PLANTATION CROPS OF KERALA CHALLENGES AND OPTIONS

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PLANTATION CROPS OF KERALA

CHALLENGES AND OPTIONS

A Compendium of Background Papers on the Focal Theme of Eleventh Kerala Science Congress

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FOREWORD

The Kerala Science Congress has rightly chosen PLANTATION CROPS OF KERALA as its focal theme at the 11th session to be held at Central Plantation Crops Research Institute. As one who has been associated with the Plantation Crops Research and Development for nearly half a century, it gives me immense pleasure to write this foreword.

The role of that Plantation Crops play in the economy of Kerala State merits special mention. A discussion on various strategies to meetthe challenges that the industry would have to face in the wake of fast changing international scenario is most appropriate. The research is taking a new turn with most modern tools being used to investigate and solve various problems and the development will have to capitalize the gains of research effectively. This compendium is unique and differs from various other publications available on the subject. The editors have chosen eminent persons to write on frontier areas of Science and development which will have a bearing on plantation crops. Genetic conservation, maintenance of ecological balance, effective utilisation of water resources, socio-economic and gender issues related to plantation crops have been covered in detail. Application of biotechnology and satellite imaging techniques has been adequately discussed. Another aspect that has been emphasised is the Intellectual Property rights. There is no doubt that the readers would find this compendium very interesting and useful. I congratulate the organizers for bringing out this publication in time to coincide with the Kerala Since Congress. I wish the Science Congress all success and hope that the discussion would help in developing strategies for increasing the productivity of this crops on a sustainable basis.

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PLANTATION CROPS RESEARCH - STATE OF ART

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Kerala is blessed with unique ecological conditions suitable for cultivation of many high value commercial crops.Of the total geographical area of 3,88,497 ha in Kerala, plantation crops occupy 46.21per cent. Coconut, Rubber, Cashew, Coffee, Arecanut, Teav Spice Crops besides Teak and Eucalyptus are the major plantations of the State. Besides Kerala, plantation crops are cultivated in appreciable extent in Tamil Nadu, Karnataka, Andhra Pradesh, Orissa, Tripura and Assam. Though plantation crops occupy only 3.2 million hectares in the country, they have generated considerable income of around Rs. 15,000 million during the year 1996-97 which is 70 per cent of the total export earnings of the agri-horticultural crops in the country.

India is the leading producer of coconut, cashew, tea and arecanut, second in cardamom and ninth in coffee. Plantation crops are confined to traditional belts and are committed to the land for longer periods. They have restricted geographical distribution and hence the possibility of area expansion is limited in traditional growing areas. Coffee, tea, rubber and to a limited extent oil palm are cultivated in an organised manner. Crops like coconut, arecanut, spices and cashew are grown by individual farmers and the production technologies advocated are not followed fully due to many socio-economic reasons thereby affecting their productivity.

In addition to the above, a large number of medicinal and aromatic plants are native to Indian forests and have been brought into cultivation to meet the Ayurved, Unani and Sidha school of medicines in the country. The primary products of these crops are of great economic value, a portion of which is consumed in the country and a major portion finds its way in the export channels. The by-products of these crops support a number of industries and generate considerable employment potential to millions of farm families. The products of these crops are a part of daily life of the population, such as "Tea, the cup that cheers", their future requirements are high. This necessitates increase in production and productivity through technological advances in crop improvement, crop production and plant protection aspects to meet the country's demand and earn valuable foreign exchange.

The national average yield of plantations is low compared to the yields obtained in plantations of the organised sector, throwing open vast challenges to fully utilize the technological advances in different disciplines in the research institutions. This can be achieved by managing the vast acreage of the existing plantation crops through agrotechniques to improve fertilizer use efficiency, water management and plant protection. The other aspect of productivity increase is through replacement of senile plantations by high yielding varieties obtained through breeding strategies and bio-technological advances.

The Indian Council of Agricultural Research through its persistant efforts has built up a vast infrastructure over the decades to achieve the goals of increased production and productivity in plantation crops.

The Central Plantation Crops Research Institute, Indian Institute of Spices Research, All India Co-ordinated Research Project on Palms, Cashew, Spices, Medicinal and Aromatic plants, National Research Centre on Cashew, National Research Centre on Oil palm and National Research Centre for Medicinal and Aromatic Plants are primal research organisations in plantation crops. The Central Agricultural Research Institute in Andaman and Nicobar Islands, ICAR Research Complex in Goa, and ICAR Research Complex for North East Hill Region also carry out research on plantation crops. Besides the above Institutions, Agricultural Universities in Kerala, Karnataka, Tamil Nadu, Andhra Pradesh, Assam and West Bengal also cary out research specific to their regions. Coffee, rubber and spices to a certain extent are handled by commodity boards. Coffee research is carried out by the Central Coffee Research Institute, Balehonnur under the Coffee Board.

UPASI Tea Research Institute at Valparai and Tea Research Association, Toklai caters to the research needs of tea in respective regions. Rubber Research Institute of India at Kottayam handles R&D under Rubber Board. The research on small and large cardamom is handled by Indian Cardamom Research Institute, Myladumpara under Spices Board. Besides research on crop improvement in general, these Institutes also work on certain aspects of harvest and post harvest technology of plantation crops. CSIR institutes like Central Institute for Medicinal and Aromatic Plants (CIMAP) and the Regional Research Laboratories at Jorhat, Bhubaneshwar and Thruvananthapuram also do research on plantation crops particularly medicinal and aromatic plants.

Significant Achievements

Coconut

Coconut is now grown mainly in 13 States in the county. There has been an unprecedented increase in area, production and productivity during the last 45 years. The area under coconut has increased from 0.626 million ha in 1950-51 to 1.795 million ha in 1995-96 and production from, 3281 million nuts to 13967 million nuts. Mathematically this accounts for 186.6 per cent increase in area and 325.6 per cent increase in production. Currently India has been adjudged as the largest producer of coconut in the world. During the decade from 1985-86 to 1995-96, the growth rate achieved in production was 7.56 per cent. The increase in productivity during the last decade was about 54 per cent.

CPCRI has the largest assemblage of germplasm, consisting of 46 indigenous and 86 exotic types from 22 countries. Exploiting the hybrid vigour, nine hybrids involving talls and dwarfs as parents and three high yielding varieties have been released for commercial cultivation. These have received attention and acceptance by farmers of Kerala Tamil Nadu, Andhra Pradesh, Karnataka and Goa. These varieties and hybrids are capable of yielding 1.62 to 2.99 tonnes of oil/ha annually. CPCRI has developed many cropping systems involving annuals and perennials grown in different tiers by exploiting soil and air space more efficiently. Coconut and arecanut based inter-mixed, multistoried-multispecies cropping systems developed at CPCRI is a major significant achievement. Coconut-cocoa and pepper cropping system provided a maximum return of Rs. 2,32,000/- per ha per year. The high density multispecies cropping system now being demonstrated in the

Institute has continued to yield very profitable returns and in the 14th year. An annual net return of Rs.1,32,800 per ha with a gross return of Rs. 93,300/- ha has been realised. Due to favourable conditions like organic matter addition, internal nutrient cycling and microclimatic conditions, these systems can be maintained at suboptional levels of external nutrient addition. These systems demonstrate the vast potential that can be profitably exploited.

About 50,300 ha has been identified as potential area for growing coconut in the semi and non-traditional areas in the country. The non-traditional areas include Bihar, Tripura, Nagaland, Manipur, Arunachal Pradesh and Rajasthan.

Drought is a common problem in many parts of Kerala especially in the northern districts. To circumvent this problem, CPCRI has screened 23 gerplasm accesions for this trait. Recent studies have indicated that West Cost Tall x West Coast Tall, Java Giant, Andaman Giant, Federated Malay States, Laccadive Ordinary x Chowghat Orange Dwarf as drought tolerant. The reduction in yield during drought years can be as high as 75.8% in drought affected COD x WCT hybrids, whereas it is only 15% and 44% respectively in LO x COD and LO x Gangabondam which have been identified as drought tolerant lines.

Root wilt disease is a serious problem leading to annual loss of 968 million nuts in eight districts of Kerala. Subjecting the carefully selected disease free palms to serological and physiological tests and by further selection and breeding work, Chowghat Green Dwarf x West Coast Tall (CGD x WCT) has been identified to show tolerance/resistance to the disease. These field planted palms are under observation. Biotechnological investigation for fingerprinting diversity using biochemical and molecular markers, embryo culture technique for germplasm collection and somatic embryogenesis are being carried out. Presently the plantations in Kerala and Tamil Nadu are threatened by an Eriophid mite infesting nuts which causes huge loss. The CPCRI, KAU and TNAU are researching in this.

Areeanut

Arecanut research has helped in increasing the production and productivity and achieving self sufficiency in the country. So far, five high yielding varieties viz. Sumangala, Sreemangala, Mohitnagar and Calicut-17 were released which can yield 8.8 to 15 kg ripe nuts/tree/year. The natural dwarf identified from Hirehalli is being exploited to produce high yielding varieties by hybridisation between dwarf and released varieties. This will to a large extent is expected to ease the problem of harvesting in arecanut in the near future. Addressing to the multivarious research needs of arecanut over the past 45 years has lead to increase in arecanut production from 76000 tonnes during 1956-57 to 3.12 lakh tonnes during 1996-97.

Oil palm

Oil palm has been recognised as one of the highest edible oil yielding crop which can yield 4-6 tonnes of oil/ha/year from 3-25 years of economic life span. In India 7.96 lakh hectares has been identified as potential area for cultivation under assured irrigation. So far 39,413 ha have been planted. Andhra Pradesh (19,500 ha), Karnataka, (7,11 ha), Tamil Nadu (5,000 ha) and Kerala (3,805 ha) are principal oil palm growing states in the country. Gujarat, Goa, Maharashtra, Orissa, Assam, Tripura and West Bengal have also been identified to grow oil palm in future on a larger scale.

Two high yielding oil palm hybrids viz. Palode-I and Palode-II were released after their evaluation since I976. These hyrids are capable of yielding 4.4 tonnes of palm-oil/ha/year under rainfed conditions of southern Kerala. The CPCRI has enough parental palms for commercial production of hybrid seeds to meet the country's requirements.

Palm oil has been receiving good consumer acceptance and India has imported 1.469 million tonnes of palm oil during 1997-98 to satisfy the edible oil deficit to meet the consumer demand.

Spices

India ranks first in terms of area and production of black pepper, large cardamom, ginger and turmeric. An all time high of Rs. 1180 crores was earned by the country with spices export during the year 1996-97. Panniyur selections are the famous black pepper cultivars released. Contribution of Indian Cardamom Research Institute in identifying superior small cardamom clones is worth mentioning. India has clear monopoly in large cardamom. Through concerted research efforts, 10 high yielding varieties/hybrids in black pepper, 7 in cardamom, 2 in cinnamon, 5 in ginger and 16 in turmeric were identified for release.

To overcome the problem of undetected male plants in nutmeg seedlings at the time of planting, a chemical compound has been i dentified which can be detected to delete accidental planting of male seedlings.

India is a global leader in development of value added products in spices and export. Besides processed whole spices, oils, oleresins, curcuminoids find global markets.

The targetted production of planting material during Eighm Plan was 80.15 million cuttings of black pepper, 2250 tonnes of seed rhizomes of each ginger and turmeric and 2,40,000 seedlings of tree spices. Plant propagation methods have been standardised for production of true to type quality planting material.

Seed spices are mainly grown in Rajasthan and Gujarat. Madhya Pradesh, Haryana, Punjab, Uttar Pradesh, Andhra Pradesh and Bihar also cultivate seed spices to a notable extent. Twelve varieties of coriander, 5 varieties each in cumin, fennel and fenugreek have been released for cultivation.

Cocoa

Cocoa cultivation at present is mainly as a profitable mixed crop in arecanut gardens, where it enhances unit area income considerably. Present area under cocoa is estimated to be about 16500 ha with an annual production of 6000 tonnes of dry beans. The beans weighing more than one gram with low acidity high fat content and high shelling percentage are preferred internationally. CPCRI Regional Station, Vittal has 128 accessions. Eleven promising lines yielding more than 2 kg of dry beans/tree/year have been identified for distribution to growers.

India has the largest acreage of 4,18,331 ha of tea in the World, of which 81.9 per cent is in north India and 18.1 per cent is grown in southern India. Tea production has reached a record level of 780 million kg in 1996 and the industry is poised to achieve 1000 million kg in the middle of next decade.

Noticiably field productivity in south India with 2300 kg/ha is considered to be the highest in the World. The domestic consumption of tea which was a meagre 75 million kg during 1950 has gone upto 595 million kg during 1995. India exports about 163 million kg made tea contributing to 1 6.3 per cent of global market.

Tea

India is leading producer as well as exporter of tea in the world with a production of 74.38 lakh tonnes of tea during 1995-96.

In tea, a total of 56 clones, 7 biclonal and polyclonal seed stocks were compared to national average of 1752 kg/ha. Some of the clones are capable of yielding 7500 kg/ha Increased productivity and reduction in production costs are required to make India a competitive exporter. The Tea Research Institute at Tocklai and UPASI Tea Research Institute at Valparai (Tamil Nadu) are the active centres of research while AAU, Jorhat and CSIR laboratory at Palampur are also engaged research on tea.

Coffee

Coffee is traditionally cultivated in Karnataka, Kerala and Tamil Nadu and to a limited extent in eastern hill regions covering Andhra Pradesh, Orissa, West Bengal, Maharashtra and N.E. States. Arabica and Robusta contribute 50 per cent each under total area of 2.93 lakh hectares. India exports about 60 per cent of the total annual production of two lakh tonnes of coffee. During 1995-96, 1.71 lakh tonnes of coffee was exported earning a foreign exchange of Rs. 1526 orores.

The average productivity of coffee in India is 860 kg/ha which compares well with that of world average estimated productivity of 505 kg/ha. Research efforts have led to evolving 12 elite arabica and three superior robusta selections/hybrids which occupy about 80 per cent of area under coffee in the country. The identification of 'Cauvery" variety of Arabica type which has shown resistance to leaf rust has revolutionized high density planting for increased productivity per unit area. Coffee cultivation can be introduced in lower elevations like that of tea. Research must be directed towards developing suitablee varieties for such non-traditional areas.

Cashew

Cashew is on of the important export earning crops, the potential of which was realised in India way back in 1900 itself. From 1.10 lakh ha in 1995-96 the area under the crop has increased to 6.35 lakh ha. The production has increased from 0.79 lakh tonnes to 4.18 lakh tonnes duning the same period. However, the productivity has remained stagnant and has shown a marginal increase to 725 kg/ha from 700 kg/ha during 1955-56. The country has earned an export earning of 1232 crores in 1995-96 from cashew. The development of soft wood grafting has revolutionised the production of elite planting materials. Millions of planting materials are being produced at Konkan Krishi Vidyapeeth, Vengrla and NRC (Cashew), Puttur. The tea mosquito continues to be a menacing pest. Even though control measures have been developed, we are far from developing tolerant lines for tea mosquito and stem borer.

Conclusions and Future Thrusts

The present status and some of the problems requiring immediate attention of different plantation crops have been given in a nut shell.in the foregoing pages. We have only touched the tip of the iceberg. The crops and the individual problems would need much more space. Manu authorities on the subject have attempted to cover these in this Compendium. There are other publicaions brought out by the Indian Council of Agricultural Reserch such as " Vision 2020" of Central Plantation Crops Research Institute, Indian Institute of Spices Research, National Research Centres on Cashew, Oil Palm and Medicinal Plants which dwell in detail the various aspects on plantation crops. The areas of science which would be used in the years to come to solve the problems including socio-economic aspects are mentioned below:

1. Conservation of biological diversity and protection from being exploited by external agencies and preserving them in gene banks or by *in situ* conservation. These aspects are to be considered in the light of Intellectual Property Rights.

2. Application of modern biotechnological tools such as molecular markers, development of tissue culture techniques for mass multiplication, *in vitro* conservation and use of bio-processing techniques for production of secondary metabolites for medicinal and related use.

3. In view of the depleting water resources, developing drought tolerant lines as well as methods of effective moisture utilisation have to be developed.
4. Safe and effective organic farming methods and utilisation of resources are important aspects to be researched upon, so that commercialization of plantation crops do not cause an ecological imbalace.
5. Development of State/district level informaation system based on conventional and remote sensing approaches in GIS environment.
6. Technology for plantation crops for the small farmers must keep in mind the socio-economic aspects including the gender issues as women form a major work and managing force in States like Kerala.

COCONUT GENETIC RESOURCES CONSERVATION - FOCUS ON *IN VITRO* AND *IN SITU* CONSERVATION

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ABSTRACT

Traditionally, field genebanks (FGB) have been the most common mode of conservation used for coconut conservation and this is an *ex situ* method. However, as several drawbacks are associated with this method if used alone, other complementary conservation methods may be needed to ensure that coconut diversity is effectively conserved and used.. The paper therefore explores the underlying principles and considerations affecting the development and successful implementation of current and potential conservation techniques and then argues for the development and use of complementary conservation methods, including *in vitro* and *in situ* methods. The paper also presents the current activities of IPGRI and COGENT in coconut germplasm conservation and research initiatives in developing the needed techniques to promote complementary conservation methods for the coconut genepool.

INTRODUCTION

Plant genetic resources (PGR) include genotypes or populations representative of cultivars, genetic stocks, wild and weedy species etc., which may be maintained in the form of plants, seeds, tissue cultures etc., (Frankel and Soulé, 1981). Functionally, plant genetic resources constitute landraces, advanced/improved cultivars and wild and weedy relatives of crop plants. The discovery by Nikolai Vavilov during 1920-1940 on centres of origin was a major milestone in the field of PGR. Later, as the association between the so-called centres and the domestication was found to be ambiguous (Harlan, 1975), these have been regarded as 'centres' of genetic diversity' and this is basically the current view. This led to the concept of genepools, which include the cultivated diversity of a crop species and its wild, ancestral and weedy relatives. These genepools are essential to human life and survival, which are frequently used by breeders for crop improvement and this has offered new opportunities for agricultural development (Chang, 1994; Harlan, 1975; Hawkes, 1983).

Coconut, *Cocos nucifera*, belongs to a monotypic genus and there are no known wild forms. The variability in its genepool, in terms of what could be described as provincial/local types (ecotypes), is reported to be the highest in Southeast Asia (Whitehead, 1976). The distribution of coconut palm is very wide, but restricted to 20° on either side of the equator. Though there is still much debate, ethnological information as well as the diversity of local types indicate Southeast Asia to be the most probable centre of diversity (Harries, 1990). Coconuts have moved from Asia in both directions, to the Pacific and Americas in the east and to Africa in the west. Most of the dispersal must have been through humans, although some nuts must have moved by flotation, judging by the coastal distribution of coconut (Burkill, 1935; Foale, 1987 and 1992).

The need for increased efforts in collection and conservation of coconut genetic resources was first recognized during the Eighth Pacific Science Congress in Manila, 1953. This was followed by several meetings over the years and considerable efforts have been made by individual countries and organizations like the Food and Agricultural Organization of the United Nations (FAO), the South Pacific Commission (SPC), Institut Recherches pour les Huiles et Oléagineux (IRHO) etc. The International Board for Plant Genetic Resources (IBPGR) established an Advisory Committee on Coconut Genetic Resources in 1975. In 1991, due to the global concern over the decline in production and erosion of genetic resources of coconuts, the International Plant Genetic Resources Institute (IPGRI), the then IBPGR, was asked by coconut producing countries and the CGIAR to initiate a network on coconut genetic resources.

While these efforts have been going on at global level, individual countries, including India, have been carrying out activities related to coconut genetic resources. Extensive efforts were made in India and the Central Plantation Crops Research Institute (CPCRI), Kasaragod has been maintaining the world's largest collection of coconut germplasm comprising of 86 exotic and 46 indigenous cultivars (Nair, 1996). Other major coconut collections are maintained in Cote d'Ivoire, the Philippines, Indonesia, and Papua New Guinea.

Conservation of plant genetic resources

It is now well recognized that for any given genepool, a number of different approaches and methods may be necessary for efficient and cost-effective conservation. The two basic approaches to conservation of plant genetic resources (PGR) are termed *ex situ* and *in situ*. The *ex situ* approach involves conserving the genetic resources outside their original habitat in the form of seed, embryos, tissues or plants. Methods of *ex situ* conservation can include cold storage, *in vitro* storage or field genebanks, depending on the propagules used. In contrast, *in situ* conservation involves the maintenance of genetic diversity of a species or genepool in the habitat in which the diversity evolved. In the definition of Convention on Biological Diversity (CBD), it includes the maintenance of diversity in farmers' fields and orchards, thus it includes the on-farm conservation. It is important to emphasize that *in situ* and *ex situ* conservation are not mutually exclusive, but are indeed complementary.

Efficient conservation of a genepool may employ a combination of methods, from nature reserves to genebanks. The appropriate strategy and the balance between methods used depend on factors such as the biological characteristics of the plants, their present management and use by humans, available resources for conservation, number of accessions in a given collection and geographic sites, the purpose of conservation, the availability of germplasm for use, and political and administrative policies. Cost, reliability and stakeholder involvement in alternative conservation methods must also be considered. The extent of a particular method used may differ from one genepool to another (Ramanatha Rao *et al.*, 1996; Withers, 1993). As coconut is monotypic, without any known wild form, we are concerned with the conservation of diversity within a single species. This species includes many so called ecotypes and cultivars.

Conservation of coconut genetic diversity

Traditionally, field genebanks (FGB) have been the most common mode of conservation used for coconut conservation and this is an *ex situ* method. Many important cultivars of field and horticultural crops including coconuts are either difficult or impossible to conserve as seeds (i.e. no seeds are formed, if formed the seeds are recalcitrant) or the species are vegetatively propagated. Hence, they are conserved in FGBs. FGBs may run a risk of being damaged by natural calamities, infection, neglect or abuse. *Ex situ* conservation of tree species using FGBs requires a substantial number of individual genotypes to be an effective conservation measure. Thus, FGBs require more space, especially for large plants such as coconut and they may be relatively expensive to maintain, depending upon the location and the complexity of alternative techniques available. An important advantage of FGB is that it provides easy and ready access to the conserved material for research as well as for use. For numerous plant species, the alternative methods have not been developed to the stage at which they can be effectively used (Ramanatha Rao and Riley, 1994). So far, this is true for coconut as well and thus, the establishment of FGBs has been playing a major role in any conservation strategy and probably will continue to do so. However, we must understand that conservation through FGB is one of the options of a complementary strategy for the conservation of germplasm and efforts to develop other methods such as *in vitro* conservation and on-farm conservation must go on.

Currently, efforts are underway to establish a multi-site International Coconut Genebank (ICG) (Ramanatha Rao and Batugal, 1996) and the ICG-South Asia will be established in Kidu Farm of CPCRI (Nair, 1996). Other ICG sites are in Papua New Guinea for South Pacific, Indonesia for Southeast Asia and Côte d'Ivoire for Africa and Indian Ocean Islands. Efforts are also underway for the identification of an ICG site in Latin America and the Caribbean. The objectives of the ICG are: to conserve nationally and regionally identified diversity; to conserve internationally identified diversity; to further assess the diversity; to evaluate the performance of the conserved germplasm and disseminate related information to coconut-producing countries; to make germplasm materials available to interested coconut-producing countries in accordance with existing protocols; and to conduct research and training in relation to the above. So, any ICG that is established should have at least the diversity from the region and should be able to evaluate the material as well as hold germplasm from other countries for future repatriation. This is the field genebank method.

With regard to conservation of coconut genetic diversity, the strategies for collecting genetic diversity and conservation are fairly well established (Guarino *et al.*, 1998; Ramanatha Rao *et al.*, 1996). There are many field collections of coconuts in various countries, usually connected with coconut research institutes. According to the FAO database on germplasm holdings, a total of 950 accessions have been reported. Often these collections are quite old and may originally have been developed in a somewhat haphazard manner. The exact origins of many of the palms in collections are often unknown. Although the establishment and maintenance of these collections represent a commendable effort, there is a need to update the collections in a scientific manner, with due regard to thorough documentation of populations, and correct and foolproof labelling. Despite all these shortcomings, the conservation strategy for coconut so far, as mentioned earlier, focused on FGB. Efforts are also underway to develop appropriate *in vitro* and *in situ* conservation technologies. These two newer technologies which can help in further developing the process of complementary conservation of coconut germplasm are elaborated hereunder.

In Vitro conservation and cryopreservation

Conservation of plant tissues and organs is another method of *ex situ* conservation of germplasm. Consideration here is for conservation of genotypes. In this context, conservation of coconut embryos is a feasible method. Slow growth and other protocols for meristematic tissue, when these become available, will permit mainly the conservation of coconut germplasm as clones and may be useful for gene conservation.

Sampling genetic diversity

As mentioned earlier, coconut belongs to a monotypic genus and hence almost all the genetic diversity is in one species. We have also seen that the diversity in coconut is mainly in the different ecotypes/landraces, and conservation of these is in fact conservation of genotypes. Using cryopreservation of coconut embryos, it should be possible to conserve most of the genetic diversity in the genepool. However, information on the extent and distribution of genetic diversity in coconut is lacking. In addition, there is very little information on genetics of most of the useful traits and hence the probability theory has to be used in the case of other cultivated plants, as noted in the collecting strategy for coconut (Guarino *et al.*, 1998). The decisions have to be made on the numbers of plants, assuming certain probability for capturing genetic diversity. Following probability theory and random sampling of plants and using in *in vitro* collecting of embryos, it will be possible to collect and conserve most of the coconut genetic diversity. Similarly, cryopreservation, as in the case of field genebank, will need sampling of large numbers of embryos to capture maximum genetic diversity, but will require significantly much less space. Because of the relative ease of collecting embryos using *in vitro* techniques, collecting large numbers of embryos per population or from more populations as needed will be comparatively easier, thus assisting in better sampling of genetic diversity.

Safety and security

If sufficient resources are available, *in vitro* conservation, including cryopreservation can become a safe and secure method for conservation of coconut genetic diversity. *In vitro* cultures require constant maintenance and monitoring and the material stored *in vitro* is lost rapidly if adequate maintenance is not ensured. Material stored under cryopreservation requires a lower level of regular maintenance but, again, the material is irremediably lost if the required storage conditions (-150 to –196°C) are not maintained. By contrast, perennial plants in field genebanks can be kept alive even after relatively long periods without any maintenance. In addition, *in vitro* conservation and cryopreservation require relatively sophisticated infrastructures and skilled human resources and their utilization for PGR conservation is therefore limited to countries where these conditions are available.

Accessibility

It is important to mention that cryopreservation is intended for long-term conservation only as a back-up or safety duplication of material conserved in field collections, since the material stored in liquid nitrogen will require numerous manipulations before it becomes accessible and usable. By contrast, field genebank material is readily accessible and usable. The use of embryo *in vitro* culture, however, will drastically improve the accessibility of germplasm since it significantly facilitates its international exchange.

Technology Development

Slow growth techniques, which allow medium-term conservation and cryopreservation techniques that allow long-term conservation, have been developed for reproductive and somatic tissues of a large number of species and are now either available or at various stages of development (Engelmann, 1997; Withers and Engelmann, 1995). The use of *in vitro* culture techniques, including slow growth and cryopreservation, represents an important additional option for the medium and long-term conservation of species like coconut. A considerable amount of work has already been conducted in coconut for the development of *in vitro* collection, culture, conservation and distribution techniques (Ashburner *et al.*, 1994; Ashburner *et al.*, 1996; Assy-Bah *et al.*, 1991; Assy-Bah and Engelmann, 1993; Blake, 1995; Engelmann and Assy-Bah, 1992; Karun *et al.*, 1993; Karun *et al.*, 1996).

Coconut has big seeds and there is no dormancy period. Mature seed (fruit) starts germinating within 2-3 weeks after it drops on the ground. These two characteristics drastically limit the amount of material which can be gathered during collecting missions. A simple and efficient *in vitro* field collecting technique has been established which involves extracting the embryos from the nuts and inoculating them directly onto culture medium at the collecting site (Ashburner *et al.*, 1996; Assy-Bah *et al.*, 1989). Embryos can be kept for two months before they are transferred to culture in a controlled laboratory environment (Engelmann and Assy-Bah, 1992). This technique is used routinely to collect coconut germplasm. Typical slow growth protocols that are now available for plants like sweet potato, banana etc., are not yet available for coconut due to the difficulties encountered with propagation techniques for this crop. However, short-term conservation of zygotic embryos has been achieved by defining culture conditions which delay their germination for twelve months (Assy-Bah and Engelmann, 1993). *In vitro* culture is fully functional for coconut zygotic embryos (Assy-Bah *et al.*, 1989). Plants can be regenerated on a one to one basis with ease, even though hardening of young plants in field conditions can be problematic in circumstances where experience in handling *in vitro* cultured material does not exist (Ramanatha Rao *et al.*, 1996). These problems were considered at the International Embryo Culture and Acclimization Workshop, 27-31 October 1997, ARC-PCA, Philippines organized by IPGRI. Common experiments at a few identified laboratories using common protocols are underway. Problems arise at the stage of clonal propagation onwards. Mass propagation by means of somatic embryogenesis is under development and limited numbers of clonal plantlets are now reproducibly produced for some genotypes (Verdeil and Buffard-Morel, 1995).

Preliminary experiments on long-term conservation have led to the development of a cryopreservation protocol which has been successfully applied to zygotic embryos of four different genotypes (Assy-Bah and Engelmann, 1992). The difficulties encountered in hardening *in vitro* cultured plantlets need to be resolved and additional work is required to refine the cryopreservation technique and to carry out experiments with additional genotypes (Engelmann *et al.*, 1995).

Conservation of plant genetic resources has to take into account exchange of germplasm as well. *In vitro* techniques have been used extensively for exchanging coconut germplasm in the form of excised embryos inoculated *in vitro*. The FAO/IBPGR Technical Guidelines for the Safe Movement of Coconut Germplasm recommend that coconut germplasm be distributed in this form to reduce chances of introducing diseased material into disease-free areas (Frison *et al.*, 1993).

Currently, the *in vitro* culture process itself, i.e. from the inoculation of embryos *in vitro* to the production of whole plants ready for transfer *in vivo* appears to be fully functional though there is scope for significant improvement of the *in vitro* step. Additional data need to be collected on the development and growth in the field of plants originating as *in vitro* cultured plantlets, in comparison with seedlings. Further research is needed to refine *in vitro* and cryopreservation techniques so that the method is fully operational for the medium-and long-term conservation of coconut. Once the technique is perfected, cryopreservation of zygotic embryos can play a major role in the overall approach to conservation of coconut germplasm. Involvement of more number of experienced researchers in different countries is critical and it is important to refine the methods to use the *in vitro* technique routinely.

Costs

The establishment of coconut *in vitro* and cryopreservation facilities may prove to be initially costly, but later maintenance may be cheaper. Long-term planning and sustained funding is needed.

Human dimensions

As noted earlier, *in vitro* conservation and cryopreservation require relatively skilled human resources. *In vitro* conservation of coconut germplasm requires knowledge of coconut biology, physiology and tissue culture techniques, which is more specialised than that needed for its field cultivation. Hence, *in vitro* conservation comparatively needs more expertise and specialized skills and thus requires specialized training.

***In situ* conservation**

As in the case of field genebanks, consideration here is for the conservation of genotypes and now it is well recognized that coconut conservation on-farm is a feasible method. However, this is a fairly new approach to most people and some elaboration on the concepts is provided here.

In situ conservation is dynamic as opposed to the semi-static nature of *ex situ* conservation. One of the reasons given for choosing *in situ* conservation over *ex situ* is the need to maintain the evolutionary potential of species and populations (Bennett, 1970; Brush, 1995; Frankel and Soulé, 1981; Ledig, 1988; Ledig, 1992). We need to note, given the fact that human activities can cause habitat destruction and loss of biodiversity in some cases, and the maintenance of biodiversity in other cases, there is a need to complement it with *ex situ* conservation effort.

It is well recognized that *in situ* conservation permits populations of crop species to be maintained in their natural or agricultural habitat (as per definition of the Convention on Biological Diversity), allowing the evolutionary processes to continue to affect the genetic diversity and adaptability of populations. In the particular case of on-farm conservation, landraces continue to evolve, influenced by natural selection as well as by selection pressures imposed by the farmer, thereby providing opportunities for continuous crop adaptation and improvement (Sthapit, 1998). We must note that farmers will not continue growing local landraces or species unless they see some advantage of growing them, i.e. genetic diversity present in the landraces has to be useful to the growers. Nevertheless, on-farm conservation needs to be continued to promote an evolutionary process that can result in recombination of useful genes, especially those that influence adaptation, in landraces under changing conditions. Though it may not be applicable to coconut, we must recognize that geneflow from the wild relatives to landraces, and from landraces to improved cultivars is a dynamic process and there is every need to maintain this process if the crop improvement efforts have to meet the ever- increasing demands of the world's population (Bellon *et al.*, 1997; Vaughan and Sitch, 1991). With continued maintenance of landraces in farmers' fields, new landraces will continue to evolve under changing environment (natural selection) and selection pressure exerted by farmers, thus providing avenues to the evolution of new diversity. Therefore, the maintenance of traditional cultivars and landraces *in situ* should be an essential component of sustainable agricultural development (Sthapit, 1998).

Requirements for *in situ* conservation

Sustainable *in situ* conservation will require community participation, control of land rights in local communities, education, extension and development of environmental awareness. Of equal importance is the principle that any *in situ* conservation programme must also benefit the local communities. Management by local communities can often be developed to effectively link conservation and use (McNeely, 1994 and 1996). It is important to consider indigenous knowledge, participation and cooperation between local people, researcher and conservationists and non-governmental organizations (NGOs). Additionally, there is need to establish areas of intensive management or high yielding plantations for long-term sustainability of any *in situ* conservation programme. Conservation activities by commercial and private agencies can also be promoted as these groups have the capacity to fund such activities. Since it will be necessary to foster sustained conservation and use of resources to derive long-term benefits from the exploitation of the resources, we believe that the commercial sector and private agencies will be interested in activities mentioned above. This can lead to much wanted linkages between public, community and private sectors in plant genetic resources conservation (Riley, 1995). It is likely that the major part of coconut diversity would be found *in situ*, in the yards or gardens of small farmers and undisturbed tropical sea coasts and uninhabited islands. The methods of management and benefits to local communities in maintaining and using this diversity must be considered while implementing an *in situ* (or on-farm) conservation programme. Although the programmes to establish *in situ* conservation of coconut have not yet been initiated, coconuts grown by small farmers have several features that should make *in situ* conservation feasible. These include the long-term perenniality of the crop which increases the sustainability of conservation; the variety of types of coconut that farmers in community or groups of communities maintain and the great value of coconut for multiple uses can encourage growing different types by specific communities.

In contrast to the suggestions made by several people in the past, it is now generally agreed that *in situ* conservation cannot be achieved through subsidies or compensation and farms cannot be maintained as museums or reserves (Sthapit, 1998). So, such strategies will not work for coconut as well. To promote on-farm conservation of coconut; one must think in terms of investments in activities that lead to farmer welfare. Such a strategy can include, among others, participatory plant breeding, empowerment of farming community through skill transfer training, and institutionalising community coconut genebank and through recognition of farmers' role in on-farm genetic conservation. This kind of indirect compensation may reach more farmers and thus be more equitable than a system of payment to a few farmers (Brush, 1992). The values of such strategy will consolidate if level of education, public awareness and *in situ* sensitive policy relief is considered (Sthapit, 1998).

Genetic diversity

As noted earlier, genetic diversity in coconut is mainly in the different ecotypes/landraces, and hence conservation of genotypes should be the main focus. Using on-farm conservation, it is possible to conserve some of the most diverse ecotypes. It will also be possible to conserve that part of genetic diversity that is most useful to farmers. However, information on the extent and distribution of genetic diversity on farms is lacking and we will return to this topic a little later. It must also be noted that, unlike most other crop species, very few coconut farmers appear to have paid special attention to phenotypic and other differences in coconut types that they grow. Generally speaking, most often coconuts are just planted and little attention is paid to the crop later, thus the so-called farmer's/indigenous knowledge may be limited. However, this may not always be true. Since the coconut farmers have tended to move their own coconut seed to different areas and cultivated on marginal soils and conditions, they have contributed to the adaptation of coconut to a range of different adaptations. This specific adaptation under farmer management needs to be understood and protected (Eyzaguirre, 1998). We noted earlier that field genebank and *in vitro* conservation of embryos require a substantial number of individual genotypes to be effective conservation measures. Similarly, a network of farm sites will be needed for conservation of genetic diversity in coconut.

In the case of coconut, most of the stands in South and Southeast Asia are in more or less intensively managed areas and the effects of growers' practices on genetic diversity are of paramount importance. In almost all these areas there is presently little information available on the status of the genetic diversity in such plantations. It is now possible to monitor and estimate genetic diversity using molecular markers (Ashburner *et al.*, 1997; Foale, 1992; Hodgkin and Debouck, 1992; Leburn *et al.*, 1995); however, the limited resources available for such work makes such proposals difficult to implement. Measurement of genetic diversity in coconut will depend largely on morphometric traits as described in the Coconut Descriptors (IBPGR, 1992; Santos *et al.*, 1996). Using morphometric traits for studying and monitoring genetic diversity in coconut farms would mean being beset with a number of difficulties primarily because they do not lend themselves to any formal analysis of genetic diversity with much precision. The mode of inheritance of characteristics is frequently unknown and may be complex and generally does not provide information on within population diversity. Increasing the use of molecular markers is expected to assist in better understanding of the structure of genetic diversity both at a specific site and across regions (Ayad *et al.*, 1997) DNA-based molecular-marker techniques have been proven powerful in genetic diversity estimations. Among them, restriction fragment length polymorphism (RFLP) was the first and is still the most commonly used in the estimation of genetic diversity of eukaryotic species. The recently developed PCR-based multiple-loci marker techniques, which include random amplified polymorphic DNA (RAPD), amplified fragment length polymorphism (AFLP), Microsatellite-AFLP and inter-SSR PCR, are playing increasingly important roles in this type of research. Significant progresses in using molecular markers to study genetic diversity in coconut are being made. Microsatellites and AFLPs will effectively complement RAPDs and RFLPs. Microsatellites have been repeatedly shown to reveal more diversity than RFLPs. They have the potential to be developed as kits which do not require radio labelling and can be deployed in a much wider range of laboratories than RFLPs using much smaller amounts of plant tissue. AFLPs, though expensive, have revealed substantial important diversity in Sri Lankan material and are not subject to the repeatability problems experienced by many groups who have tried to use RAPDs in multi-site studies and analyses. Potential now exists for developing a microsatellite kit for use with coconut. Thus, with increased facilitation of measurement of genetic diversity, conservation of coconut genetic diversity on-farm can be based on scientifically sound principles (Ramanatha Rao *et al.*, 1996).

Safety and security

Safety and security of on-farm conservation of coconut, like for other crops is directly dependent on the farmers/community. We have seen earlier that farmers will continue to grow the material as along as the diversity/genotype is valuable/profitable to them and they can change if a better alternative/option becomes available. This is acceptable in of-farm conservation and is part of the evolution of the farming system. Since it is a dynamic method, all the advantages of *in situ* conservation are present. However, the effects of growers preferences and selection pressure are limited due the perenniality as well as seed propagation in coconut. On the other hand, perenniality makes coconut a good candidate for on-farm conservation..However, problems can arise from natural disasters, attack by pests (including wild boars, rats, and even elephants). However, these are all part of the dynamic process and are the usual constraints to coconut production as well and appropriate control measures have to be taken. Such measures could become a part of the farmer welfare mechanism suggested earlier.

Accessibility

Material is readily accessible and immediately usable by the farmers/ community. Appropriate methods need to be developed for its accessibility by others, including researchers. Developing good linkages between *ex situ* and *in situ* conservation efforts and improvement programmes will enhance the accessibility.

Technology development

As noted earlier, though this method has been practised by farmers for several millennia, in the context of conservation of plant genetic resources in the formal sense, it is a relatively new approach. There is need to understand the socio-economic basis for continued cultivation of a type of coconut by farmers. Similarly, linking multi-purpose uses of coconut and high-value alternative products with suitable germplasm could promote *in situ* conservation. But these aspects need further investigation. Systematic documentation of farmers' knowledge of coconut diversity and uses is needed. Sustainable *in situ* conservation will require community participation, control of land rights in local communities, education, extension and development of environmental awareness.

Partnership between coconut researchers and farmers is essential to define the needs of conservation and potential use and benefits to farmers from of-farm conservation of coconut genetic resources. Farmer-participatory approaches to coconut genetic diversity could contribute to several objectives with rates of return (Eyzaguirre, 1998) and thus make *in situ* conservation of coconut a viable option within a complementary conservation strategy for this important crop. Using this approach, locally adapted varieties that can perform well in less favoured conditions with low level of inputs (Persley, 1992). It can assist in identifying uses and techniques to exploit and deliver greater value for a wider range of coconut products (Eyzaguirre, 1998). Farmers are experts in multiple uses of coconuts and only a few of these uses have been exploited commercially. Thus, farmer participation in in situ conservation of coconut is very essential. By bringing the holistic multi-purpose perspectives, we may be able to identify and deploy more coconut genetic diversity as a means of stabilising and expanding coconut production (Eyzaguirre and Lipman, 1998).

Costs

Among all the methods available, on-farm conservation is said to be the cheapest method. Even though on the paper it can appear to be an expensive method, if the benefits accrued over the long years are correctly entered into the equation, the costs will be minimal. The other spin-offs from *in situ* conservation include agricultural and rural development, which in turn represent high value in terms of benefits derived from on-farm conservation. There is also a need to develop proper benefit sharing mechanisms.

Human dimension

The need to understand the scientific basis of *in situ* conservation well recognized. This requires for most of us to retrain ourselves to understand the role of farmers and communities in the maintenance of genetic diversity. Training in areas like rural appraisal methods and community-based management will be needed. Major public awareness campaign will also be needed to enhance the understanding of the role that *in situ* conservation play not only in plant genetic resources conservation but also in agricultural and rural development.

In the context of *in situ* conservation, there is a need to develop a strategy for the documentation and use of the farmer's knowledge. This requires specific expertise on interacting with farmers and indigenous people. Staff working on collecting and conservation therefore require training in specialized participatory methodologies such as participatory rural appraisal (PRA), in particular the use of visual methods (sketches, ranking, diagramming, cognitive mapping). They should be able to judge as to how to choose informants, when it is best to time the consultations, whether individual interviews should be complemented with group discussions and ethical issues such as informed consent and anonymity. Farmers should at all times be seen as an integral part of the conservation team. The idea of recognizing farmers' knowledge can be better represented now that the IK Journal concept is being developed. The IK Journal concept is complementary to the methods that scientist use such as PRA and provides for a way to analyse more information.

Current IPGRI and COGENT initiatives on germplasm conservation

Based on the above principles, IPGRI and COGENT have been laying the groundwork for a global complementary conservation strategy for coconut. Towards this end, the International Plant Genetic Resources Institute (IPGRI) and the International Coconut Genetic Resources Network (COGENT) are currently implementing activities and undertaking research initiatives that would lead to a flexible and sustainable comprehensive coconut conservation strategy. These include the following:

Enhancing the development of national field collections

A total of 936 accessions are conserved in 20 sites in 17 member countries of COGENT. IPGRI and COGENT support additional collecting and conservation in national genebanks. From 1994 to 1997 a total of 150 additional populations were collected in eight countries in the Asia-Pacific region and most of these will be conserved in national genebanks. From 1998 to 2001, additional collection and conservation will be undertaken involving 20 countries in the same region. In both collecting efforts, the Government of India collected germplasm in six Indian Ocean Islands and these populations are planned to be conserved in the Indian national genebank and in the International Coconut Genebank for South Asia. Similar collecting initiatives are also being planned in the Africa and Indian Ocean and in the Latin America and the Caribbean regions.

Establishment of a multi-site International Coconut Genebank (ICG)

To further ensure the security of national collections, COGENT is establishing a multi-site ICG to be hosted by the Governments of India, Indonesia, Papua New Guinea and Côte d'Ivoire for their respective regions. The ICGs will conserve important germplasm in the region and make these available to COGENT member countries. It is envisioned that the ICGs will also facilitate safe movement of germplasm among countries in the region. To strengthen the ICGs, IPGRI and COGENT are providing technical and financial support to enhance their embryo culture capability through research projects to refine this technology.

Farmer participatory research and *in situ* conservation

To promote the multipurpose uses and competitiveness of the coconut, IPGRI and COGENT, in collaboration with IFAD, are supporting a farmer participatory research to determine the multipurpose uses of the coconut and to identify varieties which are suitable for these uses. Based on these findings, the project will also promote *in situ* conservation of varieties with multipurpose uses in collaboration with farmers.

Research to develop techniques to promote complementary conservation

The coconut embryo culture technique is being refined to enhance its effectiveness as a tool in collecting, safe movement and conservation. Through the assistance of DFID and the ADB, the embryo culture technique is being refined in nine leading laboratories worldwide and in three others using national funds. Under this project, the Institute of Plant Breeding in the Philippines will undertake a research to develop embryo culture as a medium-term conservation technique. The host countries of the ICGs are also participating in this project.

Recognizing the potential of cryopreservation for long-term conservation, IPGRI and COGENT are developing a project proposal on cryopreservation of coconut embryos. The proposal, which will involve research collaboration between an advanced laboratory and the four host countries of the ICG, will be submitted to a suitable donor soon.

IPGRI and COGENT are also undertaking a survey to obtain farmers' perceptions on why they conserved their coconut varieties in the past and what might induce them to undertake *in situ* conservation in the future. Based on the result of this survey, an appropriate technique for *in situ* conservation will be developed and promoted.

CONCLUSIONS

Several complementary methods can be used for effective conservation of coconut genetic resources to enhance sustainable coconut productivity. In the discussion presented here, two of the newer technologies – *in vitro* and *in situ* - have been elaborated in relation to various issues such as the genetic diversity that need be conserved, safety and security of conserved material, access to and use of the material, technology development, cost implications and human resource needs. The most appropriate combination of conservation methods described may be adopted for a particular collection. Taken together, the totality of these cases could lead to the development of a global complementary conservation strategy. The paper also describes the current IPGRI and COGENT initiatives towards the development of complementary conservation methods for coconut.

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IMPLICATIONS OF INTELLECTUAL PROPERTY RIGHTS FOR INDIAN AGRICULTURE

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India with more than 65 per cent population, still dependent on agriculture, contributes 27 per cent of its Gross Domestic Product (GDP) besides contributing considerably to its export earnings. As such the protection of Intellectual Property Rights (IPRs) is an issue which is bound to affect the lives of millions of farmers (overwhelmingly poor). There has been and continues to be a wide ranging debate in this country on this issue and a consensus has emerged that the traditional and legitimate rights of the farmers should be adequately protected. There is also a provision for limitation or exception to the exclusive rights under article 13 of TRIPs Agreement.

With its diverse agro-climate and socio-economic situations, India provides an excellent test case for developing policies on IPRs which would conform to the provisions of TRIPs agreement in view of its obligations as a member of WTO on one hand, and safeguarding its sovereign rights and rights of its peoples on the other. It is a tall order but could be achieved, given the resolve of all stakeholders. This could also serve as role model to other developing countries who could adopt them with requisite modifications suiting to their specific requirements/environments. This, of course, entails a healthy public debate, shorn of rhetoric and acrimony with the sole purpose of public good.

Agriculturally related IPRs in today's environment

Despite the impressive achievements of Green Revolution in India, there are many Gray Areas in which the farmers continue to use traditional plant genetic material. Ensuring free/cheap access to these farming families to improved technology continues to be an important mission and a challenge for National Agricultural Research System (NARS). To develop technologies for this set of resource poor farmers (small, marginal) requires considerable capital, including that for collection, characterisation and enhancement of genetic material. The benefits which take a long time to materialise, are difficult to capture and therefore such investments have not been attractive to the private sector. It is, thus, no wonder that the private sector in India has been active in vegetable/fruits seed sector and not much (in fact negligible) in food grain sector. Yet, with the rapid increase in population and also income growth (emergence of a large middle income group with discerning taste and capable of paying for quality goods at competitive price), much of the demand for food, feed and fibre can be met only by continued increase in the productivity of land per unit time and input, that too in a situation beset with increasingly scarce and often deteriorating land and water resources. Our agricultural sector is faced with a dual challenge - a challenge of sustaining and enhancing the quality of natural resources including germplasm, as the only way to meet the growing domestic demand and international competition (quantitative restrictions are challengeable) a challenge in which the rapidly advancing science would be of considerable value and the other of ensuring continued free/cheap access of the poor to the emerging technologies while simultaneously conserving the vital germplasm for the use of plant breeders.

Action proposed to be undertaken by the Government of India on IPR issues

Amendments in Indian Patent Act (1970)

The Indian Patent Act (1970) grants only process patents in food, medicine, drugs and substances provided by chemical processes. Under the TRIPs Agreement, a transition period of five years (with effect from 1.1.1995) is available to all developing countries to give effect to the provisions of TRIPs Agreement. Moreover, the countries that do not provide product patents in certain areas, can avail of a further transition of five years - a total of ten years are available to India for effecting amendments in its Patents Act. Notwithstanding the transition period allowed as per Article 70.8 and 70.9 of TRIPs Agreement, the member countries of WTO like India were required to provide a means for filing of applications for product patents in the areas of pharmaceutical and agricultural chemicals and on fulfilment of certain conditions, grant exclusive rights for a period of five years or until patent is granted/rejected, whichever is earlier. As the Indian Patent Act, 1970 does not provide for the grant of product patents, *inter alia* in the field of agricultural chemicals, provisions had to be made by amending the 1970 Act through an Ordinance promulgated in 1994. Since the Ordinance had to be replaced by an Act of Parliament, and as due to certain unavoidable reasons it could not be done so, the Ordinance was allowed to lapse. As per the decision of the Government, the Patent Office has been receiving product patent applications in these fields and is keeping them unexamined. These are required to be taken up for examination for 1 January, 2005 in terms of TRIPs Agreement.

The Government is actively considering to amend the Indian Patents Act, 1970 to bring it in conformity with the TRIPs Agreement. It will undertake to provide the adequate safeguards to protect the interest of the people. It is also expected to allay the fears that the floodgates to patenting of genes, living organisms and product derived from them might have been open. However, as a signatory to the Convention of Bio-diversity (CBD) which ensures sovereign rights to a country on biological resources, India is under no pressure to accepting patenting of any life forms classified as plants and animals. It may, however, have to agree to the patenting of micro- organisms and products from genetically engineered micro-organisms. As per the indications available, the Government is introducing a Bill on amendment of the Patents Act in the winter session of the Parliament.

Plant variety protection

As per article 27 of the TRIPs Agreement, a country is obliged to ensure protection of plant varieties either by patents or by an effective *sui generis* mechanism or by combination thereof. Since the Indian Patents Act, 1970 excludes agriculture and horticulture from patenting, India is required to put into place *sui generis* system by evolving a legislation on plant variety protection by the year 2000 AD.

There has been a country-wide debate involving policy makers, scientists, non-governmental organisations and other stake holders on the kind of system which would suit our needs and also provide for adequate protection to researchers as well as farmers. While there has been consensus on to legislate an Act on the matter, many apprehensions have been expressed regarding protection of rights of farmers for using the material from their harvest in the ensuing season. In India, although the spread of high yielding varieties has placed a significant role in ushering in well known Green

Revolution, there are vast areas which remain untouched by it. These areas are almost 65 per cent of our arable land which are rainfed and inhabited mostly by small and marginal farmers. It is reckoned that unless Evergreen Revolution is ushered in India encompassing areas hitherto remain uncovered, the increase in food production to cope up with the burgeoning population will be a difficult task indeed.

One of the most important factors for increasing the productivity has been timely supply of inputs-foremost being the seeds of improved varieties. Although the public sector seed companies have been doing perhaps their best (private seed companies largely keeping away from production and supply of seeds of cereals, pulses, oilseeds, and instead concentrating on seeds of vegetables and fruits due to higher rates of return), it has not been possible to provide good seed to large number of farmers-a majority of whom is marginal and small land holders-resource poor segment of our peasantry necessitating use of their harvested, material for the next season. Hence the rights of farmers to use, exchange, sale or dispose in any manner the seed produced in their farm or of the harvested, have to be protected. Even in cases where restraints are proposed to be imposed on the sale of seeds of protected varieties by farmers, there is a strong case for exempting small and resource poor farmers from such restraints. It is understood that many European legislations on the subject exempt farmers whose holdings are below a certain size from the PVP legislation. As it is well known that in India the land holdings are so small that these cannot be compared with even the smallest land holdings in Europe, there is a case that the farmers are not subject to any restraint in the disposal of seed or produce of a protected variety except when it is done on a sizeable commercial scale. Further, the views have been expressed that the legislation should not in any manner hamper the momentum of indigenous research efforts for evolution of new varieties as that could have serious implications for India's Agriculture. The restrictions on the use of protected varieties for bonafide research will have to be liberalized.

The Government have taken due note of these concerns while proposing to introduce a bill on PVP which will seek to provide adequate protection to plant breeders as well as farmers. It is understood that the draft proposals also include for setting of a Plant Varieties and Farmers'

Protection Authority, National Community Gene Fund, Compulsory Licensing and Protection of Public Interest, Appellate Board among others. The Government is also considering accession to UPOV 1978 version which allows the rights of plant breeders and farmers. The Fourth International Conference on Plant Genetic Resources held at Leipzig (Germany) gave global endorsement for farmers' rights. The Indian Council of Agricultural Research (ICAR) has established a National Research Centre on DNA Finger Printing at New Delhi which will be of great use in protecting the materials in the event of disputes arising out of IPRs. Meanwhile, pending the passage of this Bill, arrangements have been made to register the new genotypes with the Registry at National Bureau of Plant Genetic Resources, New Delhi on first-come first serve basis. The registration will provide the basis for the claim of breeders which could be staked with the Statutory Authority under PVP Act whenever it is established in event of disputes.

Protection of Bio-diversity

India is one of largest repositories of bio-diversity. An urgent need has been felt to inventories the bio-diversity to have a complete picture of our valuable resources. Little more than 150 of the world's 248,000 higher plant species are under commercial cultivation. About 20 crops provide 90 per cent of the world's food, just four of them-rice, wheat , maize and potato- supply more than half of its daily calories. Nevertheless, diversity-both within and between the species-is the basis of most small scale farming systems. It allows them to withstand vagaries of climate and disease that can undercut productivity. Farmers have painstakingly developed resilient and bountiful agricultural systems based on bio-diversity and on their knowledge of how to work successfully with them in equally complex cultural settings. There is a caution that considering agriculture as matter of commodities and mere business militates against the security that the people derive from diversity. Both community livelihoods and the international economy can benefit far more from a wider deployment of bio-diversity in agriculture including the wild species and currently under-utilised crops. It is reported that more than 2000 species of native grasses, roots, fruits and other food plants have already been classified as Lost Crops of Africa. The Africa need not be a basket case if some of those hardy cereals could be brought into the mainstream of agricultural production. Through advances in biotechnology research, such resilient crops will be vital for extending cereal production into the ever marginal lands for the increasing population.

The Wealth of India series have made concerted efforts in this direction, however, the work is complete by no means. The same holds good for our traditional knowledge both in written form as well as transmitted through words of mouth from generation to generation. Lately, efforts have been made to assert our rights on our bio-resources like withdrawal of US patent on turmeric and earlier upholding claim of our environmentalists against a patent on neem oil given to a European multinational. However the cases of patenting of Basmati and others have been causing public outcry and have prompted the Government to take resolute steps to prevent recurrence of such cases.

The Government is considering to bring out a comprehensive legislation on National Bio-diversity to legalise its bio-resources and the rights of its people. A proactive rather than reactive strategy is essentially required. Among the horticulture crops, plantation crops play a major role in the international trade, besides providing livelihood to millions of people in many sates. Our knowledge on these crops is limited with regard to the potential for patenting. Kerala Science Congress, being held at CPCRI, Kasaragod, has come at the right time to debate on issues relevant to patent laws. The deliberations should come out with concrete proposals for consideration at ICAR level.

CONCLUSION

Economic growth is based on and accelerated through technological development and the use of high sophisticated technologies. Confidence in a well-enforced intellectual property protection is a great stimuli for innovation. Technological innovation is an important element in economic development and social property and a well defined IPR regime is a basic source of technological information that research organisation 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.

Earlier, the public funded National Agricultural Research System was offering all its technologies viz. seeds/planting material/equipment etc. almost free of cost. The situation is changing fast after the emergence of liberalisation on the scene which has necessitated the relook at the present practice.

The farmers of all categories are going to be benefited immensely from the new impetus to research due to placement of IPR regime in general and IPRs in agriculture in particular. The PVP legislation and also Bio-diversity legislation will provide sufficient protection to farmers privilege and rights respectively. The farmers' privilege to use the seed from harvested material for the next season will continue to be available except in case where Terminator Gene has been introduced in the seeds which will weaken the seed viability in the next seasons tremendously and thus it will not be possible to sow the seed in the next season. The Government of India has assured the nation about its resolve to protect the country from such debutating technologies.

THE SOCIO - ECONOMIC FEATURES OF COCONUT FARMING IN KERALA

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ABSTRACT

Coconut in Kerala is essentially a homestead crop and forms a major component of diverse crops grown deliberately by the farmers. In all the holdings over 75 per cent of the area is occupied by coconut and it's proportion decreases with increase in holding size. Being small in size, most of the coconut holdings do not generate adequate income to support the dependent families. As a consequence the farmers tend to ignore coconut farming resulting in the exodus of educated rural youth in search of more remunerative occupations enjoying social respect. Another resultant problem is the slow but steady decline in the availability of traditional farm workers for attending to the seasonal agricultural activities including timely harvesting leading to low productivity and high cost of production. Mechanical climbing devices for harvesting and plant protection have not become popular.

As the planting density is high in small holdings, systematic adoption of intercropping is difficult. The plant population nears the optimum in larger holdings were timely agronomic management and intercropping become possible resulting in higher productivity of coconut as well as of the holdings under coconut. Farmers are conscious of the importance of manuring. While majority of the farmers apply organic inputs on a regular basis, less than 50 per cent of them resort to apply inorganic fertilizers. The adoption of plant protection and summer irrigation is low for reasons of shortage of labour and also on-farm water sources. The farmers, in general, favour the adoption of organic management but are not hasting R & D support for

practising the same on a sound basis. Despite having the programme of hybrid seed production in the State for over 60 years, the adoption level is low with only 5-6 per cent inspite of the fact that the farmers are convinced of the high yield potential of hybrids. Nevertheless, farmers do not favour large scale planting of hybrids because of a few unfavourable traits exhibited by the variety.

Of the total cost of cultivation, 35-40 per cent is on manures or fertilizers and their application, 18 per cent on plant protection, 14-16 per cent on cultural practices, 7-11 per cent on irrigation and 11-17 per cent on harvesting. In holdings of size below 0.5 ha, the average cost of production is Rs. 2.69 per nut. In holdings where inter-cropping and/or mixed farming is practised, the farmer level economy is stabilized and income from a unit area is much higher. This system of farming also strengthens the food and nutrition security of the dependent farm households. Coconut based farming system facilitates homegardens of below 1 ha in size to function as economically viable units. Among the different approaches for augmenting income and employment in the coconut sector, promotion of farming systems appropriate to the local conditions, marketing of tender nuts as health food, production and marketing of coconut sugar, processing of the multiple products of the palm for value addition at the farm-household and community levels, development of marketing infrastructure under the aegis of farmer's organizations or cooperatives are the most important ones for sustained results.

INTRODUCTION

The influence of coconut on the livelihood security of the people of Kerala is substantial. It strengthens the food and nutrition security through its direct contribution to the dietary energy as well as to the household cooking energy. It's influence on the agricultural income of the State and on rural economy is also profound. As such, it is important to look closely at the basic socio-economic features of coconut farming in Kerala.

Constraints to profitable coconut farming

Coconut in the State is essentially a homestead crop. There will be no homestead or homegarden devoid of coconut palms. Nevertheless, the number of palms vis-a-vis other crops shows wide variation between different agro-ecological regions. In a recent study made by Jacob John and Nair (1998) covering 400 households in southern Kerala, the size of homegardens was found to vary from 0.4 ha to 3.6 ha with 95 per cent having a size of less than 0.80 ha, though the average for all the holdings was only 0.33 ha. Between the agro-ecological regions, coconut accounted for 40.25 per cent of the total plant population in the low lands, but only 5.50 per cent in the high lands and 13.72 per cent in the midlands. When the population of tree crops alone was taken into account, the average number of palms formed 44.44 per cent of the total trees with a variation ranging from 18.29 per cent in the high lands to 51.11 per cent in the midlands and 74.99 per cent in the low lands. These findings revealed that coconut is not grown as a monocrop in the home gardens but as a major component of diverse crops grown deliberately by the farmers.

The characteristic feature of the land holdings in Kerala is the small size. In a detailed socio-economic survey conducted in 1997 in one of the panchayaths in the Ernakulam district by the Coconut Development Board (CDB), it was found that about 75 per cent of the households had an average size of less than 0.08 ha and the proportion of the total area they occupied was 24 percent. Only a little above 5 per cent of the holdings had a size of 0.4 ha, though the area they covered was 44 per cent of the total. The preponderance of small holdings was the most common in the coastal low lands. In all the holdings 76 per cent of the area was occupied by coconut. In a similar survey organised in 1998 by Peekay Tree Crops Development Foundation (PTCDF) covering 198 holdings representing the northern, central and southern regions of the State, the average holding size was found to be 0.89 ha. Among the holdings, over 90 per cent had an area of less than 2 ha with an average holding size of 0.73 ha. In all these holdings coconut occupied 78.87 per cent of the total area. Among the different size groups, holdings of less than 1 ha had 95 per cent of the total area. The proportion of coconut area showed a decrease with increase in holding size (Table 1).

It becomes obvious that coconut is grown in small holdings, most of which are homegardens. It is doubtful whether these holdings could generate adequate income to support the dependent families. This being the situation, coconut in most instances has been treated only as a food crop and/ or as a supplementary source of household income. As a consequence, the

Table 1: Distribution of total holdings by size

Classification of holdings (ha)	Total area of holdings (ha)	Holdings		Coconut cultivation	
		No	%	Area(ha)	% of total
Below 0.5	18.19	66	33.33	17.72	97.42
0.5-1.0	48.27	60	30.30	44.71	92.62
1.0-2.0	84.25	52	26.26	66.99	79.51
2.0-3.0	18.70	8	4.04	12.20	65.24
3.0-5.0	47.20	11	5.56	31.90	67.58
Above 5.0	6.50	1	0.51	2.00	30.77
Total	223.11	198	100.00	175.52	

farmers tend to ignore coconut farming and opt for more remunerative occupations. This attitude has been partly responsible for the apathy shown to farming by the rural youth and the exodus of educated unemployed in search of alternative opportunities which commanded social respect. The related social problem has also found expression in the form of shortage of farm workers for carrying out timely agronomic practices as well as regular harvesting. The inevitable result has been neglect of management needs, especially in small holdings leading to low productivity and high cost of production. The findings presented in Table 2 will reveal that the productivity improves as the size of holdings increases upto the size class 3-5 ha.

Table 2: Distribution of yield by type of palms and size of holdings

Classification of holding (ha)	Mean nut yield			
	W. C. Tall	Hybrids	Dwarf	Other Talls
Below 0.5	51	57	44	50
0.5-1.0	64	87	59	61
1.0-2.0	80	82	56	60
2.0-3.0	81	100	50	60
3.0-5.0	110	75	-	-
Above 5.0	48	70	80	-
Total/Average	75	78	56	60

High density of over 200 palms per ha is common in small holdings. Regular underplantings are done in such holdings in a haphazard manner which do not permit the normal growth and performance of the newly planted ones. Apart from this, systematic intercropping is also not possible in such holdings. The crowded plant population coupled with poor cultural management causes low productivity of coconut. Studies on plant density have revealed that as the holding size increases, the palm population decreases with the result that adequate cultural management as well as intercropping become possible contributing to higher productivity of coconut as well as of the holdings under coconut. The limitations of very small-holding size to successful adoption of profitable farming system have been brought out in these studies.

In coconut holdings, irrespective of size, the use of either organic manures or inorganic fertilizers or both is prevalent but the quantity applied is below optimum. The results of the PTCDF survey revealed that while around 90 per cent of the holdings received annual dressings of organic manures, not more than 40 per cent received inorganic fertilizers. In general, the farmers realised the importance of manuring though the quantity applied varied between different size groups. This shows that given adequate incentives and other forms of encouragement, even small farmers can be induced to adopt soil fertility management and achieve higher productivity levels.

While the traditional cultural practices are being followed in most of the holdings, plant protection and irrigation are yet to be adopted on a wider scale. Studies in this regard have found that not more than 30 per cent of the farmers undertake plant protection in their gardens. One of the major reasons for the low adoption level is the difficulty in getting the services of traditional palm climbers to apply plant protection chemicals in time. The cost of labour for such specialised work is also prohibitive. Another reason is the general reluctance of the farmers to use chemicals in their holdings which are in most cases homegardens. They prefer to follow biological methods of pest and disease suppression but appropriate technologies are not available to them. In practising summer irrigation, the constraints are scarcity of on-farm water sources and also capital with the small farmers for developing such sources and installing appropriate systems. The limitations experienced in the areas of plant protection and irrigation when removed will help to achieve higher productivity from the existing gardens.

Timely harvesting is now-a-days becoming a difficult task because of shortage of trained climbers. In many gardens where the harvesting frequency was 9-10 times a year, it has now gone down to 6 times or even less. The problem is more serious in small holdings where the farmers have to pay higher wages because of the limited number of trees. The population of traditional palm climbers is steadily on the decline as a result of the waning interest of the younger members of the community in the profession. Although mechanical devices have been introduced, the farmers have not shown fascination in their use for regular harvesting. The harvesting expenses have gone up and, presently, the charges range from Rs. 27 to Rs. 36 per palm per year for 9 harvests a year.

Consequent on the scarcity of farm labour for doing timely cultural operations and high wage rates, the cost of production of coconut has gone up over the years. In related studies, the present cost of cultivation in holdings of size below one ha has been found to vary from Rs. 25,473 to Rs. 27,455 per ha per year. Of the total cost 35 to 40 percent is spent on manuring and fertilizer application, 18 per cent on plant protection, 14-16 per cent on cultural practices, 7-11 per cent on irrigation and 11-17 per cent on harvesting. It has also been observed that in holdings of less than 0.5 ha, the most common in Kerala, with the recorded density of 185 palms per ha, and the yield of 51 nuts per palm of the West Coast Tall cultivar, the cost of production is Rs. 2.69 per nut (PTCDF 1998).

India, perhaps, is the first country in the World to produce and popularise coconut hybrids. Despite having continued the programme and produced a number of high yielding hybrid combinations, the farmers, in general, do not favour them in place of the local tall cultivars for field planting on a large scale. The present situation is that while about 92 per cent of the palm population in the State is comprised of West Coast Tall (WCT) and other tall types, only around 6 per cent forms hybrid material. In the studies on quality assessment of farmers by varieties, it was observed that out of 9 traits, the hybrids were favoured only for early bearing and higher nut production. The unfavourable traits which discouraged the farmers to opt for hybrids were undesirable crown features, alternate bearing and in some instances the declining trend in productivity after a few years of high initial yield. Further research has to take note of the observations recorded under field conditions for evolving combinations acceptable to the farmers.

Opportunities for enhancing profitability

One redeeming feature of the coconut holdings, particularly home gardens, is the utilisation of the land for growing diverse crops, both arable and woody species, leading to higher on-farm income. In the PTCDF survey, 83.3 per cent of the holdings were found to have intercrops, but only 52.3 percent have integrated livestock in the system. Such farming systems when practised systematically are known to augment on-farm income. Although the income from nuts is the major component of the total income from the commonly followed farming systems, intercrops and livestock components not only stabilise the farm level economy but also strengthen the food and nutrition security of the dependent farm households. Studies have revealed that smaller the holdings, more intensive was land utilisatlon for enhancing the income from a unit area. The observed profitability for different size classes when intercropping and mixed farming were integrated in the system was Rs. 9114 per ha for the size class below 0.5 ha, Rs. 15,801 for 0.5-1 ha, Rs. 21,918 for 1-2 ha, Rs.19,169 for 2-3 ha. Rs.30,613 for 3-5 ha but only Rs. 4,802 per ha for the size class above 5 ha. The significance of these observations is that homegardens of below 1 ha in size can function as economically viable units when integrated agriculture is practised. The profitability of coconut from holdings of size below 0.5 ha was Rs. 3,829 per ha but it rose to Rs. 9,114 when intercropping was practised. Likewise, in 0.5-1 ha holdings, the profitability rose from Rs. 12,867 to Rs. 15,081 per ha when intercropping was adopted (Table 3). These findings suggest that coconut based farming system as a strategy is to be strengthened and popularised to make coconut farming even in small holdings economically rewarding.

In many household farming units, tapping of coconut palm for toddy is practised. The farmers by themselves are not engaged in the activity but are done by professional tappers who take selected palms on rent. The rent varies widely from place to place and the common range is Rs. 75 to 250 per palm per month over a tapping period of 6-9 months a year. Other than

Table 3: Distribution of household incom by size of holdings

Classicication of holding (ha)	Nuts (Rs/ha)	Other palm parts(Rs/ha)	Intercropping (Rs/ha)	Mixes farming (Rs./ha)	Total (Rs/ha)
Below 0.05	28,366	936	4,527	6,042	39,871
0.5-1.0	39,571	751	3,597	2,270	46,189
1.0-2.0	43,656	560	5,032	1,721	50,969
2.0-3.0	41,966	139	9,112	4,096	55,313
3.0-5.0	42,174	47	5,519	1,250	48,990
Above 5.0	28,800	461	528	6,923	36,722
Total/Average	37,422	482	4,721	3,717	46,342

generating income by offering palms for tapping, farmers are also benefited from higher yield of nuts from the tapped palms during the post-tapping phase. But the sweet toddy becoming available from tapping is not made use of for further processing other than consuming it as an alcoholic drink. This situation is much different from that existing in countries like Indonesia, Thailand etc. where toddy tapping is encouraged for producing coconut sugar which is marketed in attractive packings both in the domestic and international markets. Support in different forms is extended to coconut farmers and their organisations in these countries to produce coconut sugar and undertake organised marketing for enhancing on-farm income and employment.

In Kerala, farmer's organisations and/or tapper's societies if permitted and encouraged to produce coconut sugar and explore domestic and international markets, not only the farm level economy of farmers could be improved but opportunities for employment to the rural youth in the related activities could also be created. The demand for coconut sugar is on the increase in the developed countries mainly as a nutritionally rich alternative to refined cane sugar. The promotion of sugar making in Kerala, however, would require appropriate policy decision and support at the government level.

In some countries especially in Malaysia marketing of tender coconut within and outside is developing into a profitable activity. Other major coconut producing countries are also taking advantage of the growing consumer preference for tender coconut as a health food in place of synthetic drinks. Although the consumption of tender coconut is becoming popular in the major metropolises of the country, it is not so in Kerala mainly for reasons ranging from the shortage of palm climbers for timely harvesting to marketing difficulties. Harvesting at tender nut stage apart from ensuring stable returns, as the price of nuts is not linked to that of coconut oil, also stimulates the palms to produce more number of nuts. Farmers' organisations as well as enterprising youths are to be supported in organising marketing outlets in potential areas for tender coconut. It is also important to popularise mechanical devices for palm climbing and also for easy and clean serving of tender nut to the consumer. Simultaneously technological research has to be strengthened to develop viable technologies for the profitable utilisation of tender coconut husk and shell.

The economy of coconut farming is presently dependent upon the price behaviour of coconut oil which is highly unstable and linked to that of other major oils and fats and their overall availability in the country. The coconut based economy can be stabilised only when such dependence on a single product is minimised through the promotion of farm-household and community level processing of the multiple products and by-products obtained from the palm. Technologies are available for such processing and what is needed is selection of viable ones after pilot testing and their transfer to entrepreneurs for commercial application. Simple processing technologies are to be made available for adoption at the farm-household and community levels and the units involved are also to be supported to undertake effective marketing both within and outside the State. This approach shall be an integral component of the strategy for coconut development in the State.

CONCLUSION

Coconut farming, though popular in the State, does not attract devoted attention of the farmers as a result of the prevailing socio-economic constraints to profitable production. The restraining effects find expression in the form of poor cultural management, slow spread of improved varieties, lack of diversity in product utilisation, high cost of production, low profitability and waning interest in farming. Many of the limiting factors can be tackled successfully and coconut farming made attractive and profitable. The State government, local self governing bodies and farmers' organisations have to perform specific functions as part of a co-ordinated programme to correct the deficiencies that prevent the progress of coconut development in Kerala.

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ENVIRONMENTAL IMPACT OF PLANTATIONS

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ABSTRACT

Plantations cover an unusually large per cent of the geographical area of Kerala. Their impact on the hydrological cycle, soil, atmospheric processes and climate, biodiversity and ecosystem function are discussed by taking examples from tropics and available research from Kerala. It is shown that plantations have both negative and positive impacts on environment. Adverse impacts can be reduced by taking suitable ameliorative measures. Towards this end, more research is needed in some critical areas which are identified.

INTRODUCTION

Starting with tea plantations in Peerumadu in the 1870's, the area under plantation crops in Kerala have registered a phenomenal increase over the years. Apart from coconut which is the most characteristic plantation crop of Kerala, rubber accounts for a large share of the area under plantation crops. Others are cashew, coffee, arecanut, tea, teak, eucalypts, etc. Table 1 shows the area under the major plantation crops in Kerala. These plantations (which include coconut and arecanut) now cover about 46 per cent of the geographical area of Kerala, compared to a total of 11.6 per cent under other kinds of cultivation. It is evident that cultivation of plantation crops is a major form of land use in Kerala, a unique situation compared to the rest of India.

What is the impact of such large-scale plantation activity on the environment? This paper examines this issue within the constraint of available data, and suggests ameliorative measures to reduce the adverse impacts. We also examine the future research needs. First, let us put the issues into proper perspective.

How do we define a plantation?

Although opinions may vary, for practical purposes, we define a plantation as an artificial (man-made) stand of a woody perennial crop which may be harvested from time to time. The harvest may be the fruits or any other product of the tree or the tree itself, as in the case of timber yielding species. 'Woody perennial' will exclude crops like pineapple, banana, pepper, cardamom, etc., which some may consider as plantation crops. We make no distinction between agricultural crops and forestry crops although in conventional usage, forest tree plantations cultivated for timber are excluded by agriculturists and agricultural tree plantations cultivated for fruits or other products are excluded by foresters, in their list of plantation species. In terms of environmental impact, plantation agriculture and plantation forestry share many attributes in common, although there are some differences.

Table 1. Area under major plantation crops in Kerala

Crop	Area (in ha.)
Coconut	900,700
Rubber	443,300
Cashew	105,680
Coffee	82,350
Arecanut	69,000
Tea	34,660
Teak	75,000
Eucalypts	35,000
Other forest species	50,000
Total plantations	1,795,690
Total geographic area	3,885, 497

Source: Government of Kerala(1995); Kerala Forest Dept.(1994)

How does a plantation differ from natural vegetation?

A plantation differs from natural vegetation in many ways. The most obvious difference is that plantations are monocultures, the same tree species occupying a large contiguous area, usually in even-aged stands. Secondly, many of the species typical of Kerala's present landscape are exotic in origin, eg., rubber, cashew, tea and eucalypts. Thirdly, in most plantations, except coconut, the tree cover over large areas is harvested periodically and replaced with a new crop, usually, but not necessarily, of the same species. Another major difference of plantations over natural vegetation is the management input in terms of tillage, fertilisers, pesticides, irrigation, etc., which modify the natural ecological processes.

These characteristic attributes of plantations make a large impact on the environment. We have cut down our natural forests and vegetation and have replaced them with plantations, agriculture crops, roads and buildings, factories and several other structures of economic value. Can we go on changing the face of the earth without restraint - fill the earth with plantations, agriculture, automobiles, sewage, pesticides, fertiliser residues, detergents, plastics and so on? And all these changes happening within the past few hundred years! On the other hand, can we survive without disturbing nature at all? The world woke up to these concerns during the past few decades since the 1960's, as such changes have been taking place all over the world. Average annual deforestation in the tropics during the 1980-90 decade was 15 million ha (m ha) (FAO, 1993). In contrast, the area under plantations is increasing, but at a much slower rate. India has nearly 19 m ha under plantations and Indonesia, 8.75 m ha. China's total area under forest plantation is 41.39 m ha and that of USA, 31.85 m ha (FAO, 1995). In addition, there are other traditional, non-forest plantations. Thus rubber covers 7 m ha, coconut 4 m ha and oil palm 3 m ha, in the tropics (FAO, 1993).

Spurred by Rachel Carson's famous book, 'The Silent Spring', in which she dramatically portrayed the adverse impact of indiscriminate use of pesticides and other agrochemicals in forests and agricultural farms, on our environment, the public has now become aware of the dynamic inter-relationship that exists between the various living and nonliving components of the earth and the ecosystem concept. In the resulting development versus conservation debate, extreme views have been expressed both by the development enthusiasts and the conservation enthusiasts. Our attempt here is to take a balanced look at the environmental impact of plantations. We examine this under a few major heads.

Impact on hydrological cycle

Trees play a major role in the conservation of water on land. In a natural forest, a large part of the rainfall which reaches the ground is retained by the rich humus and slowly percolates into the soil beneath. This contributes to the stream flow, recharges the water table by penetrating deeper and deeper and provides for the daily consumption and transpiration by the vegetation. This water which is stored in the soil is still available to the trees when the rains no longer fall. Even in peak summer, one can see the recharging of the rivers by small streams of water seeping from good forests. In evergreen forests subsurface sources of water are available until the water which escaped into the atmosphere through various routes returns to the earth through rainfall, completing the water cycle. Interception and storage of water facilitated by the forest cover therefore plays a crucial role in the hydrological cycle. It can therefore be expected that raising of plantations, in place of natural forests, will have an impact on the water balance.

Although Kerala is blessed with two monsoons and receives an average annual rainfall of 3000 mm, the rainfall is highly seasonal, so that nearly half the year remains dry or with very scanty rainfall. The water which reaches the ground should ideally infiltrate the soil. However, the hilly terrain of Kerala is very conducive for surface runoff. Compared to natural forests, the humus cover of plantations is very shallow. In addition, the laterisation of the ground in many exposed as well as planted areas reduces the infiltration of water . Therefore less water is available for charging the water table, which should help in sustaining the stream flow during the dry season. Some studies by CWRDM has reported a runoff of 40-90 per cent of rainfall for Kerala.

It is obvious that indiscriminate clearing of natural forests and replacing the area with tree plantations can affect the original stream flow regimes. In general, it is believed to reduce the water holding capability and the outflow (Hamilton and King 1983) although Hardjono (1980) claimed improved flow following development of plantations.

Plantations located in catchment areas of dams for hydroelectric projects and urban water supply schemes may adversely influence the quality and quantity of water yield. The choice of tree species is an important factor affecting the water relations because the evapotranspiration characteristics of the plant species have a profound influence on its water use efficiency. There are several reports of planting of fast-growing trees on grass and scrub lands considerably decreasing the dry season water yield (Mathur and Sajawan 1978; Waterloo 1994). Very few studies have been made on the hydrological impact of plantation species commonly planted in Kerala. For example, rubber, which occupies nearly half a million ha. in Kerala has not been studied for its hydrological impact. This species is a major component in the catchments of many of our reservoirs. Similar is the case with other plantation species such as cashew and teak.

Based on studies of several plantation species in Kerala, Kallarackal and Somen (1992, 1997) showed that the variation in water consumption between species can be immensely great. For example, because of identical stomatal behaviour, cashew and *Eucalyptus tereticornis* were found to have almost similar and high water consumption characteristics. Due to its deciduous nature, teak, on the other hand, was found to be very economical in its water consumption during the dry season. The species level variation in water consumption for many of our plantations in Kerala is not known. There is an urgent need to get this information because of its importance for the management of catchment areas.

The largest influence of a plantation on hydrology occur during the establishment phase of a plantation, that is, during the first 1-3 years after replanting. The first few months are especially critical because most of the soil surface will be exposed at this time. During the active growing period of the plantation, the water consumption by the trees tend to go up, thereby substantially reducing the stream flow. At the mature stage of the plantation, the water consumption tend to get more stabilised, sometimes returning to the original condition when it was forested. But all these would depend on the species.

Impact on soil

The thin layer of natural top soil which sustains the plant life is indeed a mixture of living (bacteria, fungi, algae, etc) and nonliving material existing in a state of dynamic interaction. It is the continuous exchange of materials betwen the nonliving and living components of the soil that gives it its capacity to support plants. Larger animals also contribute to the exchange in various ways. When the natural vegetation is replaced with a monoculture plantation, the quality of this interaction changes. The ecology of the soil is only beginning to be understood and we have very little data on the effect of plantations.

It is inevitable that soil disturbances occur in a managed plantation - at the time of planting, during fertiliser application or at the time of harvest. The impacts can be physical as well as chemical. The most obvious physical impact is exposure, leading to heavy soil erosion, particularly in the hilly terrain of Kerala. This leads to loss of the precious top soil. In a recent study conducted in KFRI Thomas *et al.* (1997) estimated a loss of 4 to 15 metric tonnes of soil per hectare per annum in teak and eucalypt plantations.

Yet another physical impact is compaction, which usually results from the use of heavy machinery in plantation. This may be particularly important in forests and rubber plantations where heavy trucks are used for transporting timber. Due to compaction, the bulk density of topsoil increases, particularly in wet and clayey soils, and the water holding and transmitting capacity reduces. Table 2 shows the effect of using different machinery on the soil for preparing a forest land for planting in Nigeria (Ley *et al.* 1989). Lal (1981) compared the soil erosion and surface runoff characteristics of the above treatments and found that soil erosion was only 0.4 t ha/yr for manual clearing, whereas it was 4 t ha/yr and 15 t ha/yr for crawler tractor with a shear blade and crawler tractor with a tree pusher respectively.

Chemical changes take place as a result of nutrient consumption by plantations. Most tropical soils have a mineralogical composition, the essential nutrients reserves are small, CEC is low, P-fixing capacity is high and soil aggregation is very marked. The permeability and the potential to leach cations of these soils are high. The P, Ca, Mg, Zn, S, K, Cu and B levels in these soils are considered to be low or very low.

Removal of harvestable items or successive rotations in the case of timber yielding trees will lead to marked depletion of the limited available nutrients reserves in the soil. This would result in declining productivity of plantations unless nutrient input is resorted to. Fertilisers are an important input item in plantation management. Sometimes they are applied at higher levels in order to enhance productivity. Excessive application of N or P fertilisers may alter the natural mycorrhizal relationships between plant roots and microorganisms either due to direct or indirect effects. In course of time mycorrhizal colonisation on roots may decrease and their presence could

Table 2. Soil bulk density and penetration resistance of the 0-5 cm horizon of an Alfisol in western Nigeria due to different methods of clearing the forest land for agriculture (after Ley et al. 1989).

Treatment	Before treatment		One year after treatment	
	Bulk density ($t\ m^{-3}$)	Water penetration resistance (kPa)	Bulk density ($t\ m^{-3}$)	Water penetration resistance (kPa)
Manual	0.73	44	1.46	170
Shear blade	0.81	30	1.38	144
Tree pusher	0.69	30	1.45	132
Traditional	0.69	17	1.16	121
LSD (0.05)	NS	NS	0.01	20

ultimately be reduced or eliminated from the site as the capacity to maintain viable inoculum is reduced. Ikram *et al.* (1992) found that seedlings of *Hevea brasiliensis* inoculated with VA mycorrhizas in the nursery exhibited less mycorrhizal root colonisation when soils were fertilised with P. The effect of P fertilisation on mycorrhizas is not simple and will vary with the original P content of the soil itself (Johnson 1993). It is important to know how the gradients of soil nutrients affect the degree of mycorrhizal colonisation of fine root systems and to identify threshold levels at which mycorrhizas are finally eliminated from root systems. The end result could be a plant that may have decreased growth due to metal toxicities or increased susceptibility to root pathogens (Marx 1969; Vogt *et al.* 1991).

Little information is available on the effect of monocropping on nutrient balance and nutrient cycling in plantation soils as compared to soils with its natural mixed vegetation.

Impact on atmospheric processes and climate

Trees remove CO_2 from the atmosphere through photosynthesis and store it in the form of cellulose. Therefore, the wood biomass is an important sink for the sequestered carbon from the atmosphere. Standing tropical forest is thus considered to be a net sink for atmospheric CO_2 and deforestation of tropical forests for other land uses is likely to increase the concentration of atmospheric CO_2. It is estimated that currently the atmospheric CO_2 is increasing at the rate of 1.5 ppm *yr-1* (Houghton et al. 1994). This is attributed largely to tropical deforestation. Although highly speculative, the potential impact of this phenomenon on increase in global temperature, atmospheric humidity and rainfall is a current topic of concern and discussion. Although empirical data are not available, plantations can be as effective as natural vegetation in sequestration of carbon through photosynthesis. If the harvested wood is converted to durable products so that the sequestered carbon does not enter into carbon cycle for a long time, plantations can be more effective as a carbon sink in comparison to natural forest where the wood is recycled. However, if the plantation wood is used for pulp or fuel, the tree plantations can be said to be 'carbon neutral'.

Some tree species are known to absorb toxic gases from the atmosphere and neutralise them through physiological processes. For example, *Ficus* is capable of absorbing flourides and mango tree is capable of absorbing chlorides. The pollutant absorbing capacity of several tropical trees can be seen from Table 3.

There is substantial evidence that trees remove gaseous contaminants from the atmosphere. Plant uptake increases as the solubility of pollutants in water increases. Hydrogen fluoride, sulphur dioxide, nitrogen dioxide and ozone which are soluble are readily absorbed pollutants. Nitric oxide and carbon monoxide are absorbed relatively slowly or not at all by vegetation (Pokhriyal and Nautiyal 1991; Pokhriyal and Subba Rao, 1986).

The National Botanical Research Institute, in collaboration with Indian Toxicological Research Institute, Lucknow, has extensively surveyed seven industrially polluted areas in Uttar Pradesh and identified a number of pollution tolerant species in air-polluted areas (Pokhriyal and Nautiyal 1999). Bhattacharya (1994) also has listed out a number of tree species tolerant to different air pollutants.

A natural forest containing a variety of tree species is therefore expected to ameliorate atmospheric pollution whereas monoculture plantations of a few species is unlikely to provide such benefit. There is very little data on this aspect for plantation species that are important to Kerala.

It is well-known that forests ameliorate the local climate, by lowering temperatures and increasing humidity. Monoculture plantations do not seem to do this as effectively as the polycultures as observed in Sri Lanka (FAO 1992).

Table 3: Some common tropical tree species which are tolerant to selected pollutants.

Species	SO2	Fluorides	Chlorides	MIC gas and dust	Smoke gaseous pollutants	Combined from thermal & fertilizer plants	Pollutants
Ailanthus excelsa	1	1	1			1	2
Albizia lebbek					1	1	2
Alstonia scholaris						1	2
Azadirachta indica						1	2
Butea monosperma						1	
Citrus medica						1	2
Delonix regia						1	2
Emblica officinalis						1	
Ficus benghalensis				1	1	1	2
Ficus elastica		1					
Ficus religiosa						1	2
Mangifera indica			1	1			
Mimusops elengi						1	2
Phyllanthus emblica							2
Syzygium cumini				1		1	2
Tamarindus indicus						1	2
Tecoma stans					1		

1 - Bhattacharya (1994)

2 - Pokhriyal and Nautiyal (1991)

Impact on biodiversity and ecosystem function

Natural forests contain a large variety of plant and animal life compared to plantations. For example, the Periyar Tiger Reserve with an area of 777 km^2 holds 1965 taxa of flowering plants (1440 dicots and 525 monocots) out of the estimated 3800 species of flowering plants in Kerala (Sasidharan, 1998). In addition, there are a large number of animals - vertebrate and invertebrate, microorganisms as well as different types of vegetation and landscapes which together make up its biodiversity. These plants, animals and microorganisms exist in a complex and dynamic inter-relationship which ensure the perpetuation of the ecosystem through energy flows and nutrient cycling through the producers, consumers and decomposers. We have not fully understood the changes in ecosystem functioning that can be brought about by replacing such a complex system by a monoculture of tree species, say, teak or rubber or eucalypts. Usually at the start of clearing a natural forest for raising plantation, the natural vegetation is cut down and after the commercial timber is removed, the slash is burned at site, and the area planted up with a particular tree species. During the initial few years, weeding is carried out periodically to remove other plant growth. In course of time, however, as in the case of forest plantations, other plant species invade and establish themselves within the plantation and some of the animal species may also recolonise.

Thampy (1987), examined the situation obtained in a teak plantation and concluded that a teak plantation does support many other species in course of time although the biodiversity gets highly impoverished. Chandrasekhara (1996) recorded 6 species of trees, 7 species of shrubs and 18 species of herbs per ha in a 20-year old teak plantation at Nilambur. This may be compared to between 24 to 44 tree species per ha and almost similar number of shrubs and herbs in natural forests of various types (Chandrasekhara, 1998; Swamy, 1988). Evans (1992) quotes a study in Sri Lanka summarised by Senanayake (1987) in which it is shown that the diversity of both bird species and soil fauna increased in order from pine monoculture, eucalypt monoculture to home gardens, complex home gardens with 40-50 species was close to natural forest.

For plantations of rubber in Kerala, it is customary to cultivate a cover crop of *Peuraria* which is a nitrogen-fixing runner which covers the exposed ground quickly. This prevents the growth of other species but facilitates colonisation by some smaller animals and microorganisms. Coconut plantations are also an exception since in many, particularly near homesteads, a variety of under crops and fruit trees are also grown.

In general, in a plantation, the diversity of habitats and nitches available for other plant and animal life is limited as the predominant vegetation consists of one species, with a single canopy layer. In contrast, a natural forest is multilayered, with upper, middle and lower layers of trees, ground vegetation, bushes, lianas, and epiphytes. Nesting sites for birds and other animals, specialised food plants for different kinds of animals, and the required microclimate for different groups of orchids, ferns and lichens may be absent. Obviously, changes are inevitable, when a plantation replaces natural vegetation, but the implications of such changes are not fully understood. It has become customary to qualify the agricultural farms and plantations as agro-ecosystems and plantation ecosystems, but do they maintain the ecosystem integrity and satisfy the criteria of cycling of materials? Do they represent simplified ecosystems in which the essential functions of an ecosystem are maintained? We simply do not have sufficient data to draw conclusions. Perhaps we should call them man-made agrosystems and plantation systems instead of ecosystems; obviously these systems will collapse if management inputs are withdrawn.

Loss of biodiversity due to replacement of natural forests by plantations is a loss in quantity rather than in kind as long as representative natural areas are still retained. There is no doubt that plantations reduce the biodiversity quantitatively, but what is important is to ensure that sufficient natural areas are retained to facilitate conservation of biodiversity for its multifarious benefits, both ecological and economic.

Other impacts - negative and positive

Usually plantations are raised for specific end products - timber or other products such as fruits or latex. To enhance the yield of such products, various management inputs may be given, such as irrigation, weeding, fertilisers, insecticides, herbicides and fungicides. These inputs often create adverse environmental impacts. Although the use of insecticides is not a common current practice in plantations in Kerala except during the initial establishment phase, the potential for use exists. The ecological impact of use of persistent insecticides is well known; if used indiscriminately, toxic residues accumulate and get into the food chain of various animals including man and can cause havoc. Fungicides are commonly used in rubber plantations.

Herbicides have the potential to become popular.

Heavy metals, particularly zinc, nickel, aluminium and copper accumulate in plantation soils as a result of the use of agrochemicals. They have detrimental effect on plant growth beyond critical levels (Kabata-Pendias and Pendias 1984). Very little information is available on the effects of, and the response to, heavy metals in plantations. Aluminium toxicities are very requent in some soils. Some plants like tea are able to tolerate and accumulate heavy metals by sequestering them in non-biologically active tissues (Antonovics et al. 1971; Kabata-Pendias and Pendias 1984) while many other plants are protected because the mycorrhizal associations on their roots either exclude metals or accumulate them within their mantle sheaths (Vogt *et al.* 1987; Wilkins 1991). The high acidity of many tropical soils makes them often prone to Al and Mn toxicity and low P availability, so that mycorrhizas may be particularly important for plant growth in these environments.

These toxic chemicals or their residues get into the food chain through ecological processes, or get their detrimental effects spread beyond the plantations in which they are used. Thus plantation activity can have far-reaching consequences if not practised judiciously.

Plantation activity exerts a positive impact on environment when the plantations are raised on marginal or degraded lands. In such situations it can contribute to ecorestoration, preventing soil erosion and increased carbon sequestration. It can also contribute to aesthetic improvement of the environment. Different tree species are suitable for reclamation of problem sites. *Casuarina equisetifolia* is widely used to stabilize sandy sites and for creation of wind breaks. Eucalypts have been used to drain swampy lands in East Africa (Evans, 1992). Reclamation of mined areas have been accomplished by planting *Eucalyptus tereticornis* on copper tailings in Papua New Guinea; *Pinus caribaea* var. *hondurensis* on restored opencast iron/nickel workings in the Dominican Republic, acacias and eucalypts on dolomite and bauxite mined areas in Madhya Pradesh and eucalypts on tin mined waste lands in Nigeria (see Evans, 1992). In degraded areas, planting of pioneer tree spe[illegible] itiates the gradual process of soil development through litter fall and build up of organic matter, soil microflora and microfauna. *Acacia auriculiformis* has a potential for such use in lateritic areas in Kerala.

Several species like *Acacia salicina, Casuarina equisetifolia,* *Terminalia arjuna, Melaleuca* spp., *Eucalyptus camaldulensis, E. microtheca* and *E. robusta* are adapted to growing in saline soils. Some salt tolerant species (halophytes) like *Atriplex* spp. effectively remove salt from soil and may accumulate several tonnes per hectare in their foliage (Evans 1992). Plantation activity also exercises an indirect positive impact on the environment when, by meeting the increased demand for timber it reduces man's onslaught on the natural forest.

Ameliorative measures to reduce adverse environmental impact and research needs

The goal of any plantation is to increase productivity at a site. Productivity on many sites in the tropics is below the potential and there are opportunities for increasing production by appropriate soil and stand management practices (Dyck *et al.* 1994). The idea of sustaining production at a low level for fear of the potential adverse impact on the environment will result in lost opportunity to provide a solution to the world's growing demand for food, fibre or wood. It may not be a sensible economic or environmental management strategy. It is unrealistic to expect productivity to be sustained without adding nutrients or other inputs to a site to correct deficiencies or to compensate for the products extracted from the plantations. The challenge before the researchers is to find a balance: strategies and methods designed to improve productivity while minimising impacts on the environment.

The most important rule to be followed is to ensure that plantation management operations protect the soil base and do not disrupt the ecological processes such as carbon, water and nutrient cycles. They have to be managed within known boundaries of resilience of the particular ecosystem (Nambiar and Brown, 1997). The potential maximum biological productivity of a vegetation is determined by the radiant energy. The extent to which this energy is utilised by the plants will depend on the genetic potential of the plants, soil productivity and climatic variables. However, potential productivity is limited by stress factors such as water shortage, nutrient deficiency, high or low temperatures, predation by other biota, etc. The choice of the nature and intensity of management practices in the plantation should take into account the type of stress. More research is called for to understand the stress factors in tropical plantations and plan management strategies accordingly. Long-term studies are required to understand the cycling of carbon, water and nutrients in the plantations. Such information should help us to manage the plantations with least detrimental effects on the quality of the environment.

Matching of the species for the site is a critical step in any plantation initiation. This matching should take into account the suitability of a species for the desired end product (e.g. timber, pulp, oil, rubber etc.), the environmental thresholds of the species, and the biophysical characteristics of the site. The choice of the end product will depend on the economic and social needs. The environmental threshold of the species should be deduced from its native habitat and from trials outside the native habitat. There has been a general tendency in India, in recent years, to plant any species purely based on economic desires. For example, large scale plantations of oil palm in some states of India was found to be a failure because in spite of the ample irrigation given to the plant, atmospheric drought (large vapour pressure deficit) in these locations caused very low levels of photosynthesis (Kallarackal, 1996). At the same time, the tendency to consider exotic species as undesirable should also be discouraged. Establishment of good cashew and rubber plantations in Kerala is a case in point. Tree breeding and selection of appropriate provenance or clone suitable for particular localities can help to accomplish species-site-end use matching.

In many locations the availability of water sets the limit for growth and productivity of plantations. Although the practice of irrigating tree plantations is rare in Kerala, except for coconut, it is undoubted that supply of water to plants can improve the growth and productivity. A good example is the oil palm. Oil palm plantations in Kerala suffer from low productivity because of the seasonal drought. Water shortage leads to production of more male flowers in oil palm, affecting productivity. Although managing water in plantations is more cumbersome than managing nutrition, several water conservation measures like contour trenching can be taken to improve the water availability to the trees. However, more research is needed on the effectiveness of these management practices. Similarly, wider tree spacing has been found to reduce the water consumption of eucalypt trees per unit area without sacrificing wood production (Kallarackal and Somen, 1997). Selection of species and genotypes which can make efficient use of seasonal water (monsoon rains in Kerala), but also have drought tolerance can be valuable. One such example is teak. It sheds its leaves when water stress in the soil and atmosphere reaches a certain threshold level (Kallarackal and Somen, 1992), but new flushes appear soon after the dry season is over and a full green canopy is restored.

Very little information is available at present on the configuration, geometry and development of root system of trees in relation to site and stand growth. Such basic data will be useful for refining management strategies for efficient utilisation of site resources.

Mixed species plantations have often been suggested as a replacement for monocultures on theoretical grounds, to reduce pest and disease incidence and better site utilization. The stability of natural forests have been attributed to diversity, but the diversity in man-made mixture of tree species is likely to be qualitatively different from the naturally evolved diversity in the native forest where dynamic trophic relationships have been established during the course of evolution between the plants and various levels of consumers (Nair, 1997). There is no empirical data to support the speculated advantage of mixed plantations. On the contrary, some mixtures like teak and bombax have not performed successfully in Kerala. Mixed species planting and other innovative approaches to silviculture will be possible only if we gain more knowledge on the way different species share site resources and interact. Clearly more research is needed to shed light on these and various other aspects of plantation management in the tropics. Even for the most widely practised management technique of growing nitrogen fixing cover crop in rubber plantations, we have no scientific data showing its benefits.

In spite of the adverse impacts of plantations on the environment, plantations are here to stay because of their several advantages and economic benefits.Therefore, our approach should be to ameliorate the adverse effects as much as possible, with the support of imaginative and pertinent research.

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BIOTECHNOLOGY - ENGINEERING PLANTATION CROPS FOR FUTURE

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INTRODUCTION

Kerala is one of the few States in the country which cultivates all the plantation crops. These crops play and important role in the economy of the state. Coffee, Tea, Cocoa, Rubber, Spices, Medicinal plants, Coconut, Arecanut and Oil palm are the crops included under the plantation crops. Considering their importance, lot of research is being carried out in various spheres of crop improvement and production. The frontier science of biotechnology offers great scope for improvement of these crops. The tools available to biotechnologists are tissue culture, recombinant DNA technique and molecular markers besides bioprocess engineering. The various areas, where biotechnology could be used in plantation crops are as follows (Iyer, 1995).

1. Rapid clonal propagation of elite, disease-free selections, through cell, tissue and organ cultures, especially via somatic embryogenesis.
2. Conservation of native and exotic genetic resources, through *in vitro* gene banks, under both short-term limited growth conditions as well as long-term cryogenic storage.
3. Use of molecular markers to characterize cultivars, hybrids and elite materials, and estimate genetic distances within and between populations.
4. To identify molecular marker loci linked to desirable traits such as disease/drought resistance/tolerance for effecting marker assisted selections and subsequent gene cloning and transfer.

5. Use of molecular markers to construct saturated molecular linkage maps and identify genomic regions for desirable traits.

6. Production of haploids and isogenic (inbred) lines through anther/pollen culture for use in heterosis breeding and linkage analysis.

PALMS

Although breaking the yield barrier still remains our major objective in coconut, arecanut and oil palm, the problem of disease and pest resistance/tolerance should now receive top priority attention in all these palms (Iyer and Dhamodaran, 1994). The recent finding that the causal agent (MLO) which incites root (wilt) disease (RWD) in coconut, yellow leaf disease (YLD) in arecanut, and spear-rot disease in oil palm can cross-infect each other, makes the problem more complicated and a cause for alarm (Anon, 1995). Our internal quarantine being what it is, with little or no restriction on movement of planting materials between States, utmost caution is called for in detecting one or the other disease in areas where oil palm has been introduced amidst coconut or arecanut plantations. Vector control being a very tedious, costly and impracticable operation, constant vigil is needed to eradicate palms where spear-rot, YLD or RWD is detected in any one of them, in order to reduce the inoculum level and prevent further spread of the disease. Resistance breeding work also assumes prime importance, and the sooner we develop DNA probes and RFLP/RAPD/AFLP markers for these three diseases of the three palms, the better it would be for planning future strategies.

The heartening feature in our efforts since the seventies (Iyer *et al.*, 1979) to locate palms showing resistance/field tolerance in the 'hot spots' for the dreaded RWD, is the indication of field resistance/tolerance of the Chowghat Green Dwarf (CGD) parent and its F1 hybrid with disease-free West Coast Tall cultivar located in the 'hot spots' of Kerala where the disease is endemic (Anon, 1994). If the F1 is showing field tolerance, its genetic implications need to be understood in terms of the number and nature of the gene(s) involved. Being a long-duration perennial, it is not conceivable to attribute single gene control for continued resistance/tolerance to MLO infection, since the microbial pathogen will most certainly have a faster rate of mutation for its survival in the host which lives in the farm for several decades (50-80 years for Talls and 40-50 years for Dwarfs). Only the polygenic control of this character can afford the internal buffering in the host against the onslaught of a rapidly mutating MLO. Molecular markers constitute an excellent tool for characterizing such polygenic traits, since only a single population is sufficient for identifying different genomic regions imparting disease resistance/tolerance. The strainal similarity of the MLOs causing the above three disease symptoms as revealed on cross-inoculation between the three host-palms, makes the situation alarming. Here is a strong case for constructing RFLP/RAPD/AFLP markers for these three disease-causing MLO's and their resistant/tolerant hosts.

Meanwhile, progress made on the tissue culture front is also encouraging, protocols for oil palam and coconut being worked out, and the IRHO having commercialized oil palm clones derived from leaf/inflorescence culture. Success in coconut is limited to a few clones obtained at CPCRI from seedling leaf tissues (Raju *et. al.*, 1984), and inflorescence tissue at Wye College, U.K. (Blake, 1991). Coconut tissue culture work done at none different centres in India has been summarized by Iyer (1993). All centres except CPCRI have since discontinued this work. Both IRHO (Verdeil *et. al.* 1989, 1992, 1993; 1994) and Philippine scientists (Rillo and Ebert, 1993) are closing in towards achieving success, and by the turn of this century it is hoped that coconut clones will also become a routine possibility, with advancement in our knowledge on basic aspects of this recalcitrant palm.

Success has been achieved on the routine use of embryo culture for field collection. Kumaran *et al.*, 1998 have 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 and stored (Anitha Karun and Sajini, 1994, Batugal and Engelmann 1998, Anitha Karun *et al.*, 1998) and retrieval of coconut (Assy-bah *et al.*, 1989, 1991) and oil palm germplasm. The future priority will be to standardize cryo-storage methods using liquid nitrogen, so that *in vitro* gene banks will become a distinct possibility. All the above effort, particularly RFLP/RAPD/AFLP mapping is going to cost a lot of money and questions of economy will be raised. However, considering the enormous losses of over 960 million nuts incurred from RWD alone, the above lines of work would be worthwhile and cost effective. Sources of finance will not be wanting, since organizations like Govt. of India's Dept. of Biotechnology are eager to support such inter-disciplinary and even inter-institutional research, across all bureaucratic barriers.

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 from work done in Philippines that AC adsorbs 99.5% of the 14C labeled 2,4-D by 4th day, leaving only 0.5% available for uptake by the explant (Ebert and 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.

Another aspect of *in vitro* culture that deserves our intensive attention is the production of haploids through anther/pollen culture, where preliminary success was reported both in India (Iyer, 1982), the Philippines (Thanh Tuyen and Guzman, 1983; Thanh-Tuyen, 1985), and in 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

So far this aspect has not received the attention it deserves from coconut breeders, but 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 through RFLP/RAPD/AFLP analysis, transferred to other oil plants and expressed, their oil stability can be greatly improved. Willmitzer and Toepfer (1992) have reported that several DNA sequences coding for enzymes of plant lipid metabolism have already been cloned, and most of the enzymes of plant lipid metabolism are expected to be mapped in the next couple of years. Several commercial Biotech. companies have major programmes in this area (Cubitt, 1991). Genetic engineering in rape *(Brassica napus* and *B. rapa)* leading to a modified fatty acid composition has also been achieved, besides transferring anti-sense genes from rat into rape for medium chain hydrolase.

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 14C - acetate and determining radioactivity in the triacyl glycerol fraction of labeled lipids formed (Turnham and Northcote, 1984). Sharp increase in radioactive triacyl-glycerol 5 weeks after culture, indicated the production of embryoids. Studies on developing somatic and pollen-derived embryos of *Brassica napus* and other oil crops show that embryo formation in culture parallels embryogenesis in developing seeds, e.g., in storage lipid assembly and fatty acid elongation. Specific activities of the Kennedy pathway (whose enzymes assemble the triacyl glycerols in the endoplasmic reticulum,) are found to be much higher in cultured somatic and microspore (haploid) embryos than in zygotic embryos. Such embryos could hence be used as models to help studies on assembly of storage lipids and regulation of corresponding genes in oil seeds. Thus, genetically modified embryos in culture may be useful for the prognosis of alteration in fatty acid composition of seed oils at a very early stage (Weber and Taylor, 1990).

Thus, it will become possible to develop within a few years, 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. Let us hope that in coconut and oil palm too we will 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 stress: Biotic and abiotic

Among the biotic stress factors, MLO incited diseases of palms, such as lethal yellowing (LY) in Jamaica, root (wilt) disease (RWD) in Kerala, spear rot in oil palm, yellow leaf disease in arecanut (YLD), and Tatipaka disease of coconut in Andhra Pradesh, are the major diseases to engage our concerted effort to evolve strategies to contain the spread of these diseases, screen cultivars, hybrids and natural populations for possible sources of field resistance/tolerance, and finally, to develop DNA probes as diagnostic tools as also for genetic engineering studies.

The disturbing factor is the wide host range of the lethal yellowing (LY) MLO which not only affects coconut but several other palm genera - thus threatening the valuable collection of palms at the Fairchild Botanic Gardens in Florida. Thus, in a study conducted in Mexico, MLOs were detected in coconut palms of Yucatan Province, using radiolabelled cloned DNA probes. It was found that two probes LYI-43 and LYD-9 containing DNA segments from a Florida LY MLO, hybridized at moderate frequency with DNA extracted from 6 Yucatan LY-diseased but not healthy palms, thus suggesting similarities between LY MLO from Yucatan, Mexico, and LY MLO from Florida, USA. The MAYPAN hybrids replanted in LY-ravaged gardens of Jamaica are now said to be in full bearing and show no significant losses (Harries, 1991). Commercially, losses in both Malayan Yellow Dwarf (MYD) and its hybrids are reported to be less than one percent.

In India as stated earlier, the MLO's of coconut RWD, arecanut YLD and oil palm spear-rot 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 RFLP/RAPD/AFLP analyses one can unravel the real identity of the three MLO's and the nature of homology/dissimilarities among them. This would also help in identifying the nature of field tolerance/resistance of the CGD and its D x T hybrid with field tolerant/resistant WCT palms located in hot spots of RWD (Nair *et al.* 1996, Jacob *et al.* 1998).

In fact, Harrison *et. al.* (1992) have cloned and identified 5 Eco RI restriction fragments comprising chromosomal DNA of MLO associated with lethal yellow (LY) disease of Manila Palm (*Veitchia merrillii)* occurring in Florida. When used individually as (32P)d ATP - labeled probes in dot and Southern hybridizations at high stringence, four or five probes consistently hybridized to DNA extracts derived from LY-affected palms only. However, at moderate stringency, all probes hybridized with DNA of other MLO's 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 MLO 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 MLO 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 and Randles, 1991 a,b; Maramorosch, 1993). This disease develops very slowly and cannot be unequivocally identified on the basis of visual symptoms in a single observation. Another disease of Guam coconuts called "tinangaja" is also caused by a related viroid (CTiVD). Oil palm also develops bright orange leafspots under natural infection or artificial inoculation, resulting in loss of nuts and the palm. Other palms inoculated successfully with CCCVD are arecanut, golden palm *(Chrysalidocarpus herbaceous lutescens)*, date palm, royal palm *(Roystonea regia)* and Manila palm. 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. In fact, Rillo *et al.* (1988) have used *in vitro* cultured embryos to screen coconut populations for resistance to Cadang-cadang.

In Ivory Coast, Franqueville and colleagues (1991) have located resistance/tolerance to the bud rot pathogen, *Phytophthora heveae.* Whereas, the West African Tall (WAT) was sensitive to bud rot, it was tolerant to immature nut fall. Within PB-121 hybrid (MYD x WAT) MAWA, there was considerable variability, some trees showing vertical resistance. MYD was tolerant to this disease. Other hybrids like Cameroon Red Dwarf (CRD) x Rennel Tall (RLT), MYD x RLT and D x T of Vanuatu showed tolerance to both bud rot and immature nut fall. These findings need to be confirmed in India and other countries where bud rot is prevalent due to *Phytophthora palmivora.*

Somerville (1994) at the Carnegie Institution of Washington has proposed a gene-for-gene hypothesis for molecular mechanism of disease resistance in barley against powdery mildew. The resistance genes encode receptor proteins that intercept a pathogen signal/and activate defensive responses.

Breeding for drought tolerance in coconut

The abiotic stress that adversely affects palms is drought that occurs frequently in many areas in the country. Although there is no authentic data on the extent of production losses caused by drought in coconut and arecanut, it was the unprecedented drought of 1982-83, particularly in North Kerala that led to a systematic approach to screen germplasm collections for drought-tolerance in coconut. Having identified the coconut cultivars and hybrids possessing desirable traits to withstand drought, like stomatal regulation (Rajagopal *et al.*, 1990), biochemical characterization of enzymes (Shivashankar *et al.*, 1991), and lipid peroxidation (Chempakam *et al.*, 1993); the next logical step would be to understand the genetic basis of tolerance to drought (Iyer and Dhamodaran, 1994). Application of modern techniques like RFLP/RAPD/AFLP for identification of genes controlling either stomatal regulation, epicuticular wax deposition, or specific enzyme markers, would help in opening up new vistas in drought research in coconut. For instance, the location of genes controlling the production of wax components like hydrocarbons or b-diketones, as also the synthesis or activation of enzymes like Superoxide Dismutase, in response to field stress might prove useful. Transfer of such genes to less tolerant or susceptible palms could result in evolving transgenic plants in coconut for drought prone areas. Karunaratne *et al.* (1991) have also developed an *in vitro* assay for drought tolerant coconut germplasm.

With regard to arecanut palm, in view of the self-sufficiency in production achieved through conventional breeding and selection, there has not been any attention towards biotech research. However, the use of dwarfing genes for evolving hybrids with improved talls such as Sumangala, Srimangala and Mohitnagar, is considered promising, for ease of harvesting and resistance to YLD (Ananda, 1998). Use of molecular markers for genotype characterization and DNA fingerprinting, especially of the MLO causing YLD, would be rewarding.

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.

3. Molecular characterisation of existing genetic diversity.

One of the major objectives in cashew improvement is to achieve stability of performance in diverse environments. Being a highly heterogeneous, outcrossing population, the selections and hybrids need to be tested for particular locations in order to evolve region-specific cultivars and hybrids, since their performance over locations is highly inconsistent. Nevertheless, we have exceptionally adapted varieties like M44/3 which has performed consistently well in all locations. 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. Also, the RFLP mapping of varieties will clarify many doubts regarding correct identity of germplasm collections and duplicates, in molecular terms. Selection of parents for breeding programme will acquire a new dimension of precision, so that predictable hybrids with heterotic expression of characters of qualitative and quantitative inheritance can be realized (Iyer, 1995). The work in this direction has been initiated for characterising Tanzanian cashew germplasm using RAPDs (Mneney *et. al,* 1997). 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 somaticembryos. 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 and subsequent transfer of grafts to soil has been reported by Kesavachandran *et al.* (1998).

Multiple shoot formation

Bud culture in cashew has given only a limited number of shoots, and increase in dose of cytokinin often resulted in fasciated micro-shoots. However, lowering BA levels and increase of sucrose, has induced elongation of microshoots (D'Souza *et al.*, 1994). Recently, Cardoza and D'Souza (1998) have studied salt tolerance of multiple shoots..

Immature cotyledon segments have given direct somatic embryogenesis without any intervening callus, or a very incipient callusing. This system if augmented and made regular can be used for basic studies on somatic embryogenesis, as also in encapsulation studies for developing 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 segments excised from mature trees, on media containing Thiadiazuron or BAP + GA + IBA.

Anther culture

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 mosquitoincited toxin, and further multiplication of the resistant selections is a priority area where tissue and cell culture combined with molecular techniques will pay dividents. 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). Recently, *in vitro* micrografting has been standardized by (Kesavachandran *et al.* 1998).

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 scientists working in these crops have nearly perfected the protocols for *in vitro* multiplication of elíte materials. Both tea and coffee research institutions have developed necessary infrastructure for this work, and hence are well poised to enter the new era of Bio-tech breeding.

TEA

Tea (*Camellia sinensis* (L.) O. Kuntze) is an important plantation crop. India is the leader in tea production. The Tea Research Institutes at Tocklai

(Assam), UPASI (Tamil Nadu), and CSIR Complex (Palampur) are carrying out research on tea biotechnology. The major areas where biotechnology would be useful in tea improvement are as follows:

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 blight (*Exobasidium vexans).*

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 and Mitra, 1984 Thimmappiah and Shirly, 1998; and Thimmappiah *et al.* 1999). Tea being self-incompatible, it would be worthwhile producing haploids and homozygous diploids using anther/pollen culture technique, and preliminary success was reported upto the multicelled pollen stage and haploid callus formation (Raina and Iyer, 1974, 1983, Chen and Liao, 1987).

Low caffeine tea

Evolving low caffeine tea with improved solubility, which involves the applicationn of both conventional breeding as well as molecular tools like RFLP/RAPD, 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 the modification of the biosynthetic pathway for caffeine synthesis, using antisense RNA technology to selectivity swtich off individual genes and block biochemical pathways. The other approach is through accelerated particle gene delivery (using 'gene gun') which has brought many recalcitrant crops within range for genetic manipulation.

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 in force at the UPASI Tea Research Institute using UPASI-3 clone whose *in vitro* response was good and productive.

Somatic 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, 1987). 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 and Chandra Mouli, 1991). Raj Kumar and Marimuthu (1998) have reported that Tissue Culture plants were more vigorous than vegetatively propagated tea plants, and produced higher number of laterals in response to centering and tipping.

COFFEE

There are about 70 species under the genus *Coffea* out of which *C. arabica* and *C.canephora* are the most important. India contributes to merely a 4% of the global export. Nevertheless, it is an important beverage crop of the country.The major constraints to coffee production and quality where biotechnological tools can offer solutions are as follows:

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 (Medina *et al.*, 1984) and some species resistant to nematodes (Medina *et. al.*, 1984).

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).

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 (Sreenath, 1998). This programme was carried out in collaboration with SPIC Science Foundation, Madras, where protocols for isolation of embryogenic cultures, using leaf and nodal explants were developed. Work has been initiated 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).

Coffee micropropagation via somatic embryogenesis promises to be an efficient method of propagating elite individual trees from a segregating population, which will be competitive in time and cost.

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.

Somaclonal variation in coffee would be an excellent way of shortening breeding programmes, since it provides access to genetic variability within existing cultivars, carrying few alterations, while preserving the genetic integrity of commercial varieties. This variation is either naturally occurring or induced *in vitro* during plant regeneration from callus, due to chromosome breaks, translocations, deletions, aneuploidy, polyploidy, gene amplification, transposons, somatic crossing over, or point mutations (Evans and Sharp, 1983).

In *C. arabica*, some 40 mutants have been identified which are controlled by single genes with expression of dominance, recessiveness, or partial dominance, over the alleles of *typica* variety. Appearance of mutants with monogenic inheritance indicates the partially diploidized nature of *arabica* coffee (Carvalho et al., 1969). Santa Ram and Sreenath (1998) have used DNA fingerprinting to locate coffee rust resistance genes.

Transient transformation was demonstrated in callus derived from *Arabica* coffee protoplasts co-cultivated with *Agrobacterium* carrying NPT II and 'beta' glucuronidase marker genes under control of Ca MV 355 promoter. 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. However, embryo rescue and a nther culture techniques need further refinements. Thus, biotech-breeding in coffee can lead to improvements in agronomy by reducing farming costs, superior beverage quality and stable prices. Low-caffeine coffee genotypes would be welcome, in view of the recent finding of Bangalore doctors, that high caffeine beverages increase blood pressure upto 10-15%. Shantaram 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.

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. At Coffee Research Institute's biotechnology laboratory at Mysore, embryogenic cultures from protoplasts have been reported. Another area where biotechnology is used is cryopreservation. Subsequent to th initial attempt by Kartha *et al* (1981), Jouve *et al.* (1991) reported low temperature preservation of *C. arabica* and cryopreservation of zygotic amd somatic embryos of coffee was reported by Abdelnour *et al* (1993). Subsequently a few more reports have appeared on cryopreservation (Florin *et al* 1995; Hatanaka *et al* 1995). Use of marker assisted selection and molecular markers in identification of diversity and QTL 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 as well as in marker assisted selection. Eventhough ESCA Genetics Corporation, USA has a patent for production of transgenic coffee plants, the use of the technology is in experimental stage. 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).

It is evident from the foregoing, that potentialities biotchnology has to offer in improvement of coffee are immense and in the in near future, the science of biotechnology would make major dents in coffee improvement

COCOA

Cocoa (*Theobroma cacao* L.) a native of South America is grown for its delicious seeds used in chocolate and beverage industry. The self-incompatible nature has resulted in a highly heterozygous population. This necesistates the standardization of clonal propagation for perpetuation of the high yielding material. 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 as follows:

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.
5. Genetic transformation for introduction of genes of interest.

Role of biotechnology in cocoa improvement

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. Cocoa being recalcitrant in tissue cultures using conventional protocols, scientists working in Purdue University, have 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 (Figueira *et al.,* 1991).

Mallika *et al.* (1992) have used nodal segments excised from field grown cocoa plants, and axenic seedlings as explants. Fungal contaminants were warded off by fungicidal spray (Bavistin 0.2% and Dithane M-45 - 0.3%) of the field grown plants every 3 days. Aseptic seedlings raised by mature embryo culture, were also used wherever mature tree explants gave poor response. Woody plant medium (Lloyd and McCown, 1980) containing the cytokinin 2-ip (1 ppm) + IAA (0.02 ppm), promoted bud sprouting and leaf expansion. Same medium was suitable for continued growth of shoots, but supplements of aminoacids, ascorbic acid, peptone and phloroglucinol were essential for sustained growth of proliferated shoots from field explants. Profuse callusing without differentiation could be suppressed by $AgNO^3$ (5ppm) addition to the medium. Rooting was induced by a pulse treatment of IBA in ethanol, and the rooted plantlets were gradually hardened in pots kept at high humidity and then transferred to the field.

At CPCRI, Kasaragod, Philomina Abraham *et al.* (1992) have standardized *in vitro* induction and growth of somatic embryoids from immature cotyledon segments cultured on Murashige and Skoog's (1962) medium supplemented with NAA and BAP (0.5 mg/l each) and coconut water (15%). Indulekha and Iyer (1993) have observed direct somatic embryogenesis from immature cotyledon explants, at 20% frequency, on MS medium + 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 MS + BAP (0.5 mg/l.).

The present holding of 106 accessions of cocoa germplasm at CPCRI represents a narrow variability, acquired mainly from Nigeria. We need to enrich this by collecting large bean and pleasant aroma types from Amazon, Ghana, Brazil and North and Central Americas, for evaluation. Cocoa seeds being recalcitrant with short viability, budwoods are the only means of introduction, with all the attendant problems of contamination, and transit losses. Hence, the collection of embryos and *in vitro* shoots under aseptic condition needs to be perfected for future collection expeditions. We need to select and screen available germplasm for resistance to vascular streak dieback

(VSD), canker, and vascular streak disease caused by *Oncobasidium theobromae* (Koshy Abramam *et al.*, 1998) *Phytophthora*-incited black pod diseases, combined with high yield self-incompatibility, and large bean size. Five high yielding disease-tolerant clones (CCRP-1,4,5,6 and 7) have been released during 1998 (Mallika *et al.* 1998, Koshy Abraham *et al.*, 1998).

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 RAPD for DNA finger printing of cocoa clones to select desirable cultivars.

The Technical Group on Cocoa convened in 1986 in the Ministry of Agriculture, Govt. of India had estimated a grinding capacity of 20,000 tonnes in cocoa-based industries, by 1990, and a production target of 1.0 lakh tonnes by 2000 AD. However, the present grinding capacity is about 16,000 tonnes only, and the production of cocoa beans is 7000 tonnes which has not been fully utilized due to lack of demand for finished and semi-finished products. Export prospects of dry beans is also not bright due to high cost of production. Considering these trends, the internal demand for cocoa beans is not likely to go above 12000 tonnes per annum, which can be fixed as our production target for the terminal year of 8th Plan.

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) 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. The Kerala Agricultural University has developed protocols for micropropagation of cocoa (Mallika *et al.,* 1996). 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 (El Hag and El Hag, 1986) (Sondahl, 1991, Figueira and Janick, 1994), petals (Sondahl *et al.,* 1993) and flower buds (Lopez-Baez *et al.,* 1993). 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. The use of molecular markers such as RAPD and RFLP has resulted in characterizing the cocoa germplasm. Lanaud *et al.,* (1995) was able construct 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* Muell. Arg.) introduced into India about a century ago is cultivated in large areas in Kerala and in North Eastern States, and large-scale plantations began only 80 years ago. Although the genus *Hevea* comprises nine species, *H. brasiliensis* Muell. Arg. is the main cultivated species, which has adapted to a wide range of countries in the South and S. East Asia, Central and W. Africa, China and Papua New Guinea, besides its home in Brazil. All the trees in S.E. Asia covering millions of hectares are said to have been derived only from a few trees thus showing a narrow genetic base. Being a perennial out-crossing tree, taking 5-7 years from seed to bloom, the present varieties are highly heterozygous, and inbreeding gives only a few seeds or none at all, which has slowed down the pace of rubber breeding. Rubber cultivation is beset with certain problems of low productivity, diseases and pests.

H. brasiliensis is a perennial open-pollinated tree and is highly heterozygous in nature. It is an amphidiploid with a basic chromosome number of 9 (x = 9), with 18 chromosomes in its gametes (n = 18) (Perry, 1943; Ong, 1975). 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 tissue culture of *Hevea* started at the Rubber Research Institute of Malaysia in sixties. Paranjothy and Ghandimathi (1975) reported the formation of callus from various explants and embryoid formation was observed from somatic tissues of anthers. Pollen plantlets of *H. brasiliensis* were first obtained by anther culture in 1977 (Chen *et al.*, 1977). Guo *et al.* (1982) reported recovery of plantlets from unpollinated ovules of *H. brasiliensis.*

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).

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).

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 3,4-D, and prolonged exposure to these hormones suppressed embryogenic potential of the callus. Thus, instead of 9 M each of 3, 4-D and BAP in the control medium they used only 4.5, 2.25 or 0.45M each of 3, 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 mM). High hormonal level present during induction of callus, previously thought necessary, are 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.

With regard to the problem of browning due to phenolic exudates, it was found that water soluble PVP (Polyvinyl polypyrrolidone) at 100 ppm was most effective, followed by $HgCl_2$ treatment instead of $NaOCl_2$. Shoot tip explants had higher phenolics than nodal explants. Activated charcoal had no effect in liquid media, but it delayed browning when incorporated into semi-solid media. Frequent transfers to fresh media did help in reducing casualties due to browning. There was also clonal variation in the extent of browning, RRIC-110 exhibiting the highest and PB-86 the least extent of browning.

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.b- *glucuronidase* (GUS) gene and the *NPT II* gene. Development 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 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.*, 1995). 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 (Lebrun and Chevallier, 1990; Seguin, 1992; Leconte *et al.*, 1994) and isozymes are used to study the reproductive system and pollen dispersal in *Hevea* (Leconte *et al.*, 1994)

Genetic analyses using isozymes were completed by nucleic markers (RFLP, RAPD, microsatellites) at the Cirad Agetrop/Biotrop laboratory 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) embryo rescue, (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 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 Philip and colleagues at Calicut University, Botany Department, using both shoot (Philip and 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 which 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 also 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 and Rao, 1984), and from stem and leaf callus (Nazeem *et al.*, 1993). These regeneration systems have been used in studies on *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* at the Indian Institute of Spices Research, Calicut (Nirmal Babu *et al.*, 1993, 1994). Parani *et al.* (1997) working at the M.S. Swaminathan Research Foundation, Madras, have employed RAPD fingerprinting to select micropropagated *Piper longum* plants for conservation of elite genotypes. Joseph *et al.*, (1996) of Calicut University, Dept. of Biotechnology, have reported plant regeneration from somatic embryos derived from zygotic embryogenic callus of *Piper nigrum* on solid and liquid, Schenk and Hildebrandt (1972) medium. Kelkar *et al.*, (1996) of National Chemical Lab., Pune, have obtained callus-mediated shoot regeneration from leaf explants of *Piper cohibrinum* 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*.

Tree spices have proved 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 & Blake, 1990; Mathew and Hariharan, 1990, 1992, Thara *et al.*, 1998; Mary 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 two 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 over exploitation, 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 of ICAR, CSIR and University Departments of Botany, and in Institutions like TBGRI, MSSRF etc. (Iyer, 1998).

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 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. The RFLP/RAPD/AFLP analyses will help in determining clonal fidelity, and in identifying the transformants for the major spice crops.

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WATER MANAGEMENT FOR PLANTATION CROPS IN KERALA - STATUS AND SCOPE

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ABSTRACT

The status of information on the biophysical environment, agro-hydrological characteristics of the terrain, the water related characteristics of crops, effect of water deficit, the water demand and the recommended water management practices of various plantation crops grown in Kerala have been summarized. The summary reveals the scope for long term systematic studies on various aspects referred. The relevance of watershed concept and Water Management Information System has been highlighted for the water management of plantation crops.

INTRODUCTION

Plantation crops occupy nearly four million ha of area in India which is about 2.3 percent of the total cropped area. Their contribution to the Gross National Product at the current market price comes to about Rs.2,98,000 million (George, 1997). Kerala state's contribution to the total national production varies from 8.2% as in tea to as high as 96% for black pepper. The common plantation crops like coconut, arecanut, black pepper, cashew, cocoa and coffee are grown either as mono crop or multiple crop plantations while crops like tea, cardamom and rubber are mono crop plantations. The productivity of these plantations in Kerala state as compared to national averages are given in Table–1. The state's productivity is higher in all the plantations, except in coconut

Table1 : Productivity and per centage contribution of plantation crops of Kerala state

	Productivity (Kg/Ha)		
Crop	Kerala State *	All India**	Contribution of Kerala (%) to national production
Coconut	5856	7779	38.2
Arecanut	1200	1100	30.0
Cashew	924	660	22.9
Cocoa	621	605	64.0
Black Pepper	317	272	96.0
Cardamom	107	84	50.4
Coffee	562	614	25.8
Tea	1747	1752	8.2
Rubber.	1000	915	87.4

Source: * - Farm Guide, Govt. of Kerala (1997)

** - M. V. George, Journal of Plantation Crops 25 (1) : 1 - 14, (1997) and coffee, while it is almost equal to national average in the case of cocoa and tea. These crops are mostly grown under rainfed condition and therefore, the vagaries of monsoon, especially the distribution of rainfall will have direct impact on the yield of these plantations. George (1997) has noted that the changes in area and production of plantation crops are neither uniform among the crops nor over the periods as both were very much influenced by the climatic and seasonal changes, especially occurrence of drought, disease and market prices. Drought and disease are influenced by water management practices. Excess moisture during rainy periods (Southwest monsoon period) and moisture stress during summer is a common phenomenon in the plantation area. In addition to rainfall, other natural factors like topography of the land, soil characteristics, and management practices also influence the productivity of plantations. Since the nature of water management is influenced by the factors like topography, soil, climate etc., the productivity of plantation is directly affected by water management practices.

Therefore, this review analyses the various biophysical constraints of plantation area, agro-hydrological characteristics relevant for water management, the extent of water demand and deficit, impact of water deficit, and the recommended water management practices in Kerala state. Further, the scope for future studies on water management are also identified with a view to generate better scientific information on the subject discussed.

Biophysical Environment

The biophysical environment influencing the productivity of plantations includes the land form, soil and water resources. The nature and characteristics of these resources needs to be appreciated for any scientific management of plantation crops.

Land Form

The terrain analysis of Kerala (Srikumar and Mahamaya,

Table 2: General tarrain characteristics of plantation areas in Kerala

Crop	Nature of Terrain	Slope%	Relative relief (m)	General Evaluation
Mainly Coconut	Coastal Cliff (C2)	<15	<30	Erosional feature
Mainly Coconut	Coastal Plain (C3)	<05	<1	Densely populated
Mainly Coconut	Coastal Plain - Lat (C4)	<05	<20	Densely populated
Mainly Coconut	Transitional Plain (P3)	<10	<20	Clay Laterite Interface
Coconut and Mixed Tree crops	Low Rolling Terrain (D1)	<15	>20	Partly erosion affected
Coconut and Mixed Tree crops	Moderatly Rolling Terrian (D2)	<25	<40	Partly erosion affected
Mixed tree crops	Highly Mudulating Terrain (D5)	<35	>100	Deforested and erosion affected
Tea, Coffee and Cardamom Plantations	Hilly area (D4)	>35	>300	Deforested and erosion affected
Tea, Coffee and Cardamom Plantations	Isolated Residual Hills (D5)	>35	>200	Deforested and erosion affected

Ref: Terrain analysis of Kerala (1995) State Committee on Science, Technology and Environment Department, Govt. of Kerala

1995) has shown that nearly 85per cent of the total area of the State is subjected to denundational processes. The denundational landscape with unique process of laterisation weathering results in rolling terrain of varying slope. The general terrain characteristics where plantation crops are grown are given in Table – 2. The various terrain conditions has slope ranging from <5 to >35 per cent and relief ranging from <10m to >300 m. The environmental evaluation of these indicates that these areas are affected by erosion, and deforestation and also presence of clay laterite interface in the profile. The low rolling terrain is characterized by alternate ridge and valley is subjected to gully erosion. The moderately rolling terrain have slopes ranging from <15 to <25 per cent and are intensively cultivated. The highly undulating terrain represent foot hill zones. The hilly area represents Western ghat hills with more than 35 per cent slope and relatively high relief. The above classes of terrain spread over the entire state is intensively used for cultivation of plantation crops. Because of the typical slope characteristics, these areas are subject to erosion depending on land management practices and also high rate of surface runoff of rain water. Thus, the land form in which plantation crops are grown is conducive for high soil erosion losses and quick runoff of rain water.

Soils

The soils of the State are detailed by Krishnan *et al.,* (1996). Detailed soil water characteristics of laterite, forest loam and coastal sandy soils were quantified for typical soil types in the State (Varadan and Mammen, 1995). The general soil properties where the plantation crops are grown are given in Table-3. The soils of the midland are deep or very deep and are well drained. The available water capacity (AWC) varies from 50 to 150 mm/m depth. These soils have moderately acidic pH and low base saturation. The soils of the Central Sahydhri and Wynad plateau are characterised by good soil depths, with AWC varying from 150 – 200 mm/m depth, medium base saturation and accumulation

Table 3: General soil properties of plantation area in Kerala

Soils/Land form	Occurrence in the slope range (%)	Depth of soil (mm)	Available water capacity (mm/m)	pH(Range)	Organic carbon(%)	Cation exchange capacity (mol + Kg -1)
Midlands	5 - 15	150 - 200	50 - 150	4.6 - 5.8	0.3 - 5.6	1.8 - 14.0
Central Sahyadri hills in Wynad plateau	15 - 35	125 - 200	150 - 200	5.2 - 6.9	0.2 - 2.3	5.3 - 17.0
Soils of Palghat gap	5 - 15	125 - 135	50 - 200	6.2 - 8.0	0.08 - 1.4	3.3 - 17.0
Soils of Nilgiris	15 - 35	85 - 200	150 - 200	4.8 - 7.0	0.6 - 4.0	4.8 - 7.0
Soils of South Sahyadri Hills	15 - 35	120 - 200	100 - 200	4.1 - 6.6	0.4 - 4.2	4.1 - 23.8

Ref: P. Krishnan *et al.* (1996) Soil Resources of Kerala for land use planning. NBBS pub. 48 b. (Soils of India Series (o) National Bureau of Soil Survey and Land Use Planning).

of organic matter in the surface depths. The soils of Palghat gap are characterised by wide range of AWC, neutral to alkaline pH and high base saturation. The soils of Nilgiris have acidic to neutral pH, low base saturation and moderately shallow to very deep soil depth. The soil depth, erodibility, infiltration rate of the soil and available water capacity are important characteristics of the soil with respect to water for crops. The infiltration rate vary depending on land use. The erodibility characteristics (K-factor) of the laterites and forest soils where plantation crops are grown range between 0.19 to 0.28 and 0.10 to 0.19 respectively (Thomas and Raghunath, 1980). These values indicate the susceptibility of the soil for erosion. The erosion in untreated area vary between 8 to 16 t/ha/annum. The soil erosion is accelerated (under steep slopes) in places where only mechanical measures were taken without any plant cover and it is reported for Attapady region of Kerala (Annonymous, 1995).

Thus, the soils of the state show the major degradation problem as accelerated erosion and loss of nutrients and this is evident from low pH and base saturation and varying levels of AWC. It is estimated that nearly 67 per cent of the total area of the state is affected by water erosion and loss of plant nutrients.

Water

The water availability to plantation crops which are mostly grown under rainfed condition depends on the rainfall, and evaporation which are in turn mainly affected by number of rainy days and air temperature respectively during different seasons. The hydro meteorological characteristics of typical watersheds where these crops are grown are given in Table-4.

The seasonal rainfall distribution in these areas show that 60-85 per cent of the mean annual rainfall is received during 'Virippu' (June – September) season; 8 to 20 per cent during 'Mundakan' (October – January) season and 5 to 20 per cent during

Table 4: Hydro metereological characteristics of plantations area (Typical Sub-Watersheds)

Characteristics	Sub-Watersheds				
	Chittar (Trivandrum)	Meenanthara (Kottayam)	Purapuzha (Ernakulam)	Valiyankandi (Kannur)	Baigote (Kasargod)
Mean seasonal rainfall (mm)					
Viruppu (June - September)	670	1965	1969	2466	3364
Mundakan (October - January)	805	642	696	454	311
Punja (February - May)	588	661	686	222	178
Mean annual rainfall (mm):	2063	3268	3351	3142	3843
Mean seasonal number of rainy days :					
Virippu	45	72	86	78	84
Mundakan	36	33	36	17	16
Punja	27	25	31	10	9
Mean annual rainy days :	108	130	153	105	109
Mean seasonal potential evaporation (mm)					
Virippu	300	233	214	190	301
Mundakan	252	344	316	233	464
Punja	317	723	506	410	600
Annual Mean	869	1000	1036	833	1365

Table 4 : (Contd.)

Characteristics	Sub-Watersheds				
	Chittar (Trivandrum)	Meenanthara (Kottayam)	Purapuzha (Ernakulam)	Valiyankandi (Kannur)	Baigote (Kasargod)
Mean seasonal air Temparature (oC) : Maximum:					
Virippu	31	29	29	32	29
Mundakan	32	32	30	35	33
Punja	33	34	33	37	36
Minimum:					
Virippu	26	25	24	24	23
Mundakan	24	24	23	24	22
Punja	26	26	24	26	23

Source: Hydrological data generation project (CWRDM), 1996

'Punja' (February – May) season depending on locations. The number of rainy days vary from 45 – 85, 16 – 30 and 9 – 27 for Virippu, Mundakkan and Punja seasons respectively. The rainfall is lesser than evaporation losses during Punja season implying the moisture stress period for the crops. Rao and Vamadevan (1982) have shown that moisture stress period varies between 14 to 15 weeks in southern parts and 18 to 21 weeks in the northern parts of the state. The erosivity of rainfall (EI 30) varies from 700 – 900 for 1000 – 2000 mm rainfall, 1000 – 2700 for 2000 – 3000 mm rainfall and 1700 – 3200 for 3000 – 4000 mm of total rainfall (Thomas and Raghunath, 1980). Higher the EI 30 value, greater is the energy level of rainfall which causes soil erosion. Thus, the water availability to crops based on the analysis of climatic parameters show that there is excess moisture during Virippu season accompanied by high erosivity of rainfall and soil erosion while there is moisture deficit during Punja season.

The biophysical characteristics where the plantation crops grow show the following: Denundational nature of terrain is conducive for high soil erosion and surface runoff; weathered and transported soils have low levels of nutrients and water retention and climatic indicator show water deficit for the crops during Punja season. Therefore, any water management research and development works for plantation crops should consider the characteristics of biophysical parameters described above.

Since the land use influence the hydrological behaviour of the terrain it is necessary to appreciate the agro-hydrological characteristics like slope, runoff, soil moisture, etc. under different plantations, while developing water management techniques suitable for various plantations.

Agro-hydrological characteristics under different plantations

Water entry, distribution, movement within the profile, surface runoff, ground water recharge etc. of a given terrain conditions

Table - 5 : Agrohydrologic characteristics under different plantations

Watershed (Landuse)	Area (ha)	Form factor	Basin circularity	Basin elongation	Mean slope	% of direct runoff to rainfall	% of base flow to total flow	% of total flow to rainfall	Infiltration equation
1. Koothali (Mixed)	16.6	0.50	0.7	0.8	57	14.9	73	55	50.2 x t0.43 + 6.9
2. Perambra (Cashew)	29.5	0.6	0.6	0.8	23	7.6	85	53	9.1 x t0.877 + 30.6
3. Perambra (Rubber)	1.90	0.81	0.7	1.0	40	3.0	66	66	2.8 x t 0.98 + 13.7
4. Achoor (Tea)	61.7	0.52	0.7	0.8	25	2.8	68	68	6.6 x t0.931 + 34.6
5. Beenachi (Coffee)	74.9	0.3	0.6	0.6	24	4.3	94	NA	0.03 x t 1.63 + 4.0
6. Sugandagiri (Cardamom)	3.2	0.9	1.4	1.0	46	8.1	85	85	4.5 x t0.863 +22.1

Source : Report on studies on different landuse based watersheds submitted to Department of Environment, Govt. of India, CWRDM (1988) depends on the land use in addition to the biophysical characteristics referred earlier. Therefore, for any water management practice, the hydrological behaviour under different land uses needs to be appreciated. The various hydrological parameters as influenced by different plantations are given in Table-5 (Annonymous,1988). The basic infiltration rate which is surface soil characteristics as affected by plantation show that it varies from 6 cm/h under coffee plantations to as high as 34 cm/h under rubber plantations. The infiltration equation as given in Table-5 can be used to predict the infiltration for different time intervals. The other features of surface water flow indicate that the percent of total flow to the rainfall range from 53 to 85 per cent. The quantification of these characteristics is essential for any water resource development programme for plantation agriculture.

Water related characteristics of plantation crops

Water management involve the plant water characteristics in addition to the environmental factors described earlier. Plant characteristics like the sensitive stages of growth and canopy cover, which decides the crop co-efficient (Kc), the effective root zone etc. influence the water demand of crops and also the water management practices to be adopted. Table-6 gives the details of these characteristics with respect to various plantation crops. One of the important growth stage of plantation crops is flowering. In the case of coconut and arecanut flowering phase is continuous throughout the year and so water stress at any time during the year will affect productivity of these plantations. In the case of black pepper spiking starts during early May and therefore pre monsoon rain will influence the productivity. For cardamom the panicle emergence is during January, while in the case of coffee, blossom showers during February – March will determine the production. Most of the plantation crop's productivity will be affected by moisture availability during Punja season. The depth of root zone and crop-coefficient values are necessary for determining the water demand and irrigation application.

Table - 6 Water related characteristics of plantation crops

Crop	KC	Depth of effective root zone (cm)	Flowering season	Fruit maturity period (months)	Sensitive critical stages and moisture requirements for reproductive phase	Reference
Coconut	0.75 *	90 @	Continuous - 12 to 13 inflorescences produced per year at monthly interval	11 - 12	Inflorescence initiation, spikelet primordia formation, female flower primordia formation, fruit set and endosperm development stages. Adequate soil moisture needed throughout the year since inflorescences in various critical stages are present on the palm round the year.	* Nelliat and Padmaja, (1978) @ Menon and Pandalai, (1967)
Arecanut	0.94*	45@	Continuous - 8 to 9 inflorescences are produced per year out of which 4 to 5 are harvested.	9 - 10	—do—	* Abdul Khader and Havanagai, (1991) @ Bavappa et al, (1982)
Black Pepper	1.0 *	60 @	Emergence of spike during first fortnight of May. Flowering during second fortnight of June.	4	Spiking, flowering and fruit set stages. Rainfall during first half of May and second half of June essential for better spiking and fruit set **+. Sensitive to water-logging.**	* Dorrenbos and Pruitt, (1984) @Sadanandan,(1990) **+Sadanandan,(1986)**

Table 6: (Contd.)

Crop	KC	Depth of effective root zone (cm)	Flowering Season	Fruit maturity Period (months)	Sensitive critical stages and moisture requirements for reproductive phase	Reference
Cardamom	1.0	25	Panicle emergence during January. Flowering from May to August	3 - 4	Initiation of suckers and panicle, flowering, fruit set and fruit development stages. Adequate soil moisture needed during summer season since initiation of panicle and flowering occurs during summer period. Sensitive to waterlogging.	
Coffee	0.90*	30@	Emergence of inflorescence buds during November - December. Flowering in February - March for robusta and in March - April for arabica	7 -9	Flowering, berry expansion and dry matter development stages. Blossom rains during February March (2 - 4 cm) for robusta and during March - April (2.5 - 4 cm) for arabica. Backing rain (5 - 7.5 cm) at 10 - 15 days after flowering for better fruit set.	* FAO, (1984) @ Garriz, (1978)
Cocoa	1.0*	45@	Main flowering during March - August and some flowering during November- February	6 - 7	Flowering and fruit set stages.	* FAO, (1984) @ Zevallos et al (1972)

Table 6 : (Cont.)

Crop	KC	Depth of effective root zone (cm)	Flowering Season	Fruit maturity Period (months)	Sensitive critical stages and moisture requirements for reproductive phase	Reference
Rubber	0.87*	45	February -	5 - 6 April-6	Dryness needed during Decemb January for 'Wintering' period to be of short duration @	* Jessy et al (1992) @ Webster of Banlkwill, (1989)
Tea	1.0*	30@	Not Applicable	9 – 12	Vegetative stage during January - May	* FAO, (1984) @ Ellis, (1972)
Cashew	-	60	November - February	2	Normal monsoon essential for complete flower emergence. Cloudy weather during flowering results in scorching of flowers* and incidence of pests@ Rainfall during fruit development stages affects the quality of the nut.	* Rao,(1956) @ Dasarathi, (1958)

Effect of water deficit on plantation crops

Since most of the plantation crops are grown under rainfed condition, the influence of water deficit can be assessed from the rainfall pattern. It was reported that the effect of drought on coconut yield was seen in the eighth month and continued for 12 months. A relationship was established between yield of coconut with index of moisture adequacy during summer. In the case of pepper, drought condition during April – May will affect severely the spike formation and hence the yield (Sukumara Pillai *et al.*, 1988). For cashew plantation, drought condition during October – November period severely affect flowering and hence nut production. The productivity of cardamom will be affected due to drought condition during January- May which coincides with panicle initiation stage of the crop. Rethinam and Korikanthimath (1985) have reported severe set back in cardamom growing tracts of India due to dry spells. The yield of cocoa was reduced by almost 40 per cent due to drought. The rubber yield was affected due to drought and varies with clones (Vijayakumar *et al.*, 1988). Thus, the summer rainfall is critical for most of the plantation crops, except cashew. Plantation crops have some physiological and morphological traits to overcome drought effects. The desirable physiological traits for drought tolerance in plantation crops include effective stomatal regulation to reduce transpiration loss, wax coating on the leaf surface and stability of lipid membrane (Rajagopal, 1996). The various reports on the relationship of water use efficiency, harvest index etc. with yield of plantation crops between drought tolerant and susceptible genotypes have been summarized (Table-7).

In addition to the practices of soil water conservation to overcome drought, there is scope for genetic manipulation for drought tolerance in plantation crops. The drought effect depends on the extent of water deficit and varies with the crop. One of the common method to overcome drought is irrigation based on water demand.

Table 7: Effect of water defficit on plantation crops

Crop	Drought effects	Drought tolerant cultivars/ varieties	Physiological/biochemical attributes	Reference
Coconut	Effect of drought seen in the eight month after the occurance of drought and continued for 12 months. Maximum effect during 13th month after the after the cessation of drought period1. Drought results in abortion of spadices, low production of female flowers, button shedding, under sized nuts, low copra content, etc.	West coast tall, Java Giant, Philippines ordinary and Hybrids such as LO X GB, LO X COD, WCT X GB2	High stomatal resistance and low transpiration2 High leaf water potential2 High epicuticular wax content 2 Stability in nitrate reductase activity 3,4 High dry matter production5	1. Prasada Rao, (1994) 2. Rajagopal et al, (1990) 3. Shivasankar, (1992) 4. Kasthuri Bai et al(1993) 5. Kasthuri Bai et al (1996)
Arecanut	Highly sensitive to drought. Results in abortion of spadices, low production of female flowers, poor fruit set and shedding, low yield, etc.			
Cashew	Erratic North - East monsoon and prolonged drought	carries low yield.		

Table 7 : (Cont.)

Crop	Drought effects	Drought tolerant cultivars/ varieties	Physiological/biochemical attributes	Reference
Black Pepper	Prolonged dry spell immediately after good summer showers affects flowering process and ultimate yield. Prolonged dry spell during summer causes high mortality (36 - 39%) of young vines1	—	—	1. Prasada Rao, (1994) —
Cardamom	Prolonged drought affects the growth and yield of cardamom. During 1992 - 93 drought caused about 50% mortality in many areas.	Malabar type	—	1. K[illegible]ikant[illegible]math, 1[illegible]8)
Coffee	Absence of blossom showers and backing showers causes partial to complete failure of the crop.	Robusta. Arabica selections 7,3,9 and 101	High epicuticular wax content[2] Higher osmoregulation 3 Stability in nitrate reductase activity2	1. Venkataraman et al, (1996) 2. Ramiah and Venkitaramam, (1987) 3. Venkataraman et al, (1987)

Table 7 : (Cont.)

Crop	Drought effects	Drought tolerant cultivars/ varieties	Physiological/biochemical attributes	Reference
Cocoa	Yield is reduced by almost 40% during drought years1.	NC - 29, NC - 31, NC - 232	. High stomatal resistance and low transpiration2. . High leaf water potential2. . High epicuticular wax content3 . Stability in nitrate reductase activity4	1. Prasada Rao, (1994) 2. Balasimha et al, (1988) 3. Balasimha et al, (1985) 4. Balasimha, (1982)
Tea	Vegetative growth and leaf yield are severe[illegible] affected by drought1	TV - 1, TV [illegible] 14, Teen A[illegible] 17/1/542	. High stomatal resistance an[illegible] transpiration 2,3 . Hig[illegible] leaf water potenti[illegible] . High epicuticular wax content4	1. Prasada Rao, (199[illegible] 2. Handique an[illegible] [illegible] 3. Saikia and Dey, (1984) 4. Rajasekhar et al, (1991).
Rubber	Yield of rubber is substantially reduced due to drought1	GT -1, RRII - 105, RRIM - 6001	. High stomatal resistance and low transpiration1 . High epicuticular wax content2 . Higher osmoregulation3,4	1. Vijayakumar et al, (1988) 2. Gururaja Rao et al, (1988) 3. Devakumar, et al, (1988) 4. Satheesan et al, (1982)

Water demand/ deficit in plantation crops

The water demand of plantation crops has been reported by various research workers. At CPCRI, Kasaragod, the water requirement of coconut was reported to be equal to potential evaporation rate (Nelliat and Padmaja, 1978). Jayakumar *et al.*. (1988) have reported the consumptive use of six year old coconut plantation to range from 2.7 to 4.1 mm per day, while Rao (1989) has reported a range of 2.9 to 5.5 mm per day for five year old coconut plantation. Varadan (1997) using soil-crop-climate method has reported the variation in water demand of coconut for different districts of Kerala. Thus, there is still scope for developing suitable technique for quantifying water demand of plantations. However, because of the perennial nature of the crop, and also that the time required from planting to reproductive phase of these crops, there is difficulty in continuing long term experiments with these crops. Therefore, computational methods seems to be more practical and also location specific information can be generated. The crop evapo-transpiration (ETc) of arecanut was reported to be between 4.6 to.6.3 mm per day for December to May period (Mahesha, 1987). No work has been reported on water demand of cocoa, coffee, tea etc. The ETc value for black pepper with *Erythrina indica* as standard was reported to be from 2.45 to 3.15 mm/day. In the case of nutmeg grown as intercrop in coconut, the ETc was reported as between 3.6 to 3.9 mm/day. (Satheesan *et al*, 1997). However, irrigation requirement has been reported for some of these crops (Table-8). Irrigation schedule for various plantation crops grown under different soil types and at various districts of the state for the period from October to May has been reported by Varadan (1996). The variation in the case of coconut is 32 mm irrigation depth at seven days interval at Palakkad district while it is 30 mm once in 10 days at Thiruvananthapuram district. In the case of arecanut, the schedule is 40 mm once in nine days interval for Wynad while it is 18 mm once in four days at Kasaragod. In the case of tea, the schedule is 28-30 mm once in six days interval at Idukki and Wynad district (Varadan, 1996). For

Tabel 8: Recommended water management practice for plantation crops

	Rainfed condition		Irrigated condition	
Crop	Engineering measures	Agronomic measures	Irrigation methods	Irrigation schedule
Coconut	Contour bunds (stone pitched/ earthen)	Centripetal terraces/basins Contour planting Contour cultivation Multiple cropping Mulching Husk burial	Flooding Basin irrigation Ring irrigation Sprinkler irrigation Drip irrigation	600 lit/tree once in 3-4 days for sandy soils (KAU, 1996) . 900 lit/tree once in 5 days for loam soils (KAU, 1996) . 1300 lit/tree once in 7-8 days for loam soils (KAU,1996) . 1600 lit/tree once in 9 days for silty clay soils (KAU, 1996) . 20 mm at 4-5 day interval in Kasargod (Nellit & Padmaja, 1978) . 1106 to 1488 lit/palm/month from December (Prasada Rao, 1994) 30 lit/palm/day under drip irrigation (CWRDM, 1989)
Arecanut	Contour bunds	Conservation Contour planting Contour cultivation Multiple cropping Mulching	Flooding Channel irrigation Sprinkler	. 175 lit/palm once in 7 - 8 days during November - December, once in 6 days during January - February and once in 3 - 4 days during April - May (KAU, 1996) 15 lit/plant/day under drip irrigation (CWRDM, 1989) . 30 mm at one IW/CPE ratio (Bhat and Abdul Khader, 1982)

Table 8: (Contd.)

	Rainfed condition		Irrigated condition	
Crop	Engineering measures	Agronomic measures	Irrigation methods	Irrigation schedule
Black Pepper	Contour bunds Contour platforms	Mulching Contour cultivation Contour planting	Basin irrigation Contour furrow irrigation Drip Irrigation Sprinkler irrigation	100 lit/ vine at 8 - 10 days interval from November - December to March (KAU, 1996)
Cardamom	Contour bunds Staggered trenches/pits Contour planting Earthing up Mulching	Contour cultivation Contour tillage Sprinkler irrigation Drip Irrigation	Basin irrigation Contour furrow irrigation by sprinkler method	30 lit/clump starting from Dec. (Gurumurthi et al,(1996) . 25 m m at 10 - 12 days interval (Korikanthimath, 1994) . 10 - 15 lit/clump/day by drip method (Kurup,1978) . 10 lit/clump/day by drip method (CWRDM, 1989)
Coffee	Contour bunds Staggered trenches/pits	Contour planting Conservation tillage/digging Scuffling and mulching Cover cropping	Sprinkler irrigation Drip irrigation	. 32 to 42 mm at 20 - 25 days interval through sprinklers . 8 lit/plant/day through drip system (Sopal Ram et al, 1994)
Cocoa	Contour bunds Staggered trenches/ pits	Conservation tillage Mulching Contour planting	Basin irrigation Sprinkler irrigation Drip irrigation	Irrigation once in five days (KAU, 1996)

Table 8: (Contd.)

	Rainfed condition		Irrigated condition	
Crop	Engineering measures	Agronomic measures	Irrigation methods	Irrigation schedule
Rubber	Contour bunds Contour platforms (11/2 m wide) Staggered trenches/pits (120 cm x 45 cm x 75 cm ,100 trenches ha) (* Rubber Board, Kottayam)	Cover cropping Mulching Contour planting	Drip irrigation	. 10 litres/plant/day under drip method (CWRDM, 1989)
Tea	Earthen embarkments Staggered trenches/pits	Contour planting Vegetative barriers	Sprinkler irrigation (Varadan et al, 1988)	. 21 mm at 7 days interval through sprinkler system
Cashew	Contour bunds Staggered trenches/pits	Contour planting Mulching	Basin irrigation	. 200 lit per tree at fortnightly interval (Yadukumar and Mandal, 1994)

cardamom, the schedule is 22 mm of irrigation depths once in five days interval at Idukki as compared to 34 mm once in seven days interval at Wynad. Thus, the influence of climate on irrigation demand of plantation crops was clearly shown. Rao (1996) has reported an ETc value varying from 2.8 to 3.6 mm / day during December to May period for coconut at RARS, Pilicode. Varadan (1997) has reported the water deficit for October to May period for major plantation crops in Kerala. In addition to water demand of crops, the effective rainfall was taken into account in computing the water deficit for different locations. The effective rainfall value for coconut was reported as 43% and 66% for South West and North East monsoon periods from a lysimetric study (Annonymous, 1988). The water deficit for coconut was estimated to be between 85 to 360 mm for October to May period for all the districts while it was 650 mm for arecanut at Wynad and Kasaragod districts. The deficit for black pepper, coffee, tea and cardamom was higher at Wynad district compared to Idukki district. The deficit range from 407 to 490 mm for Idukki as compared to 613 to 720 mm for Wynad district for these crops.

Thus, the water demand and water deficit reported for plantation crops grown in Kerala seems to vary with the method adopted, location of experiment etc. There is need for further detailed investigation in this respect.

Water management practices

The water needs of the plantation crops has to be satisfied either by soil water conservation or by water application through irrigation. The common recommended practices for rainfed and irrigated condition for different plantation crops are summarized in Table-8. For rainfed condition the common recommended practices irrespective of the plantations are contour bunds and staggered trenches and pits. Planting in contour platform is common in the case of rubber plantation. There is no experimental data available for various plantations with respect to the number and size of trenches or pits or the contour interval to be adopted or height of the bunds. Similarly, the common agronomic measures for plantations include multiple cropping, mulching, conservation tillage and contour planting. In the case of rubber, cover cropping is a common practice. The recommended irrigation schedule for different plantation crops are also given in Table-8. It is interesting to note that the suggested schedules vary for the same crop depending on the method adopted for quantification. This aspect needs detailed investigation taking into account various parameters, like depth of soil, soil texture, slope, effective rainfall of the location etc. in addition to crop characteristics.

The extent of area under irrigation of plantation crops is very limited. It accounts for 19%, 32% and 0.9% for coconut, arecanut and spices respectively. Therefore, the major emphasis for water management of plantation crops should be for rainfed condition on a watershed basis.

Watershed management

The concept of watershed management for water management of plantation crops seems to be appropriate considering the constraints of biophysical resources explained earlier in which the plantation crops are grown. This concept which involve soil and water conservation, land management practices, water resources development and water application on a natural hydrologic unit (watershed) will reduce the degradation of soil, improve moisture availability during Punja season and hence ensure sustainable productivity of plantations. In this connection, the water resources development programme taken up by Spices Board at Udumbachola taluk of Idukki district for cardamom plantations under Western Ghat Development Programme by encouraging. Construction of ponds, wells and check dam seems to augur well for developing irrigation facilities for cardamom (Anonymous, 1991). Such programmes if taken up along with water conservation techniques on watershed basis will be sustainable in plantation areas. Further, in an evaluation study of the impact of soil and water conservation method in three watersheds under Western Ghat Development Programme at Pulikuzhi, Edathodu and Chembankuzhi located at Thiruvananthapuram, Kasaragod and Ernakulam districts, respectively, it is reported that there is improvement in leanflow during summer months, reduction in ground water table fluctuation, improvement in soil moisture and also the general productivity of crops like coconut and rubber (Varadan *et al.*, 1996). However, development programmes to be undertaken on a watershed basis in plantation areas needs proper data base on various aspects such as the quantity of water that can be conserved, the leanflow during non-rainy season, the methods of water resources development, the calibration of water application etc. in addition to the basic understanding of the watershed characteristics under different plantations.

Suggested thrust areas

Based on the review of various components, the following areas are suggested for future programme of research for water management of plantation crops.

- w Region-wise quantification's of the effect of water on plantation crops productivity. This will be useful not only for estimating the losses due to drought but also for planning for future development.

- w Development of watershed models for different land uses and terrain conditions.

- w Quantification of hydrological impact of water conservation under plantation crops.

- w Quantification of consumptive use, standardization of soil and water conservation techniques and calibration of modern irrigation methods for plantation crops grown under different agroclimatic and terrain conditions.

- w Development and standardization of water management techniques to overcome drought and diseases of plantation crops.

- w Evolving water management information system for plantation crops for further use with modern information technology.

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SATELLITE IMAGING - ITS APPLICATIONS IN PLANTATION CROPS

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ABSTRACT

To effectively utilise the information on crops for improvement of economy, there is a need to develop information based on satellite remote sensing. In the present write-up, attempts have been made to review the existing remote sensing applications in plantation crops and analyse the spectral response pattern of crops to the electromagnetic radiation. Various vegetation indices and crop modelling methods are also discussed to understand the utility of satellite remote sensing in plantation crops.

INTRODUCTION

Remote sensing (RS) is a multi-disciplinary activity which deals with the inventory, monitoring and assessment of natural resources through the analysis of data obtained by observations from a remote sensing platform. The observations are synoptic, providing repetitive coverage of large areas and are quantifiable. In this context, any force field-gravity, magnetic or electromagnetic, could be used for remote sensing. However, currently the term remote sensing is used more commonly to denote identification of earth features by detecting the characteristics reflected or emitted electromagnetic radiation from the earth's surface. Every object reflects or scatters a portion of the electromagnetic energy incident on it depending on its physical properties. The reflectance or emittance of any object at different wave length follows a pattern which is characteristic of that object, known as 'spectral signature'. Proper interpretation of the spectral signature leads to the identification of the object. The incident electromagnetic radiation on interaction with the surface of the object experiences a number of changes in its wave length, polarisation, phase, as well as magnitude. These changes are detected by the remote sensor.

Thus, the remote sensing system consists of a sensor to collect the radiation and a platform, which can be a satellite, aircraft, balloon etc. The information received by the sensor is suitably manipulated and transported back to the earth - it may be telemetered as in the case of unmanned spacecraft. The data are reformatted and processed on the ground to produce either photographs, or computer compatible magnetic tapes (CCT's) CDs.

The photographs or CCT's are interpreted visually or digitally to produce or analyse resource information. In the present write-up we analyse the various fields of applications of satellite images for plantation crops, vegetation indices and crop modelling methods used for the applications. The spectral response of crops to electromagnetic radiation (EM) is also discussed to understand the basics of vegetation indices and crop modelling.

Applications of satellite data for plantation crops

The utilisation of space-borne multispectral data for crop acreage and production estimation started in seventies with the launching of the Large Area Crop Inventory Experiment (LACIE) jointly by NASA, USDA and NOAA (National Oceanic and Atmospheric Administration in 1974. In India, the satellite remote sensing is mainly used for the crop acreage and production estimation of agricultural crops. The methodology for crop acreage and production estimation using Landsat-MSS (Mulispectral Scanner/TM (Thematic Mapper) and Indian Remote Sensing Satellite (IRSIA/IB)-Linear Imaging Self Scanning Sensor (LISS I&II) has been operationalised for major crops, namely wheat, paddy, sorghum, soybean, groundnut and cotton in the monocropped areas (Space Applications Centre, 1990). However Never the use of remote sensing in plantation crops began in seventies. In 1970 Indian Space Research Organisation carried out a very interesting and promising experiment for IARI, in detecting coconut root wilt disease in Kerala before it was visible on ground. The perennial nature of the plantation crops and their typical spectral signatures in terms of texture, tone and pattern will help identifying and analysing them using remote sensing data.

- **Identification, area estimation and monitoring**

The specific requirement of climate and soil conditions coupled with the specialised management practices make the distribution of plantation crops rather more localised in comparison to other agricultural crops. The identification, estimation of growing stock, analysis of distribution and monitoring at regular intervals are major aspects in plantation crops. The methodologies for identification and estimation of plantation crops are based on visual interpretation of satellite images using pictorial elements like tone, texture, patterns etc. (Curren, 1985; Lillesansd and Kiefer, 1987) and digital image processing method (Jensen, 1986). Menon (1991) established methodology for digital mapping of rubber area using IIRS data in the highly heterogeneous vegetation of Kerala (See back cover).

Kimothi, *et al.*, (1997) conducted a study based on identification and mapping of horticultural plantations through remote sensing in Kumarasain Tehsil in Shimla District (Himachal Pradesh). A great deal of work have been done in remote sensing in forest plantations. Some of them are identification of teak plantations using multi-temporal Landsat MSS data (Srivastava and Oza, 1991); analysis of growth, biomass, production and dry matter distribution pattern of Eucalyptus hybrid growth in an energy plantation of Indroda, Gujarat (Mohinder and Raturi, 1991); methodology for the estimation of growing stock and stratification of bamboo (Varghese *et al.*, 1996); preparation of an interpretation key for the forest plantations of Kerala (Varghese and Menon, 1998) etc.

- **Crop yield modelling and production forecasting**

Reliable crop yield estimate is one of the most important components of crop production forecasting. In recent years considerable attention has been given to the development of yield models which could be derived with remote sensing inputs. But all these models are based on agricultural crops. Very little work has been done in the area of plantation crops. The crop yield is dependant on many factors such as crop variety, availability of nutrients and water, protection against pests and diseases and the weather factors. The plant shows the integrated effect of these factors which results in the ultimate yield. The mathematical formulation of relationship between various physical observable and yield-affecting parameters is crop yield modelling (see reflectance modelling of vegetation canopy). Spectral response of a crop is the integrated manifestation of various crop growth factors. In a given time domain, the growth and decay of spectral response indicates the crop performance. Spectral data as such or through its relation with the biometrics parameters are being used for prediction of yield. The spectral index for given segment is computed and aggregated to obtain a spectral index representing the entire district. By using IRS P3 WiFS (Wide Field Sensor) and IRS- 1C WiFS and LISS-III which have good periodicity, it may bee possible to construct growth profiles and retrieve yield-related parameters at regional level. For local-specific forecasting LISS-III or IRS-P5LISS-IV data could be used.

The information on production of crops before the harvest is very vital to the national food policy planning and economy of the country. Remote sensing data have been hitherto used for crop production forecasting in the monocropped regions owing primarily to spatial resolution limitation and to spectral similarity of different crops at a particular growth stage. The availability of multispectral data of improved spatial and temporal resolution from future IRS missions may enable production forecasting of crops.

Crop condition assessment

The inadequate supply of water, attack of insect pests and diseases are some important factors which cause stress in the plant and affect the yield adversely. The physiological changes that occur in a plant due to stress may change the spectral reflectance/emittance characteristics resulting in the detection of stress amenable to remote sensing technics. Crop monitoring at regular intervals during the crop growth cycle is essential to take appropriate measures and to assess information on fee probable loss in production. Various canopy temperature based approaches have been reported to evaluate water stress in crops. The canopy temperature variability (CTV) measurement within a field is expected to increase as soil moisture deficit increases (Millard *et al.*, 1978). The basis for the CTV index is that soils are inherently non-homogenous, causing some areas within a field to become stressed before others. Consequently canopy temperatures would show a greater variability as water become limiting than they would under well watered conditions. This variability can be used to signal the onset of water deficits Gardner *et al.*, 1981). The Cumulative Stress Degree Days (SDD), which integrates the canopy-air temperature during a specific growth period, can tell about overall plant water stresses experienced by the crop (Idso *et al.*, 1977). Crop growth and its condition is often characterised through the use of various vegetation indices such as reflectance ratio, normalised deference, perpendicular vegetation index, transformed vegetation index and greenness index (see vegetation indices). The remote sensing-based methodologies can provide information on the occurrence and the aerial extent of crop stress. However, the identification of the cause, whether by pests and diseases or by any other factor, still remains a major limitation. When stress is caused by more than one factor, the situation becomes even more complex. With the help of supplementary information e.g. from weather observations or knowledge on localised deficiency/toxicity of nutrient or pollutant elements, by inductive process one can still arrive at the cause of the stress. Coupling of low resolution data like NOAH/AVHRR (Advanced Very High: Resolution Radiometer) for crop condition at a broad scale with the high resolution data like IRS or Landsat appears to be promising for detection of crop condition, especially if the data are combined and interpreted in the geographic information system (GIS) perspective.

Integrated pest management

Integrated pest management is an important component of sustainable agriculture. Satellite remote sensing can play an important role in surveying and identifying the in accessible large desertic regions where locusts breed and lay egg, thereby developing strategies for preventing their spread and effective control measures. Methodologies need to be perfected for identification of locust breeding grounds based on vegetation or moisture status. Since the area is very large and the cycle of locust breeding, growth and its spread is very short, satellites having high temporal resolution and large area coverage like AVRR may be suited well to identify and priorities the areas to arrest and control desert menace.

Drought assessment and irrigation scheduling

The district level drought assessment and monitoring using Normalised Difference Vegetation Index (NDVI, see vegetation indices), generated from NOAA-AVHRR data helps in taking timely preventive and corrective measures for combating drought. This is yet another area wherein remote sensing data has been used at operational level (Chari, 1988). Currently, the drought assessment is being done through visual interpretation of remote sensing data. Comprehensive drought assessment would also involve the integration of information on cropping zones, soil types, coherent rainfall zones, etc. For implementation of preventive and corrective measures for combating drought condition at block level improved spatial accuracies is required. The availability of data with improved spatial resolution from IRS -1C LISS-III from future IRS P5 - LISS-IV may enable region specific assessment of drought with improved spatial accuracies.

Scheduling irrigation based on environmental parameters is useful for quick adoption of management practices suitable over large areas. Several methods for irrigation scheduling based on infrared thermometry have been proposed. Comparing average canopy temperatures of water stressed plots with non-stressed plots, Nixon *et al.*, (1973) reported that the former might not fully typify water stress. They suggested that canopy temperature variability could indicate areas of adequate or inadequate water in a field. A measure of temperature variability, therefore, might be used in irrigation management. Weigand and Namkem (1986) proposed canopy-air temperature difference (CATD) to be an indicator of crop water stress. If the plant has adequate water, canopy-air temperature difference will be zero or negative and if it is water stressed CATD may be greater than zero (Idso *et.al.*,1977). Gardner *et al.*, (1981) concluded that plots which exhibited a standard deviation Mover the well irrigated crop is in need of irrigation. The method of scheduling irrigation was associated with increased leaf temperature variability in a field with an increase in plant water stress (Clawson *et al.*, 1981; Gardner et al., 1981). Clawsom and Blad (1982) suggested canopy temperature variability (CTV) as a basis for irrigation scheduling. They also concluded that (CTV) could be used to signal the onset of plant stress but the severity of plant water stress is probably better indicated by the magnitude of the elevation in average canopy temperature above that of a well watered reference plot.

Detection of nutrient deficiencies

Very little is known about the specific effects of deficiency of different nutrients on the reflectance characteristics of plantation crops. Nutrient deficiencies in plants affect the colour, moisture content and inteinal structure of leaves and as a result their reflecting power changes. Since a significant correlation exists between levels of nutrient supply e.g. nitrogen and vegetation growth of plants, a deficiency or a variation in nutrient supply will cause a change in crop canopies and result in detectable canopy reflectance or temperature variation (Das *et al.*, 1989).0 Canopy temperature (Gardner *et al.*, 1981), canopy-air temperature differences and cumulative stress days (Idso *et al.*, 1977) have been used as indices for distinguishing nutrient stressed crops, from well fertilised crops similar to the crops suffering from water stress. Since in nitrogen deficient crops the red (R) reflectance is much higher as compared to that in the infrared region (IR), different vegetation indices based on red and IR reflectance have been developed as spectral parameters for crop canopy under fertilised and nutrient conditions (Richardson *et al.*, 1983 and Ajai, *et al.*, 1984).

Electromagnetic radiation and spectral signatures of crop

In case of plantation, the quantity of radiation reflection will depend on the roughness of natural surface i.e., the shape and size of the cavities between the leaves, area of leaves within the canopy or leaf index area, reflectance properties of back ground soil, age, phenological character and physiognomy of vegetation. In the visible postion of spectrum, the absorption of electromagnetic energy is maximum around the chlorophyll absorption band i.e. 0.675 mm wave length. If the normal strength of a plant is interrupted due to some stress or disease, it may de crease production of chlorophyll and hence there will be higher reflectance near the chlorophyll absorption bands. As the structure of plant leaves of different species is different, the spectral measurements in this range may help identification of species, diseases etc. The reflectance of healthy green vegetation is very high in the wave length range of 0.7 mm to 1.2 mm. The plant reflectance in this region is mainly from the internal structure of plant leaves.

Another characteristic of the plantations is the structure, which causes differences of reflection. Examples are the positions of the leaves (phyllotaxis) and their distribution. In relation to the angle of incident radiation, this may greatly influence the reflection. When the incidence angle of the radiation is about 500 and opposite to the viewing direction, the layered leaflets act like a mirror. Also, the growth stage or phenological stage of the plants has an influence on the reflection. This may be caused by differences of structure (shape of flowers, ears, etc.) as well as by differences in colour. Apart from these differences in reflection of the visible light, vegetation may also be analysed using energy reflected in the near-infrared or emitted in the thermal infrared regions.

It is clear from this introduction that differences in the reflection of incident radiation can provide information on the condition of plantation. Because the spectral resolution of RS could be more powerful than that of the eye, the reflection of vegetation in the various bands of the spectrum will be dealt with in detail. Three regions in the range 0.4-2.5 mm and one region in 10-14 mm may be distinguished with respect to the interaction of the plant cover with solar EM.

Visible radiation and crop characteristics

In the first range of wavelengths, the visible light (VIS) ranging from 0.4 to 0.7 mm, various pigments, such as chlorophyll, xanthophyll (yellow), and carotene (orange), influence the reflection. In most plant species two types of chlorophyll (a and b) determine the reflection, mainly by absorption of blue and red light and to a lesser degree of green light, provided leaves and stems are functioning well.

The energy in these spectral bands are used for the displacement of electrons which initiates the synthesis of carbohydrates from atmospheric CO^2 and absorbed groundwater. Green-yellow chlorophyll is present in all photosynthesising plants and plays a dominant role. Both chlorophylls absorb the visible light to a large extent, and have two absorption peaks, on in the blue (approx. 0.45mm) and one in the red (approx. 0.65mm) region of the electromagnetic spectrum (EM). Subsequently, the peak of the reflectance in the visible light occurs at approx. 0.54 mm.

Healthy plants re-emit a small amount of absorbed radiant energy in the far-red (0.65-0.70mm) and near infrared regions. This is called fluorescence. In addition, a small emission of thermal radiation takes place at the longer wavelengths. Fluorescence increases when the process of photosynthesis does not operate optimally for reasons of stress conditions in the plant. Sufficient knowledge about the detected vegetation and the growing conditions is required for a correct interpretation of this type of measurements. A growing plant lacking certain nutrients may produce less chlorophyll. The plant turns pale in places, and a distinct increase Al AL the blue and red reflectance is observed by spectrometer measurements, bringing it to an equal level with the green reflectance.

Other leaf pigments are carotene and xanthophyll (orange and yellow) and anthocyanins (red pigments), which absorb mainly in the blue region of the spectrum. However, they are not visible since the chlorophyll - usually present in the leaves in large quantities - also absorbs in the blue. It is well known that under certain circumstances, e.g., the ageing of plants, the yellow and red pigments show up clearly as the chlorophyll disintegrates. Also, at a certain instant there are differences of reflectance in the visible region of the EM spectrum of different plant species growing under the same conditions. Generally these differences occur in the green and blue reflectance produced by differences in the pigment content and of the leaf surface, such as hair, wax, etc. Under field conditions one has to take account of other factors influencing the spectral reflectance. Examples are the conditions of nutrition and the water supply of a crop causing an immediate change in both the signature of the leaves and the crop structure.

Differences in the reflectance of visible light are also produced by infections on the leaves surface, e.g. fungal spores. The discolouring of the leaves by spores of blight is well known, but bacterial and viral infections may also influence leaf colour. The reflection of the visible light occurs mainly in the uppermost leaves of the vegetation. It gives details about the state of health of the crop when the soil is fully covered. In most cases, diseases and infection of plants are accompanied by a break down of the chlorophyll, causing reduced absorption in the red and the blue regions and an increased total reflection in the visible light, making the leaves yellow and white. However, there are reflection differences in the range of wavelengths just mentioned, specific to certain plant species. This may be connected not only with the nature of the surface of the leaf (hair, wax, etc.), but also with differences in pigment content, causing differences in hue. If the soil is only partly covered with vegetation, the reflectance of the leaves may be mixed with the soil reflectance, thus generate a different spectral signature. This may become a characteristic in respect of other types of vegetation when these differences have been detected by repeated measurements in various spectral bands with a suitable sensor.

Near-infrared radiation and crop characteristics

The second range of wavelengths from 0.7 to 1,3mm approx. (near infrared radiation NIR) is mainly determined by the absence of absorption by pigments. This means that the energy passes through the leaf (the leaf is transparent) or that it is reflected. It is apparent from the various reflectance curves (measurements on individual leaves) that approximately 50%.of the NIR energy is reflected by the leaf.

Various experiments were tried to obtain an insight into parts of the leaves which are responsible for the NIR reflection. It has been established for this range of wavelengths that a leaf becomes very transparent if the air channels between the cells of the leaf are filled with fluid. This gave reason to conclude that reflection takes place in the leaf at the transition of air and cellulose cell-walls. The reflection of NIR appeared to increase at first when leaves shrivelled up. This could be explained by ruptures between the cells, producing more transitions of air to cell walls. There are also differences in reflectance between the leaves of monocotyledons and dicotyledons. In principle, leaf sections of the latter species show two different layers of cells between the outer walls. The upper layer is the palisade parenchyma, which consist of tightly packed oblong cells perpendicular to the epidermis. The lower layer, the sponge parenchyma, has a completely different structure; the cells are round in shape with many intercellular air cavities. Hence, it appears that the reflection occurs mainly in the sponge parenchyma layer with many air cavities. The reflection is also determined by the number of cell walls parallel with the epidermis of the leaf. These walls are certainly more numerous in leaves with additional layers of palisade cells. Of course, the reflection also depends on the orientation of the leaf in the vegetation. In short, it can be stated that the uppermost leaves off vegetation reflect a considerable part in the NIR region (up to 1.3mm), and that the remainder is transmitted impinging the underlying leaves. Measurements demonstrate an increasing reflectance in this NIR region as more leaves occur in the layers. Dependent on the leaf angle distribution, the reflectance increases up to five or six leaves underneath one another.

The reflectance of the NIR region (0.73-1.3mm) gives information about the total leaf area of vegetation, usually defined as the leaf area index (= the total one sided area of the leaves per unit of ground area). First, the area of healthy leaves (low reflectance in the red region) determines the rate at which the plant can photosynthesis. The faster the optimal leaf area is attained during the growing season, the more carbohydrates, proteins, etc., can be produced, as long as no other grown factors are limiting.

Various factors, such as a shortage of moisture, damage by salt and a lack of minerals, can slow down the development of a crop. This becomes apparent where the leaf area index is low, resulting in reduced infrared reflectance. Sufficient knowledge of the causes makes it possible to estimate the damage over large areas. By this principle, crop yield prediction becomes possible. Also differences in the leaf angle distribution, arising from the sub-optimal growing conditions just mentioned, will influence the reflectance both in the NE and visible red regions.

Middle- Infrared radiation and crop characteristics

In the third region of wavelengths ranging from 1.3 to 2.5mm (middle infrared radiation, MIR), a great deal of energy is absorbed by water in the cells. The absorption peaks fall at 1.9 and 1.4mm. It should be pointed out that weak absorption bands of water also occur at 1.1 and 0.96mm. Dried leaves, in contrast with fresh ones, show a considerably higher reflectance in the range from 1.3 to 2.5mm, and that in the curves, the dips caused by water absorption have vanished.

The ratio of the minimal reflectance caused by water and the maximum reflectance in the adjacent region of the curve provides specific information on the moisture content of vegetation. In view of what has been said about the changes of reflection, the region (1.3-2.5mm), a specific indication of a shortage of moisture in crop could be possible.

Emissive (thermal) infrared and crop characteristics

Leaves have adjustable pores in the lower epidermis called stomata. The opening and closing of the stomata is determined by the plant taking up sufficient water, usually through the roots, to maintain the turger. If there is sufficient moisture available there is a constant flow of water transpirating through the stomata. This withdraws thermal energy form the surface of the leaves, so that the plant temperature drops in respect of the surrounding area. The lower temperature can be measured with a remote detector as a difference of a flow of energy, e.g., in the TIR (10-14mm). This provides the possibility of tracing, e.g., a shortage of water, viral infection (raising the leafs temperature) or mycosis (reducing of temperature).

Vegetation indices

The green, red and NIR reflectance could be employed as variables to estimate, for instance, the LAI. Many investigations have been conducted to assess crop characteristics, such as biomass and LAI, by means of combinations of reflectance or digital pixel values in various spectral bands. Such a combination of reflectance values, the vegetation index, also serves to correct for undesirable influences of varying soil reflectance or atmospheric circumstances on the results. This kind of disturbances are particularly unwanted in spatial and multitemporal analyses. In addition, a vegetation index for estimating the LAI should still be sensitive to changes in LAI when the soil is fully covered (LAI >2 or 3). This means that the NIR reflectance should play central role in such an index.

The first investigations into vegetation indices concerned the NIR/red ratio (Landsat MSS band 7/band 5) by Rouse *et al.*, (1973&1974) Rouse and his colleagues found this ratio to be suitable - when applied to satellite data (e.g., Landsat MSS) for the estimation of crop characteristics owing to a partial correction for the solar position and atmospheric influence. They also used the normalised vegetation index (NVI=[NIR-red]/[NIR+red]; in case of Landsat MSS:[7-5]/[7+5]) for the same purpose. Often, this type of vegetation index is called the normalised difference vegetation index (NDVI). To avoid impracticable negative values, a transformed vegetation index (TVI=/NVI+0.5) was employed.

Wiegand *et al.* (1974) for the first time related spectral data to the LAI. They concluded that Landsat MSS(5-7) and MSS (5/7) in combination with MSS7 aid MSS6 bands were suitable, in practice, as indicators of soil cover and plant density. Simulations by Bunnik (1978,1981) show this kind of index as suitable for estimating the degree of cover, but slightly sensitive to variations in LAI after the soil is completely covered. In order to find an index independent of the influence of the soil, Richardson and Wiegand (1977) introduced the so called perpendicular vegetation index :

PVI = $\sqrt{(MSS\ 5s-MSS\ 5v)^2 + (MSS\ 7s-MSS\ 7v)^2}$, where subscripts v and s refer to the vegetation and the underlying bare soil, respectively. They found that the Landsat MSS digital data of the bare soil showed a linear relationship in a feature space plot of band 7 against band 5. The increase in the amount of vegetation agreed with the offset of the digital values perpendicular (orthogonal) to a so-called soil line in such a graph.

A similar approach to suppress variations of the soil influence has been developed by Kauth and Thomas. (1976). They applied a linear transformation to the four dimensional data space of Landsat MSS measurements of agricultural regions with various soil types. This transformation of the four Landsat-I MSS bands resulted in a so-called brightness index dominated by soil differences (soil brightness = 0.43 MSS4 + 0.63 MSS5 + 0.59 MSS6+0.26 MSS7), and a so called greenness *index* dominated by green vegetation (greeness-0.29 MSS4-0.56 MSS5 + 0.60 MSS6 + 0.49 MSS7)

In order to obtain a more precise correction for soil background, Hute (1998) developed Soil Adjusted Vegetation Index (SAVI). This index was further improved by Baret *et al.* (1989) yielding the Transformed Soil Adjusted Vegetation Index (TSAVI). Authors differ in the mathematical formulation of the relationship of such an index and, for instance, the LAIs as the relationship is mostly determined empirically. This constitutes an important problem, as it hampers comparison between sets of data.

Reflectance modelling of crop canopy

In order to obtain a reliable yield prediction, growth of crops has to be modelled by means of crop growth models. Crop growth models describe the relation between physiological processes in plants and environmental factors such as solar irradiation, temperature, water and nutrient availability. Optical RS can provide information on the actual status of crops (Crop parameter estimation), resulting in an improvement of parameter estimates for crop growth models. On the one hand RS data may be used as direct input into crop growth models, while on the other hand RS data may be used for checking the results of crop growth modelling.

By considering a crop to be built up of horizontal leaf layers, an impression of the crop characteristics which might be estimated directly from reflectance measurements can be obtained. The reflectance and the transmittance of a green leaf in the visible part of the Em spectrum amounts to 10 per cent or less each . This means the absorptance is at least 80 per cent. If 10 per cent of the incident radiation is reflected by a top leaf, the contribution to the total measured reflectance of a second leaf under the top leaf would be approximately 1 per cent of the reflectance of the top leaf. This implies that in the visible region, the reflectance of only the top layer would determine the total reflectance of a crop. The visual observation of plants confirms this reasoning. Hence, the large contrast in reflectance of bare soil and vegetation in the visible region will be ideal for estimating the degree of soil cover, the reflectance attaining a minimum value (maximum absorption) at the instant that the soil is completely covered.

In the NIR part of the spectrum, the reflectance and transmittance of a green leaf amounts to approximately 50 per cent each. A green leaf hardly absorbs any NIR radiation. Under these conditions, leaves or crop layers under the top layer contribute significantly to the total measured reflectance. In the simplest case of the reflectance and transmittance both amounting to 50 per cent, the contribution of a second leaf (or layer) would be about 15 per cent of the incident radiation, which is not negligible. The contributions of the successive leaves or layers decrease exponentially.

When modelling the relationship of reflectance and crop characteristics a number of disturbing factors should be considered. One of these is the soil reflectance, strongly determined by the moisture content of the soil. The soil reflectance greatly influences the relationships between the reflectance and the degree of soil cover, and the reflectance and the LAI. With a low degree of soil cover the soil reflectance contributes largely to the total reflectance measured in the various spectral bands. The moisture content of a particular soil type will be the most important factor determining the soil reflectance. It is important to know how it happens, and to what extent this influence depends on the wavelength in the part of the spectrum concerned. Incoming Photosynthetically Active Radiation (PAR) is partly reflected by the top layer of canopy. The complementary fraction is potentially available for absorption by the canopy. Subsequently, the fraction of absorption by the canopy is a function of. e.g., LAI, leaf angle distribution, leaf optical properties and solar elevation. The product of the amount of incoming photosynthetically active radiation (PAR) and the absorption yields the amount of Absorbed photosynthetically Active Radiation (APAR). The rate of CO^2 assimilation (photosynthesis) is calculated from the APAR and the photosynthesis light response of individual leaves. The instantaneous fraction of incoming PAR used for CO^2 assimilation per unit leaf area is called the photosynthetic efficiency of the leaf. The assimilated CO^2 is then reduced to carbohydrates which can be used by the plant for growth. Optical RS data may yield several sorts of information to be used in crop growth models.

Besides the LAI and APAR, the crop condition or (vitality vigour) is another important characteristic. The vitality of a crop is particularly shown in the rate (efficiency) of photosynthesis. This photosynthetic efficiency, besides the irradiation, is key factor in the understanding of the growth rate. The chlorophyll content is key factor determining this photosynthetic efficiency.

Leaf (or crop) colour can be an important variable yielding information about photosynthetic efficiency. Leaf colour is related to the leaf chlorophyll content, which may be ascertained by spectral measurements in the visible region (VIS) of the EM spectrum. However, at low soil cover the measured signal will be confounded by soil influence. As a result, the signals from a crop and from the soil background are difficult to separate, unless the spectral soil signature is known so that it can be taken into account. At complete coverage spectral measurements in the VIS offer information only about leaf colour. Since the signal in the VIS at complete coverage is relatively low, the signal may be heavily confounded by atmospheric effects which must also be corrected.

Reflectance models

Physical reflectance models for crops serve the important purpose of understanding the complex interaction between solar radiation and plant canopies. In principle, there are two kinds of physical reflectance models: numerical and analytical. Bunnik (1984) has published an extensive review on this topic.

A numerical model is described by Idso and De Wit (1970) where the radioactive transfer inside a crop is determined by the scattering and absorption of separate leaf layers. Goudriaan (1977) improved and extended this model in respect of a numerical solution for upward and downward diffuse radiant fluxes, to be calculated within nine sectors of each hemisphere for each individual layer. Dulk (1989) described a crop as a stack of thin crop layers. He defined 46 directions in a semispace, each representing an equal solid angle. These model directions were used both to represent radiation patterns and to define leaf angle distributions.

One of the first analytical models was described by Allen and Richardson (1968). It was based on a theory of Kubelka and Munk (1931) describing fee transfer of an isotropic diffuse flux in a perfect diffuse medium. The upward and downward fluxes were described with differential equation. Allen *et al.* (1969) have extended this model by including the scattering of the direct solar flux. The first analytical model including both the geometry of the irradiation and the geometry of the observation was developed by Suits (l972). This is an extension of the model designed by Allen and his colleagues. Suit's model also employs the geometric and optical properties of the crop. When simulations were carried out for different viewing directions, it became apparent that Suits model contains too many simplification (Verhoef and Bunnik, 1981). Therefore, Verhoef (1984) further extended Suits model by using scattering and extinction functions for crop layers built up of leaves arranged in a large number of classes according to the leaf inclination angle distribution of the plant under consideration (in contrast to Suits model which used only the horizontal and vertical components of the leaves). Verhoefs model is known as the Scattering by Arbitrary Inclined Leaves (SAIL) model.

CONCLUSION

In order to effectively utilise the information on plantation crops for improvement of economy, there is a need to develop state/district level information system based on available information on various plantation crops, derived both from conventional and remote sensing approaches in GIS environment.

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GENDER ISSUES IN HORTICULTURE

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India produces 39.47 million tons of fruits from 3.2 million ha and ranks first in fruit production in the world. In india vegetable production (65 million tons) is also very high, ranking the second in the world, next only to China. The prodction of flowers has a share of 12 per cent of the total World flower production. The availability of a wide range of agro-climatic regions and gene pools of horticultural crops, and ample skilled, semi-skilled and un-skilled human resource, and age-old traditional and modern production, value addition and processing technologies, all together provide Indian Horticulture a special status in Indian economy. Horticultural crops including plantation crops, spices and tuber crops cover only about 7% of the gross cropped area, but contribute more than 18-20% gross value of agricultural output. India has a good stand in the World in production of horticultural crops (Table1).

Table 1: India : Percentage of World production

Commodity	Percent (World)
Fruits	8
Mango	65
Banana	11
Vegetables	12
Onion	12
Flowers	12

In one of the budget speeches, horticulture was referred to by the Union Finance Minister as a "potential area of growth". The production of horticulral crops by the end of the present century is therefore, targetted very high by the National Commission on Agriculture (Table 2).

Table 2: Production target of some horticultural crops by 2000 AD

Crop	Production (Million tons)	Crop	Production
Fruit	45	Coconut	20 billion nuts
Vegitables	104	Black pepper	60,000 tons
Onion	3		
Potato	3000		
Cassava	40		
Sweet potato	10		

Human Resource and Horticulture

In India, women constitute 406.52 million (48.15%) of total population (844.32 million) as per 1991 census. The majority of women (304.05 million) comprise of rural women, of whom 81.5 million are rural women workers. Also it is reported that a majority of economically active women (78%) are engaged in agriculture compared to 63 per cent of men. The agricultural growth rate is targetted at 4.5% and horticultural crops including plantation crops, spices and tuber crops are important constituent and intimately connected with Women's farm and household activities. Women cultivators numbering 21,797,148 include the segments of those engaged in horticultural activities as well. More than 75 per cent of rural women belong to the families of small and marginal farmers. Since horticulture is women-friendly and is growing and diversifying rapidly to achieve the target of production (Table 3), the priority has been set (Table 4) and the gender issues need to be fully understood for sustainable horticultural production.

Table 3 : Food production target (million tons)

Crop/Commodity	IX Plan (By 2001)	X Plan (By 2006-2007)
Friut	53.7	70.5
Vegitables	93.6	110.7
Oil seeds	7.9	9.5
Mik	93.1	119.5
Pulses	18.4	21.5
Rice	94.0	103.0
Wheat	75.7	84.3
Coarse grain	32.6	34.4
Total	469.0	553.4

Table 4: Horticultural crop priority in R & D

Crop	Priority (L=low, M=medium, H=high)		
	Current	Needed upto 2010	Need upto 2020
Fruits	M	H	H
Vegetables	M	H	H
Flowers	L	M	H
Roots and tubers	L	M	M
Spices, medicinal & aromatic plants	L	M	H

Horticulture, nourishment and human wants

Fruits and vegetables have been recognized as major food necessities (Table 3) and categorized as protective food owing to their being rich in minerals and vitamins besides their being highly remunerative. Sound R & D efforts and the open seed policy have increased the area and production of fruits and vegetables in the country. As a result, the per capita availability of fruits has increased by 132.31 per cent in the recent past. The availability of vegetables has also increased from 85 g to 135 g per capita. Tuber crops have high biological efficiency and calorie production even in marginal lands with less inputs. Tuber crops contribute 6 per cent and tropical tuber crops, excluding potato, contribute 4.2 per cent in the human diatary in take in the world against 51 per cent from cereals. However, the gross value in terms of Rupees per ha of some tuber crops like tapioca (40,163) and sweet potato (19,809) is much more than our staple food like wheat (9,582) and rice (10,088).

Floriculture is also a highly paying business. Roses, Gladi oli, Carnation, Orchids, Anthurium, Bonsai and foliag plants have a good export potential and international demand. Other flowers showing ever increasing demand as cut flowers in the internal markets are marigold, jasmines, tuberose, lotus, vaijayanti etc. In addition, flowering and ornamental trees and shrubs and shade loving foliage plants are in great demand. Horticulture is there fore, a flourishing business owing to its vast potential of employment and income generation for women in particular, increasing production and productivity even in marginal lands, improving environment and aesthetics, leading to enhanced health, wealth and economy, cheer happiness and pleasure at work.

Gender Issues

Gender issues are defined as specific, in consequences of the inequality of women and men. Women are increasingly involved in the production and post-harvest management of horticultural crops throughout the year in different parts of the country but there is hardly any recorded document on their role in horticulture. Pandey and Pareek (1990) however, have made an attempt to give an account of this aspect, but a lot more work is needed in collecting, classifying and documenting relevant information in this regard. The role of Gender issues in horticulture is to help bring about positive changes that are forward looking and to find out opportunities for enhancing equitable participation in sustainable horticulture with equality between men and women in this respect. Gender should not be understood as a mass social movement that aims to divide men and women causing conflicts. Rather it brings together those issues relating to men and women that have brought about unequal relations and draws the attention of development workers in order to address these with appropriate measures that will help change rather than perpetuate the bias (Anon, 1997).

Gender issues are deeply involved in horticulture and sorting out these issues in a proper perspective is very vital for the growth of this enterprise. Ownership of land, access to resources and credit and decision making in the programming, operations, marketing of horticltural produce, storage, exchange of seed materials and benefit sharing are the important areas of gender issues. "Thatch greening" in Kharif season by growing cucurbitaceous vegetables on thatches and activities related to kitchen gardening, processing of fruits and vegetables and storage on domestic scale are totally in the purview of women, whereas orcharding, commercial farming of fruits, vegetables and ornamental plants, large scale storage and marketing are handled by men. "Thatch greening" in Rabi season should also be taken up and suitable varieties in some of the vegetable crops are available for this purpose. Some of the varieties developed in vegetable crops for bearing in more than one season are RG 165 of ridge gourd, "Pusa Do Mausami" and Pusa Hybrid No.2 of long fruited bottle gourd, and "Pusa Sandesh" of round fruited bottle gourd developed by IARI, New Delhi. In tomato, a thermo-insensitive variety - Pusa 362 developed by IARI can be grown round the year, except July and August. Cauliflower can also be grown almost round the year viz. Hybrid U41 and Hybrid 598 in September, Sel.476, Sel.401 and Sel.466 in December maturity group, Pusa Snowball in January-February, and Sel.23-7, Sel.41-S and Sel.98-4 in May-June maturity groups.

In flowers, marigold cv, Pusa Narangi Glenda is suitable for loose flower production for garland making and religious offerings, whereas "Pusa Basanti Genda" is suitable for growing in pots and beds. Hybrids in many other flower crops are available which can profitably be grown for domestic and export. Horticulture consists of various activities involving women who often face difficulties in undertaking some of those activities. Gender issues thus become more relevant while aiming at attaining sustainability and profitability of horticultural production. There is therefore, a need for reconciling horticultural growth with equitable distribution of benefits, providing equality of power relations, and highlighting the inter-dependnce and partnership, between men and women.

These issues should be taken up to understand and document the entire contribution of women in horticulture and to remove the gender disparity. As indicators, examples of such disparity and undervaluing of women's economic contributions are cited in tables 5 and 6 (Anon 1995).

Table 5 : Gender disparity

Characteristics	Per cent	
	Women	Men
Poor in the world	70	30
Illiterate in the world	67	33

Table 6: Under valued women's contributions in world

Contribution	Amount (Trillion US Dollar)
Estimated output	23
Invisible contribution	11

Agricultural modernization has made a definite impact on farm women in India also, on their income, expenditure pattern, behaviour, time utilization and quality of life. This change has already started showing in the pattern of shifting of more and more farm women towards horticultural enterprises. Besides this, the fragmentation of family has given enormous work load to women as home manager (Table 7). Gender issues in horticulture should therefore be viewed in the light that women in India cannot be isolated from home, as such women in horticulture are to be considered in totality.

Table 7: Home management in eastern India

Gender	Share (%)
Men	25.55
Women	55.46
Jointly	18.95

Source: Singh, Ratan (1992).

In Israel, with the rural economic propserity, women generally retreat into the home (Nevo *et al.*, 1991). Similar cases exist in Congo, where women are largely involved in the cultivation of horticultural crops in and around the urban areas and growing bananas and tomatoes in other irrigated parts (Knierim, 1996). Wetland environments in Gambia are transformed into irrigated horticultural schemes, which has made income gains to women (Carney, 1993). In Japan, horticulture is growing and the outflow of male labour into non-agricultural work has increased female labour force in horticulture (Sakai *et al.*, 1993). Also, women in Shonai district are engaged in growing melons and other vegetables in green houses built on paddy fields (Yoshida, 1993). In Germany, there is a growing concern for looking into what proportion of their students in horticultural institutions are women (Reimherr, 1992). Women constitute one third of the labour force in production of fruits and vegetables In Norway (Langvatn, 1991). In Indonesia, women play an active role in home gardening (Soerobi *et al.*, 1991).

Women-friendly horticultural trades

Seed industry is a flourishing business, which is in the hands of men. Women can also take up this enterprise with some initial training in hybrid seed production, processing and storage of seeds, as it suits their posture and temperament. Quality seeds. particularly hybrids, are required to increase the production of vegetables and flowers. Women are expected to be more efficient in making hybrids of horticultural crops than men. The private seed sector is expanding rapidly the production of hybrid seeds of vegetables, flowers and other horticultural plants. The Indo-American Hybrid Seeds Pvt. Ltd. was the first to release and popularise F1 hybrid of tomato 'Karnataka' and capsicum 'Bharat' in 1973 and has now spread its acitivities to production and marketing of hybrid vegetables seeds, flower seeds, ornamental plants and tissue cultured fruit plants. They have also started exporting hybrid seeds to U.S.A. Manjushree Plantation Ltd. being looked after by B.K. Birla Group has launched 3 hybrids in tomato, 2 in brinjal and one in okra in 1997-98.

Public sector is also engaging its attention in developing hybrid seeds of vegetables and flowers. A large number of hybrids have thus been released in tomato, brinjal and many othe vegetable crops. A large quantity of valuable seeds is lost during storage. Moisture proof containers have not been developed using 700 guage polythene or poly-lined aluminum foil packets for low moisture seeds of vegetables. Besides seed industry, women are increasingly involved in the nursery raising of fruits, vegetables and ornamental plants, fruit and. vegetable growing, flower and kitchen gardening, fruit and vegetable proeessing, and marketing of fruits, flowers and vegetables. The adoption of different horticultural trades by women depends upon locality, social taboo and access to resources and knowledge. Other remunerative fields are "bonsai" making and raising plants of orchids, anthurium, papaya, banana etc. by tissue culture. Orchid cut flower trade is a multi million dollar business. The cut flowers of *Cymbidium, Paphiopedilum, Cattleyas* and *Denodrobium* species have ready markets in U. S. A., Italy, Europe and the Middle East. Some other suggested fields are protected cultivation of vegetables and flowers, drip irrigation, vermiculture, mushroom culture, horticultural waste utilizations for organic farming, nutrition garden, coconut leafmats, coir rope and mat making, cashew processing and gardening.

Post harvest management, processing, value addition, storage and utilization of horticultural produce and products are generally the domain of women at home scale. A high priority has been accorded by Govt. of India to this area, which is in the hands of both public and private sectors. The National Co-operatives Development Corporation (NCDC) accord a high priority to the development of post-harvest management of horticultural crops (Table 8) and a dozen societies are in operation for marketing vegetables in the country. The major share of marketing through co-operative is in Gujarat (Rs.75.74 crores) followed by Karnataka (Rs. 37.03 crores), Maharashtra (Rs.22.37 crores) and Tamil nadu (15.88 crores). NAFED marketed horticultural produce and products to the tune of Rs. 314.61 crores in 1995-96.

Table 8 - NCDC assistance (Rs. in lakh)

Particulars	Amount	Year
Projects concerning efficient marketing and post harvest losses	698.12	1994-95
Projects for establishing pre-cooling and cold storage units in Maharashtra	606.97	
HIMFED marketing projects at Shimla and Lahaul; Potato Co-operative Society at Manali	359.00	
Establishing cold storage chain's in the country.	7996.00	upto 3/1996

Refinement in Technology

Technologies generated in horticulture have tripled fruits and vegetables production in the country during the last 50 years (Paroda, 1998). Most of the technologies are, however, gender neutral and some of them may require refinement to suit women enterpreneur/labour. Development of varieties of fruits and vegetables suited to processing like 'Amrapali' mango for nectar, Kufri chipasona 1 and Kufri chipasona two potato varieties for chip making, temperature tolerant strains of white button mushroom and run-off water collected in farm ponds for supplementary irrigation in ravine lands of Rajasthan, help farm women in increasing the yield of horticultural produce and products and their value addition. The two potato varieties suited for chips have more dry matter (22-24%) as against commercial cv. Kufri Jyoti (11-12%), less reducing sugars and free from browning. after chip making. Amrapali mango has deep orange colouration in juice and very sweet; therefore, preferred for nectar making. The newly released grape variety of IARI, New Delhi named 'Pusa Navrang' has deep red stable pigmentation in both peel and pulp and is therefore preferred for juice/wine making. Similarly, to minimise the drudgery of women in horticultural occupations, refinement have been made in implements/equipments/tools use in various operations (Table 8). Such refinement in technologies/implements will be required in several other aspects of horticulture, which need to be thoroughly studied, documented and research interventions made.

Creation of Data Bank

A well planned detailed study is needed to assess the participation of women in various horticultural trade and their enterpreneurship in various agro-ecological regions of India.The NRCWA has a distinct role in catalysing the process of initiation of this study in terms of women's participation and their contribution towards profit making as growers and farm workers, by providing a scientific base to the horticulture industry as scientist, teacher and extension worker. This is a programme of continuous nature. Such data base will comprise information from the Central Research Institutes(7), National Research Centres (10), All India Co-ordinated Research Project Centres (214), ICAR and NGO Krishi Vigyan Kendras, Universities of Horticulture and Forestry, Divisions of Horticulture in multi-crops, multi-disciplinary Institutes (7), State Agricultural Universities (29) and State Departments/Directorates of Horticulture (27).

Drudgery removal

Horticultural operations are full of drudgeries. Several machines/ equipments/implements have been developed to reduce drudgery . Most of those machines are used by men. Women cannot use heavy machines/ implements. There is therefore, a need for safeguarding the posture of women. However, some of those implements/tools, which can be used by women are given in Table 9. In addition, several easy operating machines/tools have been chips have more dry matter (22-24%) as against commercial cv. Kufri Jyoti (11-12%), less reducing sugars and free from browning. after chip making. Amrapali mango has deep orange colouration in juice and very sweet; therefore, preferred for nectar making. The newly released grape variety of IARI, New Delhi named 'Pusa Navrang' has deep red stable pigmentation in both peel and pulp and is therefore preferred for juice/wine making. Similarly, to minimise the drudgery of women in horticultural occupations, refinement have been made in implements/equipments/tools use in various operations (Table 8). Such refinement in technologies/implements will be required in several other aspects of horticulture, which need to be thoroughly studied, documented and research interventions made.

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Table 9: Improved tools/implements/equipments to be used in Horticulture

Operation	Traditional Technology	Modern Technology
Soil sampling	Khurpi	Auger
Pit digging	Khurpi, spade	Auger & Post hole digger
Fertilizer application	Manual broadcasting	Fertilizer broadcaster
Weeding/hoeing	Khurpi, Kudali, spade	Manual weeder, wheel hoe, garden rake
Spraying / dusting	Hand sprayer/duster without saftey device	Hand/foot operated sprayer with saftey device
Irrigation	Flooding	Drip & Sprinkler system
Fruit harvesting	Climbing on tree and using bamboo stick with netting on top	Fruit harvest with knife/ scissor mounted on top with netting
Filling of polybags	Hand	Handscoop
Watering	Bucket & mug	Watering cans
Pruning / budding/ grafting	Local knife, shear	Budding/grafting knife, secateurs
Seed treatment	Hand mixing of seeds with chemicals	Manually operated seed treatment drums
Drying	Sun drying	Solar dryers, power operated dryers, agricultural wastes fired dryer
Grading	Manual	Power operated potato/ apple grader
Storage	At room temperature	Cold storage, cool chamber
Peeling pulping,	Knife, spike	Manual & power operated peeler and slicer.
Grinding of spices	Hand operated pounder	Mills/pulverisers (power operated)

Source: (Singh, 1998).

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