in sodium alginate matrix (2.0%) and 0.69 % $CaCl_2.2H_2O$ either before or after treatment with ABA (1 µM for 11 days). Medium sized embryoids gave the highest conversion rate of >70%. In the process of encapsulation, bavistin was incorporated into it to avoid fungal damage during storage and germination.

Detailed study of the encapsulated embryos have shown that the *in vitro* germination into plants is affected by the nutrients in the gel. The addition of calcium free MS medium with 3 % sucrose, 14.4 µM gibberellic acid and 28.5 M IAA to the algenate resulted in 63 % plant recovery which is comparable with the non-encapsulated embryoids (Laura *et al.*, 1997).

The actively growing aperiodic shoots produced by severe pruning of the selected plants were another source of explants as shown by Rajasekharan and Mohankumar (1992). The browning of these explants due to polyphenols was overcome by frequent transfer of the explants to fresh medium every 6 to 8 hours. By serial transfer to fresh media containing BAP every 2 to 3 weeks, they could produce 20 to 25 shoots per explant. The separated shoots were kept on basal medium devoid of cytokinin for 3 to 5 weeks to avoid the detrimental effect of cytokinins on rooting. Such shoots showed swelling at the basal region and then rooted on media with IBA.

Cocoa (*Theobroma cacao*)

The self-incompatibility of cocoa has increased the extent of variation resulting in looking for vegetative means of propagation for establishing uniform plantations. Although the

conventional methods can be adopted, they are too slow and hence tissue culture methods might prove useful. Earlier studies have shown that the tissues of cocoa are difficult to be managed *in vitro*. Callus formation from various tissues have been reported (Archibald, 1954; Hall and Collins, 1975; Prior, 1977; Pence, *et. al.*, 1979; Pence, 1989).

Most of the studies have been with the seed or seedling tissues. Kong and Rao (1981) have described the suspension culture method for the callus multiplication as well as for the induction of somatic embryogenesis. The cotyledonary tissues have shown the best response to callus induction. The cotyledonary explants readily produced callus on modified MS medium (NH_4NO_3 increased to 2000 mgl^{-1}) supplemented with 2,4-D and kinetin. Both kinetin and BAP induced the formation of soft friable callus while addition of NAA resulted in both callusing as well as rooting. The subculture of the friable callus formed in 2,4-D could be maintained as fast growing callus on media containing Low auxin and higher levels of kinetin. Increasing the level of NAA with low levels of kinetin favoured rooting.

The immature zygotic embryos of known parentage can be multiplied through somatic embryogenesis if they are cultured before they have started accumulating pigments. Pence *et. al.* (1980) found that the embryos of size 2.5 mm to 10 mm which were white produced maximum number of somatic embryos. Even the embryos in the range 10.5 to 18 mm also responded but to a less extent. The high potential of white embryos for somatic embryogenesis appears to be associated with a period of rapid growth of the embryo. In MS medium with 8 µM 2,4-D and 10 % coconut water 7 out of 8 white embryos showed embryogenesis. Budding type and non-budding type of embryogenesis were observed.

The budding process began as development of smooth, green, ovoid outgrowths from meristematic cotyledonary tissue. The end of the ovoid structures appeared as hairy growth, which consisted of a stalk, which resembled a suspensor and a globular portion that gave rise to the embryo proper. The development of these neo formations closely resembled the development of the zygotic embryo. The tissues with the initiation of embryogenesis through budding continued to initiate more and more embryoids irrespective of the auxin or coconut water present in the medium. Liquid medium was more suitable for both the development of the embryo cultured and for somatic embryogenesis.

Cashewnut (*Anacardium occidentale* L.)

Due to the phenolic exudates from cashew tissues most of the work has been on the seedling tissues. Starting with the juvenile twigs, Sudripta Das *et. al.* (1996) reported that the survival of the explants from 5 to 10 year old seedling was only about 3 to 25 % but even they eventually browned off. The cotyledonary nodes, leaf axils with the buds and the shoot tips responded to MS medium with 4.4 µM BAP, 2.32 µM kinetin and 9.12 µM zeatin producing 12, 4 and 2 shoots respectively. The cotyledonary node explants showed multiplication at the rate of 10 to 12 shoots per culture for three successive subcultures. Maximum rooting of the micro shoots (4–6 cm) was obtained by exposing to 2460 µM IBA for two hours. The rooting was improved by dipping the rooted shoots in a suspension of *Agrobacterium rhizogenes*. Thimmappaiah and Nagaraja (1994) reported that they could develop callus from internode and leaf explants of *in vitro* grown seedlings on media containing 2,4-D and BAP in equal proportion.

Nucellus tissue formed callus in 20 % explants in MS fortified with 0.5 mgl^{-1} 2, 4-D. The callus proliferated profusely and became friable on NAA/IAA (1.0 mgl^{-1}) and zeatin (1.0 mgl^{-1}). Subculturing the friable callus to 0.5 mgl^{-1} 2iP and 15% coconut water resulted in white globular embryonic structures. These embryonic structures showed only poor shoot development but they had good rooting.

The shoot tips and nodal explants from green house grown seedlings were found to develop multiple shoots ranging from 3-5 per bud on MS medium with 3% sucrose, 0.05% activated charcoal and 0.01 % ascorbic acid and hormones (not specified). The shoots separated individually were rooted in MS medium with 1-2 mgl^{-1} NAA and 0.5 gl^{-1} charcoal (Keshavachandran and Khader, 1992). However, they could obtain only a few cultures with multiple shoots.

The shoot tip explants grown on 0.75x MS medium with TDZ and NAA (0.1 mgl^{-1} each) also showed multiple shoot induction. The exposure to TDZ for 10 days was sufficient to get an average of 5 buds per explant. In explants from mature trees, the response to microshoot formation was better in MS with 0.1 mgl^{-1} IBA (NRCC, 1997).

Coffee (*Coffea canephora* Pierre)

Coffee is basically propagated through the seeds. Micropropagation of the elite plants will have great bearing on boosting the productivity. Most of the attempts on clonal propagation used seedling or cotyledonary tissues (Staritsky, 1970; Ganesh and Sreenath 1995). Raju *et.al.*(1996) has demonstrated the successful micropropagation of a planter's selection from Coorg District starting with the tender leaves. Callus was induced on modified MS medium (organics: inositol 100 mgl^{-1}, thiamine 1.0 mgl^{-1}, nicotinic acid 1.0 mgl^{-1}, Ca panthothenate 10.0 mgl^{-1}, glycine 1.0 mgl^{-1} and ascorbic acid 100 mgl^{-1}) containing 1.0 mgl^{-1} IAA, 0.1 mgl^{-1} BAP and

100 mgl^{-1} casein hydrolysate. The resulting fast growing ,soft, creamy white callus on transfer to MS medium supplemented with 0.2 mgl^{-1} BAP and 5 % sucrose turned embryogenic. Bipolar embryos with well formed cotyledons and shoot- root axis were formed. The embryos later germinated to form full plantlets which were hardened and planted out (unpublished). The encapsulation of somatic embryos and an *ex vitro* germination technique would be worth for the large scale production of coffee propagules from the selected elite coffee plants.

The integuments (perisperm) is another potential explant for the micropropagation of selected coffee plants (Sreenath *et. al.*, 1995). Callus was formed on the explants on the basal MS medium (L-cystein and PVP added as antioxidents) without any growth regulators or with TIBA alone or in combination with low levels of BAP. The calli was initially fast growing for several months and then the growth slowed down, turned brown and became compact.on basal medium containing 0.5 mgl^{-1} IAA, 0.05 mgl^{-1} 2, 4-D and 8.6 mgl^{-1} kinetin. On transferring these calli to MS with 10 mg thiamine, 3 mgl^{-1} pyridoxine, 2mgl^{-1} nicotinic acid, 2.0 mgl^{-1} 2, 4-D and 2.5 mgl^{-1} 2iP they turned brown and more compact. Repeated subculture on the same medium resulted in the formation of friable callus and they became embryogenic. Further proliferation and maturation of the somatic embryos was achieved with 1.0 mgl^{-1} ABA. The somatic embryos later germinated in MS medium at half strength containing 0.1 mgl^{-1} kinetin. According to the authors, the various stages are critical for successful multiplication through this process.

Vanilla (*Vanilla planifolia* (Salis) Ames

Nowadays the preference is more for the natural vanillin rather than the cheaper synthetic version. Hence the cultivation of vanilla plants is picking up momentum. Again the major stumbling block is the lack of good planting material. They can be vegetatively propagated by the stem cuttings but this will reduce the yield of the plant. Being an orchid, the seeds do not germinate in nature. Hence; the seed culture method is followed for the production of seedlings. As the available genetic variability is too limited even the seed propagation will be enough to provide reasonably good planting material.

The tissue culture method using the vegetative tissues alone will ensure the quality of the propagules. Vanilla being a monopodial orchid, the excision of the terminal bud will affect the further growth and the yield from the plant. Of the different methods tried by several workers, multiple shooting procedure from the nodal segments appears promising. By this procedure (Rao *et. al.*, 1993) the plants are pretreated with systemic fungicide before explanting. MS medium with supplements of 2 mgl^{-1} IAA, 0.5 mgl^{-1} BAP and 0.5 mgl^{-1} kinetin was the best combination for the production of multiple shoots. In addition, calcium panthothenate and biotin were found to improve the multiple shoot formation. An average of 6 plants could be obtained from each explant. Rapid multiplication was obtained by repeated transfer of the proliferating mass into fresh media. Similar multiple shooting in vanilla was reported through an intervening PLB stage by Philip and Nainar (1986,1988).

Ginger

Ginger (*Zingiber officinale* Rosc.) is basically a vegetatively propagated crop. The need for relying on micropropagation is only to bridge the gap between the breeders material and widespread cultivation. Several workers have reported successful protocols (Hosoki and Sagawa 1977; Nadgauda *et. al.*,1980, Pillai and Kumar, 1982; Sakamura and Suga, 1989; Balachandran *et. al.*, 1990, Nirmal Babu *et al.*, 1992, 1994). However, the use of micropropagation in ginger is limited. The plants could be regenerated from vegetative buds, shoot tips, meristem and flower buds either directly or through an intervening callus phase. The buds respond to MS medium with a range of auxin - cytokinin combinations to produce multiple shoots. The preferred auxin for ginger is NAA and cytokinin is BAP. In case the objective is to go in through a callus phase, 2,4-D induces good callus for further manipulation and to go in for *in vitro* selection for disease resistance (Nirmal Babu *et. al.*, 1994).

The *in vitro* derived plants have to be in the field for two cycles of cultivation for maximum yield. Thus the plants produced by *in vitro* methods cannot be used for commercial plantings directly. The tissue culture methods have a major role in production of additional genetic variability which can be utilized for developing disease tolerant/ resistant types. Protocol for the regeneration of plants through the callus system was standardized (Nirmal Babu *et. al.* 1992). The callus grown on MS medium with 0.2 mgl^{-1}, 2,4-D and 10 mgl^{-1}, BAP for 3 to 4 cycles when transferred to basal media without any growth regulators resulted in organogenesis and plantlet formation.

Turmeric

The trials in turmeric for the micropropagation have been extremely successful (Nadgauda *et.al.*, 1978; Shetti *et.al.*, 1982 Yasuda *et.al.* 1988; Keshavachandran and Khader, 1989, Nirmal Babu *et. al.*, 1993). Vegetative buds and rhizome sets with axillary buds produced multiple shoots on MS medium containing NAA, BAP and coconut water at different cross combinations. Rooting has never been a

problem in turmeric tissue culture.

The alternate method of callus production and regeneration was successful. The utilization of the somaclonal variation and further selection procedure has yielded new types with higher curcumin content (Nadgauda *et.al.*, 1982).

Cardamom (*Elettaria cardamomum* Maton.)

Cardamom is usually propagated through seeds even though vegetative propagation by splitting the rhizome is possible. This conventional splitting procedure is time consuming and the yield of the clump also gets reduced. Micropropagation procedures were standardized by several groups (Nadgauda *et. al.*, 1983; Kumar *et.al.*, 1985; Vatsya *et.al.*, 1987; Reghunath and Gopalakrishnan, 1991; Lukose *et al.*, 1993). The vegetative bud can be the starting material for the micropropagation. The contamination has to be taken care of as the underground material has heavy microbial load. MS medium with BAP (1.0mgl^{-1}), kinetin (0.2 mgl^{-1}), IBA (0.2 mgl^{-1}, NAA (0.5 mgl^{-1}) and 20% coconut water was used for inducing multiple shoots. In another procedure, MS medium with IAA (2.0 mgl^{-1}), BAP (0.5 mgl^{-1}), kinetin (0.5 mgl^{-1}), biotin (0.1 mgl^{-1}), Ca panthothenate (0.1 mgl^{-1}) and 5% coconut water was used for the shoot multiplication.

The immature panicle was another suitable explant from which the floral primordia were reverted to the vegetative phase to obtain shoots. These vegetative buds were formed on MS medium with NAA (0.5 mgl^{-1}), kinetin (0.5 mgl^{-1}), BAP (1.0 mgl^{-1}), Ca panthothenate (0.1 mgl^{-1}), folic acid (0.1 mgl^{-1}) and 10% coconut water. In this procedure the shoots obtained from the panicles were separated and rooted in White's (1943) liquid media before hardening.

Callus developed from the vegetative buds or rhizome bits on 1.0 mgl^{-1} 2,4-D, 0.1 mgl^{-1} NAA, 1.0 mgl^{-1} BAP and 0.5 mgl^{-1} kinetin. Such callus on transfer to media with 1.0mgl^{-1} 2,4-D, 0.1 mgl^{-1} NAA, 1.0 mgl^{-1} BAP and 0.5 mgl^{-1} kinetin showed organogenesis and subsequent formation of plantlets. Efforts are on for selection of somaclones to withstand katte disease (Nirmal Babu *et.al.*, 1994). Due to the commercial potential many agencies are now multiplying cardamom through tissue culture for cultivation.

Cloves (*Syzygium aromaticum* (L.) Merr & Perry)

Most of the tissue culture work on cloves were using seedling tissues. The shoot tip explants produced multiple shoots on MS media supplemented with NAA and BAP. Mathew and Hariharan (1990) found that coconut water promoted the multiple shoot formation. Woody plant medium supplemented with 3.0 mgl^{-1} BAP and 1.0 mgl^{-1} kinetin also induced multiple shooting (Nirmal Babu *et. al.*, 1994). Rooting was seen in the same basal medium with 0.5 mgl^{-1} IBA.

Cinnamon (*Cinnamomum zeylanicum* Breyn.)

Attempts at *in vitro* studies of cinnamon have been limited. Shoot tips of seedlings as well as mature trees were used for multiplication. Rai and Jagadishchandra (1987) reported the formation of multiple shoots from hypocotyl and shoot tips of seedlings. Shoot tips developed multiple shoots on MS supplemented with 0.5 mgl^{-1} NAA and 0.5 mgl^{-1} BAP while the hypocotyl explants multiplied on MS supplemented with 0.5 mgl^{-1} BAP and 0.5 mgl^{-1} kinetin. They have also found rooting of the shoot tips in White's medium (White, 1943) fortified with 0.1 mgl^{-1} each of IAA, IBA and IPA. They could induce callus in the shoot tip explants on MS medium with 1.0 mgl^{-1} of 2,4-D. Nirmal Babu *et. al.* (1994) reported the formation of multiple shoots from shoot tips on woody plant medium containing 5.0 mgl^{-1} BAP and 1.0 mgl^{-1} kinetin. Though various workers have succeeded in getting multiple shoots and rooting in separate experiments a proper micropropagation protocol is yet to be developed.

Black Pepper

The culture procedures for black pepper were reported from different explants (Mathews and Rao, 1984; Philip *et. al.*, 1992; Nazeem *et. al.*, 1992; Nirmal Babu *et. al.*, 1993 a; Bhat *et. al.*, 1995). Pepper has long been a problematic material due to the incipient contamination as well as its mucilaginous nature. As systemic contamination was present, the selected plants were pre-treated with streptocyclin and bavistin at weekly intervals. Another antibiotic – norflaxicin - at 10,000 mgl^{-1} was found to reduce the contamination considerably. It was also used for the pretreatment and also incorporated into the medium (Nazeem *et. al.* 1992). The buds started sprouting on half strength MS liquid medium with 1.0 mgl^{-1} IAA and 1.0 mgl^{-1} BAP in two weeks of inoculation. A comparative study of the response of different *Piper* species (Bhat *et. al.*, 1995) showed that the nodes of black pepper sprouted with BAP while the axillary sprouts appeared in media with kinetin. The rate of multiplication was low. The shoot tips and nods on woody plant medium with 3.0 mgl^{-1} BAP and 1.0 mgl^{-1} kinetin produced multiple shoots (Nirmal Babu *et. al.*, 1993 b).

Rubber (Hevea brasiliensis *Muell. Arg.*)

This is a major commercial crop grown extensively on a plantation level. The planting materials are usually grafts of high yielding superior genotypes. As the grafting process is time consuming and labour intensive, micropropagation has

great relevance in the production of uniform planting material.

Extensive work has been carried out on the *in vitro* culture of rubber but the progress has been slow and no commercially viable method has been evolved till recently. Jayasree *et al.* (1999) has reported the successful regeneration of plantlets through somatic embryogenesis from the immature anthers. The immature anthers from 0.5 mm sized flower buds (before microsporogenesis) were cultured on to modified MS medium containing B5 vitamins (Gamborg *et al.*, 1968), 5% sucrose, $2mgl^{-1}$ 2,4-D and $0.5mgl^{-1}$ kinetin. Three types of calli were observed: friable, less friable and the compact type. The less friable callus then on to medium containing $0.7mgl^{-1}$ kinetin and $0.2\ mgl^{-1}$ NAA initially turned brown and later yellowish friable embryogeneic callus emerged from it. The various stages of embryogenesis could be observed on the same medium. The entire process was slow and took several weeks at each stage. The somatic embryos thus produced on transfer to hormone free medium resulted in the growth and formation of plantlets. Simultaneous formation of shoots and roots was rare but the shooting was followed by rooting. Almost 27 % of the embryoids could be grown into normal plantlets.

The high commercial value of the micropropagation procedures in most of the plantation crops has resulted in much secrecy and this has delayed the successful development of the technologies. The research part of developing the technique is the responsibility of the scientific community. It is difficult, time consuming and at the same time quite expensive. At the next stage of pilot scale multiplication, the cost of production is brought down and the necessary appropriations are introduced. There on the actual process of micropropagation is a simple procedure, which can be practised by any one with some working experience (Raju and Kavitha 1997,1998). With the enormous research going on for developing the micropropagation protocol, most of the plants that are now considered recalcitrant would become amenable to mass propagation. Let us hope the day of maximum utilization of this modern tool for crop improvement is not too far.

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In Vitro Conservation

V.A. Parthasarathy

Introduction

Conservation of plant genetic diversity is an important aspect of crop improvement. These natural resources are the storehouse of potential genes used in breeding programmes. Most of the important local varieties of crop plants preserved by the farmers are being replaced by newly developed varieties leading to monoculture. This has lead to the extinction of many valuable germplasm. Plant genetic resources conservation in the broadest sense is of the utmost importance to mankind's future with *in vitro* conservation being a major component of the overall conservation imperative (Withers, 1992).

Conservation Strategies

Conservation methods can be *in situ* or *ex situ*. Conservation of genetic resources in their natural habitat is called *in situ* conservation while conserving the germplasm in an environment away from its natural habitat under protected condition is called *ex situ* conservation. The most common method of *ex situ* conservation of genes is the seed bank. This is the most preferred and economical method of conservation. Seeds can be divided into two kinds for purpose of conservation namely, orthodox and recalcitrant. Orthodox seeds can tolerate desiccation and exposure to low temperatures and can be stored for years in considerable security under controlled conditions (Bonner, 1990). Recalcitrant seeds are those whose storage is impossible because of their inability to tolerate desiccation and they are sensitive to chilling. Besides they lack a natural dormancy mechanism (Roberts and King, 1982; Withers, 1992). Examples of this kind are, most of the palms, mango, jack fruit and cocoa. The third group of materials which are difficult to conserve are those which are propagated clonally. Recalcitrant seeds and clonal materials are stored in field gene banks. Seed banks can be active or base collections. Active collections are those used for medium-term conservation and for germplasm exchange, while base collections are under secure conditions for longer storage (Withers, 1992).

In Vitro Conservation

Biotechnological tools have been used to conserve germplasm very effectively and offsets the problems encountered with traditional methods. The method used is called *in vitro* conservation. Advantages of *in vitro* conservation are: Even in case of orthodox seeds, conservation is a problem because of heterozygosity involved in the seeds. Hence clonal materials would be useful. In case of recalcitrant materials clonal materials are the choice or even germinated embryos or other explant source can be conserved. Clonally propagated materials can be effectively stored. It is also an effective method for germplasm collection and exchange. Other forms of plant materials like pollen and DNA could also be stored.

There are three types of storage system described by Withers (1992) as given below:

(1) Normal *in vitro* culture and propagation

(2) Slow growth or reduced growth

(3) Suspension of growth.

Besides the above, cryopreservation is widely used.

Problems associated with *in vitro* conservation

Problems of genetic instability in callus culture (Hiraoka and Kodama, 1984) are somaclonal variation in organized cultures particularly those that involve an adventitious or quasi adventitious phase in their generation as in case of banana and pineapple (Wasaka *et al.*, 1978; Banerjee *et al.*, 1986). The method is expensive requiring expertise, space and infrastructure.

Slow growth storage

Engelmann (1997) described two methods of slow growth storage. They are classical techniques and

alternative techniques which are being described below.

Classical techniques

Manipulating culture conditions to reduce growth of cultures can be maintained. Bertrand-Desbrunais (1991) Engelmann, 1997) stored a range of *Coffea* species on standard medium at 27°C without subculturing for 6 to 12 months. Similarly, cold-tolerant temperate fruit crops have been stored in low temperature regimes (Mullin and Schlegel, 1976; Druart, 1985). Tropical species are cold sensitive and have to be stored at higher temperatures. Modifications can be made to the culture medium such as altering sugar concentrations (Ko *et al.*, 1991), addition of osmotic inhibitors like mannitol, hormonal supplementation like abscisic acid for growth reduction. The type of explants and its physiological status also influences the storage period. Kartha *et al.* (1981) found the presence of roots enhanced the storage of coffee. Other conditions that affect the storage conditions are type of culture vessel, volume and the caps used to cover the containers. When the cultures are transferred to fresh medium under optimum condition, the cultures revert to growth.

Alternative Techniques

These techniques involve modification of gaseous environment, desiccation and or encapsulation of explants (Engelmann, 1997).

Modification of gaseous environment can be brought about by reduction of oxygen available in the culture vessels by overlay of paraffin, mineral oil or using liquid medium. By using controlled atmospheric conditions by regulating the oxygen level to 1% level, oil palm polyembryonic cultures were conserved at room temperature for 4 months (Engelmann, 1990).

Desiccation of cultures (Nitzsche, 1980) has been used to develop synthetic seeds. The synthetic seeds can be progressively rehydrated using salt solution and can be sown after partial rehydration.

Cryopreservation

The two techniques of cryopreservation are classical and alternative.

Classical procedure

The method of storing living systems using chemical cryoprotectants, slow dehydrative cooling followed by rapid immersion in liquid nitrogen, storage in liquid nitrogen, rapid thawing, washing and recovery are the steps involved in classical techniques of cryopreservation (Engelmann, 1997).

The various cryoprotective substances used are dimethyl sulfoxide, sorbitol, mannitol, sucrose and polyethylene glycol. Freezing temperatures between 0.5 and 2°C min^{-1} down to prefreezing temperatures around -40°C generally give satisfactory results (Dereuddre and Engelmann, 1987). The major disadvantage of this classical method is the requirement of expensive programmable freezers.

Alternate (new) techniques

This technique employs vitrification as basis. This procedure is operationally less complex as they do not require expensive freezers and are operationally less complex. In this process, there is no ice formation during the freezing process. Because of this, it is ideal for apices or embryos requiring varied freeze induced dehydration (Engelmann, 1997).

Engelmann (1997) describes seven different vitrification based procedures: (i) encapsulation-dehydration (ii) vitrification (iii) encapsulation-vitrification (iv) desiccation (v) pregrowth (vi) pregrowth-desiccation and (vii) droplet freezing.

Table 1 summarises the results of cryopreservation of different organs of plantation crops.

Conclusion

In vitro conservation of plantation crops is an important aspect of research that needs to be intensified. Maintaining the genetic resources in field gene banks require large area and huge manpower to man them. However, many of the plantation and spice crops are recalcitrant species requiring techniques to be perfected.

Table 1. Summary of results of *in vitro* conservation of plantation crops

Sl. No.	Species	Organ conserved	Technique	Reference
1.	Coconut	Zygotic embryo	Pregrowth/ desiccation	Chin *et al.* (1989) Assy-Bah and Engelmann (1992)
2.	Cocoa	-do-	-do-	Pence (1991)
3.	Coffee	-do-	Desiccation	Normah and Vengadasalam (1992)
		Somatic embryo	Desiccation/ pregrowth	Mycock *et al.* (1995)
		Apex	Encap/dehyd.	Engelmann *et al.* (1994)
4.	Oil palm	Embryogenic culture	Pregrowth/ desiccation	Dumet *et al.* (1993)
		Zygotic embryo	Desiccation	Engelmann *et al,* (1995a)
			Encap./Desiccation	Engelmann *et al.* (1995b)
5.	Pepper	Seed	Desiccation	Chaudhury and Chandel (1994)
6.	Turmeric, Ginger and Cardamom	Shoots	Slow growth	Geetha *et al.*, (1995)
7.	Rubber	Zygotic embryo	Desiccation	Normah *et al.*, (1986)

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Biochemical Markers in Characterizing Genetic Diversity

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Introduction

Biochemical techniques have now become an integral part of many crop improvement programmes throughout the world. Two major biochemical techniques, chromatography and gel electrophoresis, have been the major sources of information on the genotypic variability of most plantation crops, through the study of phenolics and isozymes. Each group of compounds has its particular applications and limitations, and have been used for rather distinct purposes. However, more recently, these techniques have been supplemented by the development of methods of DNA analysis which enable us to describe variation in the genetical material itself.

Phenolics

The potential of phenolic compounds in chemotaxonomic studies became apparent following the pioneering work of E.C. Bate-Smith (founder of the Phytochemical Society). Bate-Smith and the early workers on chemotaxonomy, Tony Swain and Jeffrey Harborne, observed a non-random distribution of phenolic compounds in higher plants and realised their potential as a class in taxonomic studies of variation. For example, Bate-Smith (1962) observed a high correlation between the presence of proanthocyanidins and woodiness. Such restricted distributions showed a remarkable coincidence with phylogenetic classifications based on morphological characters, and it was soon realized that phenolics could be used as a form of chemical taxonomy. Subsequently phenolics were found to play a role in resistance of plants to disease-causing microorganisms and leaf-eating insect pests. In plantation crops, phenolic compounds have been used to study taxonomic variation and as resistance and quality markers.

Taxonomic variation

In general, the most useful applications have been at relatively high levels of taxonomic division (e.g. orders and families), and have been on the basis of presence or absence rather than on more quantitative distinctions. The reason for this is that the majority of diagnostic plant phenolics are the end-products of lengthy and complex metabolic pathways which are particularly susceptible to environmental and ontogenic influences. Factors such as the light regime, the carbon/nitrogen balance, the developmental stage of the plan and reaction to herbivory can greatly influence, both quantitatively as well as qualitatively, the phenolic status of the plant. Nevertheless, if attempts are made to keep environmental influences at a minimum, useful information can be obtained at lower levels of taxonomic hierarchy.

Among plantation crops, phenolic constituents as taxonomic markers have been studied mainly in tea and coffee and to a limited extent in coconut.

***Coffee*:** Chemotaxonomic studies on coffee has been made by a number of workers. Longo (1975) studied the phylogenetic relationship in *Coffea*, through chromatographic analysis of flavonoid composition in different species of coffee. As a result, *Coffea kapakata*, has been placed in *Coffea* rather than in the subsection *Psilanthopsis*. In another study, on flavonoid patterns, Lopes and Manaco (1979) drew conclusions concerning the taxonomy of the genus *Coffea*. They found *C. eugenioides* to be closely related to *C. arabica* and *C. salvatrix* of subsection *Mozambicoffea*. *C. stenophylla* seemed to be closer to subsection *Mozambicoffea* than to those of subsection *Pochycoffea*. They also postulated that *C. salvatrix* played a role in evolution of *C. eugenioides*, which in turn may have been involved in the development of *C. arabica*. They observed absence of similarity in flavonoid patterns of *C. arabica* and *C. congensis*, while *C. liberica* and *C. dewevrei* were very similar in their flavonoid composition. On the other hand, Santa Ram and Sreenivasan (1982), based on their studies on phenolic constituents (phenols, tannins, flavonoids) in *C. arabica*, 4 putative relatives and a *C. liberica x C. eugenioides* hybrid, detected close relationship between *C. stenophylla* and both *C. arabica* and *C. congensis*, while the hybrid was closer to *C. arabica* than either of the parents.

On the other hand, chromatographic profiles have also been utilized to discriminate between *C. arabica* 'Caturra' and *C. canephora* (Orozco-Castano and Cassalett-Davila, 1974) and between arabica and robusta green coffee varieties (Andrade *et al.*, 1998; Martin *et al.*, 1998). Lopes and Monaco (1978), studied flavonoids in four cultivars of *C. canephora* collected from different parts of Central and West Africa and observed a correlation between chemical affinity and geographical affinity. Andrade *et al.* (1998) also postulated a correlation between the relative

hydroxycinnamic acid and botanical origin of coffee.

***Tea*:** Chromatographic analysis of leaf flavonoids has been applied in chaemotaxonomic studies in the genus *Camellia* (Nagata and Sakai, 1985) and to discriminate between tea varieties and clones (Chkhikvishuili and Zaprometov, 1986).

Nagata and Sakai (1985), on the basis of flavonoid composition, postulated that *C. vernalis* and *C. hiemalis* are hybrids between *C. sasanqua* and that *C. tenuiflora* is closely related to *C. oleifera*. They also concluded that *C. wabisuke* is not related to *C. sinensis*.

Chkhikvishuili and Zaprometov (1986) compared flavonoid patterns of different clones and varieties of Georgian tea and detected differences between the forms.

In addition, quantitative estimation of different phenolic constituents has been undertaken in different tea varieties and clones. However, quantitative measurements are not useful as taxonomic markers due to greater seasonal and temporal variation for phenolic constituents within individual trees.

***Coconut*:** Studies on polymorphism of coconut leaf polyphenols have been undertaken at IRHO, France. Jay *et al.* (1989) analysed the chromatographic profile of leaf polyphenols in selected accessions of coconut and detected considerable diversity between accessions. Clustering based on principal component analysis, revealed grouping of cultivars based on geographical origin, indicating correlation between chemical affinity and geographic affinity.

In India, Chempakam and Ratnambal (1993) at CPCRI, Kasaragod, studied quantitative variation for leaf polyphenols in 36 different cultivars. They observed considerable variation in leaf polyphenol content between accessions and across geographic origins. In general, they recorded higher phenolic levels in Dwarfs as compared to Talls, irrespective of geographical origin.

Though phenolics being ubiquitous and varied in structural diversity offer a wide range of potential genetic markers, yet they have not been used to a greater extent in studying variation in plantation crops. However, they have been used to a limited extent as resistance markers to diseases in coffee and tea and at a preliminary level in oil palm and coconut.

Isozymes

Isozymes are the multiple molecular forms of enzymes (proteins) separable by electrophoretic procedures, occurring within the same organism and having similar or identical catalytic activities. The term 'isozyme' was first introduced by Markert and Moller (1959). Later, a related term 'allozyme' was introduced to refer to different molecular forms of an enzyme encoded by different alleles of a single locus.

The development of starch gel electrophoresis by Smithies (1955), followed by the demonstration that enzymes could be visualized directly on starch gels when stained with a specific histochemical stain and the development of zymogram technique by Hunter and Markert (1957) initiated the now widespread interest in isozymes.

Tissue extracts when placed in a supporting medium (gel matrix) like starch or polyacrylamide and subjected to an electric field, the protein molecules migrate depending on their net charge and pH of the medium. In addition, the nature (size, shape) of the charged particles being separated also affects the migration rate. Thus, the active enzymes can be separated into discrete bands and their position on the gel visualized using specific enzyme stains.

Enzymes, are the primary products of a gene. Therefore, variation in their structure should give reliable information about the variability in the genome itself, and be less susceptible to environmental influence than the so called secondary products of metabolism which are formed as a result of enzyme activity. However, one technical limitation is the fact that only those genotypic differences which result in a change in the net charge of the enzyme protein will be evident after electrophoretic separation. Another limitation is the restricted number of enzyme systems for which suitable separation and staining techniques are available.

In addition to these restrictions, isozyme patterns can show considerable variation within individual plants and between different stages of growth and development. Therefore, it is essential to standardize the stage and type of tissue sampled for isozyme analysis.

Despite these limitations, isozymes have found a number of applications in crop improvement research. They have been found to be of particular use at the lowest taxonomic levels where they can act as markers for individuals in breeding studies. The ability to identify specific genetic loci and to make genetic interpretations of banding pattern variations gives isozyme markers an advantage over multigenic products like phenolic compounds. At the population level, isozymes have been found to be useful in estimating degrees of heterozygosity and genetic distances. In plantation crops, isozymes have been used mainly to study population structure, inheritance and linkage studies of isozyme loci and as taxonomic markers for identification of clones, species, hybrids and their phylogenetic relationships.

Limited studies have been undertaken in some plantation crops to detect relationships between isozyme markers and disease/pest resistance/tolerance and stress tolerance.

Taxonomic markers

Isozymes have been used as markers at the population level, species level and individual tree level. At the population level, almost all studies of geographic variation within a species using isozyme markers have shown that most of the variation observed resides within rather than between populations. This high intra-population heterozygosity is due to the breeding systems that promote gene-flow within and between sub-populations. The knowledge of the presence of large amounts of genetic variation within populations can be of great value in crop improvement programmes. In addition, identifying sub-populations characterized by high genetic variation is of value in gene conservation, and in selection of trees for use in increasing the gene-pool of breeding populations. However, theoretically, patterns of isozyme variation cannot be used to predict genetic variation in other traits, since isozymes tend to measure selectively neutral variation while quantitative traits are governed more strongly by selection and therefore much more differentiated between populations.

Isozymes, theoretically, are well-suited to identify closely related individuals or clones, simply by comparison of phenotypic banding patterns without the necessity of understanding their genetic basis and inheritance. The main restriction is the degree of polymorphism in the available enzyme systems in the population of interest, in relation to the number of genotypes which have to be differentiated.

Coffee: At the population level, isozyme analysis has been used for phylogenetic studies and to estimate mean heterozygosity and genetic distance. In addition, isozyme banding pattern has been utilized in determining parents in interspecific hybrids, differentiating between cultivated subspecific taxa and in characterization and identification of individual trees.

Lopes *et al.* (1978) studied phylogenetic relationship in 11 species of the genus *Coffea* based on esterase banding pattern and suggested the involvement of *C. canephora* and *C. eugenioides* in formation of the tetraploid *C. arabica* and that *C. salvatrix* was involved in the formation of *C. eugenioides*. Flavonoid patterns also revealed a similar relationship (Lopes and Manaco, 1979). Medina-Filho *et al.* (1995) utilized isozyme banding pattern to confirm the interspecific origin of *Piata* coffee, from the fusion of a normal *C. arabica* gamete (n = 22) and an unreduced gamete (2n = 22) of *C. dewevsei.*

On the other hand, Berthon *et al.* (1980), calculated the mean heterozygosity and intraspecific genetic distance in 18 wild populations of coffee belonging to 7 taxa using enzyme banding patterns of 8 enzyme systems. In another isozyme study on 13 species (12 diploid and tetraploid *C. arabica*), Lopes (1993) showed that similarity among species of the same subsection is not always greater than among species of different subsection.

Isozyme patterns were used to distinguish between the cultivar Caturra (*C. arabica* x Timor hybrid) (Daza *et al.*, 1993); to distinguish between subspecific taxa of *C. arabica* and also identify individual trees within a cultivated taxa (Payne, 1975) and to characterize and evaluate *C. canephora* trees for use in breeding programmes (Montagnon *et al.*, 1993).

In *Coffea canephora*, the detection of two complementary Guinean and Congolese groups by Berthaud (1986) through isozyme analysis led to the launch of a reciprocal recurrent selection scheme between the two groups (Meunier, 1995).

Tea: Isozyme variation has been utilized to study the interspecific and intraspecific relationship in the genus *Camellia* (Nagato, 1979). Nagato and Osone (1982) studied isozyme banding pattern in Assamese (*C. sinensis* var. *assamica*), Chinese and Japanese (*C. sinensis* var. *sinensis*), tea lines and observed that the frequencies of certain minor bands varied between the populations. However, variation in zymogram patterns occurred within the groups and largely overlapped between them.

Lu *et al.* (1993) used isozyme analysis for studying the origin of tea plants. Based on their analysis of germplasm from a range of Chinese provinces, they concluded, that tea samples from South Western China are more primitive than those from Central and Eastern parts of China.

Isozyme analysis has also been used to differentiate between tea clones and hybrids (Anderson, 1994; Chen Chun Lin, 1996), and to classify tea strains and varieties (Tani and Nakagahra, 1981). Chen Chun Lin (1996) based on their studies on F_1 hybrids, concluded that greater the differences between parental isozyme patterns, the higher the frequencies of hybrid and complementary bands in the F_1 hybrids, and the greater possibility of heterosis.

Rubber: Isozyme markers have been used for rubber germplasm characterization (Seguin *et al.*, 1995, 1996) and for identification of *Hevea* cultivars and hybrids (Yeang *et al.*, 1977, 1998; Sreelatha *et al.*, 1993; Seguin *et al.*, 1995, 1996). In addition, Paiva *et al.* (1994) utilized isozyme analysis for assessing the genetic diversity in natural populations of rubber prior to germplasm collection. Isozyme analysis has also been used for determining the genetic relatedness between

cultivated *Hevea* clones (Yeang *et al.*, 1998).

In rubber, considerable genetic diversity was observed even among cultivated *Hevea* clones derived from a small number of plants, sourced from a single germplasm collection site (Yeang *et al.*, 1998) indicating the vast variability that can be tapped for rubber improvement programmes.

Isozyme markers in combination with molecular markers have been successfully applied in genome mapping and construction of the first partial genetic map of *Hevea* (Seguin *et al.*, 1996).

Cocoa: At the population level, isozymes have been used for assessing the heterozygosity and genetic diversity available in germplasm collection (Warren, 1994; Yamada and Guries, 1994; Sounigo *et al.*, 1997) and in natural populations (Amefia *et al.*, 1984; Lanaud, 1986; Ronning and Schnell, 1994). Isozyme polymorphism studies indicated that African Trinitario types were intermediate between the American Trinitario and Lower Amazonian Forastero types, and that the Lower Amazonian Forastero types have lesser genetic diversity (Lanaud, 1986). Studies on allelic variation in cocoa populations of South America, contradicated the current view that the Upper Amazonian region of Peru is the centre of origin of cocoa. Warren (1994) observed very low isozyme polymorphism due to low genetic diversity in this region and concluded that the centre of origin of wild cocoa lies further North in Eucador or Columbia.

In cocoa, unlike other plantation crops, isozyme markers have successfully grouped Trinatario types according to their geographical origin (Sounigo *et al.*, 1997). Similarly, allozyme data distinguished Caribbean and Central American groups from South American clones (Ronning and Schnell, 1994).

In addition, isozyme markers have been applied for identifying clonal material for breeding and germplasm characterization (Atkinson *et al.*, 1986; Ronning and Schnell, 1994).

Lanaud *et al.* (1995) constructed genetic linkage map of cocoa using isozyme markers and molecular markers. Warren *et al.* (1995) observed strong linkage between ACP and IDH loci with one of the loci controlling compatibility type and suggested isozyme screening of seedlings to predict compatibility type and hence pod set and possibly yield of mature tree as self-incompatible clones outyield self compatible ones.

Oil palm: Isozyme analysis has been found to be useful as genetic markers for identifying different oil palm species and hybrids (Gan *et al.*, 1983; Ataga and Fatokun, 1989) and studying genetic variability in oil palm populations (Ghesquire, 1983; Ahmad Kushairi Din, 1985; Santos *et al.*, 1993) and germplasm collections (Choong *et al.*, 1996). Choong *et al.* (1996) observed that the degree of isozyme polymorphism increased from the family to ecotype level and that the polymorphism is influenced both climatically and geographically.

Coconut: Work on isozymes in coconut was initiated at IRHO, France, way back in the 1970s. These studies indicated species level variability but low general polymorphism for the enzyme systems studied (Meunier, 1992). In general, genetic diversity was greater in Tall populations rather than Dwarf types (Meunier, 1992; Asmono *et al.*, 1993; Fernando and Gajanayake, 1997; Cardena *et al.*, 1998). In India, isozymes have been used to study isozyme profiles of selected cultivars (Shivashankar, 1990; Anonymous, 1996). Presently at CPCRI, Kasaragod, studies on isozyme variation in coconut germplasm and hybrids are in progress. In coconut, however, no correlation was observed between isozyme polymorphism and geographical origin of the ecotypes (Meunier, 1992). On the other hand, Fernando and Gajanayake (1997) postulated the existence of a relationship between the frequency of certain isozyme bands and palm yield potential that could be successfully used to screen coconut germplasm for desirable characters.

Conclusion and Future Thrust

Isozyme electrophoresis and chromatography of phenolic compounds are the most widely used biochemical markers in characterizing plant genetic variation. In addition, at the molecular level, DNA markers have been developed. Each system has its own advantages and disadvantages (Table 1) as well as characteristic applications (Table 2). However, the development of molecular techniques for analyzing the structure of the genetic material itself (DNA) has helped overcome two of the major limitations with biochemical markers. First, there is now no theoretical limit to the fraction of the total genome which is available for analysis; and secondly by analysing genes directly rather than at second-hand by the characteristics of gene products, environmental or other modifications associated with the transcriptional processes are irrelevant. However, the development of newer techniques, does not in any way make the older methods obsolete. The more traditional markers still have a valuable role to play in wide-scale surveys; for overviews of the genetic structure of species and at the population level secondary compounds and isozymes are unquestionably important markers (Table 2). Technical simplicity, speed and relatively lost cost make them ideal in such applications. However, for more refined analysis, in particular for the detection of variability in the individual tree

Table 1. Attributes of biochemical and some molecular markers

Marker	Advantages	Disadvantages
Phenolics	Low cost, rapid. Ease of analysis (some). Ecological importance. Ubiquitous, diverse.	Environmental and temporal variation. Within-plant variation. Problems of extraction and estimation (some). Complexity (tannins).
Isozymes	All species and tissues. Small samples required. Environmentally stable. Allozymes co-dominant. Simple inheritance. Highly polymorphic.	Few systems only. Toxic consumables. Variation underestimated. Variation within method. Within plant variation. Biased genome sample.
RFLP	All species and tissues. Unlimited in number. Environmentally stable. Co-dominant inheritance. Samples much of the genome. Several genomes available (nuclear, mitochondrial, chloroplast).	Expensive and slow. Technically complex. Radioactive probes. Pure DNA required. Large samples.
RAPD	All species and tissues. Unlimited in number. Environmentally stable. Genome saturation. No radioactivity. Fast and fairly simple. Small impure samples.	Dominant markers. DNA contamination problems. Spurious priming. Low reproducibility. Variation with DNA concentration, polymerase etc. Expensive consumables. Uncertain band identity.

Table 2. Principal applications of markers in tree improvement

Marker	Applications	Marker	Applications
Phenolics	Taxonomic markers at various levels; Population variation, introgression; Clonal and hybrid identity (some species); Resistance markers.	RFLP	Phylogeny and diversity at various levels; Genetic linkage maps; QTL linkages; Genotype identity; Paternity analysis.
Isozymes	Mating systems and outcrossing; Comparative population variation estimates; Gene-flow, introgression, hybridization; Genetic and linkage mapping; Crossing authentication; Clonal markers.	RAPD	Clonal, cultivar and origin identity; Population diversity; Species relationships (some); Paternity analysis; Genome mapping; QTL linkages.

level, DNA markers have the advantages of far greater versatility and resolving power. The benefits of each approach must be emphasized, and it should be appreciated that they are complementary rather than alternative.

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Molecular Markers and Marker-Assisted Selection in Plantation Crops

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Introduction

Broad-based plant germplasm resources are imperative for sound and successful crop improvement programmes and therefore, understanding and management of genetic variability is essential. In the past, morphological characters were used to characterize and classify the plants. However, the genetic information provided by morphological characters is limited. These limitations could be circumvented to some extent by deploying biochemical techniques such as isozymes and protein electrophoresis (Tanksley and Orton, 1983; Nielsen, 1985). However, these techniques have their inherent disadvantages like limited number and dependence on environment and developmental stage. DNA markers overcome all these limitations and are widely used in plant taxonomy and breeding. Since these markers allow detection of variation at the DNA level itself, the differences in gene sequence can be observed directly with great precision. These markers are of utmost use in perennial crops where analyses of traits is very difficult and time consuming due to long life cycle. Molecular markers have wide uses in germplasm conservation and breeding programmes such as (i) germplasm characterization, (ii) analysis of genetic variability, (iii) varietal identification, (iv) construction of linkage maps (v) phylogenetic analysis (v) marker-assisted selection (vi) cloning of specific genes (vii) gene pyramiding etc. During the last few years, molecular markers have been used in plantation crops also with emphasis on analysis of genetic diversity and validation 171of phylogeny. More recently, attempts have been made for construction of linkage maps also. These efforts will go a long way in improvement of plantation crops.

Molecular Markers Techniques

The use of DNA markers for detection of genetic variation was made possible by a number of discoveries during last two decades. The most significant being the identification of restriction enzymes, which cut DNA at specific sites, resulting in millions of fragment, which can be separated based on their size. Any variation at cut site results in variation in fragment size. This variation in fragment size is the basis for RFLP (Restriction Fragment Length Polymorphism), one of the first molecular markers widely used for genetic variation, molecular mapping, varietal identification, and marker assisted selection.

The development of Polymerase Chain Reaction (PCR) was another breakthrough in genome analysis since it enabled the amplification of specific fragments from the total genomic DNA. This technique is based on the properties of DNA polymerase, which can synthesize a duplicate molecule from a DNA template with the help of a primer. The product of duplication becomes the template for repeated rounds of duplication, resulting in exponential increase in DNA product accumulation. The DNA target is defined by primer annealing sites. Primers are short stretches of DNA sequence which are complementary to the opposite end of the target sequence DNA. The distance between the primary sites determine the size of amplified product.

The presently available molecular marker techniques are based on the use of restriction enzymes, PCR or both. These techniques can be divided into two classes *viz.*, Non-PCR based and PCR based.

Non-PCR based techniques

Restriction fragment length polymorphism (RFLP): In RFLP, DNA is digested with restriction enzyme and the resultant fragments are separated by gel electrophoresis and transferred to a nylon membrane by Southen Blotting. To detect the difference in the fragments from different individuals, the filter is hybridized with a labelled 'probe', a small DNA fragment having complementary sequence to the DNA strand of target DNA. The probe will hybridize to any fragment immobilized on the filter with which it shares sequence complementarity. After exposing hybridized filter to X-ray film, bands will appear only where the probe has hybridized to different fragments. The banding pattern obtained is referred to as the 'restriction fragment pattern'.

Specific probe/enzyme combinations will give highly reproducible restriction fragment patterns for a given individual. However variation between individuals can arise when mutations alter the sequence in the restriction sites or the fragment length between them by the insertion or deletion of base pairs (Burr *et al.,* 1983; Evola *et al.*, 1986; Helentjaris *et al.*, 1985).

RFLPs are highly reproducible and the same probe enzyme combination on the same samples will give exactly the same results even when ca171rried out in different laboratories. They are the codominant markers.

Variable Number of Tandem Repeats (VNTRs): Interspersed within the genomes of higher organisms are hypervariable regions, which are comprised of tandemly repeated DNA sequences. There are two classes – 'microsatellites', or simple sequence repeats (SSR), where the basic repeat unit is around 2-8 base pairs in length, and 'minisatellites' for longer repeat units of around 16-100 base pairs. Hybridization of restricted DNA with micro or minisatellite probes gives multilocus patterns, which can resolve variation at the levels of populations and individuals (Beyermann *et al.*, 1992). The variation results from changes in the number of copies of the basic repeat and is often referred to as Variable Number of Tandem Repeats (VNTRs).

PCR Based Techniques

Arbitrary primed PCR

Multiple arbitrarily primed PCR (MAAP): PCR overcomes many of the limitations of probe-hybridization based methods. Using PCR technology, a subset of techniques was developed simultaneously which involves the use of a single 'arbitrary' primer resulting in amplification of many discrete DNA products. These techniques are collectively termed as 'Multiple Arbitrary Amplicon Profiling' (MAAP) (Caetano-Annollës, 1994).

The most common of MAAP is Random Amplified Polymorphic DNA (RAPD). In RAPD, the amplified products are separated on agarose gels in the presence of ethidium bromide and visualized under ultraviolet light (Williams *et al.*, 1990).

AP-PCR (Arbitrary Primed PCR) (Welsh and McClelland, 1990) and DAF (DNA Amplification Fingerprinting) (Caetano-Annollës *et al.*, 1991) differ from RAPDs in primer length, the stringency conditions and the method of separation and detection of the fragments. Polymorphisms are detected as the presence or absence of bands and mainly result from sequence differences in the primer binding sites.

MAAP has many advantages. There is no requirement for DNA probes or 'a priori' knowledge of sequence for primer design. The technique is quick, simple and efficient and requires less infrastructure and less amount of DNA. However, it has the limitation of dominant nature of the markers.

Amplified Fragment Length Polymorphism (AFLP)

AFLP is the recently developed method and is equally applicable to all species and is highly reproducible (Vos *et al.*, 1995). It combines restriction digestion and PCR. The first step involves, restriction digestion of the DNA with two specific enzymes, one a rare cutter and the other a frequent cutter. Adaptors are then added to the ends of the fragments to provide known sequences for PCR amplification. Primers with adaptor sequence plus one or two extra nucleotides are then used for PCR amplification. Normally two separate selective rounds of PCR are carried out. In the first round only one selective nucleotide is used, whereas in the second round the same selective nucleotide plus one or two additional ones are used. This results in, between 50-100 fragments being amplified, which can be separated on a polyacrylamide gel by electrophoresis. Thus this provides an effective mean of detecting several polymorphisms in a single assay.

Site-targeted PCR: The opposite approach to MAAP is to design primers to amplify specific regions of the genome. The targeted amplified product can be compared on an agarose gel to the corresponding product from another individual, but only changes that are many base pairs in length will be detected. Sequencing resolve all possible differences and data from the aligned sequences can then be compared. A number of gel system such as TGGE (thermal gradient gel electrophoresis; Riesner et al., 1992), DGGE (denaturing gradient gel electrophoresis), single strand conformational polymorphism (SSCP; Hayashi, 1992) and heteroduplex (HD) formation (White et al., 1992), provide sensitive detection assay for sequence variation without the need to sequence all the samples. These detection systems compare differences in the stability, or configuration of the DNA caused by mutation induced change in the composition of base pairs in fragment. The difference is detected as difference in mobility in the gels.

PCR-RFLP

In PCR-RFLP or Cleaved Amplified Polymorphic Sequence (CAPS) procedures the amplified product is digested with a specific restriction enzyme and the products directly visualized on the agarose gel by ethidium bromide staining (Akopyanz *et al.*, 1992; Tragoonrung *et al.*, 1992; Ghareyazie *et al.*, 1995).

Sequence tagged microsatellites (STMS)

This technique uses primers to the flanking regions of microsatellite or simple sequence repeats (SSRs) (Beckman and Soller, 1990). They are usually a single locus, which, because of the high mutation rates is often multi-allelic (Saghai-Maroof *et al.* 1994). They are codominant markers and can be detected by a PCR assay. STMS is distinguished on polyacrylamide sequencing gels where single repeat differences can be resolved and all possible allelles detected.

Variations or combinations of the basic techniques

The above mentioned techniques can be combined. Sequence tagged sites, or STS, is the general term given to a locus defined by its primer sequences. An STS can be created by any

site, provided that the locus can be cloned and sequenced.

Sequence characterized amplified regions (SCARs) are derived from individual RAPD markers (Paran and Mitchelmore, 1993). The RAPD bands are cloned, the nucleotide sequences of the terminal ends are determined and used to design primers for specific amplification of the desired fragment.

MOLECULAR MARKERS – APPLICATIONS

Cultivar identification and estimation of genetic relatedness

Cultivar identification carried out through morphological characters earlier can be achieved very accurately from DNA fingerprint data which, can distinguish even closely related cultivars. Although estimation of relatedness between cultivars with DNA fingerprinting is complicated, however, molecular markers have been widely used for this purpose. Determination of genetic diversity and variability in various plantation crops could be made possible through DNA markers.

Genetic diversity in coconut has been studied through RFLP (Lebrun *et al.,* 1998a; Lebrun *et al.,* 1998b), RAPD (Wadt *et al.*, 1997 and Ashburner *et al.*, 1997), AFLPs (Perera *et al.*, 1998) and SSRs (Rivera *et al.,* 1997; Perera *et al.*,1999) markers in populations from various geographical regions. These studies could detect within and between population diversity and throw light on dissemination and domestication of coconut also (Lebrun *et al.,* 1998b). Dwarf coconuts in general exhibited less variation compared to tall (Perera *et al.*, 1998).

In cocoa *(Theobroma cacao* L.), variation among different cocoa populations *viz.,* Criollo, Forastero and Trinitario has been analysed through RFLP by using chloroplast and mitochondrial probes (Laurent *et al.*, 1993a), cDNA probes (Laurent *et al.*, 1994), rRNA probes (Laurent *et al.*, 1993b; Figueira *et al.*, 1992; Figueira *et al.*, 1994). These studies suggested that Criollo and Forastero populations diverged independently (Laurent *et al.*, 1993a) and Trinitario had a hybrid origin (Laurent *et al..,* 1993b). Evidences for hybridization and introgresson between trees of different origin were obtained through RFLP (Lerceteau *et al.*,-1997).

RAPD markers have also been employed to study of genetic divergence in cocoa (Russell *et al.,* 1995; N'Goran *et al.*, 1994; Figueira *et al.*,1994). N'Goran *et al.* (1994) compared the usefulness of RFLP and RAPD and found RAPD to be as efficient as RFLPs for classifying cocoa genotypes. Figueira *et al.* (1994) distinguished wild cocoa genotypes from cultivated genotypes and observed continuous variation among the generally similar but heterogenous genotypes.

Genetic divergence in oilpalm has been analysed using RAPD (Shah *et al.,* 1994) and RFLPs (Jack and Mayes, 1993; Mayes *et al.,* 1996). These studies demonstrated high levels of genetic diversity in different oilpalm populations. Jack and Mayes (1993) identified hyper-variable probes to differentiate oil palm genotypes.

In rubber (*Hevea brasiliensis* Muell. Arg.), genetic diversity among different geographical groups has been analysed using RFLP (Besse *et al.,* 1994; Luo and Boutry, 1995; Luo *et al.,* 1995; Besse *et al.*, 1993), RAPD (Low *et al.*, 1996; Seguin *et al.,* 1995), Microsatellites and DAF (Low *et al.*, 1996). Based on these markers wild accessions of rubber could be classified according to their geographical origin. However, based on RAPD analysis Varghese *et al.* (1997) reported absence of a distinct geographical grouping of clones from South East Asian countries. While analyzing wild and cultivated accessions using mitochondrial and chloroplast DNA probes, Luo *et al.* (1995) found chloroplast genome to be highly conserved in *Hevea.*

DNA markers have also been used to detect genetic diversity and validate phylogenetic relatedness in coffee (*Coffea arabica and C. canephora*) as well. Interspecific as well as intraspecific variation was observed among different accessions of major coffee species (Lashermes *et al.*, 1993). Species specific markers have been identified and interspecific gene flow was detected by Orozco-Castillo *et al.* (1994). Using RFLP markers allotetraploid origin of *Coffea arabica* was established and its maternal and paternal genome donors were identified (Lashermes *et al.,* 1995) which was further supported by similar results from RAPD analysis of 18 accessions from 11 *Coffea* species (Orozco-Castillo *et al.,* 1996). Molecular marker analysis also suggested east-west differentiation in the primary center of diversification of *C. arabica* (Lashermes *et al.*, 1995; 1996).

Genetic variability among tea (*Camellia sinensis* (L.) O. Kuntze) varieties has been detected using RFLP (Matsumoto *et al.,* 1994), RAPD (Wachira *et al.*, 1995; Wachira, 1996; Tanaka and Vamaguchi, 1996; Wright *et al.,* 1996) and AFLP (Paul *et al.,* 1997). In these studies, variation within population was observed to be higher than that between populations, and validated the present taxonomy of tea varieties. Species specific RAPD products and products potentially diagnostic of introgressive hybridization into the cultivated gene pool were identified (Wachira *et al.,* 1997).

Molecular Linkage Map

Linkage maps, which assign various traits to different chromosomes and allow to follow a trait during hybridization, greatly help to improve the breeding programmes. Due to inherent problems associated with plantation crops *viz.,*. long life cycle, heterozygosity and recalcitrance, the construction of

conventional genetic linkage maps has been far from reality. However, molecular markers have been shown to overcome such limitations and linkage maps have been constructed for a number of otherwise difficult crops.

Among the plantation crops molecular linkage maps have been constructed for oil palm (Mayes *et al.*, 1997), coconut (Rohde *et al.*, 1997), *Coffea* (Paillard *et al.*, 1996) and cocoa (Lanaud *et al.*, 1995; Crouzillat *et al.*, 1996). Rohde *et al.* (1997) used Inverse Sequence Tagged Repeat (ISTR) markers for construction of coconut linkage map using F_1 plants as mapping population. Of the 51 polymorphic markers identified, 43 could be arranged into 12 linkage groups comprising a total of 542 recombinant units.

In oil palm, a segregating population of 98 individuals was used for construction of RFLP genetic linkage map, comprising 24 groups (Mayes *et al.*, 1997), whereas a doubled haploid population was used for developing a RFLP and RAPD linkage map in *Coffea* (Paillard *et al.*, 1996).

In cocoa, backcross population (Osei *et al.*, 1995; Crouzillat *et al.*, 1996) as well as individuals from a cross of two heterozygous genotypes (Lanaud *et al.*, 1995) were used for construction of a linkage map containing RFLP, RAPD as well as isozyme and morphological loci.

Marker assisted selection (MAS)

Molecular analysis and genome mapping make it possible to locate gene of agronomic value quite accurately. Marker assisted selection involves identification of molecular markers closely linked to a trait. Then the marker can be used for indirect selection of the trait in plant breeding. This application of molecular marker is of particular advantage in breeding for disease resistance, since resistant progenies can be selected without exposing them to pathogen and at seedling stage itself, using fewer plants. Thus MAS is being increasingly used in breeding programmes. Initially more emphasis was on identification of markers linked to monogenic traits. However, recently markers have been developed for several quantitative traits, governed by multigenes. Most of the important characters like yield and yield components, drought tolerance and days to flowering, are polygenic and are termed quantitative. Molecular markers can be applied for the identification of Quantitative Trait Loci (QTLs) for trait that is under the control of small number of major genes with large environmental variance or a large number of minor genes with small effects or a mixture of two. For identifying the QTLs of a trait there should be linkage between marker and QTL and for exercising efficient MAS, there should not be crossing over between the marker allelle and the QTL. Paterson *et al.* (1988) suggested that the use of marker information could reduce the number of back crosses required by half. During MAS, instead of using a single marker for selection, if flanking markers are used, the accuracy of selection improves. Dudley (1993) suggested various approaches to marker assisted selection.

In plantation crops there are a few reports on identification of molecular markers closely linked to morphological traits. In cocoa, Crouzillat *et al.* (1996) identified two molecular markers co-segregating with *Anth*, gene controlling anthocyanidin synthesis in seeds, leaves and flowers. They used molecular linkage map to locate QTLs for early flowering, trunk diameter, jorquette height and ovule number in the BC1 generation. 2-4 QTLs involved in the genetic expression of the traits studied were identified. QTL for jorquette height and trunk diameter were mapped at same loci suggesting the possibility of pleiotropic effects in cocoa for these traits. Mayes *et al.* (1997) identified RFLP marker cosegregating with shell thickness character (*Sh*) in oil palm at a map distance of 9.8 cM.

Future Thrust

Molecular marker technology is a rapidly evolving field with new types of markers being added at a very fast rate, thus offering many exciting opportunities. While assessment of genetic diversity should continue to get the preference for the reasons explained earlier, consideration should also be given to the identification of the markers closely linked to important traits, both monogenic as well as quantitative. Identification of such markers should be followed by conversion of those markers into easily adaptable technology to make them cost- and labour-effective. A close association between biotechnologists and plant breeders is essential for effective utilization of this technology.

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Soil and Nutritional Management in relation to Crop Improvement of Coconut

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Introduction

Coconut primarily a small holder's crop with a recorded history of more than 3000 years of cultivation is now being grown throughout the humid tropics. Though, India holds first position in area and production under coconut (*Cocos nucifera L.*) in the world, the productivity of coconut is well below the potential level. The national average productivity of coconut is around 44 nuts/palm/year (Kerala - 38 nuts). However, the research station yield is around 175 nuts/palm/year and the potential yield realizable is 471 nuts palm^{-1} year^{-1}. The productivity of a plant results from its hereditary qualities interacting with its environment. Soil and nutrition being basic to the metabolism of the plant, are often a limiting factor in the level of productivity. Plant breeding may yield a strain with a high genetic potentiality, but this potential will not be fully realized unless among other factors, all the nutrients necessary for higher yield are present, and suitable conditions exist for them to be taken up in adequate amounts by the plant. Therefore, proper nutrient management is a key for exploiting the yield potentiality of high yielding varieties.

Coconut Growing Soils in India

Coconut is grown under varying soil types ranging from littoral sands to clayey soils, ill-drained low lying areas to well drained hill slopes, strongly acidic peaty soils to alkaline calcareous soils. The major coconut growing soils along the West Coast are laterites, red sandy loams and littoral sands, while deltaic alluvium, red soils and littoral sand are important along the East Coast. Eventhough, coconut is grown under various soil types, soil productivity plays an important role in realizing the higher yield potential of the palm. The ideal soil conditions for the growth and productivity of the coconut are well drained and aerated soils with a minimum depth of 80 to 100 cm, pH between 5 to 7.5, adequate soil nutrient availability and water holding capacity (Fremond, 1964). Some of the characteristics of major coconut growing soils of India have been given in Table 1.

Laterite and lateritic soil: These group of soils are found in coastal Kerala, coastal and south interior Karnataka, Maharashtra, Andhra Pradesh, Tamil Nadu, Orissa, West Bengal and North-Eastern parts of India. These soils are highly weathered soils, moderately deep to deep, loamy to clayey in texture, well drained and predominantly acidic in nature with a pH range of 4.5 - 6.8. They do not offer the tree much in the way of nutrient elements and are deficient in essential plant nutrients such as K, Mg, Ca, B and Zn. Proper fertilizer application is essential for sustained and increased productivity of coconut in such soils.

Coastal sandy soils: A strip of coastal sandy soil is found along the eastern and western coast of the country. These soils are very poor in organic matter, water holding capacity, aggregate stability with high soil temperature, well aerated and drained, but short of nutrients, these soils cry out for the use of fertilizers.

Red sandy loam soils: These soils are found in between coastal sandy tracts and laterite soils in Kerala and parts of Karnataka. These are loamy in texture, porous, well drained, deep and formed by the process of colluviation. These soils are highly productive.

Coral soils: The coral soils are found in Lakshadweep and Andaman and Nicobar islands. These soils are pebbly or gravely, more or less poor in organic matter and mainly comprises bits of coral which is rich in calcium carbonate (96%). The nutrient and water retention capacity of this soils is poor.

Acid sulphate soils: These soils are found in Southern Kerala and is also known as Pokkali, Kappadu and Kari soils. These are well drained and porous containing higher amounts of Al, Fe and Mn and are extremely acidic with a pH of 2.5 which seldom goes beyond 4.5. The soils are very fertile but not productive due to low pH, excess Al and S.

Alluvial soils: Very good for coconut cultivation and found in the Godaveri delta.

Black soils: Black soils are wide spread in Tamil Nadu, Karnataka, Andhra Pradesh and Maharashtra. Drainage and irrigation facilities are required for successful cultivation of coconut since these are in the semi-arid region.

Nutrient Removal

Coconut, a perennial crop, flowers and fruits through out the year. Therefore, its water and nutrient requirement should be maintained during the entire period. The nutrient exhaust studies has been conducted by various workers from time to time (Table 2). According to Pillai & Davis (1963), a WCT coconut palm yielding an average of 40 nuts and

Table 1: General physico-chemical properties of the coconut growing soils (Source: Pillai, 1975)

Soil group	Mechanical composition (%)			pH (1 : 2.5)	Org. C (%)	CEC (me/100g)
	Clay	Silt	Sand			
Laterite	16.8 (9.2-39.2)	10.5 (2.2-20.0)	64.4 (49.2-86.8)	5.72 (4.0-6.8)	0.55 (0.06-1.8)	5.1 (1-14.4)
Alluvial	17.9 (9.2-31.6)	6.9 (1.0-18.0)	75.1 (50.4-89.2)	5.79 (4.2-7.1)	0.69 (0.03-1.81)	4.4 (0.7-11.3)
Reclaimed marshy*	15.0 (9.0-26.4)	3.9 (0.0-13.6)	78.7 (64.0-91.0)	4.76 (3.7-6.5)	0.68 (0.23-2.91)	4.1 (0.6-24.3)
Coastal sandy	6.8 (3.6-10.8)	0.8 (0.07-7.8)	92.4 (87.2-95.4)	6.67 (5.2-8.3)	0.13 (0.00-0.46)	0.5 (0.4-5.4)
Sandy loam	17.0 (8.8-30.2)	3.8 (10.6-14.0)	79.4 (69.4-90.2)	5.81 (4.8-8.6)	0.31 (0.06-1.44)	3.7 (1.0-11.7)

Figures in parantheses denote range

producing 13 fronds per year mines 321g N, 69g P, 406g K, 196g Ca and 72g Mg from the soil. In general the proportionate exhaust of nutrients in terms of N : P_2O_5 : K_2O is 2:1:3 and the quantitative order of requirement of major nutrients for adult bearing palm is K >N > Ca> Mg> P which suggests that K is the dominant nutrient while P requirement is the least. Further, N and P are utilised more or less equally for the growth of stem and leaves and for the production of nuts, while the proportion of K exhausted through the harvest of bunches is 78 per cent and that for the growth of stem and leaves is only 22 per cent.

Nutrient Response Studies

It is an established practice to grow coconut seednuts up to one year without fertilizers. But, it has been found that, endosperm can supply food to growing seedlings up to 4th month only (Foale, 1968). Thus, the young seedlings are in short supply of nutrients for a major part of their one year growth in the nursery. It has been recommended to apply 40kg N, 20kg P_2O_5 and 40 kg K_2O per application per ha in the months of December, February and April in nurseries where seednuts are planted in the month of May-June (Nelliat, 1973). This ensures production of seedlings with favourable nutrient status to facilitate better establishment, faster growth and early bearing in the main field. Further, application of FYM @ 25t/ha and N and K @ 80 to 160 kg each/ha soil application in 3 splits has resulted in vigorous seedlings (Srinivasa Reddy *et al.*, 1998). Systematic fertilization of young palms helps faster and vigorous growth and reduce the pre-bearing age. At Veppankulam (Tamil Nadu), application of NPK at the adult palm dosage of 340g N, 230g P_2O5 and 450 g K_2O/palm/year helped the palms to flower one year ahead of the unfertilized palms. When double the above dosage was applied, the pre-bearing age was further reduced by four months (Anonymous, 1971). In general, the effect of N on vegetative growth of young palms was maximum followed by K while P showed favourable interaction with N and K. Large-scale fertilizer demonstration trials conducted all over the west coast of India showed that application of 340g N, 340g P_2O5 and 680g K_2O/palm/year had resulted in 35 per cent increase in yield of nuts and 44 per cent in copra outturn over the cultivators' practice. In certain locations where the above fertilizer dose was not responsive, significant increase in yield was obtained when the K_2O level was further raised to 900 g/palm/year. It is imperative that in an intelligent fertilizer application programme, importance of fertilizing young palms with adult palms dosage should be resorted to

Table 2: Nutrient uptake by coconut palm as estimated by different workers (kg ha^{-1} yr^{-1})

Authors	Country	Nutrient removal		
		N	P_2O_5	K_2O
Pillai & Davis (1963)	India (40 nuts/palm/year)	55	27	84
Ramadasan & Lal (1966)	India (Palms/ha = 175)	97	48	146
Ouvrier and Ochs (1978)	Philippines (Copra = 6-7 tonnes/ha)	174	20	249

The above figures vary with the locations, yield levels, environmental conditions etc.

well in advance before they come to flowering (Hammeed Khan *et al.*, 1986).

The need to supply N and K in augmenting coconut yield particularly K at increased rates have also been established. Nitrogen had beneficial effect on female flower production whereas potassium had beneficial effect on copra content. Response to N application was obtained in terms of yield from third year onwards and for phosphorus from ninth year onwards at Kasaragod. For palms yielding less than 60 nuts annually, optimum nitrogen dose ranged between 400 and 650 g/palm/year and that of potash between 890 and 1210g/palm/year. Nitrogen adversely affected all the nut characters studied, viz. weight of whole nut, weight of husked nut, volume of husked nut and copra weight per nut (Muliyar and Nelliat, 1971). Nitrogen application increased the yield by 16.9 per cent but copra yield by only 6 per cent, whereas *potassium* increased the nut production by 12 per cent while that of copra by 22 per cent. The main effect of P was marginal. Further, the importance of balanced application of N, P and K was evident from the significant NP, NK and PK interactions. In deference to the studies on the nutrient requirement of hybrids in other crops, it is generally found that higher fertilizer nutrients are required for higher productivity. However, studies carried out in coconut do not support this contention. Hameed Khan *et al.* (1986) found that high yielding WCT palms responded to higher levels of fertilization (1000g N, 1000g P_2O_5 and 2000g K_2O) whereas marginal yield improvement was reflected in the hybrids COD x WCT and its reciprocal cross. Nutrient indexing of WCT, COD x WCT and WCT x COD palms indicated that hybrid palms do not require higher N, P and K inputs for higher productivity.

Various phosphorus carriers were evaluated as source of P and rock phosphate was found to be the cheapest and ideal source for coconut palms in acid soils. Studies on rationalisation of P application to coconut palms indicated that for soil test value greater than 20 ppm P, application of P can be skipped till such time the values come below 20 ppm (Hameed Khan *et al.*, 1992). Potassium has great effect on precocity, vegetative growth, drought and disease resistance and copra production. The palms which suffer from potassium deficiency during the pre-bearing stage remained on an average 15 per cent less productive than those that never suffered (Fremond & Ouvrier, 1971). Coconut has tendency to absorb more potassium than it needs, which gets removed during harvest. Muriate of potash proved superior to sulphate of potash for coconut manuring.

Amongst the secondary nutrients, calcium and sulphur deficiencies have not been observed in India. However, magnesium, a constituent of chlorophyll, is observed to be one of the limiting nutrient elements in the nutrition of coconut, especially in acidic soils. Prolonged use of higher rate of potassic fertilizers, has been reported to depress magnesium content in plant and induce Mg deficiency. The sensitivity to induced Mg deficiency is greater in the Dwarf, the Red and Yellow Dwarfs and DxT hybrids (Manicot *et al.* 1979). Application of magnesium @ 500g Mg per palm is advantageous for root(wilt) diseased palms to restore palm vigour. Application of Mg containing fertilizers corrected Mg deficiency, improved growth and increased the production, provided the K supply was adequate (Hameed Khan *et al.*, 1994).

The addition of common salt (NaCl) has been an age old practice, very popular among coconut growers in Kerala (India), Java and Colombia. In laterite soil, addition of common salt in pits and planting seedlings was known to soften the laterite bed and helped early penetration of the roots (Hameed Khan *et al.*, 1994). Beneficial effect of NaCl on increased female flower production, number of nuts and copra content/nut has been reported (Fremond, 1964). Performance of palms in times of yield was at par with palms receiving full dose of K_2O and 50% of K_2O substituted with NaCl in laterite soil of northern Kerala (Prema *et al.*, 1987).

Micronutrients viz. Zn, Cu, Fe, Mn, Mo, B and Cl are required in relatively smaller amount. Many of these micronutrients function as activators of enzymes. In general, the tropical acid soils are in a better position with respect to micronutrients such as Fe, Mn, Cu and Zn. These cations are easily soluble and are readily available under acid soil conditions. However, availability of boron poses problems in acid laterite, alluvial and coastal sandy soils. The boron deficiency/disorder known as "Crown Choke" disease has been a serious problem in Assam and West Bengal (Baranwal *et al.*, 1989). From a survey conducted in Assam (Anonymous, 1990), 10.8 per cent of the palms were found affected by the disease and the total annual loss in yield due to this malady was estimated at 6.38 million nuts. Baranwal *et al.* (1989) reported that Ca/B ratio was significantly lower for healthy palms when compared with diseased palms. Soil application of borax (decahydrate) at the rate of 50g/palm just after the appearance of the symptoms was recommended. In slightly advanced stages, two applications of borax 50g each, at an interval of three to four months was found necessary for the recovery. The work done and the doses used by several workers have been presented in Table 3.

Even though, chlorine is a micronutrient, its removal is equivalent or greater than nitrogen. The importance of chlorine in the nutrition of coconut and oil palm was realized when Ollagnier and Ochs (1971) emphasized the role of chlorine in the physiological processes in coconut. The importance of chlorine in coconut is now accepted by most research workers. The effect of clorine is manifested more on

Table 3: Response to application of B in different parts of the country

Authors	Doses (soil application)	Yield	States
Chakraborthy *et al.* (1973)	20g borax 9 times/yr (Decahydrate)	-	Assam
Cecil & Pillai(1978))	250 and 500g/palm (borax decahydrate)	Young plants (5 yr)	Kerala
Clarson *et al.*(1986)	5kg B with 15 kg Mg/ha.	90 nuts	Tamil Nadu
Dwivedi *et al.*(1980)	300g/tree ($Na_2B_4O_7$)	Nut increased	Kerala
Baranwal et al. (1989)	50g borax once in 4 months	Recovered from crown choke	West Bengal & Assam
Davis and Pillai (1966)	227g	54.3 nuts	Kerala

the thickness of kernel. In certain experiments in the Philippines, 55.5% increased nut production, 74.3% increased copra weight per nut and 80.3% increased copra per tree were attributed to clorine (Margrate *et al.*, 1979). The field trial on potassium chloride substituted by sodium chloride at an increment of 25 per cent at CPCRI, Kasaragod has given an indication that the yield can be increased/maintained at the production rate of potassium chloride significantly after five years (Anonymous, 1994). However, correlation worked out between leaf chlorine and coconut yield did not reveal favourable relationship. Work conducted elsewhere has shown that annual export of chlorine in 6700 kg copra/ha is 125 kg besides other elements.

Under tropical situation, considerable amount of nitrogen applied in the soil has been reported to be lost on account of leaching and volatilization. This is mainly due to high rainfall during monsoon season and high temperature during summer season. This problem could be overcome to a certain extent by using slow release fertilizers. Use of slow release N and P fertilizers will go a long way in the nutrient conservation. Kamalakshy Amma and Cecil (1973) found that slow release N sources viz. Neem cake coated urea, Urea formaldehyde and coir dust coated urea are superior to urea for the gradual supply of nitrogen to the soil. The slow release N fertilizers viz. ureaform, neem cake coated urea and coir dust mixed with urea have been found to remain for a longer period in the sandy soil, thus facilitating availability of N in the more permeable soil for a longer period of time (Bopaiah *et al.* 1998).

Fertilizer Recommendation:

The general recommendation from CPCRI for fertilizing the adult bearing palms is to apply 500g N, 320 g P_2O_5 and 1200 g K_2O/palm/year in two split doses namely, one-third of the above dosage during May-June (pre-monsoon) and two-third during September-October (after the cessation of rains). This dosage may be enhanced or reduced depending on the vigor and productivity. The fertilizer inputs to be applied depending on the age of the palms is given in Table 4. The fertilizers must be spread around the palms within a radius of 1.8 m and forked in. Addition of phosphorus and potassium over years has shown build up of these nutrients in the coconut garden. Hence skipping/reduction of these nutrients from fertilizer programme may be planned based on the soil testing and foliar diagnosis.

Table 4: Fertilizer recommendations based on the age of the palms (g/palm)

Age of the palm	May-June			Sept.-October		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
First year	Planting in May-June			50	40	135
Second year	50	40	135	110	80	270
Third year	110	80	270	220	160	540
Fourth year onwards	170	120	400	330	200	800

Source: Coconut Package of Practices, Central Plantation Crops Research Institute, Kasaragod, Kerala.

Foliar Diagnosis

In perennial crops, where the crop remains on the land for a longer period of time, foliar diagnosis is the well established tool for detecting the presence of possible nutrient hunger or deficiency through chemical analysis. Coconut has a spiral phylotaxy. In an adult palm, with 30 or more than 30 leaves in the crown, 14th leaf (counted from the first fully emerging leaf) is the diagnostic leaf. In the leaf sampled, an average of 5-10 leaflets from the either side of the middle region of the frond should be collected for analysis. In the cases, where the number of the leaves in the crown is less than 30, (N+1)/2 leaf (N = Total number of leaves) counted from the first fully emerging leaf is the diagnostic leaf. Usually, palms below the age of 18 months after planting are not recommended for sampling. Leaf samples are preferably to be collected towards the end of dry season for diagnosis.

Two essential factors are involved in foliar diagnosis. i.e. critical level and interaction. A critical level is defined as that concentration of an element, above which an application of the corresponding fertilizer does not produce any response. No systematic study has been conducted in India to fix critical levels of major and secondary nutrients for coconut. However, the various data on leaf analysis and nutrient responses available in the country suggest the following critical levels (Frond 14) for the tall variety of coconut (Table 5).

Table 5: Critical level (leaf) of various elements in coconut

Elements	Critical level (%)
Nitrogen	1.80 to 2.00 %
Phosphorous	0.120 %
Potassium	0.80 to 1.00 %
Calcium	0.50 %
Chlorine	0.25 %
Magnesium	0.30 %
Copper	5 to 7 ppm
Iron	50 ppm
Manganese	60 ppm

Soil Testing

Soil fertility is a variable factor and it differs from region to region and even from field to field. A blanket recommendation based on field trials does not take into account the variability in soil fertility and cannot assure maximum productivity from a particular area. If the recommendation is based on the particular soil type on the basis of an assessment of its fertility status, might ensure maximum yield from fertilizer application.

The usefulness of soil testing in the perennial crop is limited as it is difficult to interpret the soil analysis as large volume of soil is explored by the roots. Very often the reflect of soil nutrient content is not indicated by analysis of leaves. Moreover, nutrient absorption capacity by palm is inadequately understood and often excellent growth is seen in littoral sandy soil and marginal lands (Hameed Khan *et al.*, 1994). Long-term observations led to the conclusion that 70 to 80 ppm of mineralizable nitrogen in soil and 10 to 12 ppm Bray extractable 'P' can sustain sufficiency levels of N and P nutrients for coconut. Further work at CPCRI revealed that if soil available P is less than 10 ppm, full recommended dose of 320g P_2O_5/palm/year must be applied and for a soil test value of 10 to 20 ppm, 50 per cent of the same may be applied. For soil test values of more than 20 ppm, P application can be skipped (Hameed Khan *et al.*, 1992).

Advanced Plant Nutrition at Molecular and Sub Cellular Level

Based on sub cellular fraction analysis, it was found that DxT contained high concentration of different nutrient elements in different sub cellular fractions followed by TxGB supporting the claim of high productivity and hybrid vigor of these genotypes. The correlation studies between nutrient content in sub cellular fractions with that of yield has indicated that the P fraction in pigment gave negative correlation (0.3977) while insoluble constituents yielded positive relationship (0.356). The Ca (0.370) and Cu (0.384) content in cellulose and lignin were positively correlated with yield. (Biddappa, Unpublished work).

Visual diagnosis of nutrient deficiencies

An abnormal appearance of the growing plant may be because of deficiency of one or more elements. If a plant is lacking in a particular element, characteristic symptoms may appear. This visual method of evaluating soil fertility is unique in that it requires no expensive or elaborate equipment or detailed procedure and can be used as a supplement to other diagnostic techniques. Deficiency symptoms of various elements in coconut are presented in Table 6.

Nutrient Management in Coconut Based Farming System

Nutrient management in CBCS is a difficult task owing to the involvement of varying requirements of different crops and crop communities, differential crop responses and crop residue additions. Under such conditions, whole system as a

unit must be considered. In intensive cropping with tree crops, the application of fertilizers according to the estimated requirement for each crop is certainly not the most efficient and economic way of utilizing native and applied nutrients. Bench mark data on total nutrient demand, nutrient removal in harvested and non harvested products and the rate of nutrient accumulation during ontogeny are needed for each species in a multicropped system to arrive at answers on rate, time, source and placement of various.

Generally, the most important pool of nutrient reservoir in soil is organic matter. Though, under tropical conditions it is difficult to build up the organic matter status by external additions, nevertheless, their exists possibilities for the maintenance of organic matter at a level possible under such climatic conditions. Investigations have revealed significant formation of soil organic matter during active root tissue without the intervention of soil microfauna (Martin, 1977). In addition to roots, the aerial of root tuber crops grown as intercrops and non harvestable portions of productivity of other crops (e.g. fallen leaves from cocoa) also add to the organic matter in the soil. As a result, it has been observed that organic matter content of rhizosphere soils of coconut and cocoa has improved.

Similar results have been reported, in HDMSCS experiment at Kasaragod, after ten years of cropping. It was observed that organic carbon store in the cropped area was 6898.8 kg as compared to 2915.0kg in uncropped area in 0-25 cm soil layer and 5003.3 kg and 2153.0 kg in cropped and uncropped region in 25-50cm soil layer respectively (Anonymous, 1994).

Cocoa, as a component of multiple cropping system also adds substantial quantity of organic matter to the soil, thus leading to annual internal recycling of nutrients in the system.

Table 6. Various nutrient deficiency symptoms of coconut

Nutrient	Symptoms
Nitrogen	General yellowing of the fronds. Newly formed fronds pale green in colour. Stems affected become short dwarfing, pencil point. The number of leaves very few and smaller in size. Many bunches abort, and the number of female flowers per inflorescence is small.
Potassium	Rust coloured spots on leaflets on either side of the central rib. The rusting spots invade the whole leaflet and form large patches of irregular outline. Older leaves affected first. Yellowing of the leaves in the middle of the crown in the early stages and drying up of the lower leaves in the last ones. General flacidity and drying of leaf tips.
Phosphorous	Rare in coconut. Slowing down of growth and shortening of the fronds.
Calcium	The tips of the leaflets become yellow, orange ring shaped spots on the leaflets. They became necrotic, then brown. Leaf dries up. The symptoms can affect the middle leaves before the oldest.
Magnesium	Yellowing of leaves of outer whorl, going from the tips towards the rachis of the leaf. This discoloration is worse on the parts exposed to the sun, the shaded parts remaining greener. Necorsis of the tip of the leaflets.
Chlorine	Yellowing and/or orange mottling of the older leaves with a drying up of the outer edges and tip of the leaflets
Sulphur	Young palms - yellow to orange leaves which decay at the tips and become grey. Older trees: - foliage is reduced and becomes completely decayed and hang down the trunk. Very few nuts are produced, rubbery copra and a very small oil content.
Molybdenum	It is the middle aged and old leaves, which often show symptoms of molybdenum deficiency. Frequently small and covered with necrotic spots, the leaves turn from green yellow to yellow and the edges role up. Restricted growth of plants.
Boron	Terminal leaflets are welded together with their tips taking the shape of 'hook leaf'. Emergence of shorter leaves with deformed, crinkled and rudimentary leaflets with severe tip necrosis - Crown choke.- at the last stage, coconut left with a bulbous growing point which has stopped developing.

Adapted from Manicot *et al.* (1979) and Wahid *et al.* (1994).

It has been observed that the annual biomass generated from cocoa alone is 8.8t/ha in single hedge system and 12.38t/ha in double hedge system contributing substantial quantities of nutrients for internal recycling.

Generally, coconut being a widely spaced crop, there will be soil erosion due to heavy rainfalls if the field is maintained clean. So, in general, the weeds are allowed to proliferate in the field and only after the monsoon is over, one intercultivation operation is performed. It has been observed that weed growth contributed 216 kg (dry weight) dry matter into the system thereby, loading the soil with substantial quantities of nutrients . Similarly, nutrient removal from the system and nutrient addition through rainfall in the interspaces was also worked out. It was observed that 0.07kg NH_4-N, 0.3kg P and 6.19 kg K per hectare was added through rainfall through canopy filtration during monsoon period from June to October. During the same period, 23,000 to 25,000 litres of rainwater from the plot(1.2 ha) carried with it 178 kg of soil and the resultant nutrient loss accounted for 104g N, 10g P and 112g K from the system (Anonymous, 1985).

From coconut-grass culture experiment carried out for 14 years, it was observed that organic carbon, av. N, av. Mn and Zn increased in soil cultured with grass than control. Maximum gain was recorded with org. C followed by av. N. However, rest of the nutrients showed a loss over control. Among the nutrients, potassium showed maximum depletion followed by Ca, P and Mg implying more uptake by the grass (Biddappa *et al.*, 1993).

Integrated Nutrient Management

The main factor effecting the application of chemical inputs is the cost of the inputs *per se* and constraints such as risk due to crop losses and fluctuating prices of the commodities. This discourages the small holders to apply chemical inputs. But, in integrated farming system/crop based farming system, recycling of organic wastes *viz*., crop, animal dung, urine etc. leads to a substantial saving in cost of fertilizer input thereby increasing the cost-benefit ratio. In an integrated farming system comprising pasture, fodder and cattle in coconut small holding, it was observed that the cost of fertilizing of coconut palm was Rs.2.49/palm as compared to Rs.8.1/palm annually in coconut monoculture. This led to a saving of 69% on the cost of inorganic fertilizer for coconut (Liyanage *et al.*, 1989). Nallathambi *et al.* (1988) reported that maximum economic returns was obtained with the application of 100 kg FYM + 2.4 kg urea + 1.4 kg MOP/palm/ year or 100 kg green manure/palm/year for coconut on the East coast of Tamil Nadu. In an ongoing experiment on coconut based mixed farming at CPCRI, on 1.2 ha coconut farm, involving coconut, grasses, dairy, poultry and rabbitry, 15 t of FYM, 2 t of poultry manure and 50000 litres of cow urine and cowshed washings are obtained annually, which if effectively recycled can supply 125 kg N, 78 kg P_2O_5 and 115 kg K_2O.

Application of organic manures improves the soil physical properties with direct impact on moisture retention, root growth, nutrient conservation etc. Studies conducted at CPCRI, Kasaragod, has demonstrated that all the organic sources viz. forest leaves, coconut shedding, cattle manure & coir pith in conjunction with inorganic improved significantly the soil physical conditions over inorganic in Littoral sandy soil (Anonymous, 1981). Water retention at 0.2 and 1.0 bar was higher in soil samples collected from the basins of coconut palms receiving organic matter regularly for seven years, than in samples from the basins of palms not receiving any organic matter (Anonymous, 1978).

Crop residues are more important sources of potash as compared to nitrogen and phosphorus. In case of coconut, it was observed that husk accounted for 67 per cent of the potassium and 85 per cent of chlorine. This indicates the considerable reduction in fertilizer requirement which can be achieved by leaving the husk in the field where it is quickly broken down, releasing the locked up nutrients to be recycled (Ouvrier and de Taffin, 1985). One hundred husks will be able to provide 1 kg of potash apart from 270 g N and 150 g P_2O_5 in the same period. Effect of husk burial would be observed from 3rd year onwards and beneficial effect lasts for 5-6 years.

The nitrogen fixation potential of legumes - Rhizobium symbiosis could be exploited in the interspaces of coconut as intercrops, green manures, cover legumes and forage legumes. *Pureraria phaseolides*, *Calapogonium muconoides* and *Mimosa invisa* can be grown as suitable green manure in coconut basin and also as good cover legumes. Cover cropping helps to prevent erosion, control weed growth add a large quantity of organic matter and form a thick mulch and improve soil fertility and water holding capacity. Legume cover crops also fix atmospheric nitrogen. When these legumes are grown in coconut basin (1.8 meter radius) it contribute 15-30 kg of green matter and adds 150-200 g of nitrogen per basin, when incorporated after four months. Green manuring also resulted in enhanced microbial activity and fertility of coconut soils. In interspaces, about 3-4 tonnes of green matter will be added, which will be equivalent to 20-111 kg N, 4-21 kg P_2O_5 and 15-67 kg K_2O per ha. Further studies carried out in Sri Lanka, revealed that when *Gliricidia* topping applied @ 30 kg/palm provides total requirement of nitrogen and at least part of phosphorus and potassium requirements, thus, reducing the cost of fertilizer by about 40% (Liyanage and Jayasundera, 1988). Incorporation of organic manures in basin of plantation crops leads to proliferation of microbes, thereby, increasing efficiency in the nutrient release.

Availability of Organic and its Recycling

Coconut produces huge amount of waste biomass which could be recycled, thereby improving the soil fertility status. It has been estimated at CPCRI, Kasaragod that a well managed coconut garden with 175 trees/ha produces byproducts to the extent of 7 tonnes in the form of dried leaves and 1 ton as sheathes, spadices and inflorescence. Taking the total cropped area of 1.795 million ha (1995-96), 14.36 million tonnes of waste/byproduct is available in the country for recycling and the nutrient content of usufructs and the total nutrient supply is depicted in Table 7 (Upadhyay *et al.*, 1998). Similarly, around 8 tonnes of husk is available from one hectare of coconut garden. However, the husk obtained is mainly used for extracting coir. But, the waste material viz. the pith is usually dumped without any use. During monsoon, tannins oozing out of such heaps, creates environmental pollution problems. The studies conducted at various places have shown that coir pith can serve as important source of organic manure for agricultural crops (Savithri and Khan, 1994).

Coconut occupies land for a longer period of time. Being widely spaced crop a number of inter/mixed crops can be grown in the interspaces. Cocoa, as a component of multiple cropping system adds substantial quantity of organic matter to the soil, thus leading to annual internal recycling of nutrients in the system . Approximately 8.2 and 19.8 t/ha/year (oven dry basis) of cocoa litterfall was obtained from single and double hedge systems of planting respectively (Varghese *et al.* 1978). Taking nutrient concentration of cocoa leaves to be 2.84 % N, 0.26 % P and 1.73 % K on dry weight basis, it could be assumed that about 50 kg N, 11 kg P_2O_5 and 35 kg K_2O could be returned to the soil every year through leaf fall of cocoa under double hedge system of mixed cropping.

Table 7: Quantity of nutrients supplied by coconut leaves, shedding and coir pith

Bye-products	Quantity Available (million tonnes)	Chemical composition (%)			Total nutrient supply (1000 tonnes)		
		N	P	K	N	P	K
Dried leaves	12.57	0.89	0.06	0.45	112	8.0	57
Shedding	1.80	0.66	0.10	0.50	12	2	9
Coir pith	7.50	0.68	0.03	0.36	51	9.5	27

Waste management through composting

Composting is one of the most important method of recycling the residues back to the soil. In broad terms, compost is biologically decayed refuse like leaves, twigs, roots, stubble, crop residue etc. The process of composting depends upon C/N ratio, blending/shredding, moisture, temperature, microbes involved and aeration. The most important is C/N ratio. C/N ratio of 30 in raw materials could be most desirable for efficient composting (Gaur *et al.* 1984). For materials with higher C/N ratio, an external nitrogen source must be added, for efficient composting. The C/N ratio of coir pith ranges from 80 - 120 :1. Thus, it requires a starter dose of nitrogen to narrow down the C/N ratio for microbes to act (Upadhyay *et al.*, 1998).

Various techniques have been developed for the preparation of organic fertilizers from the crop wastes. The techniques primarily involves chemical and biological processes to break down the complex organic molecules to the simpler form. The various techniques used are Hot fermentation, Cold digestion, Chemical digestion, Microbial and Vermicomposting. Studies carried out on coir pith in CPCRI revealed that chemical technique involving urea and mussoorie rock phosphate in anaerobic conditions gave highest recovery and good quality of compost (Biddappa *et al.* 1998).

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Principles and Application of Physiological Methods in the Improvement of Plantation Crops

D. Balasimha and K.V. Kasturi Bai

Yield improvement in agricultural crops is achieved by better adaptation to environmental conditions, greater resistance to pests and diseases, improved agronomic practices, increased genetic yield potential and interaction of all these. Increase in crop production has been achieved mainly by improved agronomic management. However, with the advances in scientific knowledge there has been increased interest in realising the yield potential by direct selection for yield related physiological traits.

Traditionally plant productivity has been evaluated by dry weight changes, measured by destructive samples within a stipulated period. However measurement of CO_2 exchange allows instantaneous estimation of productivity on a minute by minute basis. By this the effect of short term changes in the environment on productivity can be understood. This shows that yield is controlled by both abiotic and biotic parameters. The physiological processes such as development, expansion, production and partitioning of dry matter determine yield.

Agro-meteorological Parameters

Of all the agro-meteorological variables solar radiation and water are the driving force for photosynthesis, plant growth and productivity. The amount of radiation received sets the upper limit of biomass production. The process of photosynthesis results in the conversion of light energy to chemical energy, which is further, partitioned to vegetative and yield attributes. The net productivity depends on the energy used by plants during respiration. This implies that photosynthesis forms the basis of primary production in all eco-systems.

Light Use Efficiency (LUE)

Accumulation of biomass depends on the amount of radiation intercepted and its efficiency of conversion into dry matter, ie. light use efficiency (LUE). In the perennial plantation crops, which grow mainly under tropical climate, the net production rates are fairly high. The maximum annual net production of 35.5 t/ha/year in rubber plantation after four years of bud grafting and 30.7 to 36.8 t/ha/y in oil palm plantations at eight to fifteen years of age have been reported. Out of the total radiation received in the humid tropics, photosynthetically active radiation (PAR) is only 50 percent. It is reported that if the coconut canopy intercepts all the intercepted radiation and the canopy was operating at maximum LUE, it would yield 51 t/ha/year of dry matter. But the highest yield observed was only 31 t/ha/year. Light interception is strongly influenced by canopy size, shape, angle, orientation, vertical separation, horizontal arrangement and absorption by non leaf structures.

Leaf area Index (LAI)

Large LAI may be needed for maximum light interception. With an increase in LAI upto 5 where the canopy intercept 95 per cent of solar radiation there is an increase in crop growth rate (CGR). Increase in CGR with an increase in LAI above 5 is not significant. Hence the LAI at which maximum CGR was obtained is the critical LAI. An LAI of 3 to 5 is needed for maximum dry matter production. For several of the plantation crops a LAI between 8 and 10 have been recorded. Maximum dry matter production in oil palm has been achieved with an LAI of this magnitude. But under normal condition because of the removal of leaves during harvest resulted in increase of LA1 from 3 to 4 has been obtained. In coconut LAI ranged between 4 and 5. In tea, where the total biomass is important, an LA1 of 8-10 is required. For rubber maximum LA1 of 5.8 to 6.3 was obtained 5 years after planting. Maximum dry matter production at this LAI was 24 to 35 t/ha/year. In cocoa, the estimates of LA1 ranged between 3.5 to 6.0. Though no quantitative information is available on the relationships between canopy, LA1 and yield in cocoa, a good canopy in the range of 4 to 6 LA1 is expected to give high yield. This shows that by increasing LAI, the yield can be increased. Higher LAI, leaf photosynthetic rate and leaf angle are major determinants of CGR. But increase in LAI will shade the lower leaves and would make them parasitic on other leaves.

Canopy Architecture

The main sub units of crop canopies are leaf laminae. The leaf area growth is slow during initial phase and rises rapidly (phase II) and reaching maximum with time (phase-III). The relation between canopy leaf area and time can be described by a logistic curve. In perennials, the maximum is the balance between production of new and loss of old tissues.

The structure of standing biomass or canopy can be obtained by means of harvesting and measuring leaf and wood biomass. The quantum and structure can be determined by developing regression equations. This has been done in several plantation crops like coconut, arecanut, cocoa, rubber and oil palm.

The structure can also be studied by measuring photon flux density within the canopies by light sensors. There is a direct relation between solar radiation absorbed by plants and biomass produced. It is convenient to study the transmitted light in crop canopies using instruments which can measure incident and transmitted light. Such systems can measure leaf area index, which is defined by:

L = Np ns as

Where 'Np' is number of plant per unit ground area, 'ns' number of leaves per plant and 'as' their mean area. This can be modified to get individual plant LAI (L = leaf area/mean ground area). There are instruments which use PAR sensors to analyse the canopy system of plants.

The other option is to assess gap frequency in canopy visually or photographically. Permanent records can be obtained with angle or 'fish-eye' photographs. This technique is used in some of modern equipment like CID or Li-Cor canopy analysers. They use digital cameras with fish eye lens to perform detailed scan of the plant canopy. Image analysis is usually done with supplied software. By this it is possible to measure LA1, leaf distribution, radiation characteristics and extinction coefficient. Instruments use different methods either by measuring above and below canopy or only one measurement below the canopy.

Photosynthetic Efficiency

Genotypic variation has been observed in the photosynthetic efficiency ie., the dry matter produced to the light energy obsorbed in plantation crops. Temperature is also crucial for photosynthesis. The optimum temperature for these crops is 20-25 °C. Canopy structure also has impact on the leaf temperature tolerance. For example for tea the erect leaf type will yield higher under full sun where as the horizontal leaf type will yield better under shade. Photosynthetic efficiency can be estimated by knowing the energy content of the harvested product. For oil palm the photosynthetic efficiency, is almost 2.1 per cent and for rubber it is 2.8 per cent. However, the theoretical maximum value for photosynthetic efficiency is more than 22 per cent of the absorbed energy. But for most of the agricultural crops a value of 2-4 per cent only is obtained.

Measurement of Photosynthesis

The net photosynthesis (Pn) can be measured using portable instruments. Advanced state-of-art technology is available presently and operate either on closed or open systems, using infared gas analysis. In the closed system the derivation of transpiration and photosynthesis equations is based on analysis of mass balance of water and CO_2. In the open system Pn and transpiration are measured using airflow rate, incoming chamber CO_2 and H_2O conditions and leaf area. All computed variables like conductance, internal CO_2 and Pn are calculated and displayed in real time. Data can be logged and stored. The output to PC is through RS-232 port.

The photosynthesis measurement equipment consists of 3 basic components a leaf chamber within which temperature and humidity measurement are made; IRGA which measures CO_2 conditions and flow rate; and a control console. Air temperature, leaf temperature and relative humidity are measured in leaf chamber.

Measurement of chlorophyll fluorescence

When light is received on a plant, the energy in the blue and red components of light is absorbed by chlorophyll molecules. When a leaf is illuminated, it will fluoresce at a steady level. However, if leaf is kept in darkness for several minutes and then illuminated, fluorescence rapidly rises from a low level (Fo) via an intermediate level (I) to a peak level (Fm). The kinetics of this response are termed Kautsky effect. The difference between Fm and Fo is the variable component of fluorescence (Fv). The fluorescence measurement is both non-destructive and non-invasive and therefore well suited to procedures requiring periodic repetitive sampling or screening. The measurements can be made by use of fluoremeters like the Plant Efficiency Analyzer which can take rapid and repetitive data on the fluorescence indices. The instrument can be used to evaluate factors influencing photochemical efficiency, stress tolerance, eco-physiological aspects etc.

Respiration

For tropical crops it is reported that 50 percent of the photosynthesis are lost through respiration and for perennial plantation crops the estimation is 75 percent. Because of high respiratory loss of dry matter, it is difficult to estimate the net and gross productivity. For tea the respiratory loss is estimated to be 85 percent and for oil palm, the estimation is 80 percent. The main reason for this high respiratory loss is due to the long life span of the leaves which require maintenance of more supporting structures.

Leaf duration

Coconut palms produce about 12 to 14 leaves each year and oil palm around 20-25. Life span of these leaves are nearly 2 to 2½ years. These leaves will remain photosynthetically active for at least 21 months, afterwards light stimulated photosynthesis declines. Although rubber leaves remain on the tree for 12 months, the Pn rate declines after 30 days of leaf expansion. This indicate that rubber trees maintain an effective canopy for significantly less time.

Source-sink Limitation

Understanding of source-sink relationship is important to optimise the productivity. The various ways the yield can

be effected are (1) inadequate supply of assimilate from the source; (2) ability of the sink to accept the assimilate and (3) rate of translocation of assimilate from source to sink. If the assimilates are accumulated in the source itself there is a reduction in the sink activity. In tea tender buds are strongest sink and the canopy of the maintenance foliage act as source of carbohydrates to these growing portions. Another question arising is whether the plantation crops are sink limited or source limited. Source limitation of yield is the most common condition among tropical species. Experiments have shown that oil palm and cocoa are source limited, while tea and rubber are sink-limited. Observation in oil palm has revealed that when a portion of young inflorescence was removed the remaining fruit bunches increased. In coconut the unproductive bunches are given for tapping, thus increasing the nut set in the remaining bunches. This is mainly due to the diversion of surplus assimilates to the new developing bunches. Non photosynthetic portion of the leaf, unproductive leaves, roots, growing portions, growing inflorescence, and stem are all sinks and final productivity depends on the sink capacity of the economic produce.

Assimilate Partitioning

Because of the indeterminate growth habit of the plantation crops, there is competition for assimilate for vegetative as well as reproductive growth even after flowering resulting in source limitation of yield. Hence, yield improvement can be realized in the selection for improved partition of dry matter. The amount of harvestable product that accumulate depend on the total dry matter that are partitioned to the various plant parts.

The alternate bearing nature in some of the plantation crops like coconut, oil palm etc can be attributed for the fluctuations in the demand for assimilates that control nut setting. In rubber the dry matter production is to the extent of 10-60 percent because of high partitioning of assimilates towards latex production. It is reported that rubber trees produced 26-36 t/ ha/year of dry matter when it is untapped and tapping has reduced it to 15-20 t /ha. A shorter thinner petiole on the frond, a thinner trunk and lower rate of trunk extension are traits which demand less assimilate and are found to be good yielders.

Selection of varieties depending on the end use is highly essential for increasing the productivity. In coconut great variation was observed in the composition of nut which is the harvested produce. This is mainly because for the variation in the partition of dry matter towards the husk, the shell and the copra. Paritition of dry matter in the husk ranged between 40 to 53 per cent, shell 20 to 27 per cent and copra 27 and 35 per cent. Paritioning of total nut dry matter towards the copra at the expense of other nut components also offer great scope for yield improvement.

Water use efficiency (WUE)

The potential of palms for higher dry matter production, is reflected on the WUE. The ratio of biomass production and water use over a given period of time is known as water use efficiency. Usually the net gain in productivity in arid and semi arid tropics is 4 to 5 times less than the plants growing under abundant moisture. The term transpiration efficiency also gives an indication of the association between water loss and CO_2 assimilation.

Harvest index (HI)

The partition of total biomass towards economically important part is known as harvest index and is an important aspect of yield determination in crops. This shows that HI can be improved by better partition of dry matter to economic yield. In most of the perennial crops like coconut and oil palm vegetative sink is stronger and more stable than the bunch sink. When assimilates are limiting the vegetative sink has priority over the bunch sink. In oil palm the trees with best fruit composition has 60 percent mesocorp oil to dry fruit bunch weight plus 5 percent kernel oil. But in coconut since the copra is enclosed in shell and the husk the proportion of waste material in the harvested product is much larger. In oil palm since mesocorp is the economic product shell can be eliminated by inducing parthenocarpic fruits.

Selection for higher yield

In perennial crops with indeterminate growth habit both vegetative and reproductive growth compete for assimilate with former getting priority over the latter. Both dry matter production and partitioning are important in the breeding programmes.

It is thus clear that dry matter production and partition are important traits for higher production. The possibilities of changing the distribution of assimilates in crop either by chemical growth regulators or by breeding are some of the viable methods of which agricultural productivity can be increased.

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Stress Physiological Aspects in Improvement of Plantation Crops

V.Rajagopal

Introduction

In agriculture, crop improvement plays vital role as it involves different approaches to enable the production potential of crops. Among the constraints for production, drought ranks almost the first as most of the cultivable areas are under water-limited conditions. Since increasing the crop area under irrigation has several limitations, the major one being the water resources, the approach then has to be to identify the varieties, which can withstand the moisture stress conditions in the field. This led to the systematic investigations on drought resistance in many crop plants both annuals and perennials. Plants adapt themselves to survive drought through different ways viz., drought escape and drought resistance. The latter has two components namely dehydration avoidance which means maintenance of turgor and volume, and dehydration tolerance i.e, protoplasmic tolerance. The perennials like plantation crops withstand water stress by one of the two mechanisms.

Traits Associated with Drought Resistance

A wide range of physiological characters is determined to assess the level of resistance of crops and varieties for drought resistance. Since the emphasis is on the capacity of varieties to maintain water balance in the tissues even under field stress situations, the regulation of water loss by the stomata is an important character that has received maximum attention in different crops.

Stomatal regulation

In simple terms, this means the opening and closing of stomata in response to both external (environmental) and internal (tissue water status, hormonal level) factors. Selection for stomatal characters potentially provides great scope for improvement in drought resistance. Crop plants exhibit a range of sensitivity of stomata to stress tolerance. When exposed to stress conditions caused by high evaporative demand in the atmosphere, the varieties in a crop exhibit differential adaptability in stomatal regulation. Under these conditions, the selection of varieties with high stomatal resistance (low conductance) assumes importance as it reveals degree of tolerance. In terms of water loss from leaf tissues, it means the varieties with low transpiration rate are tolerant to moisture stress conditions.

Leaf water potential(LWP)

The LWP in a plant is controlled by the availability of water from the soil, the demand for water imposed by the atmosphere and resistance to water movement within the plant. The components of LWP are the osmotic potential (OP) and turgor potential (TP). Under conditions of soil water deficit, the LWP show decrease depending on the degree of stress. The plants under normal water supply maintain high LWP, whereas with the development of moisture stress in the field, the LWP show gradual reduction. Thus the ability of a plant to maintain a positive or even constant turgor potential as water potentials decrease is an important adaptation to drought. When screened under field conditions, the varieties show variations in LWP and those varieties which record higher LWP even under such situations are considered as drought tolerant.

Epicuticular wax content(ECW)

The soluble cuticular lipids present on the surface of various plant organs impart resistance to water loss (transpiration rate). It is well established that when prolonged water deficits prevail, there is an increase in the epidermal waxes of leaves which decular transpiration. The role of ECW on drought resistance of crop plants has been reviewed recently. Genotypic differences in ECW were reported in various crops.

Root characteristics

In tree crops, it is difficult to undertake work on root growth and other parameters. However, the indirect method of studying the root activity is to determine the soil moisture content at different depths over a period of time. In coconut, the soil water deficit (SWD), expressed as the difference between the pre-stress and stress periods showed marked variations among the tolerant and susceptible genotypes. In general, the tolerant types recorded significantly higher SWD than the susceptible types. The SWD increased with increasing soil depth in WCT x WCT, WCT and Andaman Giant among the tolerant types and in MOD and GBGD among the susceptible ones. Surface layer (0-25 cm) had relatively higher SWD in LCT x COD and WCT x COD (tolerant) and COD x WCT (susceptible) than other types. These indirectly reflect on the root development in terms of total mass and activity.

It was of interest to study the differences in the pattern of soil moisture extraction by the roots and the

transpiration loss of water through leaves between the drought tolerant and susceptible groups. Although the tolerant palms extracted more soil moisture from the entire soil profile, they could conserve water in the tissues by reducing the transpiration rate through effective control of stomata. The susceptible genotypes tended to lose more water caused by low resistance of stomata and thus became sensitive to drought conditions. For instance, although SWD from the 0-100 cm profile was nearly the same between a tolerant genotype WCT and a susceptible one MOD, the latter transpired more water than the former. Thus, the water balance in the palm depend on the rate of transpiration loss due to evaporative demand in the atmosphere.

Screening for Drought Resistance/Tolerance

From the foregoing account, it is evident that sets of desirable traits exist in crop varieties which impart resistance/ tolerance to moisture stress conditions. Cell size and number, stomatal frequency, stomatal resistance, epicuticular wax content and water potential components are the essential anatomical and physiological indicators for assessing moisture stress in annuals and biennials.

Stomatal characteristics

The stomatal frequency and its behaviour play a major role in water conservation in many plant species. Among the plantation crops, coconut exhibited variations in the stomatal frequency among the talls, dwarfs and hybrids differing in drought tolerance. The stomatal resistance and transpiration rate were used to screen 23 coconut genotypes for drought tolerance. During the moisture stress in March, some of the tall palms and tall hybrids had relatively high stomatal resistance(8.57 and 10.1 sec.cm^{-1}) resulting in effective conservation of water in the tissue (i.e. low transpiration rate), whereas the dwarfs (4.11sec.cm^{-1}) and the dwarf hybrid COD x WCT (5.0sec.cm^{-1}) were sensitive to moisture stress with a tendency to lose more water (Table 1). Similarly in cocoa, the drought tolerant accessions like NC-23, NC-29 and NC-31 (11.6 s cm^{-1}) had effective stomatal regulation resulting in decreased transpiration water loss (1.8 ugcm^{-2} s^{-1}) as compared to susceptible accessions (7.0 and 3.3 respectively). Thus the determination of stomatal resistance proved to be the most useful selection criteria for drought tolerance in plantation crops.

Leaf water potential (LWP)

Several workers studied the degree of stomatal control of leaf water potential from porometer measurements of leaf conductance(opposite of stomatal resistance) and water potential at a range of stress levels. When compared under similar conditions, the ranking of species differances in the water potential for stomatal closure persists. The coconut genotypes responded differently in their LWP measured during moisture stress in the field. The degree of tolerance to stress was indicated by a relatively high LWP in some hybrids (WCT x WCT, WCT x GBGD) and in talls such as FMS, Andaman Giant, SS Apricot (Table 2). The sensitivity of stomata affected the LWP to a great extent. For instance, in the drought tolerant hybrid WCT x WCT, high stomatal resistance (low conductance) was associated with low LWP; conversely, low stomatal resistance resulting in high transpiration rate led to lowering of LWP in the dwarfs, which were susceptible to drought. A rapid screening method based on the measurement of LWP was developed in excised leaflets in coconut genotypes. The drought tolerant nature of

Table 1: Stomatal resistance and transpiration rate in coconut cultivars / hybrids during stress period.

Genotype	Stomatal Resistance	Transpiration rate (s cm^{-1})
Talls and tall hybrids		
Andaman Giant	10.99	1.74
Java Giant	8.28	2.62
F.M.S	7.29	2.78
Philippines Ordinary	7.29	2.78
Fiji	6.50	2.84
West Coast Tall (WCT)	5.99	2.89
WCT x WCT	12.97	1.64
WCT x COD	10.89	1.72
LCT x COD	10.19	2.57
LCT x GBGD	9.59	1.96
Dwarfs and Dwarf Hybrids		
Malayan Green Dwarf (MGD)	4.45	4.04
Malayan Orange Dwarf (MOD)	3.58	4.51
Malayan Yellow Dwarf (MYD)	3.47	5.76
Gangabondam Green Dwarf (GBGD)	4.95	3.33
Chowghat Orange Dwarf (COD)	4.96	2.92
COD x WCT	4.81	3.99

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From the foregoing account, it is evident that sets of desirable traits exist in crop varieties which impart resistance/ tolerance to moisture stress conditions. Cell size and number, stomatal frequency, stomatal resistance, epicuticular wax content and water potential components are the essential anatomical and physiological indicators for assessing moisture stress in annuals and biennials.

Stomatal characteristics

The stomatal frequency and its behaviour play a major role in water conservation in many plant species. Among the plantation crops, coconut exhibited variations in the stomatal frequency among the talls, dwarfs and hybrids differing in drought tolerance. The stomatal resistance and transpiration rate were used to screen 23 coconut genotypes for drought tolerance. During the moisture stress in March, some of the tall palms and tall hybrids had relatively high stomatal resistance(8.57 and 10.1 sec.cm^{-1}) resulting in effective conservation of water in the tissue (i.e. low transpiration rate), whereas the dwarfs (4.11sec.cm^{-1}) and the dwarf hybrid COD x WCT (5.0sec.cm^{-1}) were sensitive to moisture stress with a tendency to lose more water (Table 1). Similarly in cocoa, the drought tolerant accessions like NC-23, NC-29 and NC-31 (11.6 s cm^{-1}) had effective stomatal regulation resulting in decreased transpiration water loss (1.8 ugcm^{-2} s^{-1}) as compared to susceptible accessions (7.0 and 3.3 respectively). Thus the determination of stomatal resistance proved to be the most useful selection criteria for drought tolerance in plantation crops.

Leaf water potential (LWP)

Several workers studied the degree of stomatal control of leaf water potential from porometer measurements of leaf conductance(opposite of stomatal resistance) and water potential at a range of stress levels. When compared under similar conditions, the ranking of species differances in the water potential for stomatal closure persists. The coconut genotypes responded differently in their LWP measured during moisture stress in the field. The degree of tolerance to stress was indicated by a relatively high LWP in some hybrids (WCT x WCT, WCT x GBGD) and in talls such as FMS, Andaman Giant, SS Apricot (Table 2). The sensitivity of stomata affected the LWP to a great extent. For instance, in the drought tolerant hybrid WCT x WCT, high stomatal resistance (low conductance) was associated with low LWP; conversely, low stomatal resistance resulting in high transpiration rate led to lowering of LWP in the dwarfs, which were susceptible to drought. A rapid screening method based on the measurement of LWP was developed in excised leaflets in coconut genotypes. The drought tolerant nature of

Table 1: Stomatal resistance and transpiration rate in coconut cultivars / hybrids during stress period.

Genotype	Stomatal Resistance	Transpiration rate (s cm^{-1})
Talls and tall hybrids		
Andaman Giant	10.99	1.74
Java Giant	8.28	2.62
F.M.S	7.29	2.78
Philippines Ordinary	7.29	2.78
Fiji	6.50	2.84
West Coast Tall (WCT)	5.99	2.89
WCT x WCT	12.97	1.64
WCT x COD	10.89	1.72
LCT x COD	10.19	2.57
LCT x GBGD	9.59	1.96
Dwarfs and Dwarf Hybrids		
Malayan Green Dwarf (MGD)	4.45	4.04
Malayan Orange Dwarf (MOD)	3.58	4.51
Malayan Yellow Dwarf (MYD)	3.47	5.76
Gangabondam Green Dwarf (GBGD)	4.95	3.33
Chowghat Orange Dwarf (COD)	4.96	2.92
COD x WCT	4.81	3.99

Table 2. Leaf Water Potential (LWP) in coconut genotypes (-MPa)			
Drought tolerant		*Drought susceptible*	
WCT x WCT	1.17	MOD	1.52
WCT x GBGD	1.15	MYD	1.49
WCT x COD	1.19	GBGD	1.46
LCT x COD	1.26	COD	1.46
FMS	1.10		
Andaman Giant	1.13		

the hybrids LCT x COD and LCT x GBGD was evident through the maintenance of high LWP irrespective of the time of dehydration. The leaf water potential components were determined between the drought tolerant and susceptible accessions of cocoa during the pre-stress, stress and recovery periods (Table 3). It is clear that the drought tolerant accessions maintained higher turgor potential both during stress and recovery than the susceptible accessions. Determination of the shoot water potential in tea was used as screening method for Tocklai cultivars of tea for drought tolerance, which also revealed that maintenance of high LWP under stress condition is a characteristic feature of tolerant cultivars. Drought resistant coffee cultivars possessing higher osmoregulation by more solute accumulation during moisture stress was also reported. In rubber, the drought tolerant RRII 105 was characterized by high solute potential.

Epicuticular wax content (ECW)

It is well established that when prolonged water deficits prevail, there is an increase in epidermal waxes of leaves which reduce the cuticular transpiration. Thus, the estimation of ECW could be a useful method to screen the varieties for drought tolerance. By virtue of possessing high ECW during stress period in March, coconut hybrids LCT x GBGD, LCT x COD, WCT x WCT and WCT x GBGD and the talls Java Giant, FMS and Philippines Ordinary have been grouped as drought tolerant types (Table 4). There was a clear negative relationship between wax content and transpiration rate in that the drought susceptible MOD with ECW of 77.3 $\mu g\ cm^{-2}$ had a transpiration rate of 4.5 $\mu g\ H_2O\ sec.^{-1}cm^{-2}$, while a high ECW content of 132.6 $\mu g\ cm^{-2}$ in the tolerant LCT x GBGD was associated with low transpiration rate of 1.96 $\mu g\ H_2O.\ sec^{-1}\ cm^{-2}$. Likewise in cocoa, the drought tolerant accessions had higher ECW content than the drought

Table 3: Water potential components in cocoa

Parameters	Accession type	Pre-stress	Stress	Recovery
Water potential (-MPa)	Tolerant	0.56	0.88	0.57
	Susceptible	0.35	1.08	0.68
Osmotic potential (-Mpa)	Tolerant	0.78	0.91	0.77
	Susceptible	0.78	1.09	0.78
Turgor potential (MPa)	Tolerant	0.22	0.03	0.20
	Susceptible	0.43	0.01	0.10

Table 4: Epicuticular Wax Content (ECW) in coconut genotypes

Drought tolerant	ECW (μ g cm^{-2})	Drought susceptible	ECW (μ g cm^{-2})
LCT x GBGD	132.63	MOD	77.03
LCT x COD	120.70	MYD	79.10
WCT x WCT	117.40	COD	87.60
WCT x COD	116.72	GBGD	90.30
WCT	109.00	COD x WCT	101.50

Table 5: ECW content and lipid fraction in cocoa

Parameters	Tolerant	Susceptible
ECW (μ g cm^{-2})	38.86	31.66
Total lipids ($mg.g^{-1}$ fwt)	7.39	6.27
Neutral lipid (%)	77.2	78.0
Glycolipid (%)	19.1	17.0
Phospholipid	3.7	4.9
	4.4	4.8

susceptible ones (Table 5). Higher waxiness was reported in drought tolerant rubber varieties like G1 1, RRIM 600 and RRII 105. The genotypic variation in light reflectance associated with wax content was also reported. Deposition of higher wax content on the leaves of some of the drought tolerant tea clones of UPASI was reported. During summer season, some of the coffee cultivars recorded relatively high ECW.

Biochemical markers

The metabolic and biochemical adaptations to drought are understood to limited extent in plantation crops. Biochemical characterization is an important step in identifying the specific markers for drought tolerance. Besides the metabolism involving osmotic adjustments, the routinely studied biochemical aspects are the activities of enzymes like nitrate reductase, acid phosphatase, superoxide dismutase, peroxidase, catalase etc. in some of the plantation crops under stress conditions.

Genotypic variations exist in NR activity in coconut differing in the degree of tolerance to drought. Under water stress, drought tolerant cocoa accessions showed higher stability in NR activity. There was less decrease in NR acivity during moisture stress in drought resistant coffee cultivars. The pattern of polyphenol isozymes from the osmotically stressed leaves exhibited two additional fast moving bands in drought susceptible coconut hybrid COD x WCT, while the same was absent in a relatively tolerant tall variety WCT. The relationship between peroxidation of lipids and the enzyme activities of superoxide dismutase, peroxidase, catalase and polyphenol oxidase in drought tolerant and susceptible coconut genotypes was reported (Table 6).

Table 6: Lipid peroxidation and activities of related enzymes during stress period

Genotypes	Peroxi-dation (ABS value)	SOD (Units)	Catalase	Peroxidase (Am^{-1} mg^{-1} protein x 10^{-3})
Drought tolerant				
WCT x WCT	0.076	5.19	5.04	59.24
WCT x COD	0.186	4.15	3.73	59.10
WCT	0.183	3.68	4.60	60.40
Fiji Tall	0.219	2.59	2.68	54.90
Drought susceptible				
COD x COD	0.396	2.30	2.52	38.70
COD x WCT	0.459	1.75	1.49	32.10
MYD	0.569	1.58	1.33	41.95
GBGD	0.569	1.43	1.71	35.90

Photosynthesis and water use efficiency

From the foregoing account of drought tolerant mechanisms, it is evident that stomatal control of transpiration is an important criteria for crop varieties to withstand moisture stress. Since stomatal pore also regulates the gaseous exchange, it is imperative to examine the influence of stress on photosynthesis. The variation in net CO_2 assimilation and related parameters in contrasting coconut genotypes under field conditions was reported. Table 7 depicts the variations in the instantaneous WUE between tolerant and susceptible coconut genotypes during the non-stress and stress period. A positive linear relationship has been observed between net CO_2 assimilation and stomatal conductance in the drought tolerant types but not in the susceptible ones.

Table 7: Instantaneous water use efficiency (mol CO_2 m mol H_2O^{-1}) during non stress (NS) and stress (S) periods

	Non Stress	Stress
Tolerant		
WCT	0.83	0.80
WCT x WCT	0.88	0.88
WCT x COD	1.14	0.96
LCT x GBGD	1.22	1.18
LCT x COD	1.02	0.99
Susceptible		
COD	1.07	0.86
MYD	0.83	0.80
GBGD	0.88	0.81
COD x WCT	1.14	0.91

Net photosynthesis was high in cashew (8.21 umol $CO_2 m^{-2}s^{-1}$, while cocoa exhibited high stomatal resistance. The WUE was the lowest in cashew (0.71u mol m mol $^{-1}$ and highest in coconut (1.62). It appears that the drought tolerance to great extent relates to stomatal diffusive resistance with high WUE or positive carbon balance and the extent to which the photosynthetic recovery takes place on rewatering.

Yield Responses During Normal and Drought Years

The performance of 87 coconut hybrids comprising

21 different Tall x Dwarf, 10 Dwarf x Tall, 51 Tall x Tall, 4 Dwarf x Dwarf and one three way hybrid under rainfed condition was evaluated. The cumulative yield of 18th year which is representative of its yield potential was taken for evaluation and three hybrid combinations viz; Chandrasankara (COD x WCT), Chandralaksha (LCT x COD) and Lakshaganga (LCT x GBGD) were identified as superior combinations, with nut yield of 99.8, 99.3 and 101.3 palm^{-1}year^{-1} respectively. These hybrid combinations gave 19 to 42% more yield over the local WCT cultivar. The stability in yield during normal years and drought influenced years were worked out to identify the most tolerant ones (Table 8) which indicated that there was high reduction in the bunch production (42%), female flower production (22%), setting (46%) and yield (75%) in COD x WCT, as compared to LCT x COD (19%, 11%, 5% and 15% respectively) and LCT x GBGD (21%, 11%, 22% and 44% respectively). This shows that Lakshaganga and Chandralaksha performed well under drought situations. The performance of these three hybrids in relation to other hybrid combinations is also clear from the Table 8. It is presumed that drought tolerance character is inherited from the female parent Lakshdweep Ordinary. Between LCT x GBGD and LCT x COD, the performance under drought situation was better with LCT x COD exhibiting greater tolerance as well as higher yield potential.

Breeding for Drought Resistance/Tolerance

The crop improvement in areas with limited water supply or high frequency of soil water deficits should aim at identifying the varieties which can withstand the adverse condition of soil and atmospheric droughts. The detailed discussion in the above paragraphs has indicated the availability of a range of sensitive physiological parameters which could be successfully employed as screening methods for drought tolerance in different plantation crops. The fact that varieties could be clearly identified for drought tolerance with desirable traits is a positive step towards selection for breeding strategies. The mechanism and strategies to be adopted in breeding and selection programmes will depend not only on their effect on productivity, but also on the type of drought likely to be encountered. In this connection the first step was to make crosses between identified drought tolerant / high yielding palms. Further, screening of selected crosses

Table 8 : Performance of hybrids during good and drought influenced (DI) years

Characters	COD x WCT	WCT x COD	WCT x GBGD	LCT x COD	LCT x GBGD
Number of bunches					
Good years	10.5	10.4	9.9	9.5	9.8
DI years	6.1	7.2	5.1	7.7	7.7
% reduction	42	31	45	19	21
Number of female flowers/ bunch					
Good years	35.0	32.5	33.3	26.8	30.1
DI years	27.4	24.5	24.5	29.9	26.7
% reduction	22	25	26	+11	11
Setting %					
Good years	39	35	30	37	37
DI years	22	25	21	35	29
% reduction	46	29	30	5	22
Yield - nuts/palm					
Good years	145	117	98	95	108
DI years	36	43	28	81	60
% reduction	75	64	72	15	44

from the drought tolerant and susceptible cultivars as well as cocoa accessions, along with the parents have been initiated at the nursery, for the selection of promising drought tolerant types at the seedling stage.

The Parents and the crosses in coconut are:

Parents:	Talls	WCT, LCT, ADOT , PHOT, FMS
	Dwarfs	MYD, CGD
Hybrids	T x D's	WCT crossed with CGD, MYD, COD & GBGD
		FMS x MYD, LCT x CGD,
		ADOTx CGD, PHOT x CGD
	D x T's	CGD x WCT, CGD x FMS, MYD x WCT, MYD x FMS, GBGD x FMS, GBGD x JVT

In case of cocoa, the following hybrids were screened:

11-67 x NC 29/66, 11-67 x NC 31/108, 11-67 x NC 42/94, 1-21 x NC 23/43, 1-21x NC 29/66, 1-21x NC 42/94*, 1-14 x NC 29/66, 1-14 x NC 42/94, 1-29 x NC 42/94*, 1-29 x NC 23/43*

(* is to denote relative tolerance to water stress).

Conclusions

In plantation crops, the scopes for improvement under drought condition exist through the availability of relatively high tolerant varieties. The physiological basis of such tolerance mechanisms has been well established in many of the crops. The exploitation of the already identified varieties for drought tolerance involves meticulous planning of breeding strategies. The work on developing cross combinations involving parents with not only drought tolerance but also the potential for high yield under limited water availability would be an important step for the overall improvement of crops under drought.

Future Thrust

1. Biotechnological approaches to stress tolerance. Identification of genomes for tolerant traits in the varieties and development of specific protocols of tissue culture for abiotic stresses like drought would go a long way in facing the challenges of drought.
2. Evaluation of promising genotypes under water limited conditions for yield.
3. Production of seed material of identified genotypes for overall improvement under stress conditions.

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Integrated Management of Pests and Nematodes in Plantation Crops

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Introduction

Insects and nematodes are known to be limiting factors in the production of plantation crops. Integerated pest management is a new approach, which has been necessiated primarily out of the growing concern for the undesirable side effects of large scale use of chemical pesticides and failure of the same to provide effective suppression of pests at an economic level. The IPM system inludes pest forecasting, comprehensive surveys, biological pest suppression, phytosanitation along with judicious use of pesticides. The increasing cost of chemical pesticides also induces the farmers to take up integerated methods of pest control. The perennial nature of the plantation crops also underlines the need for an ecofriendly system in dealing with pests. Important pests and their management practices on various plantation crops are given in the following pages.

Coffee

White stem borer, *Xylotrechus quadripes* chevr.

Infested plants show external ridges around the stem and yellowing and wilting of leaves, which will be distinct after the onset of monsoon. Young grubs feed in the corky portion just under the bark for about 2 months and later tunnel into the hard wood. Adult is a slender black coloured beetle with white bands. The grub stage lasts for about 10 months and the beetle completes its life cycle in about a year.

Integrated management includes the following methods: (i) maintain optimum shade, (ii) collar prune the infested plants, uproot if the borer has entered the root and burn the affected parts, (iii) remove the loose scaly bark of the main stem and thick primaries using coir glove or coconut husk, (iv) spray/swab the main stem and thick primaries, once in April-May and once or twice during October-December flight periods, with Lindane 20 EC @1300 ml. in 200 litres of water along with 200 ml. of any wetting agent and (v) Spray repeatedly with neem kernel extract.

Coffee berry borer, *Hypothenemus hampei* Ferr.

The borer infests young as well as ripe berries. Infested tender berries may fall due to injury or secondary infection by fungi. Generally only one of the beans in a berry is affected. A typical pinhole at the tip of the berries indicates the presence of the pest. In case of severe infestation two or more holes may be seen. A powdery substance pushed out through the holes reveals the active tunnelling and feeding within the leaves. The adult borer is a small black beetle with thick body hairs. Egg to adult period is completed in just over a month. The short life cycle enables the pest to complete several generations in a year in quick succession, under favourable conditions.

The IPM strategies employed are: (i) harvest the crop in time, (ii) no berries should be left over either on the plant or on the ground, (iii) spread gunny bags or polythene sheets on the ground while picking will help to minimise gleanings, (iv) if gleanings could not be collected, they may be swept along with the mulch and burried below a depth of 0.75 meter in the soil, (v) Maintain optimum shade and good drainage, (vi) dip infested berries in boiling water for 2-3 minutes, (vii) dry coffee to the prescribed moisture level to prevent breeding of beetles in stored coffee, (viii) spray Endosulfan 35 EC @ 340 ml. in 200 litre of water along with 200 ml. of any wetting agent to check the beetles in the pulp, (ix) avoid transporting of infested coffee to uninfested areas, (x) dry properly the infested coffee, fumigate and then transport using fumigated gunny bags and (xi) spray the fungal suspension of *Beauveria bassiana* immediately after the cessation of monsoon when the beetles are in the pulp.

Shot hole borer, *Xylosandrus compactus* Wich.

It is a major pest of robusta coffee, usually infesting the green succulent branches of old plants. Withered or dried branches with shot holes indicate presence of the pest. The attacked branches dry up fast. Premature falling of leaves distal to the point of attack occurs. The terminal leaves wilt, droop and dry up. The adult beetle is brown to black in colour. The larval stage lasts for 13-21 days and pupal stage for about 11 days. Egg to adult period is completed in 4-5 weeks.

Control measures are: (i) prune the affected twigs 5-7.5 cm beyond the shot hole and burn, (ii) remove and destroy all the unwanted/infested suckers during summer and and (iii) maintain thin shade and good drainage.

Mealy bugs, *Planococcus citri* Risso & *P. lilacinus* Ckll.

These are important sucking pests of coffee. They attack nodes, spikes, berries, tender branches, leaves and roots leading to debilitation of the plant and crop loss. Adult female is small, oval, elongate, soft bodied and wingless. Of the two species, *P. citri* is oval, elongate whereas *P. lilacinus* is

globose in shape. The female matures within a month.

Control measures are the following: (I) maintain optimum shade, (ii) control ants by dusting Quinalphos 1.5% or Methyl parathion 2% or Malathion 5%, (iii) destroy ant nests, (iv) remove and destroy weeds, (v) spray the affected patches with Quinalphos 25 EC or Fenitrothion 50 EC @ 300 ml. Each or Fenthion 1000 @ 150 ml. Or 4 litres of Kerosene in 200 litres of water along with 200 ml. Of an agricultural wetting agent. If the root zone is infested, drench it with any one of the above insecticide solution except Kerosene emulsion and (vi) release the parasitoid, *Leptomastix dactylopii* against *P. citri* or the predator, *Cryptolaemus montrouzieri* irrespective of the species of mealy bugs.

Green scale, *Coccus viridis* Gr.

Green scale is an important sucking pest of arabica. Continuous sucking results in excess loss of sap from the plant which leads to debilitation of the older plants and death of nursery plants. The honey dew secreted by the scale forms a film on the leaves and a black sooty mould grows on it, which prevents photosynthesis. The adult scale is flat, oval and light green in colour. It is sedentary in habit. The life cycle is completed in 4-6 weeks. Adult lives upto 2-5 months.

The IPM methods are: (I) maintain optimum shade, (ii) control ants by dusting Quinalphos 1.5% or Methyl parathion 2% or Malathion 5%, (iii) destroy ant nests, (iv) remove and destroy weeds and (v) spray green scale infested patches with 200 ml. Of Malathion 50 EC or 120 ml. Of Quinalphos 25 EC or 80 ml. Fenthion 1000 or 130 ml. Monocrotophos 40 EC or 170 ml. Of dimethoate 30 EC or 100 ml. Of Fenitrothion 50 EC with 200 liters of water with 200 ml. Of wetting agent (CCRI, 1998).

Nematodes

Root-lesion nematode, *Pratylenchus coffeae* This nematode is highly destructive to arabica coffee, while robusta is more tolerant. They feed and destroy the root system. Affected plants have loose anchorage and could be easily dislodged. Affected young plants become unhealthy with lean and lanky stem. Older leaves become yellow and drop. Bearing plants show thinner main stem and have inadequate foliage to support the crop. The nematode lays eggs in the root-lesions. Development from egg to adult takes about a month. The pest is persistent in the soil and roots all round the year.

Ectoparasitic nematode, *Hemicriconemoides* spp. : *H. coffeae, H. cocophillus* and *H. gaddi*, when associated with arabica coffee cause crinkle leaf disorder. It is characterized by production of shortened internodes and proliferation of crinkled, chlorotic leaves and production of sparse feeder roots.

Nematode Management: In the nursery, (i) dig up the nursery site and expose the soil to the sun during summer, (ii) sieve and dry jungle soil and farmyard manure thoroughly before use and (iii) avoid obtaining nursery plants from infested areas.

In the field, (i) uproot and burn the affected plants, (ii) dig up pits and expose the soil to the sun for one year, (iii) keep the pits free from weeds and (iv) plant the area with robusta or robusta-arabica grafted plants (CCRI, 1998; Kumar, 1988).

Tea

Tea mosquito bug, *Helopeltis theivora* Waterhouse

Adults and nymphs suck the sap from buds, young leaves and tender stems. The feeding punctures appear as reddish brown spots. Due to intensive feeding leaves curl up, become badly deformed and remain small. Later these shoots dry up. A single first instar nymph could make as many as 80 feeding lesions in 24 hours.

Cultural practices like plucking, pruning, shade regulation and weed control effectively checks the incidence of tea mosquito bug. Harvesting of shoot at closer interval will result in the removal of eggs of *Helopeltis* and also deny suitable material for feeding and oviposition. The insecticides endosulfan and phosalone 0.1 percent effectively controls this pest.

Mites

In Southern India, the pink mite, *Acaphylla theae* (Watt) and the purple mite, *Calcarus carinatus* (Green) are the species regularly occuring on tea and causing crop loss. The other mites of economic importance are the red spider mite, *Oligonychus coffeae* (Nietuer); the scarlet mites, *Brevipalpus australis* (Tucker) and *B.obvatus* Donnadieu and the yellow mite, *Polyphagotarsonemus latus* (Banks). The mites congregate on the under surface of leaves, especially along the midrib and petiole. Feeding results in brown discolouration of leaves, ultimately leading to defoliation.

Control measures include use of resistant varieties, manipulation of cultural operations such as plucking, pruning, shade regulation and weed control and use of chemicals like sulphur, dicofol, ethion and phosalone (Muraleedharan, 1992; Muraleedharan and Chen, 1997).

Nematodes

Root-knot nematode (*Meloidogyne brevicauda*) infects the roots, which become swollen, appear gnarled and are heavily pitted. Feeder roots are very few or absent, rendering them vulnerable to drought and their recovery after pruning is very slow. Severely infested bushes fail to recover

from pruning. Root-knot nematode, *M. incognita,* is commonly found attacking tea plants in nurseries in India. Pin nematode (*Pratylenchus curvitatus*) has been reported in large numbers from the feeder roots of tea in North Eastern India. But, there has been no positive indication of pathogenicity to tea. The root-lesion nematode (*Pratylenchus brachyurus*) is restricted to the plains of Assam and is pathogenic to tea seedlings upto three years. Infested roots show dark lesions at the point of entrance. In India, nematode problems are mostly observed in the nurseries and the following control measures are generally recommended (Rao, 1976; Muraleedharan, 1986):

a) Heat treatment of soil : Soil and sand mixture is spread on galvanised iron sheets to a thickness of 4-5 cm and heated from below. The soil is mixed thoroughly by constant turning. Sprinkle little water as and then while heating. When the soil is too hot to handle with naked hand it would have attained the correct temperature of 60-65^{0}C which is required for killing nematodes. The soil could be removed and stored in a clean place in the nursery shed and used as and when required.

b) Chemical treatment : Application of Phorate 10 G or Carbofuran 3G when applied at the rate of 1 g/kg of nursery soil gives good protection to the nursery plants. If the area to be planted has a history of nematode infestation, planting may be undertaken after soil fumigation using chemicals metham sodium or methyl bromide or after soil rehabilitation with cover crops like Guatemala grass (*Tripsacum laxum*) for about two years.

Rubber

White grub, *Holotrichia serrata* F.

It is the most serious pest of rubber at the nursery stage in India. The grubs feed voraciously the taproots, leading to total destruction of ten-month-old nursery plants, which seem to sway in fields due to active feeding of grubs at the collar region. At this stage, the foliage of the seedlings turn yellow, shed off and the whole plant wilts and dries up. The life cycle of white grubs last for one year. Females are larger than males. Adult beetles live for about two months.

An integrated pest management strategy has been worked for white grubs in India. Trapping of adult beetles with light trap incorporating mercury vapour lamp is an effective mechanical control method. Biological control agents viz., the entomopathogenic fungus, *Beauveria brongniartii* and the entomopathogenic bacterium, *Bacillus popilliae* effectively checks white grubs. Application of insecticides such as phorate 10G, carbaryl + lindane 4:4G @ 25 kg ha^{-1} or HCH 10D at 100 kg ha^{-1}, in the soil at the time of preparation of nursery beds is effective in managing white grubs. Flooding the nursery fields for longer periods is effective as a means of cultural control.

Bark-feeding caterpillar, *Aetherastis circulata* Meyr.

This is the most serious endemic pest of mature rubber trees in India. It feeds on the bark and latex vessels break at certain points and latex oozes out. This facilitates easy entry of wood rotting fungi such as *Phytophthora, Botryodiploidea, Pythium* etc., the rotting of tissues upto wood region may lead to branch snap or tree snap. The bark-feeding caterpillar is brick red in colour while the moths are white in colour. Larval period ranges from 25 to 30 days and the pupal period for 6-7 days.

The pest can be efficiently controlled by dusting fenval 0.4% D, carbaryl 5% D, methyl parathion 2%D or quinalphos 1.5% D with a power duster @10-15 kg ha^{-1} in the early morning hours (Jayarathnam, 1980).

Nematodes

Root-knot nematode (*M. incognita*) infested rubber seedlings show conspicuous swellings on the lateral roots or rootlets and wilting, dwarfing, discoloring and shedding of leaves. Severe attack leads to death of the seedlings. Incorporation of the leaves of *Pongamia glabra* (Nehru *et al.*, 1991) and replacing *Pueraria phaseoloids* Benth. by *Mucuna bracteata* D.C. as associated cover crop (Thankamony *et al.*, 1989) was effective in reducing the root-knot nematode infestation in the host. Other nematodes associated with rubber are: *P. brachyurus, Aphelenchus* sp., *Tylenchus* sp. and *Hemicriconemoides* sp. (Rajendran and Jayarathnam, 1977).

Cashew

Cashew stem & root borer, *Plocaederus ferrugineus* L.

The young grubs bore into the bark and feed on phloem and cork tissues of trunk and root resulting in exudation of gum (gummosis) from the damaged portion. The bore holes and tunnels are plugged with chewed fibres, frass and excreta. At later stages, they tunnel the sap wood tissue. In case of infestation by many grubs, the bark all around the collar region wither away. The leaves of the tree turn yellow and shed. The adult is a medium sized reddish brown longicorn beetle. The life cycle is completed in 250-354 days (Godse *et al.*, 1990).

For better management of the pest: (i) close examination of trunk is to be done at least once during the fruiting season, (ii) mechanical removal of grubs by carefully chiselling out the bark, (iii) uprooting and removal of the dead trees and those which are beyond recovery and (iv) painting a mixture of coaltar and kerosene (1:2 ratio) up to one metre height in the trunk and exposed root region may be carried out twice a year (Anon., 1990).

Tea mosquito bug, *Helopeltis antonii* Sign.

Both adult and nymphs suck the sap from tender shoots, panicles, immature nuts and apples, resulting in the formation of a necrotic area called 'lesion' around the point of entry of the stylets of the bug. The lesions later coalesce and ultimately result in shoot blight/blossom blight. In case of severe infestation, the infested trees present a scorched appearance (Devasahayam and Nair, 1986). When the immature nuts are infested, they shrivel and dry up. Older nuts and apples develop a characteristic scabby appearance. The adult bugs are slender and elongate, reddish brown in colour with a black head. Life cycle is completed within 20 days.

Monocrotophos, methyl parathion and endosulfan (0.05%) have been reported as promising insecticides against this pest (Chatterjee, 1989c). Three rounds of insecticidal treatment at times of flushing, flowering and fruiting are required to protect all stages of growth within a period of 3 to 4 months. It is absolutely necessary to keep a vigil on build up of the pest to undertake timely chemical control. In order to formulate a sound IPM for this pest, besides chemical control, work on developing tolerant varieties and biological control has to be intensified (Sundararaju and Bakthavatsalam, 1994).

Cashew leaf miner, *Conopomorpha syngramma* M.

It is a major pest, specially in young plantations, causing serious damage to the tender foliage of post-monsoon flushes. The mining in between the epidermal layers of the tender leaves and feeding by the caterpillars cause extensive leaf blisters which on drying result in distortion, browning, curling and drying of leaves (Rai, 1984).

The adult is a silvery grey moth, which lays eggs on tender leaves. Freshly hatched caterpillars are pale white in colour. Sprays of monocrorophos , methyl parathion and phosphamidon (0.05%) effectively control the pest (Rai, 1984). Biological agents, *viz.*, *Sympiesis* sp. and *Cirrospilus* sp. have been recorded (Sundararaju, 1984a; Anon.,1994).

Cocoa

Cocoa mealy bug, *Planococcus lilacinus*

It is a serious pest of cocoa in India and is present throughout the year. Mealy bug feeding on tender shoots results in reduced growth. Later they become deformed into slender hair like processes giving the appearance of a brush. The adult female bug is chocolate brown in colour. The male is winged and free living. The life cycle of male and female is completed in 17-20 and 20-25 days respectively (Nair, 1981). Foliar spraying of 0.05% fenthion, monocrotophos, quinalphos or dimethoate effectively checks mealy bugs (Nair, 1981).

Experiments using systemic insecticides indicated that dimethoate, monocrotophos and phosphamidon at 1.5 and 3.0 a.i. per plant were effective in controlling the mealy bug infestation in young plants. Native natural enemies of the mealy bug include a coccinellid beetle, *Pullus* sp. and caterpillars of the lycaenid moth, *Spalgis epius* Westw. (CPCRI, 1986). Seven species of ants are reported to be associated with mealy bugs.

Rodents: Rats and Squirrels

These animals damage the ripe pods. A large hole is bitten through the pod husk, the beans are then extracted and after the sweet mucilage has been eaten, these are discarded. The Western Ghats squirrel, *Funambulus tristriatus* Waterhouse, the South Indian palm squirrel, *F. palmarum* Linn. and the black rat, *Rattus rattus* Linn. are the most important vertebrate pests of cocoa (Kesavabhat *et al.,* 1981).

Control measures include: (i) trapping with wiremesh live box traps, (ii) baiting with plain whole grain and (iii) use of multiple dose anticoagulants like warfarin and fumarin which are very effective in controlling rats in cocoa gardens (Daniel, 1994).

Coconut

Rhinoceros beetle, *Oryctes rhinoceros* Linn.

Rhinoceros beetle is a ubiquitous pest of coconut palm. The adult beetle which is the destructive stage of the pest bores through the unopened fronds and spathes. The affected fronds, when fully opened shows characteristic geometric cuts. Spathe infestation results in drying of the inflorescence. Moreover the injured portions may attract other pests like red palm weevil and fungus.

The beetle breeds on decaying organic debris such as farmyard manure, dead coconut stumps and logs, compost etc. The fully grown grub is ash gray in colour. Beetle is large, stout built, black with a prominent cephalic horn in males. The life cycle is completed in about six months.

Integrated management consists of: (i) disposing off dead and decaying organic debris in the vicinity of coconut plantation, (ii) hooking adult from the palm crown and filling holes made by beetles with a mixture of fungicide and sand in the ratio of 3g mancozeb + 1kg fine sand, (iii) protecting young palms by filling the innermost 2-3 leaf axils with a mixture of sevidol 8G (25g) + fine sand (200g) per palm during May, September and December or with 12g (4 no.) of naphthalene balls covered with sand at 45 days interval, (iv) periodical treatment of breeding sites with carbaryl 50% WP at 0.01 on w/w basis, (v) biological suppression using Baculovirus of *Oryctes* and the green muscardine fungus - release of baculovirus inoculated beetles @10-15 beetles/ha of the plantation and green muscardine fungus, *Metarhizium*

anisopliae (Metch.) Sorokin @ $5x10^{11}$ spores/m^3 of the breeding material and (vi) setting up of breeding traps using decaying organic debris treated with 0.1% carbaryl 3-4 times a year.

Red palm weevil, *Rhynchophorus ferrugineus* Fab.

Red palm weevil attack is more serious in young palms below 20 years. The pest causes damage to the stem portion close to the crown region and the bole region of seedlings. The symptoms of red palm weevil infestation become clear only in advanced stages by which time the crown of affected palm topples. The infested palms in the early stage show yellowing and later wilting of leaves of inner and middle whorls, which can be seen only by, close monitoring. Small circular holes can be seen on the trunk with a brownish viscous fluid oozing out from them. The presence of chewed up fibers/cocoons/weevil, etc. in leaf axils, indicates the presence of the pest in the crown.

The weevil is a large sized reddish brown coloured insect with long curved and pointed snout. The female weevil scoops out small holes in soft tissues and lays the eggs. Eggs hatch in 2 to3 days into soft white legless grubs and they bore into the interior of palms. The grubs pupate in cylindrical cocoon made out of fibrous strands. The life cycle is completed in four months.

For the management of palm weevil an integrated approach is quite feasible. Periodical cleaning of the palm crown has to be done to avoid decaying of organic debris in leaf axils. Avoid making wounds on the palm. Prophylactic leaf axil filling with insecticides as advocated against rhinoceros beetle has to be done. Trunk injection with 0.1% endosulfan /dichlorvos or 1% carbaryl is an effective curative treatment. Fresh coconut logs, 50 cm long, split longitudinally and the cut surfaces smeared with fresh toddy fermented with yeast or acetic acid are effective in attracting the weevils.

Leaf eating caterpillar, *Opisina arenosella* W.

The larva of this insect feeds on the undersurface of the leaflets. The caterpillar makes galleries on the lower surface of leaflets with excreta and silken web. Dried up and green patches appear on the upper epidermis of leaves. In case of severe infestation the whole plantation presents a scorched appearance. The fully- grown larva is long, light green with black head .It pupates in a silken cocoon in the larval gallery. The adult is a greyish moth. The life cycle of this pest is completed in about 2 months.

The integrated management practices consists of: (i) cutting and burning the heavily affected 2-3 outermost leaves, (ii) release of promising parasitoids like *Goniozus nephantidis* (larval parasitoid), *Elasmus nephantidis* (pre-pupal parasitoid) and *Brachymeria nosatoi* (pupal parasitoid) at the fixed dosages 20.5%, 49.4% and 32.9% respectively of the parasitoids depending on the target stages of the pest at fortnighltly intervals till the pest population is suppressed and (iii) during sporadic outbreaks the pest can be checked to lower level by spraying with 0.02% dichlorvos or malathion/endosulfan/phosalone, each at 0.05%.

In case of severe epidemics, if the above methods are not feasible, root feeding (monocrotophos 36 wsc-10ml +water- 10ml) or stem injection (10ml of Monocrotophos 36wsc.) may be practised.

White grub, *Leucopholis coneophora* Burm.

White grubs mainly damage the roots of the palms and also tunnels into the bole and collar region of the seedlings. The attack on the nursery seedlings results in drying up of the spindle leaf followed by gradual death of the seedlings. In mature trees, continuous infestation by the grubs results in yellowing of leaves, tapering of crown, premature nutfall, delayed flowering, retardation of growth and reduction in yield. The grubs are creamy white in colour with a brown head. Adult beetles are chestnut brown coloured. Eggs are laid in soil. It has an annual life cycle with a grub period of 8 months.

Management practices against this pest include: (i) deep ploughing and digging of the soil to expose the different stages of the pest for predation by birds and other animals, (ii) collection and destruction of the adult beetles during the peak period of emergence in May-June, (iii) setting up of light traps to attract adult beetles and (iv) applying phorate 10 G @100g/palm in May-June and September-October in the active root zone of the palm evenly leaving a distance 60 cm from the base of the trunk (Abraham, 1994; CDB, 1997; Padmanaban and Sukumaran, 1998).

Coreid bug, *Paradasynus rostratus* Dist.

The adults and nymphs feed on buttons and developing nuts. They suck up the sap by piercing the stylet into the tissues just below the perianth. The feeding marks later develop into brown lesions. Infestation results in immature nutfall and formation of malformed nuts with cracks and crinkles on the surface. The adult is a brown coloured bug. Life cycle is completed in 25-34 days. Spraying the crown with 0.1% carbaryl/endosulfan is recommended to control the pest (CDB, 1997).

Nematodes

Nematode species belonging to 44 genera have been reported on coconut in India (Kutty and Koshy, 1979; Koshy, 1986a,b).

Burrowing nematode, *Radopholus similis*

The burrowing nematode infested coconut palms

exhibit general decline symptoms such as stunting, yellowing, reduction in leaf number and size, delayed flowering and reduced yield. *R. similis* infestation produces small, elongated, orange coloured lesions on tender creamy white roots. Later the lesions enlarge and coalesce to cause extensive root rotting.

Management practices are: (i) apply cowdung, farmyard manure, oil cakes, green manure *(Glyricidia maculata)* to the basins or grow *Crotalaria juncea* in the basins and interspaces and use as green manure, (ii) apply phorate @ 10 g ai./palm and @ 3 g ai./seedling in June-July and in September-October, (iii) use nematode free planting materials of coconut and intercrops, (iv) use tolerant or less susceptible cultivars or their hybrids in infested areas, (v) apply phorate 3 g ai./plant to intercrops such as banana, pepper and arecanut in June-July and September-October in infested gardens(Koshy, 1994) and (vi) introduce VA mycorrhizae, *Pasteuria penetrans* and *Paecilomyces lilacinus* in potting mixture (polybags) and planting pits.

Arecanut

Spindle bug, *Carvalhoia arecae* Miller and China

The spindle bug damage is high in South Kerala. Adults and nymphs living inside the innermost leaf axil suck sap from tender spindle and younger leaves. Affected leaves show linear water soaked lesions and later appear as necrotic patches. They dry up and drop off. Affected spindles also show characteristic linear, brown lesions. Adult bugs are red and black, while nymphs are greenish yellow in colour. Life cycle is completed in 32-34 days.

Management measures include spraying of dimethoate 0.05 % in and around the spindle and inner whorls of leaves in the morning or evening hours of the day. Tying perforated and heat sealed polyethylene sachets containing 2 gm phorate (10G) granules to the innermost 2 leaf axils in case of infestation in contiguous years. When new spindles emerge, the sachets may be transferred to the youngest leaf axils.

Root grub, *Leucopholis burmeisteri* Brencke

Root grubs feed on tender and mature roots of the palms. In severe cases the bole of the palm is also eaten up. Continuous root feeding results in yellowing and drooping of leaves, tapering of stem and reduced yield. Adult beetle is medium-sized with chestnut brown in colour. It has an annual life cycle with a prolonged, ie. 7-8 months grub period.

Integrated management practices are: (i) provide good drainage in the garden, (ii) collect beetles during emergence period between 6.30 to 7.30 PM daily, (iii) apply 15 g phorate 10 G/palm twice a year in May-June and September-October for a duration of minimum 3 years and (iv) opening of basin help in detection and predation of pests by birds.

Phytophagous mites

a. Red mite, *Raoiella indica* Hirst.
b. White mite, *Oligonychus indicus* Hirst.

Adults and nymphs colonise the lower surface of leaves and suck the plant sap. Leaves show yellow speckles initially which later coalesce and become bronze coloured. Finally the leaves dry up and wither away. The white mite completes its immature stages in 6.5 to 9 days. The life cycle of female and male red mite is completed in 12.9 days and 11.2 days respectively.

Providing shade to nursery seedlings and young palms in the field is an effective management method. In summer months adequate irrigation may be provided. Conservation of natural enemies like conccinellid beetles, predatory thrips etc. help to check the mites. In cases of severe attack of young palms and nursery seedlings, spray the under surface of leaves with 0.05% dicofol/dimethoate. (Abraham, 1994; CDB, 1997).

Nematodes

Twenty eight genera of plant parasitic nematodes have been recorded from the root zone of arecanut (Koshy *et al.*, 1975,1976; Sundararaju and Kochy, 1982). Among them the burrowing nematode is the most important.

Borrowing nematode, *R. similis*

R. similis infested areca palms exhibit symptoms like general yellowing, reduced growth, vigour and yeild. The most conspicuous symptom is the appearance of lesions and rotting on roots. Unlike in coconut, the tips of lateral and tertiary roots on infestation become black. This nematode takes 25-30 days to complete one life cycle. Maximum population of occurs during October to November and minimum during March to June.

Integrated management consists of: (i) use of tolerant/resistant varieties, (ii) use nematode free planting materials of arecanut and other intercrops, (iii) avoid *R. similis* susceptible varieties of inter crops like black pepper and banana, (iv) apply 5-10kg of green manure per palm preferably *Glyricidia* or *Crotalaria,* (v) apply 1kg of neem oil cake/palm/year and (vi) apply phorate at 3g ai/plant to the root zone of arecanut, banana and black pepper in June-July and in September-October in arecanut based farming systems (Koshy, 1994).

Oil Palm

Rhinoceros beetle, *O. rhinoceros* L.

Beetles bore into the base of the spear cluster

resulting in the breaking of spindle at the base. The leaves, which emerge subsequently, become shortened, and distorted. The beetles bore into immature male and female inflorescences, even when they are inside the spathe. The damage to the heart of the palm attracts fungi and bacteria, which induce bud rot. Management practices are like that for coconut rhinoceros beetle.

Red palm weevil, *R. ferrugineus* Fab.

Main damage is due to the feeding activity of the grubs which bore and feed on the soft tissues of stem, meristem and mesocarp of ripe fruits. Being concealed in plant tissue the pests can be detected only at a very late stage. Infested palms show gradual wilting and drying of outer whorl of fronds. Infestation if left unchecked results in the death of affected palms. Prophylatic and sanitational control measures are required for red palm weevil management. Ripe bunches are to be harvested in time. Other methods are similar to that of coconut (Dhileepan, 1994; CDB, 1997).

Nematodes

A number of plant parasitic nematode species have been recorded from the root zone of oil palm, but none of them are a serious problem at the moment. The burrowing nematode, *R. similis* has been reported from the roots of few seedlings (Koshy, 1994).

Cardamom

Cardamom thrips, *Sciothrips cardamomi* Ramk.

This is the most destructive and persistent pest of cardamom. Adults and nymphs cause damage to panicles, flowers and capsules. Injury to panicles results in its stunted growth, that on flowers leads to flower dropping and the injury produced on tender capsules develop as scabby growth on capsules as they mature. Affected capsules appear malformed, shrivelled and sometimes with gaping slits, thereby reducing the quality of the capsules. Adults are greyish brown in colour. The life cycle is completed in 21 to 32 days.

The following practices are effective in checking the pest: (i) remove collateral host plants, (ii) remove dry dropping leaves, dry leaf sheaths, old panicles and other dry plant parts immediately before the commencement of first application of insecticide, (iii) spray 0.05% fenthion/0.07% phosalone/0.05% chlorpyriphos at monthly intervals from February to November in Kerala and (iv) during peak flowering periods spray insecticide which is less toxic to honey bees viz., Phosalone.

Shoot/panicle/capsule borer, *Conogethes punctiferalis* Guen.

Larvae of this pest bore into tender panicle or unopened leaf spindle or immature capsule. At later stages the larvae bore into the shoots and feed on the central core of the pseudostem resulting in decaying of the central spindle and the characteristic dead heart symptom develops. In capsules, the larva feed on the seeds and the capsules become empty. A fully grown larva is pale purple in colour. The life cycle is completed in 41-51 days.

For effective management of the pest, the insecticide has to be targetted on early stages of the larvae, spraying of either monocrotophos or fenthion 0.075% is effective against these larvae. Injection of the insecticide solution through the bore hole effectively control the larvae in pseudostems.

Cardamom whitefly, *Kanakarajiella (Dialeurodes) cardamomi*

White fly infestation has become severe in certain cardamom growing tracts of Kerala. The first instar larva crawls on the leaf and find out a feeding site. It becomes incapable of further movement from that place and all later stages are completed at that spot. The nymphs secrete a stickly honey dew which drops on to lower leaves. On these, black sooty mould develops, which interrupt photosynthesis of the leaves. The life cycle is completed within 2 to 3 weeks depending on weather conditions.

The white flies can be attracted to sticky yellow traps. Nymphs are effectively controlled by spraying a mixture of neem oil (500ml) and Triton (500ml) in 100 lit. of water. Acephate 0.07% and Triazophos 0.04% are equally effective.

Root grub, *Basilepta fulvicorne* Jacoby

Damage is caused by the grubs of the insect . Grubs feed on cardamom roots in patches. This reduces the uptake of nutrients and leads to yellowing of leaves. The grubs after damaging the roots feed on rhizome as well. Beetles are small greenish blue or blue or green and are found in large numbers during May to July and October to February.

Management measures consists of: (i) collection and destruction of beetles during March-April and August-September and (ii) application of phorate 10G/sevidol 4G @20-40 gms/plant around the plant base on the soil during May-June and/or September-October (Premkumar *et al.*, 1994; ICRI, 1997).

Nematodes

The most important nematodes are the root-knot nematode, *M. incognita* and *M. javanica*. Mature plants on heavy infestation show stunting, reduced tillering , yellowing, premature drying of leaf tips and margins, narrowing of leaf blades, delayed flowering, immature capsule drop and reduction in yield. The infested roots exhibit a "witches broom" type of excessive branching.

Disinfecting nursery beds with methyl bromide @ 500 g/10m^2 is effective in controlling root-knot nematode. Seed beds can also be drenched with 2% formalin to a depth of 20-30 cm and covered with polythene sheets for 3 to 7 days. Application of aldicarb at 5 kg ai/ha thrice after every 3 months results in increase in growth and vigour of seedlings both in primary and secondary nurseries (Ali, 1986; Koshy, 1994).

Black Pepper

Pollu beetle, *Longitarsus nigripennis* Mots.

This is the most destructive pest of black pepper in India. The grubs bore within the tender spikes and berries and damage them by feeding on the internal contents. The infested berry turns yellow and finally black and easily crumble when pressed. The grub period lasts for 20-32 days and during this period a single group destroys 4-5 berries. Pupation occurs in the soil in oval earthern cocoons. There are four or five generations in a year. Spraying of endosulfan 0.05% during May, July and September is the most effective treatment (Nandakumar *et al.*, 1987).

Top shoot borer, *Cydia hemidoxa* Meyr.

This is a serious pest, especially in young plantations. The early instars of the larvae live within the silken webs on the tender shoots and scrape and feed on them. Later, the larvae bore into the tender shoots and feed on the internal contents resulting in the drying of shoots. Repeated infestations of new shoots affect growth of the vine. Fully grown larvae are grayish brown in colour. The larval period lasts for 14 days. Pupation generally occurs within the infested shoots and sometimes outside. Adults are small with crimson - red coloured forewings. Spraying of 0.05% monocrotophos during June and September is effective in controlling the pest infestation. Three hymenopteran parasites viz., *Apanteles* sp., *Eudederus* sp. and *Goniozus* sp. have been reported to parasitize the larvae of top shoot borer (Visalakshi and Joseph, 1965).

Leaf gall thrips, *Liothrips karnyi* Bagn.

Leaf gall thrips induce the formation of tubular marginal leaf galls within which they live. The infestation is serious at higher altitudes and in nurseries in plains. The pest infestation results in marginal leaf gall formation, reduced size, crinkling and malformation of the infested leaves. In case of severe infestation, the growth of the vine and sometimes the formation of spikes may be adversely affected. The adults are black whereas the larvae and pupae are creamy white. *Montandoniola moraguesi* Duton and *Androthrips flavipes* Schmutz are recorded as predators of this pest (Ananthakrishanan, 1978). Spraying 0.05% monocrotophos/dimethoate is effective in controlling the pest.

Scale insects

The infestation causes formation of encrustations on stems, leaves and berries. They suck the plant sap resulting in yellowing and withering of infested shoots. In severe cases the vines dry up. The main species of scale insects infesting balck pepper are *Lepidosaphes piperis* Gr. and *Aspidiotus destructor* Sign. Scale insects can be controlled (Premkumar et al., 1994).

Nematodes

Burrowing Nematode, *R. similis* : In Kerala and Karnataka, this nematode causes the slow wilt disease. The primary symptom is the appearance of a few, pale yellow drooping leaves whose number gradually increases and within 1 or 2 years, the entire foliage may become yellow. This is followed by shedding of leaves, cessation of growth and die-back symptoms.

For heavily infested areas, the following measures are suggested: (i) exclude *R. similis* susceptible trees as standards for trailing black pepper vines and avoid infested planting materials of intercrops, (ii) uproot affected vines, replant after 9-12 months with nematode-free cuttings of tolerant variety and apply phorate @ 1g ai/vine at planting, (iii) apply phorate @ 3g ai/vine in May/June and September/ October, (iv) apply 5 kg green manure (*Glyricidia, Crotalaria*), 1 kg FYM, along with the recommended dosages of NPK, neem oil cake @ 200g/vine, nematicides and earth upto 50 cm radius avoiding any injury to roots, (v) avoid susceptible intercrops like banana, ginger, turmeric etc., or treat banana with phorate @ 3g ai/plant twice a year and turmeric and ginger with phorate @ 1g ai/ha at planting and (vi) introduce VA mycorrhizae, *Pasteuria penetrans* and *Paecilomyces lilacins* in potting mixture as well as in planting pits.

Root-knot nematode, *M. incognita* : Nematode infested vines show unthrifty growth, yellowing of leaves and severe galls on roots. The interveinal areas become dense yellow thereby the leaf veins appear quite distinct with a deep green colour. The integrated management practices suggested for *R. similis* on black pepper is effective against *M. incognita* also (Koshy, 1994).

Ginger and Turmeric

Shoot borer, *Conogethes punctiferalis* Guen.

The shoot borer is the most important pest of ginger and turmeric. The larvae bore into pseudostems and feed on the growing shoot resulting in yellowing and drying of infested shoots. The presence of bore holes in the pseudostem through which frass is extruded and the withered central shoot are characteristic symptoms of pest infestation. Fully grown larvae are light brown in colour. In the field, 6-7 generations are completed during a crop season. Spraying of monocrotophos

or fenthion 0.075% is effective against this pest.

Leaf roller, *Udaspes folus* Cram.

The larvae cut and fold the leaves, remain within and feed on them. Adults are medium sized with brownish-black wings with large white spots. Spraying of carbaryl (0.1%), dimethoate or phosphamidon (0.05% each) is recommended for the control of the pest (Anon., 1985b).

Rhizome scale, *Aspidiella hartii* Ckll.

The rhizome scale infests rhizomes both in field and storage. In the field, in case of severe infestation, the plants wither and dry. In storage, the pest infestation results in shriveling of buds and rhizomes, adversely affects sprouting of rhizomes. The adult females are minute, circular and light brown to grey. The rhizome scale is preyed by *Physcus comperei* Hayat, *Adelencyrtus moderatus* Howard and two types of mites. Dipping the seed rhizomes of turmeric in quinalphos (0.1%) for five minutes after harvest and before planting is effective in controlling the pest infestation (Premkumar *et al.*, 1994).

Nematodes on ginger

Among the many nematode species reported on ginger, root-knot and burrowing nematodes are the most important (Sundararaju *et al.*, 1979a).

Root-knot Nematode, *M. incognita* : Heavily infested plants show stunting and have chlorotic leaves with marginal necrosis. Roots and underground rhizomes exhibit galling and rotting. Infested rhizomes have brown, water-soaked areas in the outer tissues. Management practices include application of decomposed cattle manure or compost, neem cake and mulching with green leaves at planting and again during the growth period. Application of phorate at @ 3 kg a.i./ha increase the yield of ginger in *M. incognita* infested fields. Introduction of *Pasteuria penetrans* and *Paecilomyces lilacinus* into planting beds is suggested.

Burrowing Nematode, *R. similis* : *R. similis* infection in ginger cause stunting, loss of vigour and poor tillering. The topmost leaves become chlorotic with scorched tips. Infected rhizomes show small, shallow, sunken and water soaked lesions (Sundararaju *et al.*, 1979b). The control measures are same as that suggested for *M. incognita.*

Nematodes on turmeric

Root-knot Nematode, *M. incognita* : Affected plants show stunted growth, yellowing marginal and tip drying of leaves, reduced tillering, galling and rotting on roots. Severe infestation induces yellowing, stunting and withering in large patches. Plants die prematurely leaving a poor crop stand at harvest (Mani *et al.*, 1987). Control measures include use of resistant varieties and application of phorate and carbofuran at 1 kg ai/ha.

Burrowing Nematode, *R. similis* : The infested plants show a tendency to age and dry faster than healthy plants. Infested rhizomes are of yolky yellow colour compared with the golden yellow colour of healthy rhizomes. Roots show rotting. The rhizomes have shallow water soaked brownish areas on the surface (Sosamma *et al.*, 1979).

Root-lesion Nematode, *Pratylenchus coffeae* : *P. coffeae* causes discolouration and rotting of rhizomes. The fingers are more severely affected than mother rhizomes. Internally, affected rhizomes show dark brown necrotic lesions (Sarma *et al.*, 1974). Application of phorate @ 1kg ai/ha is suggested.

Future Thrust

India earns considerable amount of foreign exchange from the export of products of plantation crops. U.S.A and European countries are very conscious of chemical residues in these products. Plantation crops being perennial in nature, application of chemicals in smaller quantities is likely to have accumulated effects in the long run. Hence, use of chemicals that have long residual action and those that are deleterious to the beneficial insects is to be avoided. Reduced use of chemical pesticides in the long run will be beneficial in limiting environmental pollution also. Therefore, more emphasis need to be given to other methods like cultural, sanitational and biological including use of resistant varieties.

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Experimental Designs for Perennial Crops

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oduction

The need for an experimental design arises when the erimenter wishes to compare his objects of comparison ed *treatments* with reasonable degree of confidence. The ple method of comparing different treatments in nearby ts if it is a field trial, is not adequate as better performance a treatment may be due to the better fertility status enjoyed it or due to some other chance factors. Ideally, the research rker would like to test the treatments under identical ditions. But inherent variation due to soil as well as erimental material itself comes in the way and in most of cases it is substantial to mask the real worth of a treatment. is it becomes necessary to evolve methods to layout periments in such a way so that the experimenter feels nfident about the inference drawn from the outcome of the periment.

Though statistical techniques used in experiments with perennial crops are same as those with annual crops, perennial crop experimentation pose innumerable problems. The main difficulties are the long duration of the experiments because of perennial nature of crops, large size of plots, variability within experimental units, differences in pre-bearing age, time lag between application of treatment and the resulting response etc. All these factors have to be taken into consideration while planning the experiments with perennial crops as once the experiment is laid out in the field, it is going to be there for many years. In this paper an attempt has been made to discuss the field experimentation techniques and Designs used for plantation crops.

Field experimentation techniques for perennial crops has been discussed by many workers (Pearce, 1976; Choudhary *et al.*, 1979, Anon, 1986a, Daniel, 1984a,b, Daniel and Bonnat, 1985 and Mathew, 1991).

Size and shape of plots and blocks

A commonly followed practice to find out optimum size and shape of plots is to conduct a field trial without any treatment, called uniformity trial. However, in the case of perennial crops, conducting a field trial just for this purpose appears to be a luxury as the trial with uniform treatments like any other experiment, has to be continued for many years and the results coming out from these experiments, strictly speaking apply to only the plots in which these trials are carried out. Notwithstanding, the indications given in these trials are good enough to give a 'benchmark' for plot size to be used for future experiments.

Uniformity trial

Uniformity trials give an idea of the fertility gradient in the field and help us to determine the optimum size and shape of plots for the experiments. Smith (1938) gave an empirical relationship between variance and size of the plot as $Y = ax^{-b}$, where Y is the variance of the yield per unit area, based on plots of 'x' units, 'a' is the variance per plot of unit area and 'b' is the heterogeneity characteristic of the soil and measure of correlation among contiguous units. In the case of fruit trees, Pearce(1955) modified this relationship as

$Y = V_1X^{-1} + V_2X^{-b}$

where V_1 (variance between individual trees) and V_2 (variance between single trees due to position) correspond to the genetic and environmental components of total variation. Generalization of this taking into consideration the row wise and column wise heterogeneity is $Y = ar^{-g1} c^{-g2}$, where g1 and g2 are row wise and column wise heterogeneity coefficients respectively.

Formation of plots and blocks

Several points have to be considered while deciding the plot size for perennial crops. First and foremost is ofcourse the trend in the observed variance while increasing the plot size. Beyond a certain plot size the decrease in the variance may not be substantial. Considerations are also to be given for genetical component of variation (Shrikhande, 1958), biennial tendency (Abeywardena, 1964), area available for experimentation, possibility of losing some of the plots due to mishaps and the efficiency required for estimates.

The approach to form the plots and blocks are similar to that followed in annual crops. In a replication, within plot variation is to be maximized and between plot variation is to be minimized. So, when there is no idea of fertility gradient, long and narrow plots, which account for more variation within plots (because of higher average distance between any two points when compared to square plots). Blocks are formed in such a way that they are as dissimilar as possible so that maximum variation between blocks are obtained. When genetical component is expected to play more important role than environmental component of variation, the plots and

blocks can be formed based on the past yield records as per Shrikhande (1958) with or without considering geographical contiguity. Saraswathi (1986) suggested that achieving greater homogeneity between plots within a block by creating greater heterogeneity within plots is found to be the best design approach.

Guard rows

Non experimental guard rows are generally suggested in irrigation and manurial experiments where there is a possibility of seepage into the nearby plots. Since nowadays the land for experimentation is a serious constraint, atleast for manurial experiments with perennial crops, we can think of having plots without guard rows in the light of results obtained by Kushwah *et al.* (1973) from root studies on coconut where it was noticed that 75% of the roots are confined to an area of 2m radius around the bole of the palm and also that the surface roots at a few feet around the bole of the palm are only concerned with the absorption of mineral nutrients (Patel 1938). Digging of deep trenches between plots or isolating plots by burying a film of thick polythene between the plots have also been suggested instead of guard rows.

Application

Studies on the size and shape of plots for experiments with perennial crops are limited. Though the ideal situation is to generate data from a laid out uniformity trial, experimental data after eliminating the treatment effects from individual trees may also be made use of for this purpose. The optimum plot size and shape for some of the important plantation crops are given in Table 1.

Descrete Comparison of Treatments

The common designs like completely randomized block design, randomized block design, Latin Square design etc. are extensively used for discrete comparison among treatments. Much advancement in the field of block design have yet to be tried for lack of information or technical support. These variance balanced (fully or partially) include incomplete block design and block designs with nested factors.

Incomplete Block Designs: When there are 10 - 15 treatments for comparison, the experiment can be laid in a simple RBD. But when there are a large number of treatments especially in Plant Breeding where number of varieties or strains to be compared, it will not be possible to accommodate all of them in a block because of soil heterogeneity. In other words, a part of the treatments be able to accommodate in a block. Such designs are called Incomplete Block designs. Though some information is lost by this type of arrangement, because of smaller size of the blocks, experimental error will be reduced resulting more precise treatment comparison than that by adopting a simple RBD. When all the pair wise comparison of treatments are to be made with equal precision, balanced incomplete block designs are used. The drawback of these designs is the requirement of a large number of replications. And also designs are not available for all combination of treatments and block sizes. To overcome these difficulties, the partially balanced incomplete block

Table 1. Optimum size and shape of plots for experiments with plantation crops

	Crop	Optimum size and Shape	Reference
1.	Arecanut	6 palms with single guard row	Agarwal *et al.*, 1968
2.	Coconut WCT COD X WCT WCT X COD	 8 palms 8 palms 6 palms	Anon, 1988 Anon, 1988 Anon, 1988
3.	Cardamom	12 plants (4x3 for small blocks) 18 plants (6x3 for large blocks)	George *et al.*, 1983
4.	Ginger	4 beds of size 1mx1m arranged columnwise	George *et al.*, 1982
5.	Turmeric	3 beds of size 1mx1m	George *et al.*, 1984
6.	Cashew	6 trees across fertility gradient	Anon, 1988
7.	Oil palm	8 palms	Nambiar *et al.*, 1992
8.	Coffee	8 plants across the fertility gradient	Srinivasn *et al.*, 1995

designs (PBIBD) are introduced. This is ideal when one can *a priori* group the treatments in order of precision desired.

Lattice designs: Lattice designs can be viewed as special cases of PBIBD. In this case, the number of varieties is 'V' where V is a perfect square(q^2). The designs are available for 16, 25, 36, 49 etc. This layout requires a minimum of 2 replications in blocks of q plots each. So, if there are 36 varieties, first the varieties/treatments are numbered 1-36 serially and the numbers are arranged in a square array of 6X6. First replication which may be called the X group is formed by taking the row sections as blocks; so, 6 blocks are formed this way in a replication. Second replication called the Y group will have 6 more blocks consisting in each block the varieties/treatments occurring in the columns of the array. The two groups together constitute the simple or double lattice design.

The following 6x6 array shows the layout of a simple/ Double lattice design.

1		3	4	5	6
7	8	9	10	11	12
13	14	15	16	17	18
19	20	21	22	23	24
25	26	27	28	29	30
31	32	33	34	35	36

Here, the first replication (X group) consists of 6 blocks, each consisting of treatments mentioned in the 6 rows of the array. The second replication (Y group) consists of another set of 6 blocks consisting of treatments mentioned in the 6 columns. These two sets of blocks constitute the simple lattice design for 36 treatments.

As mentioned earlier, a number of block designs are now available to suit most of the experimental needs. One interesting field is the non-proper variance balanced design which do not insisting upon equal block size. Another area is where plots are nested within blocks. A complete coverage of different aspects of block designs are beyond the scope of this cahpter.

Treatments as Two or More Factors

Factorial experiments

Factorial experiments are conducted when the experimenter's interest is in finding out the desirable combination of different factors tried in the experiment. For example, one may be interested in finding out the optimum dose combination of irrigation and fertilizer for a crop. One way of doing is to experiment first with irrigation and arrive at an optimum dose and then conducting another experiment using the optimum dose of irrigation already found with different doses of fertilizer. But this method is not only time consuming but also erroneous; because if the two factors are interacting, the dose of irrigation which was found optimum earlier may not be really optimum at lower/higher doses of fertilizer. So, in such situations, only way is to take all possible combinations of the two or more factors in one and the same experiment and try to find the optimum combination. The factorial experiment can be laid out in a CRD or RBD depending on the experimental material and land.

Confounding: When there are more than two factors and more levels for each factor, there will be too many treatment combinations. In a field trial especially with perennial crops, it is difficult to get large uniform area to accommodate all these combinations. Since a smaller area is expected to be more homogeneous than a larger area, a portion of the treatment combinations can be tried in these homogeneous blocks; thus a replication wherein all the treatment combination appear once consists of more than one block. This procedure of dividing the replication into two or more homogeneous compact blocks is called as **confounding**. Such a subdivision of a replication disturbs the precision of treatment comparisons and some effects will be mixed up with block differences. However, with judicious allocation of treatment combinations in different blocks, it is possible to retain all the important comparisons intact.

The following example of a 2^4 experiment will illustrate method of confounding. In a 24 factorial experiment 4 factors (say a, b, c, d) each at two levels (say absence and presence) are tried so that there will be a total of 16 treatment combinations. These can be listed as (1), a, b, ab, c, ac, bc, abc, d, ad, bd, abd, cd, acd, bcd, abcd. Where, (1) represents the absence of all the factors and 'a' the presence of factor 'a' but absence of other factors and so on.

The following blocking system with treatment combinations in the respective blocks in one replication is an arrangement which confounds the highest order interaction **ABCD**. Here the effect **ABCD** is mixed up with block differences.

Block 1 a, b, c, d, abc, abd, acd, bcd

Block 2 (1), ab, ac, bc, ad, bd, cd, abcd

If there are 2 or more replications in the experiment and same treatment combinations as above are tried in the two blocks of the other replications also, then ABCD cannot be estimated at all and it is the case of **Complete confounding** the effect ABCD. **Partial confounding** is an arrangement so that the effect confounded in one replication can be estimated from other replication(s).

Fractional factorial designs

In a factorial experiment, if the factors are in large number a single replication itself will have unmanageable number of treatment combinations. For example, even in comparatively small experiment like 26 factorial experiment there will be 64 combinations. For estimation of main effects or two factor interactions even half this number of combinations will be enough without much loss of precision. So, it is a great saving if we can reduce the number of treatment combinations to a manageable level and still get all the main effects and important interactions. Such factorial experiments where only a fraction of the treatment combinations are tried in a replication is known as fractional factorial experiments. These types of experiments are very useful in industry, where sometimes the combinations are in thousands for a single replication and it will be physically impossible to carry out the complete trial. However, by using half or one fourth of a replication, we will be mixing up certain effects with some other effects called **'aliases'**. So, for example, while estimating the effect of say A, the alias of the component A (which is normally a higher order interaction) also is included in that. Mostly, these 'aliases' are so chosen in the layout such that effects of them can be neglected. This means that it is necessary that we know few basic things about the experimental material before laying out the experiment so that an effect, which is an alias of another effect, will not be simply ignored.

The following example illustrates laying out a 25 factorial experiment in fractional replication by using a *half replicate*. There are 32 treatment combinations. The highest interaction is **ABCDE**. So, the treatment combinations can be divided into two sets such that from one of these all the main effects and 2 factor interactions can be estimated. The 3 factor and 4 factor interactions which can be assumed as negligible go as 'aliases' of these 2 and 3 factor interactions. The 5 factor interaction **ABCDE** is taken as defining contrast which cannot be estimated. (see box below)

Response surface designs

Experiments of factorial structure may also be designed to determine the levels of factors that provide optimum response based on the dose-response relationship usually represented by a suitable degree of polynomial function. Function of this kind is called response surface and the designs that allow the estimation of its parameters (with certain desired features) called response surface designs. One criterion of estimation could be that the variance of the estimated response at any point is function of the distance of that point from the origin. Such designs are called as Second Order Rotatable Designs (SORD). The response function assumed here is quadratic. Response surface designs like any other designs optimize the resources as well. For example, with 4 factors, a SORD use only 25 points (units) to estimate the parameters. Also note that these design points are constructed to include 5 levels each for the 4 factors! In other words, if the objective is to know about the response surface, there is no need to conduct an experiment of magnitude 2^5. Another application of response surface designs is the estimation of rate of change of response (slope) at a point (levels of factors). Many results in this field are scattered in various research publications.

Experiments with mixtures

Another variant of factorial experiments is the one in which the treatments are either a combination of two or more factors whose total input quantity is fixed (i.e., their levels are not independent) or the total quantity of inputs applied at different stages of experiment (stage is a factor here))is fixed. In such situation the treatments may be referred to as mixtures. In experiments with mixtures the procedure of analysis is to formulate a suitable model for prediction of response and

The combinations that come uner the 2 sets with ABCDE as the defining contrast are:

1st set	a,b,c,d,e,abcde,abc,abd,abe, acd,ace,ade,bcd,bce,bde,cde	+ABCDE
2nd set	abcd,abce,abde,acde,bcde,ab, ac,ad,ae,bc,bd,be,cd,ce,de,(1)	-ABCDE

Taking the first set only in the experiment i.e half replication, we can estimate the following main effects and interactions (along with the respective aliases ofcourse).

Main effects	A	B	C	D	E					
Alias	BCDE	ACDE	ABDE	ABCE	ABCD					
Interaction	AB	AC	AD	AE	BC	BD	BE	CD	CE	DE
Alias	CDE	BDE	BCE	BCD	ADE	ACE	ACD	ABE	ABD	ABC

also to obtain a measure of influence of factors (singly and in combination) on the response (Khuri and Cornell, 1987).

Split plot design

In factorial experiments, when we consider two dissimilar factors (ex: irrigation and spacing) first factor (irrigation) usually shows larger differences than the second (spacing). With a factorial layout, both the above factors will be tested with equal precision. So it is possible that the differences between spacing may go unnoticed as the other factor produces larger differences and both are tested with the same error which will generally be large because of the first factor. One way of reducing the error is to restrict the randomization of the factors producing smaller differences within compact blocks instead of scattering them throughout the replication. So, a replication is divided into as many blocks as the levels of first factor and the levels of first factor are allotted randomly to these blocks (main Plots). Within each of these main Plots, the levels of the 2nd factor are allotted at random. Similar procedure is followed in other replications also. The resulting layout is called **Split Plot Design**. Since two types of plots are involved, larger plots for the main plot treatments and the smaller plots for sub plot treatments, two errors variations are involved one for the main plots and the other for sub plots and the interaction. The comparison of subplots thus becomes more precise as the main plot comparisons are done with the separate error. Split plot design has several practical advantages and is found to be very useful in field experiments. In this design greater precision is obtained for the sub plot treatments and interaction - of course at the cost of main plot treatments. Therefore we have to be careful in choosing the factors for the Main plot treatment.

Strip plot design

This is analogous to split plot design. When two factors can be tried on larger plots, one set of factors is superimposed over the other at right angles. So, a replication is first divided into as many strips as there are levels of first factor horizontally and then into as many strips as there are levels of second factor vertically. Both the sets of treatments are allotted at random within a replication. Such an arrangement is called **Strip** plot design. Since there will be three types of plots in this layout, three different error mean squares are involved. The test of significance for interaction is more sensitive by virtue of large number of error degrees of freedom available for the corresponding error.

Designs For Plant Breeding Trials

Progeny Row trial

The objective of progeny trial is to select superior genotypes. Mass selection consists of selection of a number of plants that appear to have superior value in respect of the character(s) under selection, and continuing the similar process in next generations. This method is inadequate since in each generation the selection is subject to large amount of environmental or nongenetic variability. It was felt that if instead of bulking the seeds obtained from different selected plants if was sown in separate progeny rows and selections made on the means, the selections would be more reliable as representing superior genotypes. This could be achieved by carrying out the trial using a simple Randomized Block Design. The plot size in these trials is kept as small as possible and the number of replications as high as possible. The analysis is carried out as in the case of RBD. Since characters like yield for small plot sizes are very sensitive to changes in number of plants, it is advisable to adjust it for variation in population in the plots by using the technique of covariance.

Compact Family Block Designs

This is analogous to split plot design. Here the principal of local control is used in a better way as progenies are randomized within the family plot and not over the entire block. Hence, first Families are randomized within a block and then progenies belonging to a particular family are randomized within the family plot. Therefore, the progenies belonging to the same family are sown side by side within the family main plot. The analysis of the data is done in two stages. In the first stage, the simple RBD analysis is done for families. Later within each family, progeny differences are tested again by RBD analysis. The significant heterogeneity of error variances within progenies of each family gives an idea of the magnitude of genetic variability in the different families. If the results of the main plot (Family) analysis shows that some of the important characters for a family/families are inferior, the analysis of progeny plots in such families need not be undertaken. This will help to reduce the work load especially when a large number of families are tried.

Augmented design

In investigations with screening of new varieties/ treatments, there may be shortage of material for enough number of replications. In augmented designs we use single replication for the new variety/treatment but along with that use enough number of replications for already tested old treatments. So, if there are 'v' old treatments with 'r' replications then the experiment is laid out in complete or incomplete blocks depending on the size of 'v', and to these blocks the new treatments are augmented to accommodate all the new 'k' treatments. Thus if c1, c2, c3, c4 are the old treatments and t1, t2, t3, t4, t5, t6, t7 are the new treatments and if there are 3 replications for the old treatments, then the layout of the experiment before randomization may look as follows:

Rep1. c1, c2, c3, c4, t1, t2, t3
Rep2. c1, c2, c3, c4, t4, t5
Rep3. c1, c2, c3, c4, t6, t7

New treatments should be augmented to the blocks in such a way that all the blocks remain nearly equal. The ANOVA is carried out for the old treatments only. So, if EMS is the error meansquare, then,

SE(for the difference of two new treatments occurring in the same block) $= \sqrt{(2EMS)}$

SE(for the difference of two new treatments occurring in different blocks) $= \sqrt{((2(v+1)EMS)/v)}$

The treatment effect for m^{th} new treatment in the i^{th} block $= t_m - b_i$. where t_m is the response for the m^{th} new treatment and b_i is the mean for i^{th} block. Therefore, to test the significance of the treatments say t_2 and t_4 we calculate

$|t_2 - t_4| / SE(t_2 - t_4)$

and compare this value with $t_{0.025}$ (at error df) and if calculated value is greater than the table value, then the null hypothesis of equality is rejected.

Calibration and Use of Covariance Analysis

Pearce and Taylor (1950) defined calibration as a method of taking measurement at an early stage in the development of the plots and forecasting it's future performance. The idea is very old (Chandler, 1921; Vaidyanathan, 1934) and it had widespread application. As genetic variation is generally higher in tree crops, reduction in experimental error could be achieved through calibration and by using this variate as an auxiliary variable to adjust the analysis by covariance technique. Abraham and Kulkarni (1963) found out that for coconut about two years data immediately prior to the experimental period were sufficient for covariance analysis. Agarwal *et al.,* (1968) while working out optimum plot size for arecanut experiments got highest correlation between two year pre experimental yield with total yield in the post experimental period which suggests that two year yield prior to the experiment can be a calibrating variable to be used in analysis of covariance. Abeywardena (1970) has observed that about 30-50% reduction in experimental error by using two years pre-experimental yield as calibrating variate. This has been later confirmed by Mathew and Vijaya Kumar (1984). Anon. (1986) have given in detail about the recommended auxiliary variables for fruit and tree crops.

Analysis and Interpretation of Data

Experiments with perennial crops are of long term in nature. In fertilizer experiments it takes generally a minimum of three years for the effects to show up in yield. In coconut it has been reported by Muliar and Nelliat (1971) that the effect of phosphorous treatment was not seen for the first nine years. Same is the case with Varietal trials as they may have to be continued for several years after they reach a stabilized yield stage to study their true potential.

Method of compilation of yield data is again important in the light of studies made by Mathew *et al.* (1986) in coconut wherein they have shown that conclusions drawn can be different if calendar year yield data is used instead of Agricultural year and suggested to use two year averages for analysis to overcome this problem. In another study Mathew and Vijaya Kumar (1984) found out that pooling of the data for consecutive years reduces the experimental error by over 60% and suggested to use progressive average yields for analysis instead of analyzing the annual yield data every year.

For application of tests of significance in the in the analysis of variance, normality of data is a prerequisite. Mathew and Kumar (loc.cit) have shown that annual yield data for coconut does not follow the normal distribution and have suggested the transformation $\sqrt{(x+10)}$ for analysis. This is essential even when data for consecutive years were pooled or when palms were considered in groups. Similar studies carried out in arecanut by Bhagavan (1985) showed that for both number of nuts and wet weight of nuts a transformation of the type $\sqrt{(x+3/8)}$ is required for normalizing the yield data

Pooled Analysis of Data in Perennial Crops

In annual crops it is a usual practice to repeat the experiment in different seasons/years and then carry out the pooled analysis to study treatment X season (year) interaction. But in perennial crops such a procedure is impossible because of obvious reasons. Usually, data are analyzed separately for each year and in the case of yield, cumulative yield up to each year can be done. Since the yields in the same plot in successive years are correlated, the experimental errors in different years are not independent and this brings in the difficulty to combine the data over different years. Patterson(1939) has given a method to overcome this and has suggested to do a 'Split plot' type of analysis in which treatment totals over the years are tested in the main plot analysis and a subplot analysis is done for finding out treatment X years by taking years as 'subplots' over each treatment. Applications of these procedures in coconut experiments can be seen in Govinda Iyer (1958) and Muralidharan et al. (1998).

Duration of Experimentation in Perennial Crops

Duration of experiment in perennial crops generally depends upon the objective of the study. Since they continue

to yield for a long time there should be an objective way of deciding when to stop the experiment. General consensus is ofcourse to continue the experiment till the yield is stabilized. It would be however better to continue the experiment till that age when yield at that age is correlated with all future yields as per Ramachander *et al.* (1979) based on his studies on oranges.

Use of Non Parametric Methods in Experiments with Perennial Crops

Most widely used tests of significance like 't' and 'F' tests are based on the assumption that the populations from which the samples are drawn are distributed normally. While moderate deviation from normality will not distort the conclusions drawn from the tests, a departure more than moderate from the normality is bound to affect the conclusions. In coconut it had been already proved that the distribution of yield data is far from normal for individual trees, an average of group of trees or even when data for trees are pooled over years (Mathew and Vijaya Kumar, 1982). Their suggestion is to transform the data to $\sqrt{(x+10)}$ where X is the yield. But when the departure from normality is severe this also does not help. Nonparametric or distribution free methods in such cases are useful as these do not make any assumptions about the parent population. Besides, they have also the added advantage that it is enough to have ordinal measurements like ranks rather than the exact value of the observation-a property which will be extremely useful when experiments are laid out in cultivator's fields where it is difficult to get the exact data. Studies conducted at the Central Plantation Crops Research Institute (Anon, 1994, 1995, 1996, 1997, 1998) showed that **Kruskal wallis** and **Mann-Whitney** tests may be preferred to CRD analysis and t-tests respectively when exact data are not forthcoming. **Friedman's test, Van der Waerden's Normal score test or Quade test** are suggested for the data of experiments conducted in RBD and if data do not satisfy the requirements of ANOVA.

Conclusion

While deciding upon a statistical design it should be kept in mind that though statistical requirements are very important they are not the only things to be considered. Whichever design used should be practicable and easy for the experimenter to conduct it for a long time especially in the case of perennial crops. Pearce (1955.loc. cit) who is an authority in the field of experimentation in perennial crops says "a design must be satisfactory in several respects. before any trial is proceeded with it must be possible to answer 'yes' to three questions: Is it practicable? Is it statistically sound? Are the treatments really what they purport to be? A failure in any of these respects can be disastrous"

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Sampling Techniques and Yield Estimation

M V George, K Muralidharan and C H Amarnath

Introduction

Sampling and yield prediction techniques receive prime consideration in the field of agricultural statistics. Sampling techniques are used in plantation sector to estimate area under crops, yield, disease incidence, pests infestation and crop loss assessment and also to evaluate the socio-economic aspects.. In field experiments, sampling a fraction of the whole plot is sometime advocated.. Following a resume on sampling theory and methods, a compilation of sample surveys carried out in the plantation sector is provided in the next section.. The section that followed is devoted for short term prediction of yields.. As in other crops, the weather parameters and biometrical characters are used for yield forecasting of plantation crops.

Sampling Techniques

The term 'sampling' is used to refer the process of selection of units from a finite population.. We are more interested in 'random sampling' as it provides valid estimates of error and based on probability theory objective conclusions be drawn .. The commonly used sample designs are simple random sampling, stratified sampling, cluster sampling, systematic sampling and multi stage sampling.

Principal steps

Defining the sampling units and population is fundamental to any sample survey.. The list of sampling units that divide the population into non-overlapping parts is called the sampling frame.. Other considerations include clarifying the objectives, degree of precision desired, availability of resources, selection of the sample and organization of the field work. The sample size for specified precision is also need special mentioning. The sample size should not be either too large, or too small. The sample size required for estimating the population parameters with a specified precision at a given cost can be worked out by using suitable formulae (see Chapter 4 in Cochran, 1984)

Sampling designs

Simple random sampling: Simple random sampling is a method of selection of units out of N population unit, such that every one of the ${}_{N}C_{n}$ samples has an equal chance of being selected. In practice, a table of random numbers is used and sampling is without replacement. The population mean is estimated as the average value of units in the sample. But its standard error involves a factor f = (N-n)/N, the finite population correction. Denoting the 'sample variance' as S^2, (obtained by dividing the sum of squares by n-1), the estimate of standard error is S*sqrt(f/n).

Stratified sampling: It is obvious that a reduction in 'sample variance' will lead to estimates with less standard error. The stratified sampling is devised for this purpose. In stratified sampling the population of N units is first divided in to sub populations of $N_1, N_2, N_3, \ldots N_L$ units respectively such that $N_1 + N_2 + N_3 + \ldots\ldots N_L = N$. These sub populations are called strata. If a simple random sample is taken, independently, in each stratum, the whole procedure is described as stratified random sampling. By stratification we can get any desired degree of representation of the different parts of the population by taking them as strata (e.g. irrigated and unirrigated etc.). The topics under stratified sampling are too many and is beyond the scope of this chapter.

Cluster sampling: In some situation, the units exist in naturally formed groups (clusters). It will then be convenient and cost effective to sample the clusters. All the units in the selected cluster will be included in the sample.

Systematic sampling: The sample in this method is constituted by units at fixed interval in the population. Estimation of error and possible bias arising from unrecognized trends or cycles in the population are the drawbacks of this method.

Multistage sampling: If each unit in a sample can be sub-divided into a number of smaller units or elements, further sampling can be done from each of the selected first stage units. The sampling design is then termed two-stage sampling. The subdivisions of the fist stage units may sometimes further be divided and sampled as third stage units and so on.

In plantation crops mostly a combination of the aforesaid sampling designs are used with suitable modifications to suit to the particular situations (Sadasivan and George, 1974).

Estimators

The estimators of population mean, proportion or total are to be selected with care. If auxiliary information is available, ratio estimator may be considered to achieve more precision. Another class of estimators are the regression

estimators. It is sometimes relatively cheap to take a large preliminary (first) sample to measure the auxiliary variable and then a sub-sample of smaller size for measuring the variable of interest. This technique is known as double sampling.

Sample Surveys in Plantation Sector

Sample survey techniques are successfully used in plantation sector for the estimation of area under and production of crops, incidence and severity of disease, pest population, crop loss due to pests and disease, to study the socio-economic aspects, collection of germplasm etc.. Some of the surveys were very classical and large in terms of area covered and agencies involved. Though a design of a particular survey is not advised to be adopted without any change for another (even at a different occasion), a description of few will be of useful for planning future surveys. Besides, it will give fairly a practical information on application of sample surveys in different fields.

Distinct features of plantation sector to be considered

The perennial nature of plantation crops, complexity of disease symptoms and multiplicity of pest infestation are some of the several constraints in carrying out sample surveys in the plantation sector (George, 1987). Generally plantation crops are grown in mixed cropping with plot to plot variation for plant species grown and for plant density. The age of various crop with in a garden itself will be different. The heterogeneity of age group, species and crop density will affect the yield and also pest/disease incidence, perhaps rubber, tea and partially coffee are the exceptions. Since the crop last for several years, a single crop itself could be attacked by a number of pests/pathogens. In certain situation disease pests interaction may also occur. For example George *et al.* (1979) observed a large number of palms affected by root(wilt) disease were also infested by *Oryctes*. Another major constraint is the non-availability of the list of population. Some of the crops like cardamom, pepper etc. are cultivated in large areas in the high ranges and forest region that might have not included under cropped area. Therefore estimated production of such crops are generally unrealistic. The trade estimates of pepper production for example are reported to have 25 - 30% more than the official estimate. The crop statistics may also be affected due to the shifting/rotation of crop. In Kerala ginger and turmeric are seldom cultivated in the same place in successive years. In crop loss surveys the measurement/quantification of disease severity is an important component. Most of the plantation crops are of multiple harvesting in nature (e.g., 6 to 8 harvest in case of coconut, for arecanut and cashew the harvesting season last about three to four months and for cardamom it is about 6 to 7 months). Hence recording of annual yield is not straight forward in these crops. Also the crop cutting experiments in plantation crops are highly combursum and time cons Involvement of a large number of technical perso various discipline and co-ordination among various a are essential for carrying out large scale surveys in pla crops. Adequate training is to be imparted to the investigators.

Estimation of disease incidence and crop loss

The Central Plantation Crops Research Institu carried out a number of studies on assessment of sever major diseases of coconut, arecanut, pepper and gin different parts of the country. The disease severity is us measured by using an index developed on the princip regression analysis. Such disease indices are also used in experiments for the comparison of alternative co measures and field tolerance of competing varie accessions. A resume of these studies are given in following.

Root (wilt) disease of coconut: The severity of root (w disease is measured by using an index based on the th major visual symptoms viz., flaccidity, yellowing and necro on all the leaves on the crown as proposed by George a Radha (1971, 1973). Nambiar and Pillai (1985) proposed simplified index by taking into account only the leaves prese in the third spiral. In a recent attempt at CPCRI, Jacc Mathew (not published) included a score for leaf rot disease.

A survey on incidence of root(wilt) and leaf ro disease and *Oryctus* infestation in Kerala was attempte during 1971-76 by CPCRI (George, *et al.*, 1976, 1979, 1980, 1985). A three stage sampling procedure was followed. About 20% of the revenue villages from a district were selected at random as the first stage units. From each of the selected villages four clusters of 5 consecutive survey sub divisions were selected at random as the second stage units. Total area, and number of palms in these clusters were recorded. The palms were grouped as healthy(H), *Oryctes* infested(O), diseased early(DE), diseased moderate(DM), diseased advanced(DA) and their combinations DE+O, DM+O and DA+O. Three palm each from the first two groups and two palms each from the remaining groups were selected at random as the third stage units and the average yield per palm were estimated. The overall loss in yield due to *Oryctes* infestation, root(wilt) and leaf rot diseases was estimated as 419 million nuts annually.

Again, during 1984-85, CPCRI in collaboration with 7 other agencies carried out a survey to assess the intensity of production loss due to root (wilt) disease (CPCRI, 1985). A three-stage cluster sampling design with taluk as the stratum was adopted for enumerating the coconut palms. Fifty per c of the revenue villages in each of the taluks were selec random in the first stage. From each of these villag

clusters of 5 survey sub divisions were selected at random as the second stage units. All the palms in these survey sub divisions were counted and categorized according to disease severity, age, bearing and non-bearing stages. In each cluster, a key plot (i.e., a survey sub division with at least 6 bearing palms), was identified for enumeration of yield. Two palms each from three groups viz., root (wilt) free, disease early, disease advanced were selected at random starting from the key plot as the third stage unit. The palms selected for yield observation were given bands with paint for future identification. Number of nuts in bunches, which are five months and above in maturity, was counted and recorded by climbing on to the crown. The youngest bunch so counted was also tagged. The observations were recorded in two rounds with a gap of 180 days. The total number of nuts which are five months and above in maturity in two rounds is taken as the annual yield of nuts from the palms for that year.

The production loss consequent on the development of root(wilt) disease is estimated as the difference between mean yield of disease affected palms over those palms which are not affected. The average loss in yield per palm for the diseased early and diseased advanced groups in each taluk has been obtained by deriving the difference in the mean yield of palms in each of these categories with that of disease free palms. The average loss so derived is multiplied by the estimated population of bearing palms in the respective categories in different taluks. These figures have been added up to arrive at the production loss in each district and the overall loss due to the disease. It was estimated that the total loss due to root(wilt) disease during 1984-85 was 968 million nuts.

Other diseases of coconut: An index for measuring severity of stem bleeding disease was developed by Mathew *et al.* (1989) as 1.8*l + 4.3*t, where l is the lesion size expressed in 1000 square cm and t is the score for tapering. Tapering of the stem generally appear when the palms are in the middle stage of the disease. Maximum visual score of 4 was given to those plants where the girth of the trunk apex at breast height was almost half that of the base portion; proportionate scores between 3 to 1 other wise.

Crown choke disease of coconut in Assam: A three stage systematic cluster sampling design was used with subdivisions as stratum (George *et al,* 1990). Twenty five percent of the VLEW ELKAS were selected as primary sampling units. From each of the selected ELKAS the list of homesteads was prepared and serially numbered. Twenty percent of the homesteads were selected at the second stage by following systematic cluster sampling. (e.g., if homesteads of serial numbers 21 to 25 selected as first cluster, then leaving a fixed number, say 20 the second cluster will be 46 to 50 and so on until the list is over). All the palms in the selected cluster were examined for the disease and classified. Two disease affected and two healthy palms were selected at random for each selected cluster as the third stage units and the required observations were recorded including yield. The total loss in production due to crown choke disease of coconut in Assam is estimated at 6.38 million nuts.

Diseases of arecanut

A sampling procedure to assess the yield loss due to 'Koleroga' of arecanut was given by Anandaraj *et al.* (1987). Since the fruit rot of arecanut occurs only during south-west monsoon, the double sampling procedure was adopted to estimate the yield loss. A larger sample of n" groups (each group consisting of 6 randomly selected palms) could be selected for recording the fruit fall from the third fortnight and consequent sub-sample of n' groups could be selected from the larger group to record the fruit fall for the whole season. Using the regression of total fruit fall on the third and fourth fortnights, an estimate of the mean loss in yield per sampling unit was obtained as $m_t' + b*[m_3'' - m_4']$ in which m_t' is the mean of total fruits fallen per sampling unit based on n' units for the whole season; b is the estimated regression coefficient; m_3'' and m_4' are the mean fruit fall per sampling unit for the third and fourth fortnight based on n" and n' units respectively.

A technique for quantifying the severity of yellow leaf disease of arecanut was proposed by George *et al.* (1980) based on three easily recognizable foliar symptoms viz., yellowing, necrosis and reduction in crown size. Due weights were assigned to the symptoms based on the frequency of occurrence of these symptoms in the natural population of arecanut palms growing under various ecological conditions in Kerala and Karnataka. The disease index for a palms is worked out as ((Y + N)/L + R)*10 where Y, N and R are scores for yellowing (0-7), necrosis (0-2) and reduction in crown size (0-1) and L is half the number of leaves in the crown.

Yellow Leaf Disease of arecanut in Kerala and Karnataka:::A Stratified multistage random survey was conducted during 1976-77 to estimate the intensity and extent of YLD incidence in Kerala and Karnataka.(George *et al* 1985). The survey was conducted in all the districts of Kerala except Palghat and Alleppey where arecanut is not grown to any significant level and in Karnataka only in Koppa and Sringeri taluks wherein some incidence of YLD was reported then. Taluk in each district was stratified as growing arecanut as a major crop and medium crop, omitting other taluks where arecanut is grown as minor crops. One fourth of the villages were selected at random as first stage unit. Four clusters of five survey subdivisions where selected at random and all the palms were examined for disease incidence. In Kerala about 84 million areca palms were found diseased out of 233 million palms. In Karnataka the incidence was found only in four villages.

Another comprehensive survey was conducted in the five arecanut growing districts of Karnataka viz., Dakshina Kannada, Kodagu, Chimagalur, Shimoga and Uttara Kannada during the year 1991-92 with the massive help from the Department of Agriculture, Horticulture and UAS, Bangalore. 25 % of the gardens were selected at random and all the palms were examined for disease incidence. From the selected gardens five palms each of healthy, diseased early, disease advanced were selected and yield, age etc., were recorded. Out of the 66 million palms surveyed 0.77 million palms were found diseased resulting an annual loss of 508 tonnes in terms of chali. (CPCRI, 1991, 1992).

Other crops

AASurvey was conducted for assessing the disease incidence in major ginger growing areas of Kerala during 1984 and 1988 by Duke *et al.* (1988). For the survey 8 routes were used. Three gardens from each village was selected. Each garden was divided into 4 parts and 4 beds from each part was selected at random and were inspected for rhizome rot and bacterial wilt infection.

Balakrishnan *et al.* (1986) attempted estimation of the extent of loss due to quick wilt disease of black pepper in Calicut. The design of the survey was stratified multistage with two strata of villages. The villages with large scale pepper cultivation were grouped into one stratum and moderate scale into another. Other villages were omitted from the purview of the survey. Four out of 18 and 3 out of 10 villages were selected at random from the first and second strata respectively. From each selected village, 5 survey subdivisions were selected at random. Four adjacent subdivisions were added to the originally selected survey subdivisions to form clusters of five survey sub divisions each. The selected survey subdivisions were visited for three consecutive years during 1982-1984 for complete enumeration of total number of healthy and disease affected vines per plant. Eventhough mean yield per standard per plant could not be estimated by crop cutting methods, an indirect estimation procedure was followed. In each garden, a random sample of vines per standard were selected and the number of spikes (NS) in one metre portion of the vines at breast height was recorded. In addition, each metre of the vines was categorized into poor, medium or high yielding based on visual judgment of spike density and was given a numerical score of 1, 2 or 4 accordingly (YS). The yield is estimated as exp(3.73+0.78*ln(YS)+0.58*ln(NS)/3). Prabhakaran (1998) applied regression analysis of principal components to assess the yield losses due to pests, diseases and draught in black pepper.

Pests

A technique to estimate the field population of coconut leaf eating caterpillar was reported by George *et al.* (1984). Leaflet size and leaf wise counts of th recorded from 50 young palms for 36 months. leaves and leaflets were found to lodge more caterpillars than the other parts of the palm. Linea equations were fitted for estimating the total pest p a palm by counting the pests in the middle 41-60% of the first 20% of leaves from the bottom. G (1980) conducted a survey to assess the *Oryctes* Kerala following a multistage sampling procedure.

AA sampling technique to estimate population in coconut garden was proposed by Mohan *et al.* (1997). The total number of whitegr in the root zone of a palm can be estimated as 3.78 + 1.7938 * (number of insect stages found up of 40 cm at a distance of 50-100 from the trunk of the palm).

Mathen *et al* (1972) worked out a tec estimate the field population of lace-bug *stephanit* Distant from a sample consisting of the number present on 20% length at the middle region of 20 The innermost leaves were taken in each palm. Th population multiplied by the constant 3.78 gave the population within 5% error on groups of 10 or more p

Yield and its Attributes

One of the most popular application of statis forecasting. The simplest and most commonly used p to fit a known function to the data (e.g. the growth The concept of 'compound growth rate' is often util comparison of two series over a common period of more detailed analysis of time series data involve::i) c for trends, seasonality and cyclic variation; ii) mak series as a stationary by removing these compone differencing); iii) selection and fitting of an appr ARIMA model. For diagnosis we use the concepts correlations and spectrum analysis. More valid forecast made when functional relationship crop productio weather variables is established. For short term predicti relationship of biometrical characters with yield is us linear relationships in particular. Weather parameters ma be included in the equation. The causal relationsh biometrical characters and weather parameters on important plantation crops and applications in the fie discussed in this section.

Forecasting of crop yield: Estimates of crop productio customarily obtained by multiplying area under the respe crop and yield per hectare. Of these the crop area statistic collected mostly on complete enumeration basis and now become available before harvesting under the ti reporting scheme (TRS) for many crops. The estimatio yield rates on the other hand which are obtained thr

random sampling crop cutting experiments becomes available only after the harvest. Therefore, crop production estimates are available only after the harvesting. However reliable forecast for crop production are needed by the Government and other agencies much before the harvest.

Yield rates: The estimates of yield rates are obtained by two methods referred to as traditional and random sampling. In the traditional method the average yield estimated by multiplying the *normal (standard) yield* and the condition factor. Normal yield is defined as the average yield on average soil in a year of average character and is determined by revenue official based on crop cutting experiments. The condition factor depends on the condition in a village in comparison to the normal crop and is subjective and judged by the revenue officials. Hence the other method viz., the objective method of crop cutting surveys are being used quite extensively. The statistical design adopted for these survey is one of stratified multistage with district or taluks as needed cluster sampling or systematic sampling are also used at different stages of sampling as required by different situation.

Crop forecasting techniques: Basically there are two different methods of forecasting the crop as stated earlier. Of which the traditional method make use of the condition factor determined visually by the farmers or officials of revenue and agricultural Departments is highly subjective. In the other method multiple regressing models are used for yield prediction. One approach is to use the biometrical characters as explanatory variables in the forecasting model. Another approach is to use the environment factors like weather parameters as explanatory variables. In the case of model using biometrical characters the integrated affect of weather at least up to the stage of recording the observations will be also be accounted indirectly. However one can intuitively feel that a model based on a combination of both these approaches may be superior to either, but much models for plantation crops not yet been tested.

Forecasting based on biometrical characters: A careful consideration on the forecasting model, choice of explanatory variables and the appropriate sampling design are the prerequisites. The application of such techniques in plantation crops is summarized in the following.

For predicting the yield of cashew based on biometrical characters, studies were conducted during period 1976-'82 (George and Vijaya Kumar, 1979; George *et al.* 1984). The analysis of weekly data on seven characters revealed that yield can be forecast by a one time observation made during the peak flowering period (February-March) ($R^2 = 0.64$). The number of variables could be brought down to 3 viz., number of nuts on the tree, condition of flowering (0-5 scores) and canopy area, without substantially affecting the estimate ($R^2 = 0.61$).

For predicting the yield of cashew in a plantation George *et al.* (1989b) used a double sampling procedure. The ratio estimate was obtained by using a small sample (n) for detailed observation and a large sample (n') for recording an easily observable character. In gardens ranging between 100-300 cashew trees a maximum 200 trees for recording the character, condition of flowering graded 0 to 5 and a sub-sample of 20 trees for recording canopy area and estimated number of nuts at all stages of maturity are sufficient to give an yield estimate of the garden with 20% deviation at 5% level of significance. Double sampling was relatively 2 to 3 time efficient than simple random sampling. This methodology can be safely adopted to forecast the total yield from large plantations by subdividing the area into blocks of 150-300 trees considering the natural boundaries and selecting a small sample from such blocks, according to any suitable sampling design. Field evaluation of this procedure is explained by George *et al.* (1989a).

Estimation of coconut yield based on snap observation is described by Arulraj *et al.* (1979) and Mathew *et al.* (1986). Prabhakaran *et al.* (1991) observed that among the characters, number of leaves and rate of leaf production are the maximum contributing characters for explaining yield variability in young coconut palms. AApractical approach adopted for yield estimation in coconut in many surveys (George *et al.*, 1976, 1979, 1985) is the counting of nuts which are five months and above in maturity taken in two rounds in a interval of 6 months.

Satyanarayana *et al.* (1992) reported that dry weight of tea leaf have a direct and significant association with the actual leaf area, which in turn exhibits a positive relationship with the estimated leaf area. Sadananda and Srinivasan (1998) studied the relationship between morphological characters and yield in cauvery coffee genotypes.

For predicting the yield of pepper plants Balakrishnan *et al.* (1986) used visual score for yield as a predictor variable. This method was also field tested and found satisfactory.

Sankaran *et al.* (1996) undertaken a study to develop a model for forecasting the yield in cardamom plantations. Based on the observations at 6 locations covering various agro-ecological zones with 6 parameters viz., number of tillers, number of leaves per tiller, number of bearing tillers, number of panicles, panicle length and number of racemes per panicle, the yield can be estimated with around 70% accuracy during the first stage (May-June). With the additional data on number of capsules per panicle, during the second stage (Aug-Sept.), the yield can be estimated with around 77% accuracy.

Crop-weather relationship: The relationship of weather variables with coconut yield is reported in many studies (Mathew *et al.*, 1988, Vijayakumar *et al.*, 1989) and reviewed by Rao (1991). Relative humidity (FN), hours of sunshine and vapor pressure (FN) of 17-20 meteorological weeks of the previous year, minimum temperature of 21-24 weeks, humidity (FN) of 25-28 weeks two years previous and minimum temperature of 29-32 weeks three years previous were identified as important for production of coconut yield.

In a study on effect of weather parameters on arecanut yield in West Bengal, Reddy and Vijayakumar (1993) found that 97% of yield variation is explained by minimum temp. of April (two years earlier), and relative humidity of November and minimum temperatures of December of previous year. At Vittal, Karnataka, the arecanut yield was influenced by relative humidity, pan evaporation and rainfall while temperature influenced cocoa yields (Vijayakumar *et al.* (1991).

In perennial crop like cocoa, which gives yield throughout the year, the seasonal observations in yield cannot be considered as independent observations and hence the usual regression technique may not be suitable for the yield variability studies (Jose, 1996). The results indicated that in addition to the seasonal variation and trend, the random deviation in production for the previous two quarters also influence the cocoa yield of the present quarter. The moving average process of order 2 was found to be the best fit for quarterly yield data.

Biswas *et al.* (1996) found that temperature difference and mean vapor pressure of second and fifth week and rainfall of fourth week prior to plucking week contribute more to crop yield in tea (fairly irrespective of place and year). The yield of cardamom is influenced more by the distribution of monthly rain fall rather than the total rain fall and the number of rainy days (Subbarao and Korikanthmath, 1983).

Germplasm collection

The IPGRI manual on standardized research techniques in coconut breeding provide the following guide lines for collection of germplasm. The first step is the description of the populations *in situ* from where the collection is to be made. Two aspects bear in mind:: a) identification of populations in accordance with the IBPGR list of descriptors and b) characterization of certain number of plant and fruit components. These measurements should be taken from a random sample of a minimum of 30 normal palms in the chosen site. Depending on the field situation one may adopt random palm sampling (most ideal technique) or random heap sampling. In the first method the collector chooses at random 30 sample palms and obtains one representative nut per palm. The second method is adopted when nuts from the samples palms are already harvested and heaped or piled at the time of the visit.

Coarse-grid sampling method is recommended for the systematic coverage of coconut grown area. The basic requirements are a) knowledge of the extent of coconut-growing areas and distribution. b) knowledge of the degree of environmental diversity in the areas where the crop is grown. This method is followed by the Breeding and Genetics Division of the Philippine Coconut Authority. The steps are 1) Obtain a suitable sized map of the area and mark the grids (say 40 x 40 km size) following latitude and longitude divisions/ degrees 2) all grids which are coconut-growing areas may then be identified and according to relative size of hectarege, the number of sampling sites determined per grid. Each grid may be surveyed using 5 to 6 sampling sites with intervals between sites determined according to any noticeable changes in ecological conditions e.g., coastal to upland. If one encounters something new, outright collection may be made.

Future thrust

Method of estimation of yield is an important component of the surveys in plantation sector. Forecasting techniques were standardized and field tested only for coconut and cashew. Such attempts have to be perfected for other crops. Similarly measures of disease severity need to be standardized/refined wherever necessary. Complexity arising from superimposition of multiple pests at different time points on the same plant need special attention. Methodological investigations need to be carried out in this regard before attempting any surveys for estimation of intensity, extent of damages and yield loss due to pests. The problems related with estimation of area under and yield from multiple cropping system are not yet attempted.

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Multivariate Techniques and Database Management

K. Muralidharan

Introduction

Multivariate techniques deal with the simultaneous relationships among variables. The more commonly used procedures for the analysis of research data on plantation crops are described in detail. Various aspects of database management is discussed in the second part.

Multivariate techniques

The multivariate analysis is concerned with the relationships of sets of dependent variables. A series of univariate analysis carried out separately for each variables may lead to incorrect conclusions as the correlations or interdependence among the variables are ignored in that case. The multivariate techniques may be broadly grouped as dependence methods or interdependence methods according to the nature of association among sets of variables. If variables of one set are the realization of certain dependent or criterion measures, the appropriate techniques would be the dependence methods. On the other hand, if no such distinction is made among the variables, one uses interdependence methods. Procedures under dependence methods are multiple regression, multivariate analysis of variance (MANOVA), discriminant analysis, canonical correlation analysis and logit analysis. Principle components analysis, factor analysis, cluster analysis, metric or nonmetric multidimensional scaling and log linear models are interdependence methods (Dillon and Goldstein , 1984).

Multiple regression

Multiple regression is the study of the dependence of a variable on a set of predictor variables. This technique helps in estimating or predicting the mean value of the dependent variable on the basis of known values of the predictor variables. When the multiple regression is attempted after standardizing each variable to have variance equal to unity, it is called as path coefficient analysis. The least squares technique is used to fit a regression model. The non-stability of the model (i.e., different estimates with different subsets of data) is a major concern in regression analysis. In many a situation the errors need not be normal and/or variance homogeneous. The outliers (extremes) in the data will pull the estimated regression response towards them. Another problem is due to the multicollinearity (high correlation among the predictor variables). Regression diagnostics are therefore important. The examination of residuals (difference between observed value and value predicted by the model) is very helpful in checking for violations of the assumptions. For the detection of influential points, a number of statistics are proposed such as the leverage of every data point, change in regression coefficients/predicted value on removal of each data point from the analysis and the ratio of determinant of the covariance matrix so obtained with that of original one (covariance ratio). Multicollinearity may be detected by variance inflation factors and eigen values of the correlation matrix. For a thorough discussion on these topics the reader may consult by Draper and Smith (1981) and Sen and Srivasthava (1994).

MANOVA

The extension of univariate analysis of variance to the case of multiple dependent (critirion) variables is termed multivariate analysis of variance (MANOVA). It is used for the simultaneous test of equality of sets of means as against individual means specified in ANOVA. It is assumed that the data is drawn from a multivariate normal population with the same variance-covariance matrix in each group. The test involves first the extraction of eigen roots of the matrix product W-1D, where W and D are sum of product matrices due to 'residual' and 'deviation from hypothesis'. In a RBD set up, D=W+B, where B is the between sum of product matrix. The test statistics, Pillai's trace or Wilk's lambda can then be computed as sum or product of the inverse of eigen roots respectively. The former has more power and is also robust. MANOVA procedure is also used to

analyze treatment-by-time interaction. This procedure is suggested when the assumption of equal variances (at each time) and equal covariances (between pairs of time) is violated. Whenever this assumption holds good, the split block analysis may be attempted. Muralidharan *et al.* (1998) discussed the related issues in the context of analysis of coconut experiments.

Discriminant analysis

This analysis attempts to obtain a linear combination of measurements of a given object so as to enable one to accurately assign that object in to one of the two groups. If there are more than two groups, it is referred to be as the multiple discriminant analysis. In that case, discriminant analysis may be considered as a special case of canonical correlation analysis. In **canonical correlation analysis,** two linear combinations of variables (one for the predictor set and another for criterion set variables) are obtained such that their correlation is maximum.

Applications of multiple discriminant analysis are (i) to obtain uncorrelated linear combinations of the variables having the property that the ratio of between group variation to within group variation is as large as possible; (ii) to determine the dimensionality of the discriminant space; (iii) To successfully assign new observations of one of the several groups based on its scores on the linear composites; and (iv) to determine which of the variables contribute most to discriminating among the group. By denoting the between variance-covariance matrix as B and within variance-covariance matrix as W, the coefficients of the discriminant functions are determined as the eigen vectors of $W^{-1}B$. The characters contributing maximum towards divergence are decided according to the magnitude of these coefficients.

Principal components

The principal components analysis consists of finding an orthogonal transformation of the original variables to a new set of uncorrelated variables, called principal components, which are derived in such a way that the first component accounts maximum possible variance, the second accounts next to the first and so on. Hence principal component analysis is considered as a data reduction technique. In algebraic terms this is equivalent to the extraction of eigen roots and vectors of the covariance matrix. If the variables are in different scales of measurements the correlation matrix is appropriate. On multiplying the elements of the eigen vector by the corresponding eigen root, the principal component loadings are obtained which provide information regarding the importance of characters in that component. Characters with high principal component loadings corresponding to the eigen roots of value near to zero may be eliminated from further analysis.

Factor analysis

Factor analysis is a common term for a number of statistical techniques for the resolution of a set of observed variables in terms of underlying causative factors that will account for the inter-correlations of the observed variables, in the sense that when the factors are partialled out from the observed variables, there no longer remain any correlation between theses variables. The factor analysis is to reveal the underlying causative factors in multivariate data responsible for the inter-correlations and interdependence among the variables. Several solutions are proposed for factor resolutions that include the maximum likelihood method, canonical factor analysis, generalized least squares method, principal factor analysis, centroid method, miners solution of factor loadings, etc.. To facilitate easy interpretation, the factor loadings may be subjected for rotation (linear transformation).

Cluster analysis

Cluster analysis is to identify a smaller number of groups such that elements of a particular group are, in some sense, more similar to each other than to elements belonging to other groups. Classification of objects may be carried out by following four types of approaches; (i) partitioning (or non-hierarchical) methods, (ii) hierarchical methods, (iii) clumping methods and (iv) geometrical methods (Gordon, 1981). We restrict our discussion with the first two approaches. In the partitioning method, clusters are formed by trial and error so that the intra cluster distance is less than inter cluster distance. Among different methods of hierarchical clustering techniques, the average link method is simple. At each stage of this method, a pair of existing groups (a group may also be of single element) is amalgamated such that the amalgamation leads to the minimum increase to the average distance.

Database Management

The advancements in information technology can be optimally used for applications in research and development if only the relevant databases are created. The database at present referred to a computer based record keeping system, whose overall purpose is to record and maintain information. There are two types of databases - integrated and shared databases. By integrated database we mean that the database that may be thought of as a unification of several otherwise distinct data files (tables), with any redundancy among those files partially or wholly eliminated. By shared database we mean that individual piece of data in a database may be shared among several different users in the sense that each of those users may have access to the same piece of data and may use it for different purposes. For processing and storage of large information different software packages like dBASE IV, FOXBASE, FOXPRO, SYBASE, REFLEX, LOTUS, ORACLE, PARADOX, MSACCESS are in use.

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Application of Quantitative Genetics

T.S. Raveendran and P. Rajendra Kumar

Introduction

Quantitative genetics is concerned with the inheritance of those differences between individuals that are of degree rather than kind, quantitative rather than qualitative (Falconer, 1989). The present day plant breeders are working for the improvement of a vast number of quantitative characters across species. Baker (1984) suggested that an understanding of quantitative genetic principles is critical to design the efficient breeding programmes. Because many of the most important traits with which breeders work are inherited quantitatively, quantitative genetics must be of concern to breeders. With the rediscovery of Mendel's laws in the beginning of this century, genetic principles began to be applied to plant breeding. Smith (1966) traces the developments from 1901 to 1965, including developments in statistical theory that had vital implications for plant breeders. Because most of the traits of economic importance are under quantitative genetic control, quantitative genetics became an important contributor to plant breeding theory.

Basic Tools of Quantitative Genetics

Since the quantitative trait is the product of genotype and environment, a major contribution of quantitative genetic theory was to provide methods for separating genetic effects from environmental effects.

Description of heritable variation

Based on the work of Fisher (1918) and the elaborations by Cockerham (1954) and Kempthorne (1954), procedures for describing genetic variation in a population were developed. These procedures are based on first describing within–locus variation in terms of average effect of substitution of an allele and the deviations from that average effect. Variation associated with the average effect of substitution is called additive genetic variance and variance associated with deviations is called dominance genetic variance. Variance associated with interaction among alleles at different loci is termed as epistatic genetic variance and can be subdivided into additive x additive, additive x dominance, and dominance x dominance variance when two loci are involved. When additional loci are involved, higher–order interactions can be described. Genetic variance components can be estimated from covariances between relatives as described by Cockerham (1963).

For estimating genetic components of variance, the general procedure is to device a mating design that will estimate covariances between relatives (such as the covariance of full-sibs or half-sibs). The mating design is then grown in an enviromental design. The environmental design includes the choice of environments (usually locations and years) and environmental stresses (such as plant population, irrigation, fertility levels, etc.) as well as the experimental design (such as a randomized complete block, incomplete block, or other type of design). From the appropriate analysis of variance, design components of variance are estimated and equated to covariances between relatives. Estimates of covariances between relatives are then equated to expected genetic variance components and genetic variances are estimated (Cockerham, 1963). Such estimates have limitations. Assumptions usually include linkage equilibrium in the population from which the parents of the mating design were obtained and negligible higher–order epistatic effects. The epistatic effects assumed negligible vary with the mating design, eg., if only one covariance between relatives, such as half-sibs, is estimated, then all epistatic effects are assumed negligible if the covariance of half-sibs is assumed to be an estimate of a portion of the additive genetic variance.

Description of non-heritable variation

In crop improvement, the breeder selects the plants based on their phenotype. The effectiveness of selection would largely depend on the proportion of phenotype due to genotype. Therefore, it becomes important for the breeder to know the extent to which environment influences different quantitative characters.

For any plant breeding programme to be successful, the environments in which the cultivars being developed are to be grown must be defined. Selection is then concentrated on developing cultivars that can take maximum advantage of that environment. The one factor that dictates extensive, expensive testing of genotypes in a plant breeding programme is the existence of genotype–environment interaction (G x E). The genotype x environment interaction signifies that the relative performance of various genotypes is affected by the environment.

Four aspects of G x E interaction need to be considered. First, does G x E exist? Comstock and Mol (1963) described in detail methods of estimating G x E components of variance and detecting the existence of G x E.

Second, if G x E does exist, are genotypes ranked the same in different environments? If G x E effects are significant because of differences in magnitude of differences between genotypes in different environments (non-cross over interaction) rather than differences in ranking of genotypes between environments (cross over interactions), then the G x E effects are of little consequence to the breeder. An extensive discussion of methods of measuring the importance of cross over and non-cross over interaction effects is given by Baker (1988). Third, which genotypes respond most favourably to changes in environment? Regression of performance of a genotype on the average performance of a set of genotypes in an environment (Finlay and Wilkinson, 1963; Eberhart and Russell, 1966) has been used to identify genotypes that respond favourably to environments or that which do not respond to increased environmental inputs. Detailed discussion is found in Lin *et al.* (1986) and Romagosa and Fox (1993). Fourth, measures of G x E have been used to define geographic regions with similar environments inorder to identify areas in which test sites should be located (Ouyang *et al.*, 1995). Clustering procedures described by Ouyang *et al.*, emphasize detecting cross over interaction and allow computation of distances between enviroments for unbalanced or missing data.

Predicted Gain Equation

The development of an equation for predicting the gain from selection is one of the major contributions of quantitative genetics. Griffing (1994) reviewed the historical development of the prediction equation beginning with Fisher's (1918) consideration of the ratios σ^2_A / σ^2_P and σ^2_D / σ^2_P as measuring the relative importance of additive genetic and dominance contributions to correlation analysis. Wright (1921) originated the concept of broad-sense heritability and Lush (1935), using Fischer's least square gene model, partitioned the hereditary contribution into additive and non-additive portions. From this work came the concept of the ratio σ^2_A / σ^2_P as a measure of heritability in the narrow sense.

In simple terms, the predicted gain equation has been expressed as

$$R = i \sigma^2_A / \sigma^2_P,$$

which can be recast as

$$R = i h^2_A \sigma_P,$$

where R is response to selection, i is the standardized selection differential, and h^2_A is narrow-sense heritability. Because selection in plant breeding programmes is based on progenies and these progenies vary in the types and proportions of genetic variance expressed, the appropriate types of genetic variance to be included in the numerator of the selection equation vary. In addition, the estimate of phenotypic variance to be included in the denominator varies with the experimental and environmental designs used. The basis for comparison of results from the prediction equation may also vary. Finally, the choice of whether recombination is such that selection is based on both the male and female parents of the next generation or only on one sex will play a role in progress from selection.

A generalized prediction equation for gain per year can be written as follows (Empig *et al.*, 1972):

$$R = cis^2_g / y \sigma_P$$

where c is a pollen control factor (1/2 if selection is after pollination, 1 if selection is prior to pollination, and 2 if selfed progenies are recombined); y is the number of years per cycle; i is the selection differential expressed as number of σ_P; s^2_g is the appropriate genetic variance for the type of selection being practiced and σ_P is the appropriate phenotypic standard deviation for the progenies being evaluated.

Correlated response equation

The correlated response to selection is the basic property of quantitative traits under the control of polygenic system and is because of either pleiotropism or linkage. When selection is applied, changes are likely to occur, not only in the trait for which selection is being practiced but in other correlated traits also Falconer (1989) presents the correlated response equation as

$$CR_y = i h_x h_y r_A \sigma_{Py},$$

where CRy is the correlated response in trait Y when selection is based on trait X, i is the standarized selection differential of X, h_x and h_y are the square roots of heritability of traits X and Y, respectively, r_A is the additive genetic correlation between X and Y and $_{Py}$ is the appropriate phenotypic standard deviation for Y. Multiplying CR_y by c/y generalizes the equation to a form corresponding to the predicted gain equation. Hallauer and Miranda (1988) described calculation of genetic correlations. If $r_A h_x > h_y$, indirect selection for X will be more effective than direct selection for Y, all other factors being equal. If, in addition, selection for X allows progress in an environment where Y cannot be measured, as may be true for marker-assisted selection, then additional benefits accrue from indirect selection.

Multiple trait selection Index

The cultivars arising from plant breeding programmes must satisfy a number of criteria to be useful. Three general procedures have been proposed by Falconer (1989) for the simultaneous improvement of a population for multiple traits *viz.*, tandem selection, independent culling levels and index selection. A number of forms of the equation for gain from index selection for multiple traits are available. Smith (1936) was the first to present the concept of index selection. The equation reads as

$$I = b_1 x_1 + b_2 x_2 + \ldots\ldots b_m x_m$$

where I is an index of merit of an individual and $b_1 \ldots b_m$ are

weights assigned to phenotypic trait measurements represented as x_1 .....x_m. The b values are the product of the inverse of the phenotypic variance – covariance matrix, the genotypic variance – covariance matrix, and a vector of economic weights. A number of variations in this index, most changing the manner of computing the b values, have been developed. These include the base index of Williams (1962), the desired gain index of Pesek and Baker (1969), and retrospective indexes proposed by Johnson *et al.* (1988) and Bernardo (1991). The emphasis in the retrospective index developments is on quantifying the knowledge experienced breeders have obtained.

Application of Quantitative Genetics to Plant Breeding

Plant breeding consists of selection of parents, crossing those parents to create genetic variability, selection of elite types, and synthesis of stable cultivars from the elite selections. Quantitative genetic principles play a role at each of these stages.

Selection of elite genotypes

Most of the characters that are of interest in connection with tree improvement are controlled by a number of additive effect genes. Studies of the heredity of the characters in such perennial crop species must be made on populations and not on individuals. The genetic composition of a population is often expressed in the form of gene and genotype frequencies. To find a relation between gene frequencies and the quantitative differences evident in measurable characters, we may introduce a new term, the term "value", expressed in the units in which the character is measured (Falconer, 1964).

The values of the individuals and the variances of the population (in the form of variance components) may be set out as follows:

$P = G + E$; $V_p = V_G + V_E$; and also

$P = A + D + I + E$; $V_p = V_A + V_D + V_I + V_E$

Where V_p, V_G, V_A, V_D, V_I and V_E are the variance due to phenotypic, genotypic, additive, dominance, epistatic and environment respectively. The components of variance can be traced to variations and therefore we call these components as *causal* variance components.

On the contrary, if we wish to measure the degree of relationship between related individuals, another distinct division must be made in the phenotypic variance, the grouping of individuals into families. These components can be directly estimated on the basis of phenotypic values, and therefore we call them *observed* variance components. To avoid confusion, we will use V for the causal components, σ^2 for the observed components. The four most usual kinds of relationships are: (i) The progeny and one of the parents (the other taken at random from the population); (ii) The progeny and both known parents. (iii) Half-sibs and (iv) Full- sibs.

In a plant breeding programme, only the phenotypic values of individuals can be directly measured. A knowledge of the degree of correspondence between the phenotypic values and the genotypic values or otherwise called as *breeding values*. It is the breeding value of parents, which determines the genetic properties of the progeny. These values form the basis for the estimation of heritability and genetic advance, which are very important parameters.

Heritability is defined as $h^2 = V_A / V_P$. An equivalent meaning of heritability is the regression of breeding value (A) on phenotypic value (P), .i.e $h^2 = b_{AP}$

It is important to realize that the heritability is a property not only for a character but also of the population sampled and of the environmental circumstances to which the individuals are subjected. Since the value of heritability depends on the magnitude of all the components of variance, a change in any one of the variances will affect the heritability. All the genetic components are influenced by gene frequencies and therefore, may differ from one population to another according to past history of the population. In particular, small populations maintained long enough for an appreciable amount of fixation to have taken place are expected to show lower heritability than large populations. More variable environmental conditions reduce the heritability and uniform conditions will increase it.

In parent–progeny regression method, the heritability is estimated from the degree of resemblance between relatives. The covariances of various relatives is given in Table 1.

From the regression (b) or correlation (t) expressed in terms of heritability, the following relationship can be established.

$$h^2 = b/r \text{ or } t/r$$

where, 'r' is the coefficient of additive variance in the covariance or the theoretical correlation. Thus when expressed in terms of correlation or regression between relatives, the heritability is the observed correlation as a proportion of the correlation that would be found if the characters were completely inherited (i.e.) if all the variance were additive genetic.

The choice of what sort of relatives to be used for the estimation of heritability depends on circumstances. The closer the relationship, the more precise is the estimate because the observed correlation or regression must be multiplied by a larger factor (1/r) with more distant relatives. Further,, the standard error of the correlation or regression must be multiplied by the same factor to give the standard

error of the estimated heritability. In general, half-sib correlation and the regression of offspring-male parent are the most reliable estimates because offspring-female parent correlations are likely to be vitiated by maternal influence. Full-sib correlation is the least reliable of all because full-sib covariance is augmented by dominance component besides environmental component.

Genetic advance is another reliable parameter for selection. Improvement in mean genotypic value over the base population is known as genetic advance. It depends on the genetic variability in the base population, the heritability of the trait and selection intensity. Genetic advance can be estimated as

$$G_A = k\,\sigma_P\,h^2,$$

where G_A is the genetic advance; k is the selection differential and it varies with the intensity of selection, h^2 is the heritability of trait under selection and $_P$ is the phenotypic standard deviation.

Marker-Assisted Selection

The first step of classical genetics is to identify the genes and to locate them on linkage maps. This was successful as far as the qualitative characters were concerned but locating the genes controlling quantitative traits are not easily amenable because of nature of variation, non-identifiability of genotypes and dependence on environment. Apart from these impediments, the main practical limitation of the technique seems to be the availability of suitable markers, and the time that can be given to the considerable work involved. This problem has been overcome by the development of linkage maps occupied by large number of molecular markers.

The quantitative genetic principle behind marker–assisted selection on a single locus basis is relatively simple. Gain from selection based on marker genotype is a form of indirect selection in which the heritability of the marker is 1.0 (Dudley, 1993). However, for quantitative traits several markers are usually involved. This introduces the complication of how to weight each marker's contribution when selections are made. One method is to determine the marker genotype of each individual or line being tested, sum the additive effects of the marker loci showing a significant marker effect, and use the sum as an index value for the individual being considered for selection. This procedure has the advantage of taking into consideration the difference in magnitude of effects of the loci being included in selection.

As reviewed by Dudley (1993),, gain from marker–assisted selection will be greatest when the proportion of the additive variance accounted for by marker effects is greater than the heritability of the trait. This suggests selection based on markers have its greatest advantage when heritability of a trait is low. However, identification of marker–QTL associations require precise experiments in which heritability is as high as possible (Dudley, 1993). Thus, maximum benefit from marker–assisted selection may occur when marker–QTL associations are identified under conditions of high heritability and selection is done when the trait of interest cannot be measured.

Quantitative Genetics of Perennial Species

Heterozygosity and fitness

Even trees intensively bred for traits with high economic values must survive in relatively uncultivated conditions for a long period. Therefore, despite the limited evidence for strong non-additive effects, there are continuing efforts to understand if heterozygosity at particular loci or general multi locus heterozygosity affects fitness or survival of trees. While general heterozygosity may be important for survival over a long lifetime (Gregorius, 1986), it is difficult to attribute any relationship between fitness and heterozygosity to overdominance types of gene actions as distinct from many other types of epistasis (Turelli and Ginzburg, 1983). Thus, the presence of excessive heterozygosity in some populations may not be sufficient to suggest selection for heterozygosity.

Table 1. Covariance of various relatives

Relatives	Covariance	Regression (b) or correlation (t)
Offspring and one parent	$\frac{1}{2} V_{AA}$	$b = \frac{1}{2} h^2$
Offspring and mid parent	$\frac{1}{2} V_{AA}$	$b = h^2$
Half – sibs	$\frac{1}{4} V_A$	$t = \frac{1}{4} h^2$
Full - sibs	$\frac{1}{2} V_A + \frac{1}{4} V_D + V_{EC}$	$t \frac{1}{2} h^2$

The inbreeding depression frequently observed in selfed trees could be interpreted as evidence for heterozygote advantage. However, estimates of inbreeding depression now appear to be weakly supported (Burrows and Askew, 1982) and can be interpreted as implying the existence of deleterious mutants at many loci with no heterotic effects. If the latter hypothesis is true, then selfing or sib mating could purge populations of such alleles, and the subsequent populations could be more fit than their ancestors, even if the progeny are more inbred than the parents. With this hypothesis, purging of deleterious alleles through inbreeding or haploid doubling and selection could be useful in breeding (Kang, 1982). After purging, random intercrossing among any unrelated individuals or different sub populations would be sufficient to recreate populations with higher level of heterozygosity. If heterozygosity is important to fitness and overdominance is clearly demonstrated, directed pair-wise hybrid-breeding populations would be needed to develop highly fit populations.

Selection for Adaptability traits

Breeding to use genetic variation in the mechanisms of tree responses to environmental variables has focussed not only on less-than-optimum environments but also on optimum use of "normal" environments. If heritable variations exist in response functions in growth or its components, the physiological interactions may well favour relative homeostasis in some traits at the sacrifice of homeostasis in others. But if variations also exist in the response functions, different developmental pathways must exist for any homeostasis to exist. That is, since any observed homeostasis could not have been maintained by an identical homeostatic mechanism in all trees, different developmental mechanisms must exist. These may have originated under selection in different microsites or may be due to the existence of isolated populations. In either case, it may be possible to select for different modes of adaptation and to breed for a homeostasis of economic value functions that natural selection has not yet generated. (Namkoong and Kang, 1990).

Selection of mother trees

Breeding for high yield and vigorous plant growth has been successfully applied to coffee. Individual plant selection followed by progeny evaluation, hybridization, and pedigree selection are the most usual methods employed. Since environment accounts for a great deal of the observed variability in the yield, it is an extremely difficult task for the breeder to identify elite mother trees. Even under controlled conditions the variation is high. The best evaluation of elite mother trees is undoubtedly done through replicated progeny tests at multiple locations and during multiple growing seasons. Since the economic life of the crop spans 20 or more years, the maximum yields are not attained until between the eleventh and fourteenth year and this aspect has to be taken into account when selections are made. A successful cultivar must start producing early and maintain high yields over many years. Thus, it is not surprising that in selected progenies, overall vegetative vigour is highly correlated with yield (Medina – Filho *et al.*, 1984).

Although reliable evaluation of yield performance can be obtained only by determining yields during a number of years, dynamic breeding programmes cannot usually afford such a time–consuming procedure. Correlation studies between cumulative yields ranging from 2 to 19 years have indicated that the best progenies after 19 years could have been chosen on the basis of the first 6 years of consecutive yields. During the first 4 years, 29% of the best individual mother trees and 52% of the best progenies could be identified (Fuzuoli, 1977).. . These studies have been of fundamental importance in speeding up coffee breeding programmes in Brazil.

Future Prospects

During the past several years, some most exciting developments related to quantitative genetics and plant breeding have taken place. Among them, one important aspect has been the development and availability of large number of molecular markers, which will help in marking relatively small segments of chromosomes. Currently, the main bottleneck for gene transformation is the lack of cloned genes controlling both tree and fruit traits. Linkage between DNA markers and these genes will most probably assist their isolation. Thus, DNA markers linked to QTLs are not only a tool for marker-assisted selection, but will serve as an important technique to detect and isolate genes for the production of transgenic plants. As transformation becomes more common, questions such as the importance of genetic background for the introduction of new genes will be important. Evaluation of questions such as this will require use of quantitative genetics.

A question of primary interest to plant breeders is how can favourable linkage blocks be held together while introducing new favourable alleles into an existing genotype? The combination of molecular marker technology, transformation, quantitative genetics, and the science of plant breeding can provide the answer to this question.

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Statistical Genetics of Coconut: An Overview

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Introduction

Area expansion and replanting of unproductive gardens are part of the strategies followed for enhancing production and productivity in plantation crops. A large number of quality planting material is to be made available every year for this purpose. The short-term objectives of crop improvement programmes in plantation crops are therefore formulated to meet this requirement leaving limited scope for a detailed examination of the genetic properties of all the respective breeding populations. Lack of readily available tools for the analysis of experimental data from perennial crops also complements to this situation. The statistical procedures, data generation techniques, estimates of genetic parameters and other related aspects are discussed below.

Genetic Diversity

Assessment of genetic divergence is important for any breeding programme. The realization of heterosis in coconut necessitates the selection of populations for diverse origin. Conventionally, a field trial consisting of various cultivars of interest may be laid out and proceed with evaluation. Such a trial with coconut will occupy large area and requires many years for its completion. The data from such a trial will be voluminous and all the characters need not be of equal importance. Also not all characters may be available for different trials at different locations. Some characters may be more conservative than others. The fruit components of coconut are less affected by the growth of palms and management and hence preferred by many workers (e.g., Rao and Pillai, 1982). Fruit components may also be of use in periodical assessment of field genebanks. Multivariate techniques are sensitive to the inter correlation among variables, the possibility of variable reduction need to be examined before employing such techniques (Muralidharan *et al.*, 1993). To avoid duplicate accessions in the gene bank, the divergence analysis is employed at the time of collection (e.g., Zizumbo-Villareal and Pinero, 1998; Kumaran *et al.*,, 1998).

A number of procedures are available to measure the genetic diversity which include the coeeficient of parentage, Shannon-Weaver diversity index, Jacquard's coefficient, Nei-Li's genetic distance, modified Roger's distance, Euclidean distance, Mahalanobis' generalized distance principal component analysis (PCA), metroglyph analysis and discriminant analysis. Following the construction of a similarity or dissimilarity measure, the populations have to be grouped for which many methods are in practice such as unweighted pair group mean analysis (UPGA), average link (AL) method, partition method (PM) etc. Some of these procedures were employed to assess the genetic diversity in different regions and is summarised in Table 1. No general recommendation on the suitability of a procedure can be made from the results of these studies.

Santos *et al.* (1997) suggested the use of Mahalanobis' distance for studying inter population variability and PCA to represent a set of individuals without preliminary grouping and Fisher's discriminant functions for studying within population variability. Besides the ambiguity in selection of a procedure for studying genetic divergence, problems are encountered while interpreting the results. Selection of parents for hybridization based on divergence analysis need not give disired results always. For example, the devergent types viz., Andaman Giant Tall and Laccadive Micro Tall, as obtained in a study at CPCRI, when hybridized did not give heterosis for seedling characters in the F_1. Another aspect of divergence analysis is the set of characters to be included in the study. In two of the in situ studies with fruit components as the set of characters clearly identified the distint types viz., Red Dwarf (Ovasuru, 1993) and Coco Gra Tall - a makapuno type (Kumaran *et al.*,,1998).

Questions are also raised on the reliability of divergence analysis in coconut (Raveendran, personal communication) as each palm of a cultivar will be a half sib and therefore the within population variation will be confounded with the genetic variation. This aspect need to be considered while fixing the minimum size of population to be required for attempting divergence studies.

Diversity in coconut is available in uninhabited or far off coasts and islands especially wild, self-sown natural stands. Due to inherent transport and communication constraints, most of these sites are either unvisited or little time is available during visit. Under such difficult situations, data recording could be restricted to a few important characters identified by Kumaran *et al.* (1998) such as length and breadth of leaflet, spikelet length, inflorescence stalk length, husk thickness or husk to fruit proportion.

Table 1. Procedures employed for the analysis of genetic diversity in coconut

Location	Procedure	No. of populations	Reference
In situ diversity			
Papua NewGuinea	Eucledian dist./UPGMA	78	Ovasuru (1993)
Madagascar, Mauritius and Seychelles	PCA/PM	15	Kumaran *et al.* 1998)
Orissa (India)	PCA/PM	10	CPCRI (1998)
West Bengal (India)	PCA/PM	11	CPCRI (1998)
Mexico	Eucledian dis./UPGMA	41	Zizumbo-Villarrealand Pinero (1998)
Pacific Ocean Is.	Mahhattan metric/UPGMA	29	Ashburner *et al.* (1997)
Ex situ diversity			
IRHO, Ivory Coast	Canonical Analysis	17	N'Cho *et al.* (1993)
CPCRI, India	Mahalanobis' dist. /AL	70	CPCRI, communictaed
KAU,India	Mahalanobis'dist. /PM	24	Balakrishnan and
TNAU, India	Metroglyph	23	Ravindra *et al.* (1987)
Japan (Philippines data)	PCA/.PM	39	Sugimura *et al.* (1997)

Field Gene Bank and Evaluation Trials

Establishment and maintenance of coconut gene bank in the field is a tedious task. The requirement of large area, time and monitoring for pests and disease make it difficult to have large number of palms per accession. For evaluation trials, 40-60 plants per accession per replication were suggested by Rao and Batugal (1996) and 30 plants by Santos *et al.* (1997). A database management software to access palmwise data of an experiment is being prepared by COGENT.

Sampling procedure and size

A suitable strategy for sampling populations has to be devised. Because, a breeder is confronted with problems of huge populations, fast rate of gene erosion detecting useful low frequency alleles and unpredictable future needs.

Namkoong (1988) recommends dispersed sampling perennial crops to deal the problem of defining independent notypes in age, reproductive and spatial heterogenity. Marshall and Brown (1975) in sampling a species of bdivided populations, *one approach is to disperse the* mples into N locations, with n genotypes per sampling site. single allele of interest exist at frequency q in only certain ilations, and those populations exist at frequency p, then

Q of a single site sample would be,

$Q = [(1-p) + p(1-q)^{2n}]$ and multi-site (N) sample with n genotypes

$Q = [(1-p) + p(1-q)^{2n}]^N$

where Q is the probability of saving the allele.

Santos *et al.* (1997) recommends coarse and fine grid sampling method for germplasm collection. One fruit sample per tree is collected at random for F.C.A . IPGRI /COGENT recommends a minimum of 30 (Talls) or 10 (Dwarfs) individuals per site. Collection of seed nuts from more sites rather than from more individuals in a site has also been advised. A sample of 200 nuts or 600 embryos per population is essential to represent a population. Santos *et al.* (1997) has given a simple formula to arrive at sample size (N) required at the desired confidence interval (C.I) for a given CV (coefficient of variability %) as, N= 1.96*CV/CI.

Estimates of Genetic Parameters

Partitioning of variance to its causative components and expressing the relative contribution of each component are helpful to know about the genetics of quantitative characters. *The variance components are often obtained* through the conventional least squares approach for balanced data. In reality, seldom the data are balanced and variances homogeneous. Added to these are the problems arising from

the long generation interval and time requirement for completing the evaluation of successive crops. Estimation and comparison of genetic parameters at different stages of a breeding programme are therefore a difficult task in this crop. Nevertheless few attempts were made in different countries in this direction. Two approaches are commonly followed for genetics studies of quantitative characters viz., controlled matings and correlation between relatives.

Mating designs

Only limited attempts were reported on application of mating designs in crop improvement of coconut. In a diallel experiment with selected palms of cultivar in Sri Lanka, Fernando (1996) obtained the heritabilility of nut weight as 0.45. The results of this study suggested the use of intermediate performing parents for crossing programmes as they combine both additive and on-additive components of genetic variation. In India, using palms of relative homogenity, a diallel was tried with nine cultivars (8 talls; 1 dwarf) which helped in identifying the best general and specific combiners. However, assumptions for a diallel program (Hayman, 1954) such as homozygosity of parents, absence of linkage between characters under study and lack of meternal effects cannot be expected to hold good with coconut. This is because (l) economic traits like copra and tendernut water being the endosperm components will have two-third contribution from the maternal parent and (ii) some palms (e.g., pre-potent) may have close linkage for desired characters.

Most of the coconut tall types are cross pollinated. Therefore, palm wise combining ability studies have to be undertaken. Such studies are reported to be helpful in refinement of released hybrids in Ivory Coast. Another approach could be the application of North Carolina Designs. Ravindran (personal communication) suggests line x tester matings similar to Kempthorne's sire x dam mating design which will provide information on combining ability and other genetic components of variance from the analysis half- and full- sibs. At IRHO, tall x tall and dwarf x tall hybrid improvement programs are based on reciprocal recurrent selection of half-sib families (Burdeix, 1998; Burdeix *et al.*, 1993). More studies are required to work out the relative merits and demerits of different mating designs in coconut.

Data on relatives

Estimation of genetic components of variance from data on relatives is advocated in many crops. Parental and juvenile selection are two common practices in coconut cultivation and breeding. Selection of mother palm is mainly based on annual yield (number of nuts per palm). Other characters of importance for mother palm selection include the number of functional leaves, length of stem (Patel, 1937), spherical or semi-spherical crown, short and stout bunch stalks and high copra yield (Menon and Pandalai, 1960). Though the assessment of genetic variability of these characters has been handicapped by (i) inadequacy of comprehensive germplasm (ii) limited population size in the genetic stocks and (iii) lack of well laid out experiments for their comparisons (Bavappa and Nampoothiri, 1974), estimates of heritability of nut yield for few populations were reported (Table 2). No standard error is provided to these estimates. The standard error is a function of sample size. For instance, with regard to a population of 55 open pollinated progenies of 5 West Coast Tall palms, the regression estimate of heritability for average annual yield over a ten year period was obtained as 0.3 ± 1.4. Because of this large standard error, the estimate was found to be non-significant. The non-adequate

Table 2. Estimates of heritability of coconut yield

Description of population	Method of estimation	Character	h^2
A total of 57 open pollinated progenies (at Pilicode) of 14 West Coast Tall palms (at Kasaragod) (Lakshmanachar, 1959)	Offspring-Parent Regression	Average annual yield over 10 year period	0.49
i) A total of 93 self pollinated progenies of 12 WCT palms	-do-	Annual yield (a single year)	0.24
ii) 16 open pollinated progenies of 6 WCT palms (Nambiar *et al.*, 1970)	-do-	-do-	0.71
540 progenies derived from 108 palms grouped into 6 yield levels ('lines') which were pollinated in 3 different ways ('testers') (Nambiar and Nambiar, 1970)	(1) Line X Tester ANOVA (2) Parent-offspring Regression (high yield groups)	No. of nuts -do-	0.47 0.22

sample size is a major problem with many coconut field experiments.

It is known that the heritability of a character will be increased when determined on the average of several measurements (Jain, 1992). Corresponding to Lakshmanachar's (1959) estimate, the heritability of annual coconut yield can then be worked out as 0.27 and for the biennial average it is 0.37. The repeatability of these two characters was taken as 0.5 and 0.7 respectively as reported by Muralidharan and Vijayakumar (1999). In summary, the annual nut production in coconut cannot be considered as a highly heritable character. The genetic gain from the practice of 'mother palm selection' based on annual or biennial yield alone is therefore expected to be marginal. Further, unlike the 'mass selection' as practiced in annuals where the selected individuals are put together en masse for mating, in coconut, open pollinated progenies are produced. A consequence to this is that the value of heritability to be considered for working out the genetic gain has to be halved as selection is applied only for one of the parents. Palms yielding more than 80 nuts per year are usually selected. Another suggestion was to select only the best 10% palms in a population. There can not be much difference by following these two criteria as it was reported by many workers that only 8 to 10% palms yield more than 80 nuts in Kerala (Satyabalan, 1984). Now with a moderate phenotypic selection differential as 40 nuts and heritability as 0.3, the expected genetic gain would be 6 nuts per generation. Dividing it by the generation interval as 15 years, the genetic gain per year will be 0.4 nuts per palm per year.

As mentioned earlier, selection is also practiced at the seedling stage. Nampoothiri *et al* (1975) studied the relationship of seedling characters with yield and found that selection could be based on the number of leaves and girth at collar. The genotypic correlation of these two characters with yield were reported to be 0.53 and 0.41 respectively. Mathew and Gopimony (1991) worked out the heritability of different seedling characters such as number of leaves (0.65), girth at collar (0.76), leaf area (0.76), height of seedling (0.63) and age at leaf splitting (0.63).

When multiple measurements of a character are available, the partitioning of variance corresponding to 'repeatability' too has some practical implications as the estimates of other genetic parameters are often not available. When a rectangular lay out of large number of trees (planted at random) are available, Pearce (1956) put forward a different method of partitioning the total variance into components due to the 'positional' and the rest, by including the coefficient of soil heterogeneity in the model. This approach was followed by Shrikhande (1958) and Pankajakshan (1960) to partition the variability of average annual coconut yield over even number of years into genetic and environmental. Muralidharan and Vijayakumar (1999) further partitioned the *environmental variation into 'special-' and 'general-'* environmental and attempted a non-linear fit to obtain the combined estimates of the parameters. The repeatability estimator thus obtained will be denoted as $r_{P\text{-}S}$, the suffix is to read Pearce-Shrikhande.

The increase in nut yield on advancement of the bearing age (Rao, *et al.* 1978; Muralidharan *et al.*, 1993) and the biennial pattern of bearing are the two major systematic variations associated with the coconut yield. The systematic variation due to the former cause may be removed by converting the yield of second and later years of bearing to the basis of first year (Muralidharan *et al.*, 1993). The problems arising from bienniality is generally overcome by taking average yield over even number of years or by converting the annual yields to first order moving averages as Wahi (1994) suggested. He also proposed an estimator of repeatability.

Smith *et al.* (1998) has developed a program PLANTVAR for rapid estimation of broad based heritability based on data of genotypes planted in bulk without progeny testing. This program could also be of very good help in coconut. Using the data available on many accessions at one location or few accessions at many locations heritability of many important agronomic, economic, physiological, and biochemical characters can be worked out. Earlier studies were restricted to single accession or few accessions for a few economic characters or colour markers.

Genotype-by-Environment Interaction

The analysis of data from multilocational trials in coconut is not straightforward. Only few cultivars may be common to all the trials. Also there may exist cultivar x year interaction in these trials, as agroclimatic conditions are known to have influence on nut yield. A common error in the analysis of cultivar x year interaction is the choice of an incorrect factorial model with year as one of the factors. Such an incorrect model was used by Patil *et al.* (1991) while analysing cultivar x year interaction in coconut (Muralidharan *et al.*, 1998). A correct approach could be based on the covariance structure of annual yields. However, under randomly assigned conditions (time), a split-block model is adequate provided, the compound symmetry properties (i.e. equal variances and equal covariances) hold good. The split-block anova is different from that of a split-plot for one additional source of variation viz. replication x time. The assumption of compound symmetry may be tested by using Box's criterion. On violation of this assumption, alternative methods are to be followed; the easiest being the

multivariate analysis. The general multivariate model may not always be estimable or efficient especially when the covariance of successive observations depends on the times of measurement and the number of measurement times large. Consequently more parsimonious models like 'random effects' or autoregressive (AR) models for the covariance structure are need to be considered. Application of rank stability statistics for comparison of sensitivity of cultivars over years may be seen in Muralidharan *et al.* (1993).

Problem of WideVariation

There are three levels of variation one has to encounter in coconut breeding viz., intra-individual (one palm may give variable number of nut/bunch in an year due to seasonal differences etc.), Intra-population (within a population, palms may differ in bearing capacity))and Inter-population. Populations belonging to different cultivars differ in many characters, which could be genetic or environmental, or interaction of both. Suitable methods to study the above mentioned three levels of variation could help to get clear interpretation of the results.

Bienniality in bearing and fluctuation in yield of nut or copra from year to year are major problems in comparing the performance of hybrids / varieties of coconut. To overcome the bienniality, CPCRI uses the mean yield of two successive years and for tackling year to year fluctuations cumulative nut yield over a period of 10 -15 years.

To measure the bienniality of a palm, use of Hublin's index seems to be an ideal method. It is the average of ratios of absolute difference between adjacent years to the corresponding sum

$1/n\ [^{n}_{j=1} Y_j - Y_{j+1} / (Y_j + Y_{j+1})]$

where Y is the yield recored during n number of consequetive years and $_j$ being the serial number of year when years are arranged in ascending order). Differences in intra/inter cultivar pre-bearing age and advancement of bearing years with increase in nut production pose problems in direct comparison of cultivars in initial years. To overcome this problem, Muralidharan *et al.* (1993) suggested correction of the yield by converting the yield of second and later years of bearing on first year basis.

Rao and Pillai (1982) have suggested the use of ratios instead of absolute figures for overcoming the problem of high CV. Normalisation of yield data attempted by CPCRI reveals the use of $(x+10)^{1/2}$ transformation in reducing the skewness and kurtosis. Calibration of a palm using an integrated index with principal component scores of vegetative characters as developed at Sri Lanka (Mathes *et al.*, 1996) could also be of help for dealing the problem of high CV.

Sometimes we confront practical problems like death of palms in a particular plot. Use of missing plots or nearest neighborhood analysis could help us here. In cases where a plant in the neighborhood dies or a plant grows better than other plants of same genotypes in the same plot because of a favourable environment like its proximity to water source, the difference could be analysed by nearest neighborhood analysis.

Ledig (1974) gives a formula for analysing the ratio of the responses to selection (R_{ct} is the response at control and R_t being the response of treatment) as

$R_{ct}/R_t = (1-r)\ [(n-I)/\ n(1-t)]^{1/2}$.

Here n is the number of trees used for comparison, r the degree of relationship between the candidate tree and those around it and t is the intra-class correlation coefficient measuring similarity within groups.

The method developed at CPCRI for predicting the annual yield (Y) of coconut based on total count of nuts above fist size $X_{1\,\text{ft}}$ and that ofbelow fist size X_2present in the crown at the time of observation could be useful in many cases.

Rainfed :	Sep. to Feb.	$Y = 1.09X_1 + 0.44X_2$	($R^2 = 0.92$)
	Mar. to May	$Y = 1.02X_1 + 0.52X_2$	($R^2 = 0.88$)
Irrigated :	Sept. to Feb.	$Y = 1.09X_1 + 0.42X_2$	($R^2 = 0.92$)
	Mar. to May	$Y = 1.08X_1 + 0.42X_2$	($R^2 = 0.82$)

Future Thrust

The major problem with respect to statistical analysis in coconut germplasm evaluation and field trials is that these analyses have been done either exclusively by statisticians or by plant breeders with poor knowledge of biometrics. Further, the experimental methods and interpretations have been analogous to that of annual crops which are not exactly applicable to perennial crops having long pre-bearing phase and purity of the planting material is doubtful due to the allogamous nature. So coconut requires statistical techniques which are tailor made for the crop. Therefore a lot of work has to be done this regard. A mannual developed based on the contributions of experienced coconut breeders and biometricians of different countries could be useful tool for coconut researchers.

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Post Harvest Technology and Processing of Plantation Crops

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Introduction

Plantation crops play a vital role in Indian economy. Post harvest processing determines effective utilization of harvested produce and the quality of the end product, which ultimately tells upon the consumability and acceptability of the produce. It has been estimated that there is considerable loss in many of the agricultural products after harvest. This is either because the post harvest technology has been not developed to the desired extent in some crops or the problems in marketing of produce or both.

Coconut

Coconut is an important source of vegetable oil used for both edible and industrial applications. It is estimated that nearly 50% of coconuts in India are consumed raw, and the rest is converted to copra to extract coconut oil. Coconut meat (kernel) the endosperm of the fruit contains carbohydrate 20%, fat 36% and protein 4% at moisture content of 50%. Coconut oil can also be extracted from fresh kernel.

Coconut processing is broadly classified as dry processing and wet processing. Storage/seasoning, husking and deshelling are the major unit operations involved in any coconut industry. It is a common practice to season the harvested nuts before they are further processed. (Grimwood, 1975). Traditionally husking is done manually by skilled workers with the aid of an iron spike driven to the ground. The work calls for skill and is strenuous. A coconut dehusking tool has been developed by Kerala Agricultural University, called 'keramitra' for domestic use which is a very handy one and is being used widely. A manually operated coconut dehusker has been developed by CPCRI. The dehusker can husk 110 nuts per hour. Later CPCRI has developed a power operated dehusker which can dehusk about 600 nuts per hour.

Dry processing of coconut

Main end product of dry processing is coconut oil. Copra drying is one of the major unit operation in the dry processing. Fresh coconut meat contains 50-55% moisture content, which is to be brought down to 5-6% by drying. Drying must be carried out within 4 hours of splitting since coconut meat deteriorates very rapidly due to growth of mould and bacteria. Microbial activity in the form of slime is seen if temperature is 30°C and relative humidity around 80%. The surface shine continues to develop and within 48 hrs penetrating mould appears (Nathaneal, 1968). Microbial activity is reported to be more, above 20% moisture content (Nair, 1984). The methods generally used for drying of copra are (1) solar drying, (2) smoke drying or kiln drying and (3) indirect hot air drying.

Sun drying: The conventional system of copra drying is by spreading the cups on any open surface for sun drying. This operation takes about 8 days and quality deterioration due to deposition of dirt and dust of wet meat is nearly unavoidable. Again if the atmosphere is cloudy and the temperature goes down during the initial days of drying, the copra will get infested with mould.

Solar dryer: The drying time can be reduced to 3-4 days if proper solar dryers are used. If the dryer is an enclosed type, quality deterioration due to deposition of dirt can be avoided. A batch type solar cabinet dryer developed at CPCRI takes only 3 days for drying (Singh *et al.*, 1982, Patil, 1984).

Indirect drying: Due to considerable capital investment and high rate of fuel used it was considered earlier that indirect dryers were economical only in relatively large scale. Hence the earlier reported dryers were all building type and having large capacity such as Samoa dryer, Camaro dryer, New College copra dryer, Iron hot table dryer, Tonga hot air dryer (Grimwood, 1975). But in CPCRI, an indirect type copra dryer of 400 nuts per batch capacity using agricultural waste as fuel was developed. It consists of a drying chamber, plenum chamber, burning cum heat exchanging unit and a butterfly valve to control the rate of combustion and also the drying air temperature. The dryer required only $3m^2$ area for housing and could be carried by 2-3 persons. The drying time required per batch was 36 hours spread over 4 days (Patil, 1984). So far, more than 100 units of this dryer have been sold to various copra makers and they are satisfied with its performance. This dryer was further scaled up and suitably modified at CPCRI to raise its capacity to 3500 to 4000 nuts. This dryer is suitable for copra processing societies and for large holdings.

An electrically operated dryer with forced hot air circulation was also developed at CPCRI to dry

1000 coconuts per batch. It consists of 6 nos. of 1 KW strip heaters and a blower. The drying time taken is about 28 hr.

Copra moisture meter

So, for safe storage of copra, the optimum level of moisture content recommended was 6%. In the field, moisture content of copra is often estimated subjectively by the texture of copra or by seeing its inflammability. This method is only approximate. To estimate the moisture content in a scientific and accurate way, CPCRI has developed a moisture meter, which works on the principle of electric conductivity. It is calibrated to read the moisture content from 5% to 40% so that the moisture at the different stages of drying can be found out (Madhavan, 1986). This moisture meter is being used by various agencies in Kerala as a quality-testing instrument in their copra procurement programs.

Chemical treatment to wet kernel of copra

Preservation of fresh kernel becomes essential when drying is delayed due to uncertainty of weather conditions . Sreemulanathan *et al.* (1979) reported that application of thin coat of glacial acetic acid prevented microbial growth during open sundrying. A chemical treatment of dipping fresh kernels in 1000 ppm propionic acid for 60 min. to preserve it up to 49 days without further drying had been developed at CPCRI. This was found to be useful and simple to overcome the spoilage of kernel due to sudden onset of inclement weather.

Copra storage

The safe moisture level of 5-6% can not be maintained in copra if stored under conditions of high relative humidity and wide fluctuating temperature. The wet copra should not be mixed with dry copra and storage structure should be such that there is minimum fluctuation in temperature compared to ambient to avoid. moisture migration effects in the structure. Studies conducted at CPCRI has shown that copra can be safely stored if kept in saturated atmosphere of neem leaf gas, bio gas or SO_2. Painting of roof with mat white reflective paint has been reported to reduce temperature fluctuations within 10 degree centigrade, thus preventing serious condensation effect.

The walls also should be provided with sufficient number of adjustable ventilators. The floor of the structure should be water proof, smooth and easy for cleaning. The cracks and crevices in the structure must be regularly cleaned out and filled in with mortar so as to eliminate residual population of insects. If the commodity is bagged, it should never be stored directly against the wall, and should be provided with proper dunnage. reported that copra could be safely stored in plastic lined gunny bags even during rainy season.

Extraction of oil from copra

In the rural areas and villages copra is crushed in the primitive `chakku` driven by bullocks. The power driven chakkus or rotaries are used in larger establishments and are driven by steam, diesel or electricity. In the organized sector, copra is crushed by expellers. A double crushing unit gives better extraction; hence, series of expellers are preferred. The clean copra is passed to disintegrator, where it is converted into a coarse meal. The meal is heated in the cooker by steam up to 88°C. The pulped copra is fed continuously to the expeller from which the oil and the cake are forced in different streams. The first expeller gives 50% extraction and the second extracts the remaining, leaving about 10% oil in the cake compared to 70% in copra.

The oil can further be extracted from cake with hydraulic pressing but these presses have gone out of business due to higher cost of maintenance. For removing this oil, the solvent extraction method with hexane is followed or the cake as such is used as cattle feed.

Coconut oil is one of the major edible products of coconut. This is referred to as lauric oil in the world market because of its high lauric acid content. USA absorbs the major portion of oil followed by EEC Countries. Coconut oil is used in India (a) for culinary/ edible purposes (b) for toiletry purposes (c) for soap making and (d) as an illuminant and lubricant. The industrial application of coconut oil is mainly attributed to the presence of maximum lauric acid and glycerides which are not present in other vegetable oils.

Storage of coconut oil

Unrefined coconut oil is susceptible to rancidity due to the presence of certain proportion of free fatty acids . This is accelerated by the presence of moisture, air, light and fat splitting enzymes leading to the formation of peroxidation products. These usually originate from the copra itself, if it is not properly processed. Further studies have shown that the shelf life of coconut oil can be improved by the addition of either antioxidants or preservatives. Thus addition of either common salt (1%), tamarind (2%) or citric acid (500 ppm) to coconut oil enhance the shelf life to more than one year.

Wet processing of Coconut

In this process the white coconut meat is ground in to slurry from which coconut milk is separated by pressing the slurry. The residual powder is desiccated coconut of medium fat content. The milk is sieved and concentrated. After separation of coconut cream it can be dried in to a powder or packed aseptically as such. The cream is stirred vigorously to get the virgin coconut oil by a process called phase inversion. This oil is clear nutritious and having low FFA. The water phase is concentrated to a syrup like product termed as honey.. The residual solids obtained at the bottom of the centrifuge is

dried to produce medium fat desiccated coconut.

Desiccated coconut: Desiccated coconut is the white kernel of the coconut, comminuted and desiccated to moisture content of less than 3 percent. This is a very important commercial product having demand all over the world in the confectionery and other food industries, as an ingredient in the fillings of chocolate and candies. Sri Lanka and Philippines are the major desiccated coconut producing countries. In India, only small units of production are available and the annual production is only around 10,000 tones. The small production units, however, do not utilize modern processing technologies, particularly in the drying and related areas. On an average, 7000-8000 nuts give one tone of desiccated coconut. The oil content ranges from 68 to 72 percent, but should not contain more than 0.1 percent free fatty acids.

Coconut byproducts

The major coconut byproducts like husk, shell and coconut water can be converted to value added products like activated carbon, shell charcoal, shell flour and shell based handicrafts. Lack of efficient technologies and unorganized setup are the main reason for the slow pace on the development in this area. The husk usually forms 35 to 45% of the weight of the whole nut when ripe. About 30% of the husk is fiber and 70% is coir dust. Apart from the usual coir and coir products, coir pith finds varied uses as manure, as a mulch material and for making briquettes, with a good export potential. The briquettes can be used as a substitute fuel in place of firewood used in tile and brick industries and for other industrial heating purposes. Coir pith has also been put into trial for the production of biogas, light weight building bricks and also as a soil conditioner for moisture retentivity.

Coconut shell powder is preferred to many other similar materials like wood bark powder, peanut shell powder etc. because of its uniformity in size and chemical composition. Shell charcoal is also another product having extensive demand in the manufacture of activated carbon. Shell charcoal is prepared by burning the shell in a limited supply of air, so that the shells are only carbonized and not burnt in ash. The most modern method of manufacturing shell charcoal is using the Waste Heat Recovery technology. Here, the flue gases evolved during carbonization is burnt in a furnace to produce process heat for application in the coconut processing industry like copra making and desiccated coconut.

Another product, which is gaining attention, is the activated carbon. Coconut shell based activated carbon is the most superior material for gas absorption because of its small pore size and also its high mechanical strength. This is an energy intensive process and hence technologies for minimizing the operating cost by cutting down the energy utilization should be devised.

Coconut wood processing

Freshly cut coconut trunks from senile coconut trees can be used as timber if treated with preservatives, to increase its shelf life. Research work is in progress at CPCRI in this field. Philippines has already developed a technology known as HPSD (high pressure sap displacement) treatment. It is a process of preserving the strength and durability of freshly felled trees by forcing out the sap from the trunk using a waterborne preservative solution. This process uses a high-pressure sap displacement apparatus. Treated coconut timber can be used as electric poles, telecom poles and for interior uses such as to make furniture, window and door frames.

Arecanut

Arecanut has been widely used since long throughout south and South-East Asia and the Pacific Ocean Islands. While its primary use has been as a masticator, it is also finding use among the local populations in native systems of human and veterinary medicine, in certain religious and social functions and in farms and households (packaging, construction etc.,).

Harvesting of the arecanut is done by skilled climbers who cover about 50 -100 palms in a day. The arecanut climbing device developed by M/s St. Mary's Industries, P.O. Chemberi, Kannur Dt, Kerala is a useful one. The stage of harvesting depends on the type of produce to be prepared for the consuming markets. There are two main types viz., one prepared out of immature green nuts and the other from ripe nuts. In each case, the maturity at which the fruit is harvested and the season of harvest affect the quality of the processed nut considerably

Preservation

Several age-old and crude methods are followed for preserving arecanut to keep the moist chewing feel. This is done by steeping ripe arecanuts in water. Discoloration of outer husk and foul smell result in this due to bacterial attack. The inner core is practically well preserved. CFTRI has developed a method of blanching followed by steeping the ripe arecanuts with sodium benzoate and potassium metabisulphite for storing upto 10 -12 months. (Mathew *et al.,* 1963).

Drying

The most popular trade type of arecanut is the dried, whole nut, known as 'chali' or 'kottapak'. Ripe nuts are dried in the sun for 35 - 40 days on dry level grounds. To facilitate quick drying and easy dehusking, sometimes the fruits are cut longitudinally into two halves and sun dried for about 10 days. The kernels are scooped and given a final drying. This type of products is known as 'parcha' and is produced mainly in Kerala and Karnataka.

A mechanical through-flow drier has been recommended for making 'chali' and 'parcha (Namboodiri *et al.*, 1963).. . In this type of drier, the hot air is allowed to penetrate through the bed of material kept in trays. The drier has a cabinet, which is connected to a heat exchanger through a centrifugal blower. The bottom section of heat exchanger is connected to an oven and the top to a chimney. Drying will be completed in 60 - 70 hrs over a period of 7 - 8 days at progressively increasing temperature between 45 and 70°C. The drying procedure consists of 8 hr consecutive drying followed by equilibration for 16 hrs outside the dryer.

Multipurpose dryer, using agricultural waste as fuel, developed at CPCRI for coconut drying has successfully been used for drying of arecanut. About 150 kg of arecanut can be dried in this dryer in 100 hrs (10 days)..

Kalipak

It is another important form of processed arecanut. The nuts of 6 - 7 months maturity is soft and finger nail can be pressed into it. Outer skin is dark green in colour at this stage. The processing consists of dehusking, cutting the soft nuts into pieces, boiling cut pieces with water or dilute extract from previous boiling, 'kali' coating and drying. The extracts obtained from processing are concentrated nearly 10- fold by boiling over open fire to produce 'kali'. Polyphenols are the major components in it.

Both sun drying and oven drying are adopted for 'kalipak processing'. During monsoon, artificial drying over an open fire is done. Though drying is accelerated, smoky off flavor is not desirable. A well-dried product with a dark brown colour, glossy appearance, crisp chewing feel, well toned astringency and absence of over mature nuts, is most welcome and is rated superior.

Scented supari

There are many varieties of scented suparies. Dried arecanuts are broken into bits, blended with flavor mixture and packed. Scented supari is made both from chali and kalipak. The chali supari is more popular. About 75% of the marketed produce is consumed after processing either as kalipak or chali.

Alternative uses of arecanut

Tannins: Tannins are obtained as a by-product from the process of preparing immature betel nuts for masticatory purposes. It was found that tannic acid from the nut, when mixed with ferrous sulphate in warm distilled water gave black writing ink of acceptable quality. He used immature fallen nuts for this purpose. Other uses of tannin are as adhesive in plywood industries and as a textile dye.

Fats: The nuts contain 8-12% fat. Fat from arecanut, can be extracted by solvent extraction using hexane. Areca fat has comparable characteristics with hydrogenated coconut oil. Areca fat can be made edible by refining with an alkali. The fat could be softened by fractional crystallization using hexane (25°C) and randomization using sodium methoxide which gave products desirable for use as confectionery fat. Simple blending of areca fat with butter fat and cocoa fat at 3:1 ratio followed by interesterification of areca fat and cocoa fat at 1:1 ratio gave good products acceptable in confectioneries.

Arecanut husk: It is the outer cover of area fruit. It constitutes 60-80% of the total volume and weight of the fruits (fresh weight basis). It is now being largely wasted except for being used as an inferior fuel and mulch several processes have been developed for utilization of area husk for making hard boards, plastic and brown wrapping paper . Area husk is used as a substrate for mushroom cultivation.

Areca leaf sheath: Leaf sheath is yet another raw material obtained from the arecanut palm. In a year palm sheds 5-6 leaves . About 1000 million leaf sheaths weighing about 23300 tones are available annually in India alone. A process has been developed at CPCRI for making plyboards from areca leaf sheath. These boards can be used for making suitcases, fileboards, and tea chests: (Menon *et al.*, 1982) CFTRI has developed a leaf sheath cup making machine which makes arecanut leaf sheath cups of different sizes and shape.

Arecanut stem and leaf: Arecanut stem forms a useful building material in the villages and is widely used in arecanut growing area for a variety of construction purposes. (Nayar *et al.*, 1981).. The leaves are good source of organic manure. Their approximate composition is N_2 (0.94%); P_2O_5 (0.096 %) and K_20 (1.00 %) (Biddappa, 1960).

Cocoa

The cocoa beans are derived from matured cocoa pods. Major products from cocoa beans are cocoa powder, cocoa butter, and chocolate. Cocoa harvesting is done from April-Aug. and from October-January. A special knife for harvesting cocoa pods was developed by CPCRI. It consists of a curved steel blade with both edges sharp attached to a long aluminium handle.

Curing

Curing of cocoa beans is an important step in cocoa processing. It involves fermentation and drying. The chocolate flavor is developed in the beans during this process. Fermentation involves keeping a mass of wet cocoa beans, well insulated in order to generate and retain the heat and at the same time allow air to pass through. This process takes about four to seven days depending upon the variety of the beans. The pulp or mucilage sticking to the beans then disappears. The colour of the inside portion

of the beans changes from purple or violet to light brown. Dead or germinated beans do not develop the desired flavor during fermentation. Overripe pods should not be fermented as they might have germinated.

The temperature of the beans during the fermentation process must be stable at about 50°C during the period. Lower temperatures give rise to under-fermented purple beans or unfermented beans. Small quantities of wet beans cannot be properly fermented because retention of the required heat is difficult. The removal of carbon dioxide surrounding the beans during fermentation is done by turning the mass at intervals. There are a number of methods of fermentation depending on the quantity of beans available. Small quantities of wet beans (5 to 10 kg) can be fermented keeping them in small bamboo or cane baskets. Large quantities (40 to 100 kg) will need wooden boxes. If the quantity exceeds 200 kg, wooden trays or boxes can be used. In normal conditions, the following checks are carried out to determine the level of fermentation: (a) Portions of pulp adhering to the beans should be red brown as against the original dull white. (b) When the fermented beans are squeezed, the colour of the exudate should be reddish brown. When fermented beans are cut, the colour inside should be brown. The cut half of the bean when bent, should reveal irregular cracks on the cut face.

Drying

Generally drying is done using indirect type of dryers. KAU, Trichur has developed an electrical natural convection dryer with electric bulb of 400 Watts in a box. About 10 kg of wet beans can be dried in 48-72 hrs at 50-55°C. CPCRI has developed an electrical dryer with 500 Watt heaters. In this dryer 40 kg of wet beans can be dried in 60 hrs. For quantities of 200 kg Samoan type of commercially available cross flow electrical dryer may be used. The cocoa beans dryer developed at CPCRI can also be used to dry cocoa beans. About 40 kg of wet beans at 10 cm bed thickness can be dried in 18 hrs (over days) with tempering of 1 hour every 3 hours after 8 hrs continuos drying. The fuel required is 23 kg/batch. The dryer costs about Rs.1700/-. The drying air temperature is maintained at 70°C.

Processing of Cocoa

The processing of cocoa beans can be classified as primary and final. Primary processing refers to fermentation and drying of the wet beans extracted from harvested fruits.. There are two types of techniques used in the final processing of cocoa - the expelling method and the roasting method. The press system, as the latter is called, is the modern method and has been adopted by all large scale processing plants. The expeller system considered as less economical still prevails in some parts of the world. Effective laboratory control at all stages of production is important in the processing of cocoa beans. The beans before cleaning and roasting should be subjected to laboratory tests which should continue through all the stages of production.

Cocoa liquor can also be used directly to produce chocolate bars. Its important applications are in the manufacture of chocolates and preparation of certain sweets. But these uses are very minimal. Cocoa powder is used in confectioner's coatings, cakes, cake mixes, and breakfast foods, chocolate mild, other beverages and ice creams

Tea

Tea is the most widely consumed stimulating beverage with pleasant aroma and unique taste. The tea leaf has to undergo several physical and chemical changes before it can be rendered fit for consumption. Based on the method of manufacture, commercial tea is broadly classified as (a) green tea, (b) black tea, and (c) oolong tea. The basic difference lies in the degree of fermentation adopted to each type of tea during manufacturing process. While green tea is produced without fermentation, black tea is fully fermented and oolong tea is produced as a result of partial fermentation. Besides these three types instant tea is also produced in a limited quantity. Of all black tea is produced to the maximum extent, which accounts for about 75% of world tea production

Black tea processing

It consists of the following unit operations:: Withering (partial removal of moisture); rolling/disruption (size reduction); oxidation/fermentation (biochemical reactions in the presence of oxygen); drying; and sorting (fiber removal, grading based on size).. . Withering is the storage of green shoots for about 12 to 24 hours with the partial removal of moisture from the leaf. The advantages of withering are: (1) caffeine content increases (2) improves the flavor index and aroma (3) increases the level of organic acids and improves polyphenol oxidase (PPO) activity. Fermentation is done by keeping the leaf in fermenting drums, racks, or floors. The completion of fermentation is judged by the change in colour (green to coppery) and the pleasant aroma that develops. Drying fermented dhool has got three major objectives - to terminate the biochemical functions by heat denaturation of the enzyme; to reduce moisture to increase shelf stability of black tea and finally to enhance chemical reactions responsible for black tea character and flavor. Drying reduces the astringency, sugar present in the fermented leaf are caramelised. Tea is a hygroscopic material and while cooling and sorting it picks up moisture. Drying tea to 3% is advisable and when packed it should not be higher than 5-6%. (Ramaswamy, 1995).

Tea is packed either in bins, plywood chests, or HM HDPE lined gunny bags.

Coffee

It is the most widely exchanged commodity in the international trade scenario. Coffee is processed by wet method to produce washed coffee and by dry method to produce unwashed coffee. The wet processed coffee is superior and is predominantly followed in processing *Indias arabica* coffee(75%) and part of *robusta* (15%).

Wet process

Coffee seeds are harvested as and when they become ripe. They are sorted to remove immature, diseased, pest infested, dry berries and also leaves. Only fully ripped and matured berries having adequate mucilage and natural pectinolytic enzymes are to be taken for wet processing of coffee. After sorting coffee berries are pulped. Pulping refers to the mechanical removal of red outer skin from the fruit to obtain parchment coffee. It is followed by fermentation. The pectin degrades enzymes, which are inherent to mucilage itself, hydrolises in about 26 to 36 hours in case of *arabica* and 72 hrs. for *robusta*.. Fermentation is complete when parchment feels gritty and no longer sticky when rubbed between the hands. After fermentation they are soaked in clean water for a period of 8-12 hrs by which the colour and quality improves. Drying is an important process in coffee preparation. The wet parchment coffee has a water content of 55% and has to be brought down to 10% for safe storage. At this moisture level enzymatic activity and mould growth is minimum (Sunalini Menon, 1989).

Dry process

In dry process, the entire cherry is directly dried after harvest. The outer skin dries out to form the husk which is then removed mechanically during hulling. Drying in the sun takes 12 to 15 days, depending on the thickness of the layers of the cherries, ambient temperature and the amount of daily sunshine.

Spices

Spices and spice products are the most important natural flavoring materials those have wide applications in the field of food and non-food items including meat and fish, baked foods, sugar, confectionery, beverages, pharmaceuticals and fragrance.

Black pepper

Generally pepper takes about 180-230 days after flowering to reach full maturity. Harvesting at immature stage reduces the bulk density. The first step in the processing is despiking. Trampling with legs is the traditional way, but mechanical devices are also available for despiking which is more convenient, hygienic and time saving. After despiking the pepper is dried to bring down the moisture content from 40% to 8-10% which takes about 6-7 days for sun drying. Drying on cement floor or on polyethylene sheets can reduce the drying time. Solar dryer and electrical dryers can also be used for drying to reduce the drying time. Some of the precautions to be followed for pepper processing are: (1) select varieties which ripens uniformly having good berry size, oil and oleoresin, (2) harvesting immature seeds lead to loss of weight and delay in harvesting lead to berry shedding, (3) berries treated for red ants while harvesting may be washed thoroughly before mixing with other spikes, (4) store pepper in clean bags in well ventilated and moisture free rooms which are free from rodents, and pests. White pepper is prepared by removing the outer pericarp of the berries by any of the following techniques: (1) water steeping technique, (2) steaming or boiling techniques, (3) decortication techniques. Other value added products from pepper are pepper oil, pepper oleoresin, piperine, green pepper in brine etc.

Cardamom

The peak period of harvest is Oct.-Nov. Just ripened fruits or physiologically ripened fruits are harvested. More splitting of capsules is observed in matured capsules. Percentage of dry recovery is highest (30%) in the fully ripened capsules followed by the one harvested at physiological maturity (24%) and in immature stage (14%).. Capsules may be washed in water to remove the adhering soil and a treatment with 2% washing soda for 10 minutes enables to retain the green colour and prevent mould growth.

Curing/ drying is done to reduce the m.c. from 80% to 12%(wet basis). Sun drying takes 5-6 days and the green colour also gets bleached. Electrical drying is a better method wherein capsules can be dried in 10 to 12 hours at 45-50°C retaining its green colour. Pipe curing is the best method from which high quality green cardamom can be obtained. Cardamom oil is the major value added product. Cardamom contains 5-9% oil. Immature cardamom has more oil.

Ginger

Ginger rhizomes should be thoroughly cleaned before peeling. Extreme care is necessary while peeling to prevent loss of volatile oil. Wooden scrapers of bamboo stick is ideal for peeling. Knifes or sickles may leave dark spots. Ginger can be dried on clean bamboo mats or cement floor. Depending on availability of sun light full drying period may vary from 7-14 days. The value added products of ginger are ginger oil, ginger oleoresin and fresh ginger.

Turmeric

Turmeric rhizomes should be washed for removing adhering soil. Then it should be boiled and dried. For boiling

use clean water. The bulbs and the fingers should be boiled separately. While boiling, water should be filled to cover the entire contents. Heating should be uniform for 45-50 minutes. The end point of cooking can be tested by passing between fingers or by piercing a small stick through the rhizome which will easily pass through if properly boiled. Cow dung smeared floor or mats should not be used for drying. It will take 10-15 days for drying. Polishing can be done by sprinkling turmeric powder using a mechanical drum.

Cinnamon

Cinnamon barks and leaves are commercially important. Bark is used to extract oil and oleoresin and leaf for oil. Bark oil has high cinnamaldehyde content and leaf oil has high eugenon. Cinnamon bark is extracted when the red flush of the young leaves is beginning to turn green and the spa is flowing. The process consists of stripping and preparing quills from the inner bark. The stripped stem is rubbed briskly with a heavy brass rod to loosen the inner bark. Two cuts are made round the stem about 30cm apart and two longitudinal slits are made on the opposite side of the stem. The curled pieces of inner bark are next assembled into quills or pipes. The important value added products are bark oil, oleoresin, leaf oil and cassia oil.

Nutmeg and Mace

It is generally harvested when the fruits split. The seed with surrounding scarletaril is removed from the pericarp. Later the mace is taken off and is dried separately from the nutmeg. The proportion of dried shelled nutmeg to dried mace is 20:3. After harvesting nutmegs are dried in the shells either under sun or by mechanical dryers. The important value added products are nutmeg butter, oleoresin, nutmeg oil and mace oil.

Clove

Clove clusters are picked by hand when the buds have reached their full size and most of them develop a pronounced pink flush. From these clusters, cloves are separated from the stems consisting of peduncles and pedicel. Then it is dried. Traditional method of drying is exposing it to sun. Green buds are spread out in a thin layer. It may take about 4-5 days to produce a spice of desirable colour. The important value added products are essential oil, oleoresin and leaf oil.

Rubber

Seventy to eighty five per cent of the crop harvested from rubber plantations in the form of latex. The remaining portion is collected in coagulated form which is collectively known as field coagulum or scarped rubber. Latex in the latex vessels of the rubber tree is sterile, but gets contaminated during collection and processing, by bacteria which leads to premature coagulation of the latex. Important unit operations in the rubber industry are collection, preservation, concentration and coagulation/fermentation. Collection is usually done in the morning hours. The main attributes of the latex preservative are to enhance the pH of the field latex, to deactivate the harmful metallic ions and to hinder the growth of the bacterial population. Ammonia is usually used as preservative.

Concentration of the latex involves removal of a substantial quantity of serum from field latex. It is necessary to reduce the cost of transportation and to get high density, better uniformity in quality and higher degree of purity. Two important commercial methods of concentration are centrifuging and creaming. Different forms of natural rubber are sheet rubber, crepe rubber, technically specified rubber, specialty rubber, graft rubber, deproteinised natural rubber and apoxidised natural rubber. Important steps adopted in the production of sheet rubber are collection, sieving and bulking, dilution, addition of chemicals, coagulation, sheeting and dripping and then drying. About 75%%f the total rubber produced is as sheet rubber.

Cashew

Cashew is one of the most important export oriented commercial crops in India. Being a seasonal crop harvesting of nuts is done during march to June. Before further processing or for storage it is to be dried to bring down the moisture content to 6-8% (d.b.). The processing is mostly done manually and consists of roasting, shelling, kernel drying, peeling, grading and packing.

Roasting

It is done to make the shell brittle and to loosen the kernel from the shell. Nuts after roasting are shelled manually or mechanically. The output per worker is estimated to be 14 to 22 kg of kernel in 8 hrs. Kernels are further dried to reduce the moisture and to loosen the adhering testa. The most commonly used dryer is Borma dryer. The nuts are placed in wire mesh trays and loaded in the drying chamber which is indirectly heated by the gas from the furnace at the bottom. the moisture content of the dried samples will be in the range of 2-4% (d.b).

Peeling is the removal of testa from the kernel. The average peeling capacity is 7-10 kg. / person/ day. Kernels are graded on the basis of specification prescribed by Govt. of India under export act, which recognizes 26 different export grades of kernels.

Cashew nut shell liquid (CNSL): It is a naturally occurring phenol which is contained in the softy honeycomb structure between the shell and the kernel of the cashew nut. It is obtained during the processing of nuts in isolation of kernels.

Oil Palm

Palm oil is derived from the fleshy mesocarp of the fresh oil palm fruit. After harvesting the fruits are to be processed immediately to inactivate the enzyme lipase which otherwise increases the FFA content in the palm oil. The various processes involved in the extraction of palm oil are sterilisation, stripping, digestion, pressing, clarification, and vacuum drying. The raw palm oil is stored in tanks provided with steam coils. A small scale palm oil extracting unit of capacity 200 kg of FFB/h has been developed at CPCRI which can cater to the need of oil palm plantation of 30 ha. All the machines required for the extraction unit were developed indigenously. The extraction efficiency of the mill is 18.2 per cent and the process efficiency of the mill is 83 per cent. The cost of processing of one kg. of FFB is Rs.0.31 and the cost of extraction of one kg. of crude red palm oil is Rs. 1.68. and the processing cost for one tone of FFB is Rs. 310/-.. . A larger capacity palm oil extraction unit, developed by Regional Research Laboratory, Trivandrum, is also available.

The minimum details on the post harvest technology aspects of plantation crops only provided in this review. A detailed treatment of the topic may be seen in an exclusive publication by CPCRI (Bosco *et al.*, 1998).

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Role of Coordinated Projects in Evaluation and Release of Improved Varieties and Hybrids with Special Reference to Plantation Crops

H. Hameed Khan

Introduction

The Indian Council of Agricultural Research(ICAR has established a large number of All India Coordinated Research Projects (AICRPs), that link up research programmes in ICAR research institutes, the State Agricultural Universities (SAU) and private non-governmental institutions in a cooperative frame work. Under the programme, Scientists with common interest from different institutions and devoted to a particular item of work are brought together. The coordinated projects have substantial funds allocated to them, and they have become an important instrument in collaborative agricultural research in different agricultural institutions in the country.

The first phase of these Coordinated projects on improvement in maize was established with the beginning of Second Five Year Plan in 1957, preceding the period of reorganization of the Council. The setting up of All India Coordinated Agronomic Experiment Scheme in 1953 involving a number of institutions, has given sufficient experience in the Council to start other programmes. Even before 1953, an All India Coordinated Wheat Rust Scheme was in operation since 1947. Following all these and the experiences gained, 82 different All India Coordinated Research Projects were in operation by the end of Eighth Five Year Plan.

Out of 82 Coordinated Projects in the country, 33 are under Crop Science Division, 16 under Horticulture Division, 16 under Soil and Agronomy, 10 under Agricultural Engineering and 7 under Animal Science Division. During the past three decades large number of coordinated research projects have been set up and some very diverse areas of research have been addressed in these projects.

The All India Coordinated Research Project consists of a national coordination unit and a large number of cooperating centres located in different states, under State Agricultural Universities and ICAR Institutes, depending upon the research programme in progress at these centres. The coordination unit is headed by a Project Coordinator and assisted by a small group of scientists from different disciplines. Mostly, the headquarters of the Coordinator is located in ICAR Institutes, although few of them are also in the SAUs. The Project Coordinator helps define priority areas of research in AICRP Group Meeting (Workshop) of scientists from coordinating centres and different cooperating institutions.

The coordinated projects provide an institutional mechanism for exchange of resources and improved material for use in research programmes of different groups of scientists in the SAUs and ICAR institutes.

Advantages of coordinated projects

(I) Focus on national programmes: Coordinated projects help in focussing on selected high priority area of research relevant to the agricultural development policy of the central and state governments as well as the needs of the farmers. Important decisions on this are taken in the group meetings for implementation of common national and regional programmes.

(II) Multilocation testing: India is a large country with diverse agro-ecological conditions and much heterogenity in farming conditions with large, medium and small farmers. It is important that recommended technologies are tested both for their wider adaptability as well as stability of performance under different conditions of management. This also helps one to understand the performance/potential of a specific genetic material when put under different agroecological conditions.

(III) Evaluation for pests and diseases: The acceptance of a variety or hybrid for release depends not only on the yield improvement realised over the local check but also on their disease/pest reaction. Hence, the varieties are also screened for resistance to major pests and diseases. New sources of resistance to diseases and pests are identified, as the genetic material from different cooperating centres are entered in the coordinated trials and are tested under a wide range of conditions.

(iv) Exchange of scientific information:: Coordinated projects bring together scientists from various institutions and provide an unique opportunity for exchange of ideas and cooperation.

(v) Inter-institutional and inter-disciplinary linkages: Most of the production technologies require a multi-disciplinary approach. Coordinated projects serve as a link to foster a multi- disciplinary approach and perspective.

(vi) Development of strategic plans: In view of the wide network, coordinated projects have helped in identifying problems and defining national priorities.

Linkages with international programmes:: : The ordinated projects are programmed to develop close kages with Consultative Group on International gricultural Research(CGIAR). A great deal of germplasm nd new technologies that flows into India are from onsultative Group Centres. These are channelled through e Coordinator.

(viii) Information or technology base:: The AICRPs have rown as technological base for National level planning and anagement of resources.

x) The annual/biennial group meetings create a sence of sponsibility and involvement for the scientists. It creates a althy and competitive atmosphere to project the hievements of their centres.

) The recommendations on new technologies emerging out f group meetings are more authentic as they are thoroughly ield tested and satisfied.

Involvement of AICRP's in release of varieties

The coordinated projects play a major role in release of varieties. As indicated earlier an extensive testing mechanism has been evolved under AICRP network to undertake multilocation testing for identification and release of stable varieties and hybrids

In India, cropping patterns and practices of cultivation differ widely. Thus, genotypes developed for one egion may not show the same performance in other regions. Keeping in view of the climatic and edaphic factors, the country has been divided into different zones for annual crops. The zoning is also crop specific depending upon the area of ultivation of a crop:

e.g. a) *Rice*::Zone-I (Tamil Nadu, Andhra Pradesh, Kerala, Karnataka, Pondicherry, Maharashtra, Gujarat , Goa)
Zone-II (Orissa, West Bengal, Bihar, Eastern UP, Madhya Pradesh, Assam, Meghalaya, Arunachal ,Pradesh, Mizoram, Tripura, Manipur
Zone-III (Himachal Pradesh and Uttar Pradesh)

b) *Cotton* North zone: Haryana, Punjab, Rajasthan
Central zone: Gujarat, Madhya Pradesh, Maharashtra
South zone: Andhra Pradesh, Karnataka, Tamil Nadu.

c) *Sugarcane*: Tropics : Andhra Pradesh, Gujarat, Karnataka, Maharashtra, Orissa, Tamil Nadu
Sub-tropics: Bihar, Haryana, Punjab, Uttar Pradesh, Rajasthan.

d) *Oilseeds:* (Rape-seed and Mustard) - Six zones

Several statistical proceedures for selecting a optimum environment has been indicated as an alternative to testing over locations and years is expensive in terms of time and money. By using these methods, environmental testing can be restricted to those environments which are most likely to provide maximum information (Khem Singh Gill, 1992).

Criteria for identification of variety could be at least 20% yield advantage over the most recently released variety used as a standard check. Nevertheless, where such yield advantage is not apparent, the variety should not be inferior, but superior in at least in one of the characters of considerable importance. A variety has to be tested for three years prior to its identification. The vareities are tested under Initial Varietal Trial (IVT) at national level followed by Advance Varietal Trial-1 (AVT-1) and AVT-2 etc. at zonal level (Fig.1). The number of locations vary depending upon the trial. They are 10-12 for IET and 20-25 for AVT.

The Coordinator normally visits the testing centres to oversee the technical aspects of cultivation and evaluation. After recieving the yield data, decoding is done by the Coordinator to establish the orginal identity of a variety with reference to yield and other characters. The system of zoning and varietal testing has lyielded good results. However, there is scope for improvement on scientific basis (Khem Singh Gill, 1972).

Based on all available data, variety identification proforma are filled and submitted by breeders during the workshop for consideration of the Variety Identification Committee. The proforma calls for details about parentage, breeding methodology, important morphological distinguishing features, year of entry into coordinated project varietal trials, quantity of breeder seed available, summary yield data fof three years in that zone etc. Besides the above adaptability of the variety/hybrid to changes in agronomic conditions, reaction to major diseases, reaction to insect pests and quality characteristics are also to be furnished. The verity identification committee is constituted by the ICAR which is chaired by the Dy. Director General/Asst. Director General and some senior experts nominated by the ICAR which

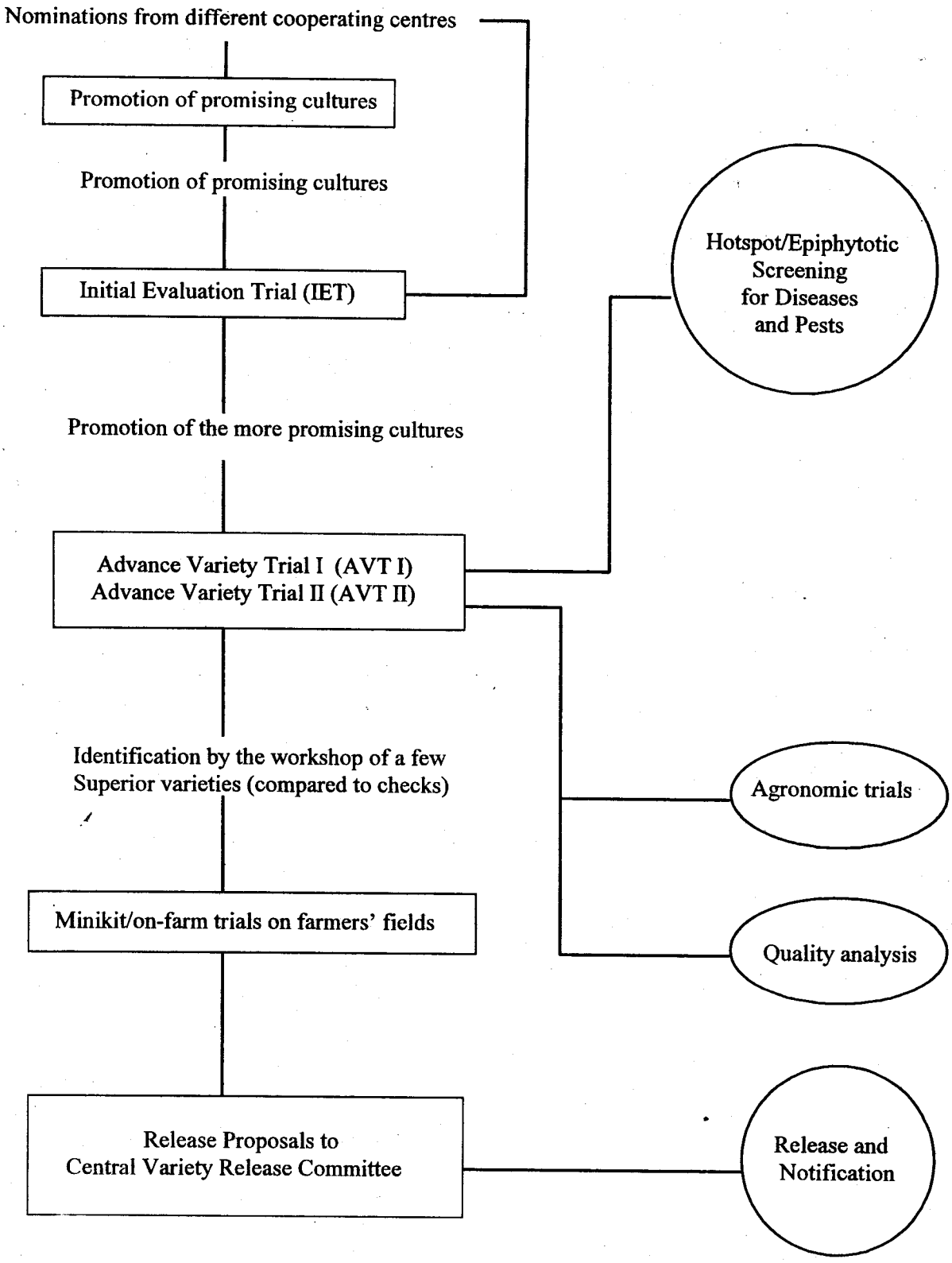


Fig. 1: Procedure for varietal testing and release through coordinated projects

include Director of Research of host University, NSC/SFIC/ Seed Corporation, Seed Division (DAC), concerned Directors of crop improvement programmes, representatives of private sectors, all principal investigators etc. The Project Director/ Project Coordinator acts as a Member Secretary.

Once the variety is identified by the workshop, the breeder sends the proposal for release and notification by the Central Variety Release Committee, which is a Statutory Body under Department of Agriculture and Cooperation, Govt. Of India. The Committee is chaired by the Dy. Director General, ICAR. All Directors of Agriculture of different states, Directors of seed certification agencies, the concerned Project Coordinator and some representatives of seed industry, as well as farmers are also members. The Committee deliberates on the proposals,, recommends and or rejects the variety based on its strength. Once a variety is released and simultaneously notified by the committee, its certified seed production programme lcan be undertaken by either public or private seed organizations. No seed can be certified unless the variety is released and notified through this procedure.

Obviously, the coordinating system is a powerful mechanism for ensuring the release and production of only well tested superior varieties for different agroclimatic conditions.

As indicated earlier, one of the guiding principles of these coordinated projects is the interdisciplinary and inter-institutional linkages. Joint efforts of breeders with pathologists, agronomists, nutritionists, entomologists, nematologists, physiologists etc. Have helped in developing multiple disease and pest resistant varieties, varieties possessing drought tolerance, good quality traits and also appropriate production and protection requirements for achieving higher production as well as sustainability.

The proformae for submission of proposals for release of crop variety is almost similar for annual crops and plantation crops. However, detailed guidelines for filling up the proformae are available separately for annual crops and plantation crops. Guidelines for filling up the proforma for plantations crops is appended.

Plantation Crops (Coconut, Arecanut, Cashew)

Unlike annual crops where new varieties can be evolved early, it is difficult in plantation crops since they have a long gestation period. Plantation crops are put under trial for many years which require considerable time to ascertain their stability and agronomic evaluation.

In the research institutions of ICAR and SAUs, scientists have access to introduced germplasm and standard evaluation procedures are followed to identify desirable traits and they are well documented. Wherever possible juvenile characters are studied and correlated with adult palm characters especially the yield. These elite germplasm is thoroughly evaluated in the research institutions and at the same time are put into state/regional trials in the Coordinated project network under well defined set of management practices. This enables the scientists to test a variety or hybrid under different agro-climatic conditions. From the seedlings stage, all biometrical characters are recorded in each region covering the vegetative and reproductive phases. Based on the desirable yield characters, the variety/hybrid is proposed for release. Under the guidelines for filling the proforma, the requirements of yield, its performance in relation to local checks and other pre-requisites for release of a variety in plantation crops are indicated.

Important points to be considered in filling up the proforma *for variety release (coconut)*

1. *Mean yield of the palm considering the average yield of* last four years (with reference to fertiliser responsiveness).
2. *Highest yield recorded and age at which the yield was* obtained.
3. Yield data – atleast for ten harvests from second annual harvest to 11th harvest.
4. Provide comparative yield performance in relation to the variety/hybrid recommended for the region.
5. The kernel characters are to be recorded as an average of ten nuts.

Besides the above, certain local germplasm which have been cultivated extensively over a long period whose performance is assessed to be superior has also been considered for release as a variety.

Some of the meetings where the variety release *proposals submitted are: Advisory Committee Meeting of* NARP; Zonal Research Advisory Council; State level Workshop on Package of Practices; National Workshops of *All India Coordinated Research Projects; NARP National* Workshops etc. The proforma has been revised time and again under the guidance from Central Sub Committee on Crop Standards, Notification and Release of Varieties for Horticultural Crops. The proposals for release of variety will be delibrated in a special session on Variety Release in the AICRP Workshops (e.g. Palms, Cashew). Following its acceptance 20 copies of the proposals will be submitted to the Central Sub Committee on Crops Standards, Notification and Release of Varieties, for notification of the variety.

Particulars of varieties released

Coconut

In coconut two high yielding varieties and seven

hybrids have been developed and released under the Project for cultivation in different coconut growing states. The details of the released varieties/hybrids are provided in Table 1.

In addition to this, the Coordinating centres have recommended, on their own, six coconut varieties/hybrids for release and cultivation in different states. The details are given in Table 2.

In drought prone areas, planting of LCT x COD and LCOT x GBGD hybrids which show good performance under drought conditions is recommended.

Arecanut

Based on the evaluation of arecanut germplasm, three high yielding varieties viz., Sumangala (VTL-11), Sreemangala (VTL-17) and Mohitnagar, which produced 53.5 to 81.7% higher yield than the earlier released variety (Mangala) have been recommended for release by the

Table 2. Varieties/hybrids released by Centres

Variety/hybrid	States/centres
Kerasree (WCT x MYD)	Kerala/Pilicode
Keraganga (WCT x GBGD)	-do-
Anandaganga (ADOT x GBGD)	-do-
Kera Soubhagya* (WCT x SSA)	-do-
VHC-1 (ECT x GBGD)	T N /Veppankulam
VPM-3 (Andaman Ordinary)	-do-
Philippines Ordinary	Kerala, AP, Maharashtra and West bengal
COD (As a tendernut variety)	

* Proposed for release

Table 1. Details of coconut varieties/hybrids released by AICRIP Palms

Sl..No.	Variety/hybrids	Year	Centres involved	States for which recommended
1	Chandrakalpa (Laccadive Ordy.)	1985	Ambajipeta, Kasaragod Ratnagiri, Veppankulam	Kerala, Karnataka, AP, Maharahtra
2	Lakshaganga (LCTx GBGD)	1985	Pilicode Kasaragod	Kerala
3	Chandrasankara (COD x WCT)	1985	Pilicode Kasaragod	Kerala
4	Chandralaksha (LCT x COD)	1985	Pilicode Kasaragod	Kerala
5	Pratap (Banawali green round)	1987	Ratnagiri	Maharashtra
6	VHC-2 (ECT x MYD)	1987	Veppankulam	Tamil Nadu
7	Kerasankara (WCT x COD)	1989	Kasaragod, Ambajipeta Pilicode, Tatnagiri	Kerala, Coastal Andhra, Coastal Maharashtra
8	Godavari Ganga (ECT x GBGD)	1991	Ambajipeta, Veppankulam	Andhra Pradesh
9	Double Century (Philippines Ord.)	1993	Ambajipeta	Andhra Pradesh
1	**Oil Palm** Palode-I & Palode-II	1998	Palode	

Workshops of All India Co-ordinated Research Project on Palms. The details are given below::

Name of the variety	Mean chali yield (kg/palm/year)	Increase over Mangala (%)	Year of release
Mangala	2.02	-	-
Sumangala	3.28	62.4	1985
Sreemangala	3.10	53.5	1985
Mohitnagar	3.67	81.7	1991

PROFORMA FOR SUBMISSION OF PROPOSAL FOR RELEASE OF PLANTATION CROP-VARIETY TO CENTRAL SUB-COMMITTEE ON CROP STANDARDS, NOTIFICATION AND RELEASE OF VARIETIES

1. Name of the Crop and Species :

2.a) Name of the variety under which tested::

b) Proposed name of the variety

3. Sponsored by

4. a) Institution or agency responsible for developing variety(with address)

b) Name of persons who helped in the development of variety :

5. a) Parentage with details of its pedigree

b) Source of material in case of introduction

c) Breeding method

d) Breeding objective

6. State the varieties which resemble most closely the proposed variety - in general characteristics :

7. a) Whether recommended by Seminar/Conference/ Workshop/State Seed Sub-Committee :

b) If so, its recommendations with specific justification for the release of proposed variety :

c) Specific areas of its adaptation

8. Recommended ecology

9. Description of variety/hybrid

a) Plant height

b) Distinguishing morphological characters(For each crop, distinguishing morphological characters are given separately):

c) Reaction to major diseases under field and controlled conditions(reaction to physiological strains/races/bio-types to be indicated wherver possible)

d) Reactions to major pests (under field and controlled conditions including store pests)

e) Agronomic features(fertilizer responsiveness etc.)

f) Reaction to stresses

11. a) Yield data in regional/inter-regional/ district trials year-wise (levels of fertilizer application, density of plant population and ***superiority over local control/standard variety to be indicated***)

b) Yield data from national demonstration large scale demonstration

c) Average yield under normal conditions (yield in kg/hectare)

12. a) Agency responsible for maintaining breeder seed

b) Quantity of breeder seed in stock(in kg)

13. Information on the acceptability of the variety by farmers/consumers/industry

14. Specific recommendations, if any, for Seed Production

15. Any other pertinent information

Signature of Head of Institute

Guidelines for submission of proposal for release of Crop Varieties in Plantation Crops

For release of varieties in Plantation Crops, the existing proforma for release of crop varieties may be used. Guidelines for filling up proforma for each crop are given below:

I. COCONUT

- Under item **2 (a)**, the parentage of the hybrid is to be furnished e.g. WCT x MYD.
- Under item **5(a)**, parentage with details of its pedigree should include the details of the original source of the parental material. In case the parents are derived from *inter-se*, the source populations and in case of introductions, the source from which the original parental material introduced, is to be given. The description of the parents is to be appended separately.
- Under **5(d),** breeding objectives, the characters anticipated in the hybrid based on the parental characters, is to be furnished.
- Under item **9,** description of variety/hybrid, the following characters are to be given:

a) Habitat

b) Average number of functional leaves on the crown (mean for last four years)

c) Age at first flowering alongwith leaf axil number in which the first flowering is noticed

d) Annual production of female flowers (average of last four years)

e) Mean nut yield/palm (average of last four years)

f) Highest yield recorded per palm alongwith age at which it was recorded

g) Colour of the nut

h) Mean weight of nut (average of ten nuts)

- Under item **11(a),** the yield data in regional/inter-regional and district trials should include detailed annual yields atleast for ten harvests starting from second annual harvest to 11th harvest. While furnishing the yield data, comparative performance in relation to the variety/hybrid recommended for the region is also to be furnished.
- Under **11(c),** average yield under normal conditions should be given for the last four years

i) Mean weight of husked nut
ii) Mean weight of copra per nut
iii) Mean copra yield per palm per year

- Under **12(b),** quantity of breeders' seed in stock including the number of female palms available and the production potential of the centre for supply of parental material as well as hybrid seedlings annually should be furnished.
- Under **14,** the specific recommendations, if any, for seed production, the information on the availability of the parental lines in the existing seed gardens in the country, etc. is to be furnished.
- The proposal for release of tender nut variety should include data on following characters of tender nut water.

a) Volume of water
b) Total soluble sugars
c) Reducing sugars
d) Free amino acids
e) Content of K and Na
f) pH

II. ARECANUT

The guidelines detailed above for coconut are also applicable to the arecanut. The detailed description of variety/ hybrid should include the following characters::

:

1. Crown shape
2. Girth above fixed mark
3. Internodal length (cm)
4. Number of leaves
5. Number of leaflets
6. Number of mid ribs
7. Length of oldest leaf (cm)
8. Breadth of oldest leaf (cm)
9. Leaf sheath length (cm)
10. Leaf sheath breadth (cm)
11. Number of female flowers/inflorescence
12. Number of bunches/year
13. Colour of ripe nut
14. Nut shape
15. Fruit length (cm)
16. Fruit breadth(cm)
17. Fruit weight (cm)
18. Husk thickness (cm)
19. Kernel length (cm)
20. Kernel breadth (cm)
21. Dry weight of kernel (g)

While furnishing the yield data for the variety/hybrid, comparative performance in relation to any of the already released varieties *viz.* Mangala, Sumangala, Sreemangala and Mohitnagar is to be given.

III. CASHEW

- The breeding objectives in cashew are identified as follows:

(a) Early to mid season flowering

(b) Short/Medium duration (61-80 days) of flowering

(c) High yield (more than 8 kg nut yield/tree/year after 10 years of planting)

(d) Medium to bold nut size (min 7 g nut or 2 g kernel)

(e) Medium to high shelling percentage (25-30%)

(f) Low kernel counts (210-240 wholes/lb).

- Under item 9(a), the following data pertains to morphological characters are to be furnished

1. Plant height (cm)
2. Branching
3. Number of laterals/leader
4. Flowering time(specify months) from..... to.....
5. Flowering duration (number of days)
6. Harvesting time (specify months) from..... to.....
7. *Panicle shape*
8. Sex ratio (male to female)
9. *Setting percentage*
10. Number of fruits per panicle
11. Coherence of nut with apple
12. Nut weight (g)
13. *Number of nuts per kg*
14. Shelling percentage
15. Kernel count (wholes/lb)
16. Apple colour
17. Apple shape
18. Apple weight (g)
19. Cumulative yield (for clonal progenies the data for minimum six annual harvests to be reported, while for seedlings progenies minimum of 8 annual harvests is to be given).
20. Mean annual yield (For the last four years)
21. Highest yield of a single tree recorded (specify age of the plant and weight of nuts)

- Under item 19 and 20, comparative yield performance of variety recommended for the region is to be given
- As the maturity from seedlings to seed is not applicable to cashew, the same may be deleted. Similarly the maturity group specifying early, medium and late is already covered in the morphological characters, this could also be deleted from the proforma.
- Under item 9(d), the quality of produce of grain, forage/ fibre including value, where relevant, may be modified as 'quality of kernels'. The data on kernel sugars (mg/100 g of defatted kernel flour); kernel phenols (g /100 mg kernel flour); kernel proteins (g/100 g defatted kernel flour) and kernel lysine (g /mg kernel protein) may be included.

Reference

Khem Singh Gill, 1992. *Zonalization-vis-a-vis varietal evaluation, ICAR. Feb. 24-26.*

Participatory Plant Breeding Programmes

S. Arulraj

Prelude

As we enter the 21st century, we observe that agriculture in India faces enormous challenges. Production in industrial and green revolution agriculture is now close to or above levels that can be sustained by the natural resource base. Yet the demand for food and non-food products will grow as populations expand, thus increasing further the pressure on natural resources. Agriculture expands into hitherto uncultivated forests, grasslands and waste lands; degrades on-farm resources through erosive and environmentally damaging practices and transfers some of the cost of production off the farm to other sectors of the environment and economy. The growing food requirements will have to be met, atleast in part, through improvements to agriculture in the resource-poor regions of the country. But the farming households in these regions have poor access to external resources in the form of credit and nutrient and pest control inputs and are rarely adequately supported by research and extension services.

Technology Spread Among Resource-Poor Farmers

During the past fifty years, agricultural development policies have been remarkably successful by emphasizing external inputs as the means to increase food production. This has led to growth in the consumption of pesticides, inorganic fertilizer, animal feed stuffs and tractors and other machinery. Consequently, we have achieved outstanding agricultural progress in the recent years. However, there has been little effect of green revolution technologies in most of the holdings of the resource-poor farmers. New technologies rarely spread beyond the large/resourceful farmers and the aggregate impact remains small. But it is the declared intention of the Government in our country to increase production from these holdings as well, both to improve the standard of living of these hitherto neglected sector of farmers and also to make a greater contribution to our country's increasing needs. Where extension does reach them, the approach has been to attempt the transfer of technologies proven to work on research stations rather than on farmers' fields. Consequently, new technologies rarely spread beyond the large farmers and the aggregate impact remains small. This lack of progress by resource-poor farmers is a feature of agricultural development in many countries and it has been argued that it is largely due to its inappropriateness of the transfer of technology (TOT) approach used in many research and development programmes.

The Linear Model

World-wide, most scientists and economists implicitly use the 'popular' linear model of KGEU (Knowledge Generation, Exchange and Utilization). This linear model underpins the design of most of the national agricultural knowledge institutions, the World Bank's T&V system of extension, the training of agricultural scientists and so on. The model is linear and sequential, in that research first generates knowledge, which is then transferred by extension and finally utilized by farmers. The one-directional flow is from national agricultural research system (NARS) to subject matter specialists, to extension workers, to contact farmers and from them to follower farmers. The model does not consider farmers as experimenters and technology developers but as passive receptors and users. In its extreme form, TOT can be summarized as an approach where scientists develop high input technologies on research stations where there are no constraints on resources and often with little or no direct contact with target farmers; these technologies are then 'transferred' to farmers via a process of demonstration and 'education'. The problem with modern agricultural science is that technologies are finalized before farmers get to see them. If new technologies are appropriate and fit a particular farmer's conditions or needs, then they stand a good chance of being adopted. But if they do not fit and if farmers are unable to make changes, then they have only one choice. They have to adapt to the technology or reject it entirely. While this approach has undoubtedly worked in many of the more favourable regions, it can have serious limitations for less favourable regions because the developed technologies can so easily be wholly inappropriate for an environment which is both physically and socio-economically poor. Furthermore, in the less favourable regions, the likelihood of TOT approach developing inappropriate technologies is often exacerbated by a very limited understanding of the real needs and constraints of the resource-poor farmers.

Participatory Technology Development (PTD)

The alternative to overcome the present malady is to seek and encourage the involvement of farmers in adapting technologies to their conditions. This constitutes a radical reversal of the normal mode of research and technology generation, because it requires interactive participation between professionals and farmers. Participatory Technology Development (PTD) is a process in which the knowledge and

research capacities of farmers are joined with those of scientific institutions, whilst at the same time strengthening local capacities to experiment and innovate. Farmers are encouraged to generate and evaluate indigenous technologies and to choose and adapt external ones on the basis of their own knowledge and value systems.

Emergence of PTD

In the recent years, increasing numbers of agricultural development projects have demonstrated that agricultural production can be improved in resource –poor regions through the adoption of technologies provided that farming households themselves are fully involved in the generation of technologies, in their extension to other farmers and in the experimental adaptation to local conditions. In many locations, small revolutions in institutional support and farming practice are occurring; returns to investment are rapid; the poor became better off and more secure; the region produces surpluses and the country as a whole benefit. But, of course, researchers and farmers participate in different ways, depending on the degree of control each factor has over the research process. The most common form of 'participatory' research is researcher designed and implemented, even though it might be conducted in farmers' fields. Many on-farm trials and demonstration plots represent nothing better than passive participation. Less commonly, farmers may implement trials designed by researchers. But greater roles for farmers are even rarer. In a few researcher-designed experiments, even though farmers "participate" in implementing the trials, there is widespread uncertainty about what researchers are actually trying to achieve. Farmers misunderstand experiments and reject the new technologies. The reason is that "cooperation between farmers and researchers implies two groups continually listening carefully to one another. Most of the farmers are avid listeners to the researchers. The challenge is for all the on-farm researchers to complete the circle".

Although this means that technology development must involve farmers, it does not mean that scientific research has no place. Research will have to contribute on many fronts, such as in the development of resistant cultivars, knowledge about the life cycle of pests, biological control methods, suitable crops for erosion control and process in nitrogen fixation. Such research also gives insight into complex processes such as the movement of nutrients in the soil and their accessibility for plants. But all these contributions must be seen as providing choices for farmers as they make farm-specific decisions and move the whole farm towards greater *sustainability*.

Participatory Plant Breeding Programme

The history of crop domestication is essentially the application of farmer selection techniques to the genetic diversity presented in their fields. Farmers are capable of maintaining a large number of varieties of crop and can select plants with desirable characteristics for continued development. Thus the majority of examples used to support the proposal of giving farmers the leading role in on-farm experimentation involve testing new varieties or new crops (Farrington and Martin, 1988). However, participation, if it is to become part of the research system, must clearly be interactive and empowering. Any pretence to participation will result in little change. Allowing farmers just to come to meetings or letting a few representatives sit on committees will be insufficient. One of the justification for giving more emphasis to farmer participation in breeding programmes is the argument that farmers have knowledge, experience and an ability to experiment that have been virtually ignored by conventional agricultural research. Participatory research is also put forward as a step towards "empowerment", a way of enabling farmers to organize and either demand attention from the State or perform for themselves those functions that the State is unwilling or unable to provide.

Typology of Participation

Pretty (1994) described the following seven grades of farmers' participation in technology development and transfer and it would be ideal if we could progress in the participation ladder from the present lower grade to the highest possible grade for ensuring success in our participatory plant breeding programmes.

Passive participation **:** People participate by being told what is going to happen or has already happened. It is a unilateral announcement by the scientists without any listening to people's responses. The information being shared belongs to the external professionals.

Participation in information giving *:* People participate by answering questions posed by scientists using interview schedule or similar approaches. People do not have opportunity to influence proceedings, as the findings of the scientists are neither shared nor checked for accuracy.

Participation by consultation **:** People participate by being consulted and scientists listen to their views. Scientists define both problems and solutions and modify these in the light of people's responses. Such a consultative process does not concede any share in decision-making and scientists are under no obligation to take on board farmers' views.

Participation by material incentive **:** People participate by providing resources, for example land, water and labour, in return for cash or other material incentives. Much on-farm research falls in this category, as the farmers provide the fields

but are not involved in the experimentation. It is very common to see this called participation, yet people have no stake in prolonging activities when the incentives end.

Functional participation: People participate by forming groups to meet predetermined objectives related to the mandate of the research institution. Such involvement does not tend to be at the early stages of project cycles or planning, but rather after major decisions have been made. These instructions tend to be dependent on scientists, but may become self-dependent.

Interactive participation: People participate in joint analysis, which leads to action plans and formation of new local institutions or the strengthening of existing ones. It tends to involve interdisciplinary methodologies that seek multiple perspectives and make use of systematic and structured learning processes. These groups take control over local decisions and so people have a stake in maintaining structures or practices.

Self-mobilization: People participate by taking initiative independent of research institutions to change systems. They develop contacts with research institutions for resources and technical advice they need, but retain control over how resources are used.

Stages In Participatory Programme Implementation Process

Chamala (1995) suggested a detailed six-stage participative action management planning process (Fig. 1.) which would serve as a guide for scientists in implementing an effective participatory plant breeding programme.

PTD - A success in Developed Countries

It is well documented in both Euro-America and many developing countries that the farmers have been actively involved in identifying and prioritizing agricultural problems, seeking solutions to the problems and extending information on successful solutions to other farmers. This capacity existed prior to the establishment of national agricultural research and extension services in places such as the U.K. It is also apparent that farmers continue with their own research and extension agenda outside of the public with their own research institutes to provide these same functions in the United States and Niger.

Indian Experience

ICRISAT model: In India, Participatory Technology development Projects have been taken up by a few centres and a detailed documentation on the experiences gained through these projects are yet to be done. During late eighties, ICRISAT conducted a participatory plant breeding programme to select promising pigeon pea types suited to selected districts. Farmers were involved in all the stages of plant breeding process, right from the selection of parents to final evaluation, selection and multiplication. The Institute reported its experience as highly rewarding and documented the entire process in the form of a video cassette and provided the same to all the interested scientists.

Experience of a NGO: Similarly, in a project implemented in West Bengal by the Ramakrishna Mission Lokasiksha Parishad, based on the prioritized problems, on-farm studies were undertaken by the farmers on varietal evaluation for lowland with water stagnation upto 50 cm water to identify rice varieties for increasing the productivity level in the low-land rice ecosystem.

Project at Sugarcane Breeding Institute: Considering the importance of assessing the relevance of the Participatory Technology Development (PTD) approach under Indian conditions, a collaborative research project entitled "Use of Participatory Technology Development and Indigenous Technical Knowledge in sugarcane development programmes - an exploratory study" was conducted by the author during 1993-97 at Sugarcane Breeding Institute, Coimbatore and Annamalai University. Selection of sugarcane clones suitable for cultivation in wetland conditions as prevalent in the study area was listed as one of the priority areas of research in the "Transect analysis" conducted in the villages for listing and prioritising the problems. In the trial under discussion, 14 pre-release sugarcane clones were tried. Farmers were involved at various stages of experimentation from laying out of the trial to the collection of data on germination per cent, tiller count, cane yield etc. The results obtained in the trial are presented in the Table 1.

Table 1. Yield of different clones of sugarcane tried in the PTD Project

Name of the sugarcane clone	Cane yield (t/ha)
Co 8362	122.25
Co 8371	141.00
Co 85019	137.00
Co 86002	149.25
Co 86010	148.00
Co 7704	124.75
Co 7914	182.75
Co 8014	121.75
Co 8021	162.75
Co 8122	150.25
CoG 93076	178.75
Co 87044	143.00
Co 87025	140.75
Co 86032	156.00

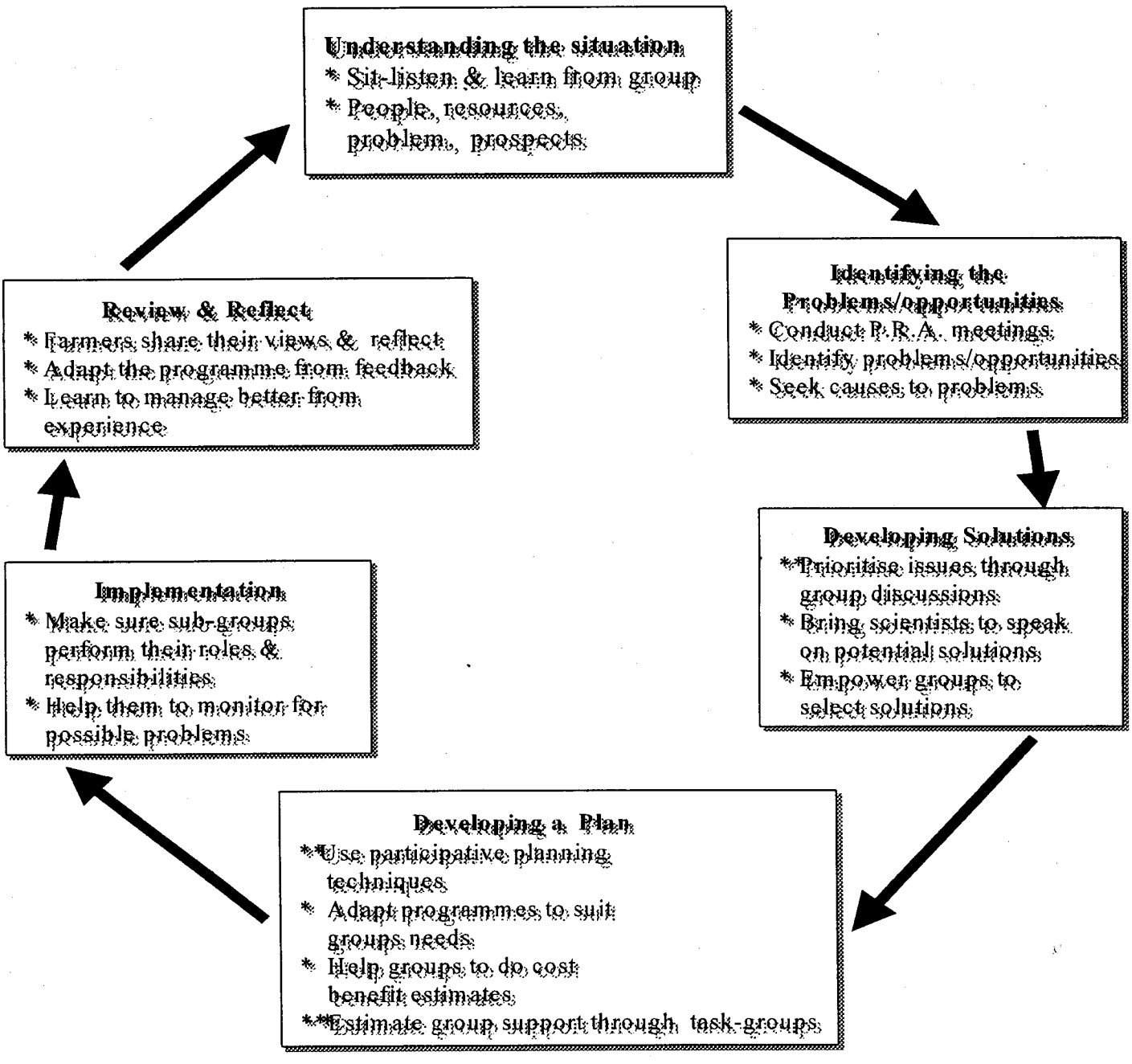


Fig. 1. Detailed six-stage Participatory Programme Implementaion Cycle

At the Farmer-Scientist Workshop conducted at the end of the crop season, the decision taken on the follow-up action to be taken up was as follows: "Taking into consideration of the cane yield obtained from different clones, morphological characteristics as observed by farmers at various stages of crop growth in the trial plot and also their latest status of resistance reactions to red rot disease, it was decided that the farmers in the village would take up planting of CoG 93076, Co 8021 and Co 86010 on a commercial scale". It is to be noted that the clone CoG 93076 was subsequently released for commercial cultivation in the State based on its performance in the multilocation trials conducted by the State Agricultural University. While the development personnel in similar areas were struggling to multiply the variety faster in their areas of operation, the variety was spreading in the study area very fast due to the informal one to one communications among the farmers. Based on this experience, it was inferred that though the participatory varietal selection programme might look laborious and cumbersome, extent of efforts needed to spread new varieties thus identified would be greatly reduced as compared to the present system of transfer of technology process.

Shortcomings in the PTD approach

The relationship between local people and outside researchers and facilitators can be problematic. The process of Participatory Technology Development is usually prompted by the suggestion or initiative of outsiders who-because they have a preconceived idea of how the process should work-tend at least in the early stages to dominate decision-making. Enabling a take-over of ownership and control by the rural participants requires a suppression of normal professional attitudes and behaviour. In addition to this, the transaction costs of participatory methods are extremely high, raising questions about the feasibility of scaling up from small-scale intensive activities to large scale participatory programmes. In addition, farmers' acceptance of this methodology itself may pose a problem. For example, in the study conducted by the Sugarcane Breeding Institute referred above, the author faced the problem of 'a number of trials that failed'. The trial for the selection of sugarcane clones for upland conditions from among 12 pre-release clones failed as the farmer who has volunteered for conducting the trial in the Interaction Meeting, later became pessimistic about the cane yield that could be obtained from new sugarcane clones and refused to take up this trial. Similarly, another clonal trial for identifying sugarcane clones suitable for drought prone areas also failed as the excess irrigation given by the farmer (over-enthusiasm?) during the early phase of the crop has severely affected the germination of the seed materials. Hence the experiment was discontinued.

Suggestions

The success of participatory technology development process (including participatory plant breeding programmes) as implemented in a number of developing and developed countries would lead to the following suggestions:

1. Participatory plant breeding approach could be used as an important tool in the identification of location-specific varieties.

2. The initial response to this approach from science managers, scientist colleagues, extension personnel and farmers may be less encouraging. However, when the approach is continued to be implemented with determination, the level of success would improve significantly.

3. In developing countries like India, State sponsored agricultural research programmes may have to be continued for some more years. The fundamental research and the first level applied research may be conducted by the state supported agricultural research system. Farmers' participation may be encouraged, in the beginning, in the pre-final and final level clonal testing programmes. As the farmers gain experience in this type of research, the scope for further participation in the higher levels of varietal evolution and evaluation may be explored at a later stage.

4. Reform of national and regional research, extension and planning is required to create a dialogue with farming households with particular emphasis upon sensitive PRA survey techniques and the promotion of technology generation including varietal identification and adaptation by farmers themselves.

5. Adoption of participatory approaches requires a major change in attitude, behaviour and skills. All the personnel in a research organization must share a common vision. To realize this objective, the following strategies are suggested for improving the client participation in the research organisation's activties (adapted from MANAGE, 1999)

Capacity building : Capacity building of the scientists and technical staff on management aspects is an important requirement. This enables scientists to adopt a participatory approach.

Business process reengineering : Change towards participatory approach requires a modified structure that would facilitate the project team to function in a self directed manner. The mechanism of supervision and monitoring needs to be decentralized so that the team leader has autonomy in directing the project and operating the project funds.

Incentive system : The present system of assessment needs to be modified in favour of participatory research and extension.

Management of change : The change may be managed in a gradual manner rather than adopting a quick and administrative approach. The participatory approach would require a major change in attitude and responsibility of persons at different levels.

Developing trainers : There is a need to build a team of local trainers within each organisation to impart skills on process management in developing efficient teams

and to develop skills for adopting participatory plant breeding programmes.

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Intellectual Property Rights: World Trade Organization and Trade Related Intellectual Property Rights

C.V.Sairam

Introduction

The agricultural development strategies followed in India since late 1960's has helped the country to achieve commendable growth in production of different food and commercial horticultural crops, livestock, poultry, and fisheries products. In Indian economy, the agriculture and its allied sectors continue to play a major role and their share accounts to nearly 28 per cent of the Gross Domestic Product, 20 per cent of the total annual export earnings and about 65 per cent of total employment. However, the realized growth rate in these sectors is far below the true potential growth rate. During the past five years, the average annual growth rate of Indian agriculture is about 3.5 per cent and the average productivity of Indian agriculture is still around 1.6 t/ha, which is lower than other developing countries such as China, Brazil etc. The country's share in the world agricultural export accounts to only 0.5 per cent.

Since the liberalization of Indian economy during 1991, the following changes have taken place in the agricultural sector viz., i) removal of restrictions on domestic movement of agricultural commodities, ii) partial rationalization of exports, iii) progressive reduction in food and fertilizer subsidies and iv) membership of World Trade Organization (WTO). It is claimed that all these policy reforms will improve resource allocation in agriculture, induce private investment and result in higher growth of production, exports and income. However Vyas (1994), Hanumantha Rao (1995) and Johl (1995) have looked into the complexity of these policy reforms and contributed to the discussion in an informed manner.

In view of economic liberalization and being a member of the World Trade Organization, certain macro and micro level changes are expected to take place in the primary sector of Indian economy. Since GATT aims to boost agricultural trade through substantial reduction in protectionism, prices of agricultural commodities in member countries are expected to move closer to international prices. Hence to compete in international markets, product price and cost of production of agricultural commodities produced in the country should not be higher than those in exporting countries. To meet these challenges, Indian agriculture has to maintain an higher level of technical and economic efficiency through higher productivity.

India, being a member of World Trade Organization, is bound to follow certain rules and regulations with regard to international trade as laid down by the agreement of WTO. This agreement was reached based on the comprehensive Uruguay round of multilateral trade negotiations held under the aegis of General Agreement of Tariff and Trade (GATT). For the first time in the history of GATT, all the agreements or provisions made were equally applicable to both developed and developing countries. The only concession given to the developing countries was in terms of transitional periods. The major differences between GATT and WTO are given in Appendix I.

This article highlights the effect of WTO Agreement on Indian agriculture with reference to Intellectual Property Rights (IPR) and Trade Related Intellectual Property Rights (TRIPS).

IPR and TRIPS in WTO Agreement

Intellectual Property Rights (IPR) as proposed in WTO agreement refers to the legal ownership by a person or a business of a discovery or an invention attached to a particular product or process, which prohibits others from unauthorized copying or imitation. There are seven types of IPR viz., Copyrights, Trademarks, Patents, Geographical indications, industrial designs, Integrated Circuits and Trade Secrets.

The issue of IPR was brought for the first time into the Uruguay round discussions on GATT and because it had a bearing on the trade related aspects, the agreement is known as Trade Related Intellectual Property Rights (TRIPS). The TRIPS agreement laid down norms and standards for all the seven types of Intellectual property.

India, through her laws and jurisprudence, is already in compliance to a substantial level with the TRIPS standards on copyright and related rights, trademarks, geographical indications, industrial design, trade secrets and with some of the provisions on patents. However new legislation is required in the area of layout designs for integrated circuits (Watal, 1997).

IPR and Plant Breeding

IPR has become a serious matter of concern for Indian agriculture and a wide range of apprehensions and misconceptions like farmers would have to buy seeds every year from multinational companies, the future threats to the Public

ution System and threats to her genetic wealth are being ssed widely by the researchers, planners and policy makers. k of proper information on these subjects is the major reason for all these apprehensions.

The International Union for the Protection of New Varieties of Plants known as UPOV was formulated during 1961 with the purpose to ensure Plant Breeder's Rights (PBR) on those New Plant Varieties, which are sufficiently homogeneous, non commercialized, stable and distinct from existing commonly known varieties. Under UPOV 1978, a new plant variety produced by a breeder could only be produced and marketed by him. But it had allowed two important exemptions viz., the Breeder's exemption which allowed other plant breeders to use the protected variety for breeding purposes and the Farmer's Rights which allowed the farmers to use their own seeds for the next cropping season.

However under UPOV 1991, the breeder's exemption was almost taken away, paving way for royalty payments to the PBR holder from the breeders if their new variety has resemblance to the protected variety. Besides, farmers cannot use farm-saved seeds from protected varieties without paying compensation.

This is neither acceptable to Indian farmers nor to plant breeders since unlike in countries like USA, where holdings run into hundreds of hectares producing hundreds of tonnes of seed materials, India has more than 100 million farmers with less than two hectares of land relying directly on each other for procuring seed material. Hence there is a need to protect the rights and interests of the small farmers to use and save their own seeds. Hence the plant variety legislation is being modified to suit the interests of farmers, plant breeders and the Indian seed industry.

In this connection, the dialogue on "Methodologies for recognising and rewarding informal innovation in the conservation and utilization of plant genetic resources" held in Chennai from 28-31 January 1994 had incorporated the following features viz., i) retain breeder's exemption so as to promote dynamic breeding programme, ii) strengthen farmers' privilege in order to ensure that resource poor farmers have access to new varieties, iii) provide a mechanism for giving operational content to the concept of Farmer's Rights and iv) suggests the creation of a Community Gene Fund to which the royalties due to farmer-conserves can be credited and which can be used for strengthening the *in situ* and *ex situ* conservation practices of tribal and rural families (Swaminathan, 1995)

The document of the final act of WTO had indicated that the members should provide for the protection of plant varieties either by *sui generis* system or through patents or a combination of both.

Sui generis (meaning of their own kind) system provides a framework of PBR through which protection is given to Plant Breeders, researchers and farmers with regard to use and exchange of seeds and plant genetic material. In this connection the proposed draft by Government of India on the Protection of Plant Varieties (PVP) ensures that the farmers can raise their own seeds and retain them even to exchange with other farmers as per the existing tradition and the researchers shall be able to produce new varieties from the protected varieties.

A patent is a statutory privilege granted by the Government to inventors and to other persons deriving their rights from the inventor for a specified period, to exclude others from manufacturing, using or selling a patented product or process. The criteria for an invention to be patented include i) novelty, ii) non-obviousness, iii) utility on a commercial scale, iv) the scope of protection granted must be in proportion to the invention and v) it must relate to a technology where patents are permitted. At the time for which the privilege is granted, the patented invention is available to the general public. Indian Patents Act (IPA) 1970 had included only the process patent and not the product patent and had excluded the management practices of agriculture and allied activities from patentability. But as per Uruguay agreement, in addition to process patents, India is bound to introduce product patents.

One of the most important tasks ahead of Indian Scientists is to produce and patent more number of product and process technologies at the earliest possible time frame. The problem is more tedious in case of agricultural research since the Scientists are bound to patent the most important and unique varieties of different crops. At present India produces about 4000 patents a year which is very low as compared to countries like USA where the number of patents exceeds 1.1 lakh per year. The cost of patenting a technology is very high for an individual, however this could be solved through increased participation of private entrepreneurs. The timely efforts taken by the Indian Government have made us to assert our rights on our bio-resources like withdrawal of US patent on turmeric and earlier upholding of the claim made by our environmentalists against a patent on neem oil given to a European multinational.

During 1997, Rice Tec, an agro based company in USA has patented novel rice lines viz., Texamati, Jasmati and Kasmati which produce grains having characteristics similar or superior to those of good quality basmati rice grains produced in the Indian subcontinent. India has challenged this in the WTO's Dispute Settlement Panel (DSP), but the case only goes to prove that basmati is not an unique product.

As per Geographical Appellation Bill of TRIPS, geographical indications pertain to "indications which identify a

goods as originating in the territory of a member, or a region or locality in that territory, where a given quality, reputation or other characteristic of the commodity is essentially belonging to its geographical origin". Had such legislation existed in India, conferring an unique status to the climatic and soil conditions and cultivation practices of basmati, India's case in WTO would have probably emerged stronger. Hence there is an urgent need to amend the existing Patent laws in India. The differences between existing laws of India and WTO are given in Appendix II.

Protection of Bio-Diversity

India is one of the largest repositories of bio-diversity. In the self provisioning economies of the third World, producers are simultaneously consumers and conservers. In fact, it is recoginsed that 'the total genetic change achieved by farmers over the millennia was far greater than that acheived by the hundred or two years of more systematic science-based efforts' (Vandana Shiva, 1995). Hence there is an urgent need to make inventories of the bio-diversity to have a complete picture of our valuable resources and to formulate new laws to deal with all aspects of bio-resources and policy governing their use.

Convention on Biological Diversity (CBD) was a treaty signed during December 1993 by the member countries under WTO and India ratified the same during February 1994. This convention has three broad objectives viz., i) the conservation of bio-diversity, ii) sustainable use of its components and iii) fair and equitable sharing of profits that come from the utilization of genetic resources (Rana, 1998).

These new laws should be formulated based on the conditions of the CBD and these are i) to establish ownership rights over biological resources found in the soverign territory of India, ii) to formulate the guidelines and structures for prior informed consent according to which the user parties will have to seek the permission of some kind of National Authority authorized to grant or refuse access to genetic resources and iii) the conditions for material and information transfer agreements will have to be laid down so that the use of biological resources is just equitable and sustainable (Suman Sahai, 1998)

Future Strategies

By the turn of the Century, Indian agriculture has to face multi-fold problems, the most important being the food security. By 2025, the country has an uphill task of feeding 1.4 million people which requires about 300 million tonnes of food grains. In this era of globalization, competitive edge based on technology is considered as the only way to achieve this target. Moreover economic growth is accelerated through technological development and confidence in a well-enforced intellectual property protection is a great stimuli for innovation. A well defined IPR regime is a basic source of technological information that research organizations have at their disposal. This will also boost the level of foreign investment in the country since many multinationals especially in biotechnology sectors would like to be assured of a strong IPR regime in place before deciding on investment (Ilyas, 1999).

Being a member of WTO, India has to comply with its regulations related to IPR. If the country fails to properly handle the IPR related issues, it will be at the cost of the country's future prosperity. For this the Indian Government, planners, policy makers and the bureaucrats should make a clear cut strategic plan and implement the same at the earliest possible time.

The first thing is to remove the apprehensions and misconceptions about IPR among the public. The patent system in the country should be strengthened especially in the field of agriculture. The country has vast human resources, technical man power, adequate infrastructural facilities, aspiring private entrepreneurs etc.. These components should work together for developing and introducing product patents and marketing them globally.

India had already initiated pipeline protection for patents in its gradual march on the course of WTO to form a proper patent regime by 2004 AD. But it needs careful examination that the proposed safeguards are in line with the TRIPS.

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Appendix I. Differences Between GATT and WTO

S.NO.	GATT	WTO
1.	Was essentially concerned to issues arising out of international trade of goods at the international level	It has annexed vast spaces of national decision making to its domain. Entire spectrum of Intellectual Property protection has been lifted out of national domain and are subjected to the most rigorous and demanding international discipline
2.	It did not seek to intrude into the sphere of autonomous decision making of its member countries	The trade in services has been defined in an open ended manner to bring all possible activity under GATT
3.	It specifically listed a number of exceptions and recognized the departures from the rules of the border paradigm under certain circumstances	The National Public Distribution System will henceforth have to reckon with the parameters laid out in the agreement
4	Recognized the autonomy of members to have and enforce laws and regulations relating to the protection of patents, trade marks and copy rights, conservation of natural resources, restrictions on export of domestic materials and the laws and regulations essential for the acquisition or distribution of products in short supply	The National Investment regime will similarly be subjected to the international discipline evolved in the agreement of Trade Related Investment Measures (TRIM)
5	Provided for its members the fundamental right of non discriminatory treatment at the hands of other members of the system in regard to international trade in goods	The fundamental right of non- discriminatory treatment was destroyed. New obligations can be added and can be enforced on all members, if there is a prescribed majority endorsing such a decision. The continued enjoyment of Most Favoured Nation (MFN) will be subject to that memebers' acceptance of the new discipline.

Appendix II. Patent Laws in India visa-vis WTO

INDIAN LAWS	WTO RULES
Provides only process patents in food, pharmaceuticals and chemical sectors	Requires both product and process patents
The burden of proof on "process" patents lies on the complainant	It is on the defendant
Duration of the patent is seven years for food and pharmaceutical sectors and 14 years for all the other sectors	It is uniformly for 20 years for all patents
Provides automatic compulsory licensing in case of food, pharmaceutical and chemical sectors without the patent holder being heard	Permits compulsory licensing on the merits of each case but the patent holder will have to be heard
No system for protection of plant varieties	Requires effective "*Sui generis*" system of PVP
Does not allow patenting of life forms	Requires micro-organisms to be patented

Agricultural Information Systems / Services and Electronic Media

M. P. Ramesh Kumar

Introduction

To gain momentum for agricultural development continuous flow of information is mandatory and it has become impossible to keep up with one's own field of specialisation. Agricultural information systems have to play an ever greater role in the dissemination of knowledge and experience. Developments in the field of Science and Technology has given rise to a proliferation of scientific literature and information and the same holds good for agricultural and allied sciences. The quantum of output is so large, no individual organisation or a country can handle it properly. Information management in agricultural sector is complex in nature involving whole process of information generation, publication, organisation and dissemination to wide range of users. .For regulating information flow, many of the international information systems/services are operating in agricultural sector, some are on global scale and others are at regional or national level.

International Information Systems

Major systems on international scene are AGRICOLA, AGRIS, WAICENET and CABI. These are organised collection of different subjects, which could be bibliographic or full text. Bibliographic databases consist of citations or references of documents. Enhanced by computer capabilities, databases provide more access points than printed abstracting or indexing journals. Most of the databases are accessible through commercial vendors that load the databases in their large computers and provide software to retrieve information held by them.

Agricola

This database is produced by National Agricultural Library (NAL)) of United States Department of Agriculture which focuses more on information generated on agriculture in USA, containing more than 3 million records. It is the best source for tracking publications by USDA and other associated agencies. The coverage in database includes references to journal articles, government publications, technical reports, thesis, etc. It corresponds to printed products like Bibliography of Agriculture, NAL Library Catalogue and Food Nutrition Quarterly. It is available in magnetic tape since 1970 and online access is possible through DIALOG .It gives information on what is being done, personnel undertaking the project, organisations affiliations, place, year of commencement, progress of project and publications emanating from the project. .AGRICOLA is available on CD-ROM covering from 1970 containing 3 million records in and about 100,000 records are added annually. Indexing is done using AGROVOC

Agris

It is an international information system working under FAO of UN, providing access to world information in the field of agriculture and related fields. It is a cooperative and decentralised system covering both conventional and grey literature wherein 171 countries and 24 regional and international research centers participate. Annual input is about 1,30,000 items. .Each participating country /institute prepare an input sheet collecting a wide-range of information on scientific and socioeconomic information in the form of journal articles, books, reports, etc. and provide in different media like magnetic tapes, floppy diskettes or in input sheets to AGRIS Processing Unit located in IAEA, Vienna, Austria, where data is merged into main database. Such data so received is processed and hard copy in the form of AGRINDEX is produced for sale distribution. In turn, each participating country/institute receives AGRIS tapes thereby generating SDI. AGRIS was conceived to function in two levels, i.e. AGRIS Level i and AGRIS Level ii, which are briefly described as follows

AGRIS Level i: In this level, AGRIS functions to have comprehensive coverage in providing documentation service and current awareness in all fields of FAO mandate. It became operational in 1975 AGRIS and available on CD-ROM published by SilverPlatter. The records from 1975-1991 are available on a set of 5 CDs and current discs are updated quarterly.

AGRIS Level ii: AGRIS Level ii was conceived as a network of existing specialised centres, analysis centres and databanks with responsibility in specialised subject fields, i.e., in providing informative abstracts and reviews with detailed indexing under specific subject. The emphasis on level ii is Information network among specialised centres for information transfer. Althogh AGRIS Level ii has not taken off inspite of several studies and recommendations ,but many developments have taken place in establishing specialised information analysis centers (SIAC) at many international organisations providing variety of information services, which fulfil aims and objectives of Level ii. It has 23 members spread over Africa, America, Asia, Europe and Oceania.

Commonwealth Agricultural Bureaux International (CABI)

It is an inter-governmental organisation based in Wallingford, UK, Established in 1920 provides a wide range of agricultural information services in support of agricultural research with extensive coverage from commonwealth countries. It provides information to a wide range of users including farmers, researchers, extension staff, agro-business and trade. CABI services provides an efficient, reliable, cost-effective and selectively comprehensive information services tailored to meet the sectorial needs of its multidisciplinary users population. CABI has adopted internet as serious publishing medium and publishing products are made available to readers desk top via internet. They provide free access to web editions of journals to subscribers of relevant print versions. Around 14,000 journals and 500 non-serials are scanned and selectively covered in the database. Pertinent grey literature also covered by keeping liaison with organisations in both developed and developing countries. CABI holds about 3 million records in printed form; and about 1,50,000 abstract are added to database annually. The records are indexed using CABI Thesaurus. CABI provides document delivery through network of special libraries throughout U.K. and ensures to acquire and supply photocopies of most source documents that have been abstracted and covered in its database.

The WAICENT

World Agricultural Information Centre (WAICENT), plans to provide fast, economical access to FAO's vast sources of information on agrculture, fisheries, forestry, nutrition and rural development. FAO launched the WAICENT project in 1989 for the consolidation of some 40 separate databases that have been developed over the years and are housed throughout the Organization. WAICENT allows users to retrieve information-initially in English, French and Spanish from a wide variety of databases containing statistical, textual and multi media information. Individual FAO technical units continues to be responsible for entry, validation and processing of the different types of information. The editing and dissemination of information is centrally managed by WAICENT, which is part of the Library and Documentation Systems Division (GIL). WAICENT aims to provide information retrieval from a wide variety of media (such as floppy disks, CD-ROM and mainframe tapes), extending to "on-line" access through computer networks and voice and data lines. Following a broad restructuring programme, the AGRIS/CARIS Co-ordinating Group has ceased to exist, and has been incorporated into the WAICENT/FAOINFO Dissemination Management Branch (GILW). which continues to be responsible for the processing of all AGRIS data.

Agricultural Databases

Biological abstracts

Biological Abstracts is published by BIOSIS, Inc., Philadelphia, USA, and has broad coverage of the life sciences literature. It contains citations to the biological and biomedical literature published in over 7,000 primary journals

CAB Abstracts

CAB abstracts is an archive of agricultural information available for online searching. All the CABI CD-ROM titles are updated quarterly.

Agrisearch

Agrisearch incorporates five databases covering agriculture, food technology, nutrition, biotechnologyand other related areas. An ideal source of worldwide information. AGRI-SEARCH includes U.S.Departinent of Agriculture,ICAR (Inventory of Canadian Agro-Food Research) from the Canadian Agricultural Research Council, ARRIP from the Australian Standing Committee on Agriculture, and AGREP from the Commission of the European Communities. It is a good tool for the scientists, administrators, research managers, funding agencies and others who are concerned with research and development in agriculture and food.

Medline

Medline is an online database of Index Medicus published by the National Library of Medicine, Bethesda, USA. Over 8,000,000 records are contained in the online database and 300,000+ references are, added annually. More than 3400 biomedical journals, published in 70 countries, are scanned for updating the database. The monthly service on CD is offered to the subscribers.

Agricola

Agricola is available via several vendors such as Dialog, STN and on firstSearch. The CD-ROM version is produced by SilverPlatter.

Current Contents

Current Contents is published weekly by Institute for scientific information. It gives access to table of contents of latest journal issues published Current contents with abstract provides abstracts also.

Food science and Technology Abstract

FSTA abstracts are published by International Food Information Service, U.K and gives references on food science, biotechnology, economics, engineering etc

Abstracts on tropical agriculture

Published by Royal Topical Institution the

Netherlands. Topics covered are Farming systems, Crop production ,Crop protection, Soils etc.

The National Agricultural Research System

The National Agricultural Research System of India has necessary infrastructure and is equipped with laboratories, libraries, manpower, etc. With the growth of ICAR Institutes, and the state agricultural universities ,more libraries were opened and they played a vital role in the research and education programme. The old institutes like IARI, NDRI and IVRI have libraries with good collection .All important committees constituted for assessing status of ICAR libraries have stated that ICAR libraries were in poor condition in terms of collection, library manpower, physical facilities and financial resources to meet the information requirements of the scientists of their respective institutions. So far as the budget was concerned, the libraries of ICAR have shared hardly 2% or less than that of the budget of their respective institutes. There is a Standing library Advisory Committee (LAC) of ICAR to deal with policy matters concerning agricultural libraries and they gave substantially useful recommendations for the development of agricultural libraries in the country

Agricultural Information System(ARIS)

As we are moving towards the twenty first century, ICAR has given priority to build an agricultural Information System (ARIS) .During 8th plan ,ICAR started a project called ARIS to bring the power of IT to NARS with the financial support of world bank under the National Agricultural Research Project. The project is being extended to the nineth plan under NATP. Under this scheme a survey was conducted by National Centre for Software Technology (NCST), Mumbai which showed that ratio of PCs to scientists at ICAR institutes and SAUs is very low. Thus, every campus as well as ICAR institutes and project directorates have been provided with LAN server and three or four PC workstations with associated LAN cabling. Software for networking, e-mail as well as office automation have been provided along with the equipment. It also included infrastructure equipment like uninterrupted power supply and air-conditioning units to provide necessary environment for longer life of these equipment Besides creating infrastructural facilities, four information modules Agricultural Research Personnel Information System (ARPIS), Agricultural Research Financial Information System (ARFIS), Agricultural Research Library Information System (ARLIS), and Agricultural Research Management Information System (ARMIS).

Agricultural Research Library Information System (ARLIS)

One of the important exercise under ARIS will be to modernise libraries and to put the library information on the ARIS network. All libraries of ICAR and SAUs will be computerised and linked to IARI library which has been identified as National Agricultural library. This will provide scientists an opportunity to access information electronically. Besides thisthe creation of databases on both national and international agricultural research will be a major work under ARLIS. Agricultural Research Information Centre (ARIC), New Delhi is involved in compilation of information on AP Cess Fund schemes and other research projects funded by ICAR. Also ARIC is serving as National Input Centre for International Information System (AGRIS) for the Agricultural Science and Technology and Current Agricultural Research Information Systems (CARIS) projects of Food and Agriculture Organisation (FAO) and SAARC Agricultural Information Centre (SAIC).

Coconut Information Services

Asian Pacific Coconut Community: APCC is an intergovernmental organisation tasked to promote, coordinate and harmonize all activities in the coconut industry. APCC secretariat serves as regional Centre of coconut information network It is linked to national information centers of member countries through E-mail. Regional Centre assists in collecting, organizing and exchanging information relating all aspects of coconut industry and disseminate information in various forms of publications. National information centers in turn disseminate information to end users in their respective countries. In India Coconut Development Board acts as the National Centre.

BUROTROP: BUROTROP is an international non profit association whose activities are established and followed up by its board of directors where both donor and producer countries from Africa Asia and Latin America and the pacific are represented.It was created to strengthen and enhance the coordination of research and development activities of coconut and oilpalm and to exchange information and experience among organisations concerned with perenial oil crops.

Information Services from Central Plantation Crops Research Institute

New Additions list: This is a publication containing informations on new addition of books, technical reports to the library. This is being supplied to all Divisions at the Head Quarters, Regional Stations and Research Centres as well as other ICAR Institutions.

Contents Page Service: This is a bi-monthly publication containing Contents page of the periodicals (Indian and Foreign) received in the library supplied to the regional

stations and research centres for reference. Xerox copies of articles of interest are supplied to scientists.

Periodicals Directory: A directory on current periodicals of CPCRI libraries is being brought out every year in order to inform the readers about the periodicals received at various centres of the institute. Both foreign and Indian periodicals are arranged in one sequence alphabetically indicating the centre where they are subscribed.

Catalogue of periodical holdings: Catalogue of periodical holdings of CPCRI Libraries at Headquarters is brought out.
CD ROM Search: Library subscribes to Agris, Agricola, CAB pest CD and Hort CDs and readers are allowed to search topics of interest in a networked environment. and down load data in floppy or to take print outs .CD network facilities helps readers to make searches.

International Collaboration:: There has been a close collaboration with various research institutes for the exchange of information

Selective Dissemination of Information (SDI): All the journals received are screened regularly to find out the relevant scientific articles of our area of research and the same is brought to the notice of the scientists concerned for reference.

Subject Bibliographies: Annotated Bibliographies have been compiled which are priced and availble for sale.

Coconut Development Board

The Coconut Development Board, is the major economic/marketing agency in the country where one of the Important objectives is to serve as an information Centre for economic and marketing aspects of coconut. The Board collects all Information pertaining to various aspects of coconut cultivation, processing, marketing and trade practices.

Impact of Recent Advances in IT

In the past two decades, we have been observing impact of modern technologies on information handling activities. Individually, the electronic, computer, telecommunication, multimedia and reprographic revolutions have directly affected and enhanced information processing, information storage capacities. Increased efficiency of information retrieval systems paved the way for a new breed of industry ie 'Information Industry'.

CD-ROMs (compact disc-read only memory): The use of CD-ROMs is often presented as an ideal solution to the difficulties in identifying and delivering research information. CD- ROM discs have huge storage capacity (the equivalent of 1500 floppy discs or 2,00,000 printed pages) and are easily portable. The application of CD-ROM is superior to its printed equivalent. A large number of CD-ROM databases are available on almost all subjects. Multimedia databases are now increasingly becoming popular. If CD-ROM databases are subscribed and if they are made available on CD-NET, many can access them on networks from remote distances. The majority of the agricultural databases are available on CD-ROMS.

Selection of Databases

The selection of CD-ROM databases for a library is crucial. Selection of overlapping databases should be avoided. For instance, VETCD may be enough for a veterinary library to meet the requirements of its users. Supplementing VETCD with CABCD will be duplication of the same literature, and it will be a wasteful investment.

There are two options for putting CD-ROMs to use in the libraries. Creating a multi user environment through the implementation of CD-ROM network or establishing a stand-alone work station. Initial set-up costs for a CD-ROM network are high, though incremental costs for adding extra workstations or products will remain relatively low. Access to several databases and sharing of resources are the biggest advantages of this approach. It may not be a feasible and cost-effective option for small libraries, but network environment weighs in favour of large libraries. While deciding the implementation of CD-ROM network or dedicated workstation in libraries, the decision makers have to take into consideration a number of factors such as availability of funds, users' needs, database requirements, and status of library automation. If the funds are not a constraint, the current trend is for the network environment

Hardware/Software Selection

The hard ware and retrieval software are important issues involved in the establishment of a CD station. No single operating environment will be suitable for all the CD products. Specific operating environments are required for each CD-ROM. Another problem is of compatibility of hardware and software with its different versions. There are product specific software which is supplied by the vendors of CD-ROM products. SilverPlatter has developed its own retrieval software and marketed under the name SPIRS (SilverPlatter Information Retrieval System). SPIRS is available for operation in different environments..

Internet : Yet another development in IT applications is the emergence of Internet. The Internet has made distances insignificant for discussions or group research work. Today it interconnects thousands of computer networks and millions of individual computers across the world using TCP/IP as the computer communication protocol. Starting with basic network services like E-Mail and Telnet (remote login), the

Internet has made quick progress with the development of tools like Gopher, WAIS (Wide Area Information Server) and the World Wide Web. WWW has made the Internet easier to use and enhanced its value as a communication medium. 'Hypertext' is the fundamental concept of WWW. It refers to of links within an HTML page (Web page) pointing to other documents. The linked documents could comprise text, images, graphs and charts, and audio-video clips. These documents need not exist in just one computer. They may be distributed among different Web servers located at different geographic locations. There are two key components to the WWW: Web servers and Web browsers. Web servers host Web documents, written in HTML, and transmit these over the Internet using Hyper Text Transmission Protocol (HTTP), which operates on TCP/IP. Web browsers are user interface software packages, which receive and display Web pages from the servers. Web browsers are available for numerous operating systems like Windows, Unix, etc. Two very popular browsers are Netscape and the Internet Explorer. Various kinds of documents that are available on the Net and examples of some titles are given below.

Electronic Journals

Major publishers of science journals like Eisevier, Academic Press and Blackwell and professional organisations like the IEEE and IEE have set up their own Web sites to deliver a variety of scientific information, including journals and announced Web access to their journals. There are two types of e-journals. Electronic versions of print journals and serials published and accessed on networks with no print counterpart. Some e-journals have only text content, but the trend is towards Web access to both text and images.

Content pages of Journals

Major publishers of science journals today deliver content pages of their journals by E-Mail, mostly free of cost. 'Contents Direct' service by Elsevier delivers content pages of about 800 journals by E-mail over the Internet. The service allows users to register for journals whose content pages they wish to receive. Web access to content pages is also provided by most of the publishers today. A very popular service is the Uncover service provided by the CARL agency providing free access to content pages of over 16,000 journals. Institute for Scientific Information (ISI), U. S.A., has recently initiated a content page alerting service.

Discussion forums

Discussion forums are a major network resource that serve the purpose of current awareness. They use E-Mail to set up informal discussion among people of specific research interests via the Internet. Forum software (e.g. Listserv) maintains a list of E-Mail addresses of all subscribers/ members and the messages posted to the forum are distributed automatically to all subscribers. Joining (subscribing) and leaving (signing off) the forum and posting messages are carried out through E-Mail. Participation in discussion forums help the participant to keep up-to-date with current developments in a field, which are often not reported fast enough in print media.

Technical reports

Technical reports provide details of on-going or completed R&D projects and Ph.D theses. Large number of reports can be easily accessed, often free of cost in Web. For example, a well developed system called NCSTRL (Networked Computer Science Technical Reports Library)) now exists for world wide access to technical reports in computer science research.

Library catalogues

A large number of library catalogues can be accessed online via the internet. Generally available free of cost, these are useful for finding books not available locally, to identify and select books for local acquisition, bibliographic data verification and to search holdings of periodicals. Most do not need any login, some accept 'guest' logins and a few require authorisation.

Search tools

Looking for a specific piece of information on the internet is quite like searching for a needle in a hay stack. Search tools, resource directories and current awareness services offer some solution. Search tools use spider programmes (robots) which periodically visit Web sites around the world, gather the Web pages, index these pages and build a database of information in these pages. There are very powerful Web search tools today with varying indexing and search capabilities. Alta Vista developed by the Digital Equipment Corporation is one of the most powerful search service, allowing full-text searching. With the spread of the Web, traditional online database vendors like the Knight Ridder and STN International are now providing Web interface to their databases. Silver Platter, a major CD-ROM database publisher, now provides WWW gateway to CD-ROM databases mounted on Unix servers using its ERL (Electronic Reference Library) software. Cambridge Scientific Abstracts, another major publisher of science databases, was among the first to provide Web access to its databases. ISI has recently announced an, Intranet solution to the Science Citation Index

Problems

The internet also have several problems like the uncertainty about the quality of the information and durability of the Internet sites. The quality of many free sites is suspect. A solution to this is rating services like Point and Magellan Directories that evaluate resources included in their catalogues. Another serious problem is the poor response time. Quick

access to e-journals requires good network speeds. With the increasing use of internet for business and commerce and delivery of multimedia files causing delays in information transmission. There are moves to create internet 2, a very high speed network for the exclusive use of the scientific community. The cost of setting up a Web site with a reasonable bandwidth of 64 KBPS is very high. Besides, the telecommunication in India is among the highest in the world. Such high costs discourage developments related to the setting up of Web accessible databases

Summary and Conclusion

We have made an attempt in this paper to give an indication of developments that are taking place in the generation and dissemination information . As information is widely accepted as a valuable commodity and as an important resource, which has to be acquired and properly monitored to accelerate agricultural development. The world's major information systems have been playing an important role in providing much needed information for agricultural development particularly in developing countries. The impacts of modern information technology have given rise to a new breed of information industry thereby better agricultural information management. Each kind of information sources used to generate services in libraries is available on the Internet. Only a knowledge of what is available and how to access the documents is required to make optimum use of the internet . The only constraint here is the availability of internet access to libraries. Effective techniques should be identified to store and search such down loaded information. Since CD ROM databases are becoming popular collection development policy makers should take care of such trends.

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