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**PROCEEDINGS OF THE SEVENTH SYMPOSIUM ON
PLANTATION CROPS
(PLACROSYM VII, 1986)**

Editors

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INDIAN SOCIETY FOR PLANTATION CROPS

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EDITORIAL

The Indian Society for Plantation Crops, Kasaragod, in collaboration with other cosponsoring organisations like Cardamom Board, Cochin (now Spices Board), Central Coffee Research Institute, Balehonnur, Central Plantation Crops Research Institute, Kasaragod, Rubber Research Institute of India, Kottayam and United Planters' Association of South India, Valparai, has been organising symposium on plantation crops (PLACROSYM) at specified intervals. The Seventh PLACROSYM was conducted from 16-19 October 1986 at Coonoor, Nilgiris, Tamil Nadu under the auspices of UPASI, the host institute for the symposium. Dr. K.K. Krishnamoorthy, Director of Research, UPASI was the general Chairman of PLACROSYM VII a foreword from whom has been given in the beginning of this volume. In the earlier years of the PLACROSYM, the proceedings of the symposia used to be brought out as separate publications by the ISPC. But in 1986, the Standing Committee of PLACROSYM proposed that the proceedings may be published as a supplementary issue of the Journal of Plantation Crops, the scientific journal of ISPC. This was approved by the General Body of the ISPC. It was also decided that Dr. M.K. Nair, the then Editor of JPC will be the editor of this volume also. The editor was free to coopt any scientist for helping him in editing and bringing out the publication.

The proceedings of the PLACROSYM VII are divided into nine chapters to correspond with the nine sessions in the symposium including plenary session. An author index also is added at the end.

The Editors wish to keep on record their deep sense of appreciation to Dr. Keshava Bhat, ex-Secretary, ISPC for his good services and help rendered in bringing out this volume. Their thanks are also due to Shri C. Venugopal and Shri P.A. Radhakrishnan for typing the manuscript for the press.

Kasaragod
1-4-1989

Editors



DR. K.K. KRISHNAMOORTHY
General Chairman
PLACROSYM-VII

FOREWORD

This volume of PLACROSYM VII comprises the full text of papers presented at the Seventh Symposium on Plantation Crops Research held at Coonoor, Nilgiris, Tamil Nadu during 16-19th October, 1986. Seventy four research contributions covering various disciplines and aspects of plantation crop research are discussed in eight sessions. This is the first time that separate sessions on "Germ Plasm" and "Biotechnology" are introduced.

Session I is devoted to Biotechnology and Plant Physiology in which 10 research papers are presented and discussed. Session II consists of 8 papers on Processing, Product Diversification and Equipment. Session III is dealing with the Marketing, Extension and cost of production of the different plantation crops discussed in 3 papers. Pest Management and Disease Management are discussed in sessions IV and V in which 12 research papers each are presented. The VI session comprising 6 papers is devoted to Germ Plasm. Crop Varietal Improvement has been discussed in session VII in which 8 papers are presented. The scientific investigations and relevant results on crop Husbandry are presented and discussed in 15 papers in session VIII.

The PLACROSYM provides a good opportunity of bringing together scientists of all disciplines of plantation crops so that they can discuss the results in a common forum. It is interesting and heartening to note that compared to the earlier PLACROSYMS, PLACROSYM VII has attracted a large number of papers as many as 86 setting up a welcome and encouraging trend for the future and has generated a great deal of very valuable, useful and practical knowledge and information on plantation crops research which will culminate in the better transfer of technology to the farmers at large. The sincere efforts of all the scientists to make PLACROSYM VII a grand success are complimented.

K.K. Krishnamoorthy
General Chairman, PLACROSYM VII

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PLANTATION CROPS – RESEARCH AND DEVELOPMENT IN THE 21ST CENTURY*

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Out of a gross cultivated area of 177 million ha in India, plantation crops are grown on 2.97 million ha, thus constituting a fragmental area of only 1.68%. But yet from the point of view of national wealth and capacity of earning foreign exchange, apart from the internal consumption, plantation crops play a very vital role in the agrarian economy of our country.

As seen in Table I, there has been a significant and continuous enhancement in the production as well as the productivity of the plantation crops, particularly in the past one and a half decade.

This has been possible mainly because of the intensified and sustained research work on the various crops by the research scientists of the plantation crops' research institutions. In southern India, for instance, in the case of tea, the yield has increased from a mere 650 kg/ha in 1950, to about 2000 kg/ha in 1984, which amounts to a 3-fold increase. However, in certain crops there has been an erratic trend in the production, sometimes registering a low productivity and production. It is time for all those concerned in the plantation industry to go into a malady-remedy analysis and find out the

ways and means of not only enhancing the production but also to sustain it without sacrificing the quality of the produce.

An analysis of the pros and cons of the possibility of bringing more area under cultivation of these crops reveals that this proposition is not encouraging, owing to the rigidity of our land use policy. On one hand we have to preserve our existing forest area and on the other, substantially increase the forest wealth from the present level of 20% to 33%. Hence, the possibility is to bring only a marginal area for expansion of these crops. Alternatively, all our efforts in research, development and extension have to be made to bring the maximum productivity in unit area with unit manpower with a minimum cost of production.

The present status of production and the target to be achieved in future are considered below:

Tea: From Table II it is apparent that from 178.9 million kg in 1935, the production of tea has increased to 657.2 million kg in 1985. The quantum of tea sold in auctions has also increased from 48.3 million kg to 504 million kg in this period. Similarly, an increase in export from

*Keynote address delivered at the Inaugural Function of the Seventh Plantation Crops Symposium held during 16-19th October 1986 at Coonoor.

Table I. *Production and productivity of plantation crops.*

Crops	1970-'71		1975-'76		1982-'83	
	Production ('000 t)	Productivity (kg/ha)	Production ('000 t)	Productivity (kg/ha)	Production ('000 t)	Productivity (kg/ha)
Tea	435.5	1221	487.1	1341	581.5	1444
Coffee	109.0	799	84.0	490	152.1**	720
Rubber	92.2	454	137.8	614	165.9	830
Coconut*	6077.7	5813	5829.4	5449	5664.3	5088
Arecanut	141.0	843	160.0	901	184.5	1024
Cashewnut	176.7	584	171.4	465	195.8**	407
Pepper	26.2	218	28.5	235	28.5	257
Cardamom	3.1	41	3.1	31	8.8	85

*Production in million nuts and productivity in number of nuts/ha

**Earlier figures repeated

146.94 million kg to 222.4 million kg with an average price realisation from Rs.0.99 to Rs.23.36/kg with an export value from Rs.19.8 crores to a phenomenal increase of Rs.711 crores has been realised in this period. This upward trend shows a tremendous scope for a still better future for tea industry.

From the present production of 657 million kg of tea with an average yield of 1,659 kg/ha grown in an area 396,000 ha, it has to be stepped up to 1,100 million kg with an average yield of 2,444 kg/ha in an

area of 450,000 ha. With this level of production a foreign exchange of Rs.1,300 crores could be earned as compared to that of the existing Rs.750 crores (Table III).

Coffee: Coffee earns a foreign exchange of Rs.200 crores with a production of 182,000 t on an area of 217,000 ha with an average yield of 837 kg/ha. The future target of an increase in area to 300,000 ha, for the production of 307,000 t with an average yield of 1,023 kg/ha with a foreign exchange of Rs.340 crores is envisaged (Table IV).

Table II. *Indian Tea - 50 year profile.*

Year	Production Million kg.	Sold in auction in India million kg.	Average price Rs/kg	Export million kg.	Export value Rs. crores
1935	178.9	48.3	0.99	146.9	19.8
1945	229.0	48.3	2.04	167.6	36.2
1955	307.7	166.3	4.35	166.7	113.6
1965	366.4	221.1	5.35	199.3	114.9
1975	487.1	286.6	10.59	218.1	244.6
1985	657.2	504.0	23.36	222.4	711.1

Table III. *Tea.*

	Area '000 ha	Production '000 t	Yield kg/ha	Foreign exchange Rs. crores
Present	396	657	1659	750
Future target	450	1100	2444	1300

Table IV. *Coffee.*

	Area '000 ha	Production '000 t	Yield kg/ha	Foreign exchange Rs. crores
Present	217	182	837	200
Future target	300	307	1023	340

Cardamom: At present cardamom is cultivated on an area of 103,000 ha with a production of 8800 t and the average yield of only 85 kg/ha. is rather low. In order to achieve a target of 16,500 t the area has to be increased to 110,000 ha and the average yield has to be increased to the level of at least 150 kg/ha (Table V).

Table V. *Cardamom.*

	Area '000 ha	Production '000 t	Yield kg/ha
Present	103	8.8	85
Future target	110	16.5	150

Rubber: A quantity of 208,000 t of rubber is currently being produced on 236,000 ha with a yield of 880 kg/ha. The projection for future is 625,000 t in an area of 500,000 ha with an average production of 1,250 kg/ha (Table VI).

Coconut: Coconut is now grown in an area of 1,113,000 ha with a production of

Table VI. *Rubber.*

	Area '000 ha	Production '000 t	Yield kg/ha
Present	236	208	880
Future target	500	625	1250

5,664 million nuts, the average being 5,088 nuts/ha. A future target of 12000 million nuts is envisaged on an increased area 2,100,000 ha with a yield of 5,714 nuts/ha (Table VII).

Table VII. *Coconut.*

	Area '000 ha	Production million nuts	Yield nuts/ha
Present	1113	5664	5088
Future target	2100	12000	5714

Pepper: Pepper is at present cultivated in an area of 126,000 ha mostly as an intercrop. The annual production is 30,000 t and the average yield is 238 kg/

Table VIII. *Pepper.*

	Area '000 ha	Production '000 t	Yield kg/ha	Foreign exchange Rs. crores
Present	126	30	238	15
Future target	—	60	476	30

ha. There is a vast scope for increasing the production to 60,000 t without significantly increasing the area by stepping up the yield to 476 kg/ha, thus a foreign exchange of Rs.30 crores could be realised from exports as compared to that of the present 15 crores (Table VIII).

Cocoa: The production of cacao at present is 7.71 million kg, cultivated as an intercrop in an area of 30,000 ha, the average yield being 257 kg beans/ha. A futuristic target of 12 million kg of cocoa with a productivity level of 300 kg beans/ha in an area of 40,000 ha is to be achieved (Table IX).

Table IX. *Cacao.*

	Area '000 ha	Production '000 kg	Yield kg/ha
Present	30	7710	257
Future target	40	12000	300

Though research efforts in the past have yielded good dividends in the matter of higher production, yet concerted efforts have to be made to intensify and integrate research on different dimensions to achieve the future targets mentioned above. Unlike in the case of field crops, strategies to be adopted in plantation crops are slightly different because of their perennial nature and inherent plant characteristics.

1. *Germplasm:* In order to have a research breakthrough, the available genetic resources of plants, animals and microbes should be explored since exploitation of genetic diversity will have a pivotal role in enhancing and sustaining production. Hence, there is an imperative and urgent need for a systematic collection, and preparing an exhaustive inventory of all the genetic resources with relevance to plantation industry. Germplasm centres may be identified and established so that collection and conservation and efficient utilization of these materials in the breeding programmes are ensured.

2. *Crop varietal improvement:* The crop varietal improvement programmes in the plantation crops should include not only the traditional methods but also new and innovative approaches. Apart from mass selection, hybridization, mutation breeding, new methods like cellular hybridization, molecular transformation, anther culture, *in vitro* culture, etc. have to be taken up. In this task, the specific aspect of breeding plants for resistance to pests and diseases and adverse conditions like drought, frost and flood should be given special emphasis, while the maximum biomass production should be obtained with the best quality of the produce and its availability and amenability for efficient processing have to be borne in mind.

3. *Biotechnology*: In the case of perennial crops like tea, coffee, rubber, coconut etc, evolving new crop varieties by conventional methods of selection and multiplication is beset with difficulties and is time consuming. In order to overcome this, quicker methods of plant improvement techniques like clonal multiplication, nursery grafting etc, are to be adopted but still to cope with the ever increasing demand for the high-yielding and quality material, a quicker process of multiplication is warranted. This could be achieved only by adopting modern techniques like tissue culture, protoplast culture and exploitation of genetic engineering. It is gratifying to note that already some headway has been made in this direction by some leading research institutions in our country and this will go a long way in achieving the goal set for production in the 21 century.

4. *Crop husbandry*: Since soil is the ultimate basis of all production the health and fertility of the soil has to be given top priority at all times. Many of the plantation crops being grown in hilly areas and undulating terrains proper soil, water and organic matter conservation measures are of paramount importance. The aspects of water use and fertiliser use efficiency have to be looked into very thoroughly. Attention has to be paid and vigilance exercised in assuring the proper quality of inputs like fertilisers, pesticides, fungicides, weedicides, plant growth regulators etc, in order to maximise their efficiency. Wherever possible biofertilizers could be used to augment the inorganic fertilisers. Similarly bio-control agents like predators and parasites could be used for plant protection.

5. *Pest and disease management*: In the

past, experience in plant protection has revealed the fact, that it is really impossible to absolutely eradicate a pest, disease or weed. The advent of usage of many new chemicals has also been found to be resulting in resistance, and resurgence problems. Under these circumstances the only key and the solution for combating the problem is adapting a strategy of integrated plant protection measures. In the present context of introduction of high yielding varieties which take huge cost of chemical inputs and labour, the minimal and judicious use of these chemicals has to be resorted to. This necessitates the fixing up of economic threshold values for their usage. Even the use of the most efficient chemical is not of avail, if suitable application equipment is not employed. Hence, standardisation of application equipment is a crying need of the hour coupled with their cost effectiveness and maintenance. While integrating the control measures, incorporation of bio-control agents such as parasites, predators and microbes should be considered to tackle the plant protection problems more efficiently.

6. *Processing, product diversification and equipment*: The plantation crops offer a tremendous scope for processing and diversification of the products. Any processing for that matter has to be aimed at for the best quality of the produce and suit eminently to the consumer demand and preference. The keeping quality of the processed material and its export potentialities to earn the maximum amount of foreign exchange have to be taken into consideration. In case of tea a wide array of value added and diversified products such as green

tea, black tea, instant tea, soft beverage like tea cola, flavoured teas besides by-products like caffeine and triacontanol are already developed. Similarly in other crops like coconut, cacao, cardamom, coffee and rubber also value addition and diversification of products could be taken up to augment the resource potential and to meet the consumer demand.

7. Marketing, extension and cost of production: The high capital cost of establishing new plantations, the long gestation periods, and the labour intensive nature of the plantation industry result in mostly as an unremunerative enterprise. The exports of plantation commodities in general have not shown much growth during recent years owing to severe competition in the global market. The elasticity of demand of plantation crops is low with respect to income and price. In order to obviate these difficulties and ensure better remuneration for the producer on the one hand and economic delivery of goods to the consumer on the other it is very essential that intensive research on the market potential of plantation crops, which is lacking very much now, should be taken up on priority. Cost effectiveness should be the watch-word right from planting through processing and marketing in the plantation industry. The government should encourage market promotion activities within the country as well as abroad and

at the same time evolve suitable judicial policies for stabilising the price of the commodities through international agreements. In this connection it is desirable that on the planters' side it is time for them to go in for a mixed cropping pattern rather than sticking on to monoculture of one particular crop. This to a great extent could stabilise the economy of production on the plantation.

8. Basic research: To cater to the need of the plantation community, the research institutions, have always been engaged in research towards bringing about need based and practically oriented results which could be transferred immediately to the field. No doubt this is very essential, but at the same time the importance of fundamental research to understand various aspects of the biochemistry and physiology of plant nutrition, soil-water-plant interaction, genetic variability, mechanism of resistance to pest, disease, drought, frost and flood should be looked into. The relationship between various production parameters, the inputs that go in for production, the final quantity and quality of the produce and their marketability should be studied in great detail for which enough time, money and facilities should be earmarked from now on so that rapid strides of progress, as envisaged, could be made in the 21st century.

CHAPTER I

BIO-TECHNOLOGY & PLANT PHYSIOLOGY

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PROSPECTS OF BIOTECHNOLOGY IN PLANTATION CROPS

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INTRODUCTION

The advent of new technologies in the field of molecular biology has opened up a new vista of possibilities, so far unknown, to manipulate the genetics of crops for their improvements. The last decade has registered rapid progress in the field of plant biotechnology, and the list of crop plants which have been subjected to these new techniques is ever increasing. In general, woody tree crops are the most difficult for such manipulations and much more efforts are needed to cross certain technical barriers now slowing down the progress of work on these crops. Besides the classical tissue culture work, very little has been done in the field of molecular biology and genetic engineering in plantation crops. This paper, therefore, is confined to review briefly the progress made in other crops and to speculate the potential fields of activities which can be extended to different plantation crops. The review describes briefly some of the concepts used for transfer of genes and the problems associated with these methods. The literature cited is only indicative and by no means complete.

Once our knowledge of gene action is improved and the techniques employed in various aspects of biotechnology are refined, such studies at molecular level can be extended to more crops including plantation crops. Some of the areas

where research can be initiated for plantation crops are listed below.

Micropropagation

Micropropagation techniques have been successfully employed in numerous plants eg. *Lilium* (Robb, 1957); tulips (Wright and Alderson, 1980); gladiolus (Hussey, 1977); gerbera (Murashige *et al.*, 1974); pineapple (Mathews and Rangan, 1979); sugar beet (Hussey and Hepher, 1978); apple (Jones *et al.*, 1977; Lane, 1978) etc., to mention a few. A wide range of tree species have also been propagated by this *in vitro* technique eg. plum (Garland and Stolz, 1981); pear (Lane, 1979); teak (Gupta *et al.*, 1980) date palm (Tisserat, 1979) and ornamental and forest trees such as fagus, quercus and ulnus (Chalupa, 1979) etc. *In vitro* studies have also been reported in some plantation crops like coconut (Guzman *et al.*, 1978; Pennitier and Buffard Morel, 1982; Iyer *et al.*, 1983); oil palm (Smith and Thomas, 1973; Jones, 1974); coffee (Sondahl and Sharp, 1977a, 1977b; Nsumbu, 1979; Dublin, 1980); cacao (Esan, 1982); tea (Phukan and Mithra, 1984) and rubber (Satchithananthavale, 1974; Sinha *et al.*, 1985.)

The technique micropropagation involves the *in vitro* sterile multiplication of plants on a precisely defined growth medium, incorporating specific growth regulators known to elicit specific growth

responses in plant tissues. This process can be used to maximise the elite individuals rapidly.

The general procedures used for *in vitro* propagation are:

- (i) Selection of suitable explants.
- (ii) Proliferation of shoots on multiplication medium.
- (iii) The transfer of shoots to a rooting medium if required and planting out of rooted plants.

Advantages of Micropropagation

- (1) Micropropagation can be profitably utilised for maintenance and mass-scale multiplication of desired genotypes.
- (2) Propagation throughout the year.
- (3) Lesser space requirement.
- (4) Possibilities of rejuvenation from mature tissues.
- (5) Disease indexing.
- (6) *In vitro* selection of plants.

Somatic embryogenesis

Krikorian and Kann (1979) regarded mass somatic embryogenesis from cell suspension cultures as the ultimate goal in plant propagation and plant improvement. Steward (1958) was the pioneer worker in successfully achieving embryogenesis in carrot. Somatic embryoid production has been reported in numerous other crops eg. cotton (Price and Smith, 1979); date palm (Tisserat and De Mason, 1980); grapes (Srinivasan and Mullins, 1980); pearl millet (Vasil and Vasil, 1981, 1982); rice (Sriwardhana and Nabors, 1983); mango (Litz *et al.*, 1982; Litz, 1984a); Eugenias (Litz, 1984b) and the list goes on. Little progress has been made on this topic in plantation crops

with the exception of coffee (Lanand, 1981; Sondahl *et al.*, 1984).

Applications

Difficulties do exist in transferring the somatic embryoids to the field, once efficient mass somatic embryogenesis has been obtained. Techniques involving trapping the developing embryos together with necessary nutrients in plastic strips or pellets can be used for bringing the naked embryos to the field. Refinement of fluid-drilling technique also would help in the transfer of somatic embryos/developing plantlets and their trouble-free establishment in the field.

Protoplast culture techniques and somatic cell hybridization

Protoplasts can be isolated from a wide range of species and can be induced to fuse by a variety of different fusogens to produce heterokaryons (Power and Davery, 1979). A pre-requisite for any use of protoplasts in crop improvement is the ability to regenerate plants. Success has already been achieved in several crops such as tobacco (Takabe *et al.*, 1971); rapeseed (Thomas *et al.*, 1976); cassava (Shahin and Shepard, 1980); potato (Shepard and Totten, 1977; Thomas, 1981) to name a few. Somatic hybrid plants have been produced between species that are difficult or impossible to hybridise conventionally, eg. *Lycopersicon esculentum* and *Solanum tuberosum* (Melchers *et al.*, 1978); *Datura innoxia* and *Atropa belladonna* (Krumbiegel and Shieder, 1979) and *Petunia parodii* and *P. parviflora* (Power *et al.*, 1980). No successful attempt is known to have been made in protoplast fusion in any of the important plantation

crops. The most difficult part of the procedure is to induce regeneration of plants.

Applications

- (1) Production of hybrids between sexually incompatible species;
- (2) Production of heterozygous lines within a species which is normally vegetatively propagated;
- (3) Transfer of limited parts of the genomic elements, particularly cytoplasmic organelles; and
- (4) Production of somaclonal variants.

Somaclonal variation

Somaclonal variation occurs in plants regenerated from cultured tissues or cells and has been observed for morphological, physiological, bio-chemical and genetic traits (Larkin and Scowcroft, 1981). Such useful variants have been detailed in various crops like sugar cane for high sucrose content as well as disease resistance (Heinz *et al.*, 1977; Krishnamurthy, 1982); potato for its growth habit, tuber colour and uniformity, date of maturity and resistance to diseases (Shepard *et al.*, 1980; Thomas *et al.*, 1982); tiller number and seed protein in rice (Sun *et al.*, 1983); wheat for height, grain colour, tiller number and yield (Larkin *et al.*, 1984; Ahloowalia and Sherington, 1985).

Gene transfer in higher plants

Genes have been introduced into plant cells using donor materials in a variety of forms. Purified DNA is also capable of transforming recipient cells but the frequency of transformation is almost three orders of magnitude lower than that obtained using somatic cell hybridization

(Cocking, 1983). Gene transfer can be done through DNA/RNA vector systems, through Ti plasmids etc. In order to develop a new organism through genetic engineering and/or gene transfer, various factors such as DNA structure, protein purification etc. have to be studied in detail. Genetic engineering is a novel technique used for changing the plants genetically-techniques that do not rely on pollination; instead involve genetic manipulations at cellular and molecular levels. This technique promises to be a powerful adjunct in modern plant breeding. But excellence in knowledge and techniques is a primary requirement to do anything worthwhile in this field.

DNA/RNA vector systems

Plant viruses received adequate attention from molecular biologists, due to their potential use as vectors for gene transfer in higher plants. The RNA genomes of some plant viruses are suitable for using as vectors for gene transfer.

Gene Transfer in higher plants through Ti-Plasmid

Crown gall is a neoplastic disease caused by the soil bacterium *Agrobacterium tumefaciens* in many dicotyledonous plants. Van Larabeke *et al.* (1974) reported that the tumour inducing capacity of the bacterium resides in large extra-chromosomal plasmids known as Ti plasmids (the T-DNA is that moiety of the DNA of the plasmid which integrates into the host cell DNA). Because the disease involves gene transfer from a bacterium to plant cells and subsequent expression of characteristics, crown gall has great potential as vector for genetic

manipulation of agricultural crops. Under natural conditions, *A. tumefaciens* cells in the soil enter the plant tissues through wounds and attack themselves to specific sites on the cell walls. A circle of DNA in the pathogen known as Ti plasmid then mobilises the transfer of a piece of DNA into the plant cell where it becomes attached to the plant's nuclear DNA (Van Larabeke *et al.*, 1974). The subsequent expression of this implanted DNA, the T-DNA, results in proliferation of tumour and produces opines, which in turn serve as food sources for *A. tumefaciens*.

Ti plasmids are useful in (1) manipulation of genes by gene transfer techniques and (2) stable introduction of foreign genes into plant cells without affecting the morphogenetic potential of the cells. This is an important pre-requisite for successful genetic engineering of plants.

Recombinant DNA Technology

It is known that recombinant DNA technology plays a pivotal role in the molecular analysis of genome organisation and its function. The application of recombinant DNA techniques to plant chromosomes has been extensively reviewed by Flavell (1980) and Bedbrook and Kolodner (1979). The main objective of recombinant DNA technology, in addition to the above mentioned analytical investigations, is the genetic modification of organisms. This includes the transfer of foreign or modified genes into eukaryotic or prokaryotic cells.

Isozymes in Plant Breeding

Isozymes are multiple molecular forms of an enzyme derived from a tissue of an organism. One of the most useful aspects

of isozymes is that they are sometimes linked to important economic traits. Linkages between isozyme markers and important economic traits are being exploited in tomatoes, since the lack of effect of isozymes on appearance and performance renders them superior to the customary marker genes used for this purpose. Linkages with isozyme loci also assist in breeding programmes dealing with quantitative characteristics such as earliness or yield (Rick, 1982).

Plantation crops can be improved by some of the techniques stated earlier. However, the potential fields for immediate improvements where investigations can be intensified are given below:

Rubber:

1. Micropropagation is useful in developing elite clonal materials with its own root system to avoid stock-scion interaction or to evolve ideal stock clones.
2. Cell selection methods/somatic embryogenesis techniques can be tried to evolve clones resistant to drought or cold.

Cardamom:

As cardamom is propagated by seed (the crops is cross-fertilized) micro-propagation techniques can be used for rapid multiplication to generate high yielding clonal materials.

Coconut:

Rapid multiplication of desired clones with special emphasis on disease resistant ones.

Cashew:

Rapid clonal propagation to obtain high yielding cultivars by meristem tissue culture techniques. More scion material can be generated by the above technique for use in grafting and to evolve rooted plantlets which are tolerant to pests and pathogens.

Coffee:

Evolving cultivars resistant to coffee rust disease by selection and regeneration of resistant cell lines using dual cultures of fungi and host callus tissue.

Oil palm:

Evolving elite conal progenies which give higher yield than seedling populations by either somatic embryogenesis, micropropagation techniques, etc.

Tea:

To obtain tea cultivars with leaves of better quality either by micropropagating the elite individuals or by producing new ones exploiting somaclonal variations.

In view of the current biotechnological achievements in other crops, similar techniques can be utilised in plantation crops. Several long term programmes can be envisaged to meet this objective. Some opportunities for using molecular plant genetic engineering in plantation crops can be categorised as follows (Qualset, 1982).

- (1) Transfer of genes from one species to another that would not be possible with non-molecular methods.
- (2) Transfer of genes at a single step, rather than through repeated crosses or back crosses.

- (3) Transfer of only the target gene, without undesirable genes linked or otherwise associated with it.
- (4) Transfer of genes rapidly in species with long generation times.
- (5) Conservation of plant genes in cloned DNA gene banks.
- (6) Assessment of genetic variation and genetic relationship among species by molecular methods.
- (7) To capitalise on 'spinoff' technology for use in conventional gene transfer systems – for instance, tissue, cell or protoplast culture methods.

Requirements

The research work in the field of modern biotechnology requires sophisticated laboratories, high level of expertise and easy availability of necessary biochemicals. As long as constraints exist in acquisition of necessary equipment that will work trouble-free, availability of wide-range of ultrapure chemicals and trained man-power, the progress in this field of biotechnology is bound to be slow. Some suggestions are given to provide a conducive atmosphere for plant biotechnological research work:

- (a) A central agency should be entrusted with import of required equipment, chemicals, etc. in bulk based on national requirements, so that the user agencies can purchase these from them on rupee payment without having to undergo the procedural delay in importing vital items for research.
- (b) The facilities for training and conducting refresher courses for the scientists working in this field should be strengthened. Biotechnology should be

taught as a separate and independent discipline and its graduate and post-graduate programmes should be offered at leading Universities.

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CLONAL MULTIPLICATION OF OIL PALM (*ELAEIS GUINEENSIS* JACQ)

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ABSTRACT

Five mm long tender leaf explants and leaf base explants taken from 3-year-old seedlings were cultured on defined media supplemented with various auxins and cytokinins. Cultures were incubated in the light. The explants produced callus from the veins at the cut surface in 2-3 weeks on R medium containing 20 mg l^{-1} 2,4-D and 0.1 mg l^{-1} BAP. Somatic embryoids developed on lowering the 2,4-D concentration and replacing it with NAA. Bipolar and tripolar embryoids originated as snow-white protuberances from the sub-surface layers of the callus. The process of germination of the somatic embryoids was similar to that of normal zygotic embryos. However, the formation of adventitious roots was enhanced with the addition of 0.01 mg l^{-1} IBA to the medium.

INTRODUCTION

Crop improvement in oil palm through conventional methods has been slow due to its perennial nature, long juvenile phase and high level of heterozygosity due to cross pollination and lack of conventional methods for vegetative propagation. The crop is essentially seed propagated and the commercial plantations are with hybrid *tenera* (*dura* $\times$ *pisifera*) palms. The use of hybrids comes in the way of establishing uniform plantations as the inbred parental lines are not available (Nwankwo and Krikorian, 1982). Recently much emphasis has been given to the oil quality aspects as well. It is thus attractive to develop methods for the vegetative propagation in order to establish uniform plantations of elite genotypes. There are many reports on the vegetative propagation of oil palm through tissue culture (Jones, 1984;

Rabechault and Martin, 1976, Paranjothy, 1984; 1986). In this communication the development of clonal oil palms from tender leaf explants of three year-old *tenera* seedlings through somatic embryogenesis with a minimum callus phase is presented.

Explant

The central tender leaf column of the seedling along with a covering leaf sheath was dissected with the growing apex and wiped with 70% ethanol and flamed. After trimming the cut ends which came in contact with ethanol the covering leaf sheath was removed. Tender leaf was then cut into 5 mm long explants with 2 or 3 leaf folds.

Callus Induction

For callus induction the leaf explants

were placed on a medium containing 2,4-D. Addition of charcoal to the medium seemed necessary to minimise the toxic effects of the oxidative products of polyphenols released by the injured tissues. The cultures were incubated at $29 \pm ^\circ\text{C}$ under varying intensities of fluorescent light (16h photoperiod). The relative humidity was 60-70 per cent.

The best results were obtained where 2,4-D (20 mg l^{-1}) was used along with BAP (1 mg l^{-1}). After two to twelve weeks of incubation depending on the plant used, callus proliferation appeared at the morphologically lower cut end of the explant (Fig. 1). In some cultures proliferation was seen at the other end also. The callus at the lower end had small compactly arranged cells with dense cytoplasm while at the other end it was filamentous with large round vacuolated cells.

Somatic Embryogenesis

The explants with a few cell layers of thick primary callus were cultured on a series of media in which 2,4-D was gradually replaced by NAA. This led to the development of somatic embryoids in about 8 – 20 weeks. The somatic embryoids appeared as small, white, club shaped structures (Fig. 2) on compact calli. These structures attained a size of 3-5 mm in length within 6-8 weeks of their appearance. They had well defined shoot and root poles (Fig. 3). 10-15% of the embryoids had a tri-polar structure where the third pole represented the haustorium (Fig. 4) which never developed beyond 5 mm in length.

The embryoids were not connected to each other or to the explant by vascular

elements. They were independent structures which developed from different regions of the callus. After the embryoids had attained a minimum of 2 mm size, the embryoids could be separated from the explant tissues easily.

Germination of Embryoids

Once the embryoids attained a minimum length of 4 mm, they could be handled individually. On a germination medium over 50 per cent of the embryoids had shoot emergence first (Fig. 5), 30 per cent had simultaneous shoot and root development, 15 per cent with root development followed by shoot and 5 per cent shoots failed to grow after root development.

Hardening

The plants after attaining a size of 5 cm with at least two roots having laterals were transferred to a mixture of sand and vermiculite moistened with Hoagland's solution with 0.01 mg l^{-1} IBA in mineral pots and kept under high humidity conditions (Fig. 6). The growth of the plants was faster in the potting mixture. In three weeks time they were transferred to the garden mixture. Over 80 per cent of the plants survived in the garden mixture.

DISCUSSION

Ever since the success in clonal propagation of oil palm was demonstrated by Jones (1974) much attention has been centred on the commercial exploitation of this method. Tissue culture method currently followed comprises the elaborate callus phase followed by shooting from meristemoids and rooting (Paranjothy, 1986). In

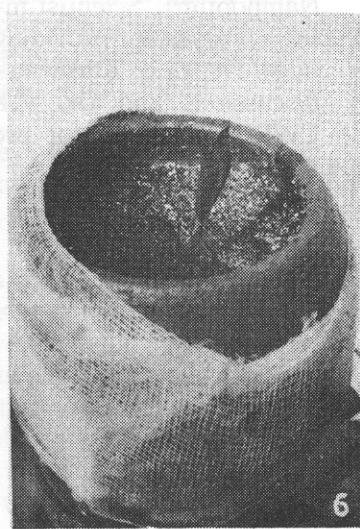
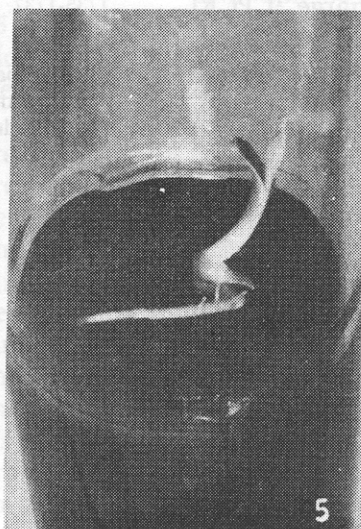
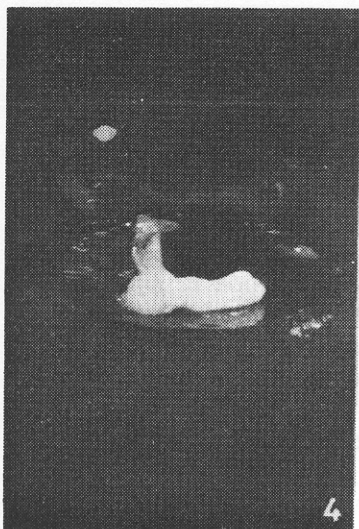
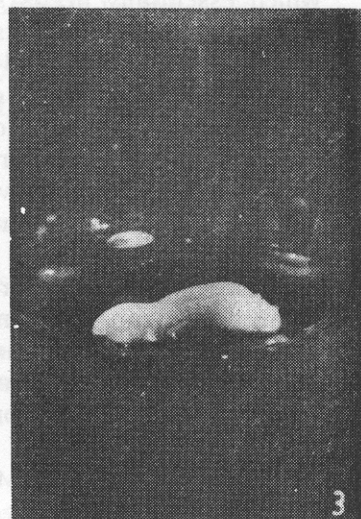
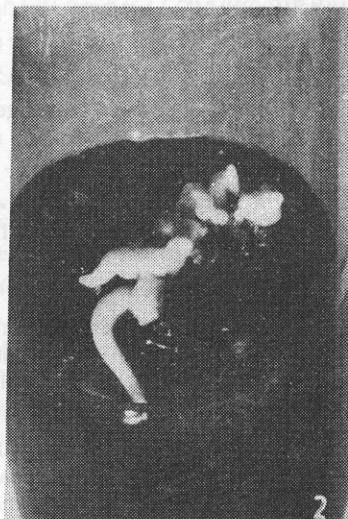
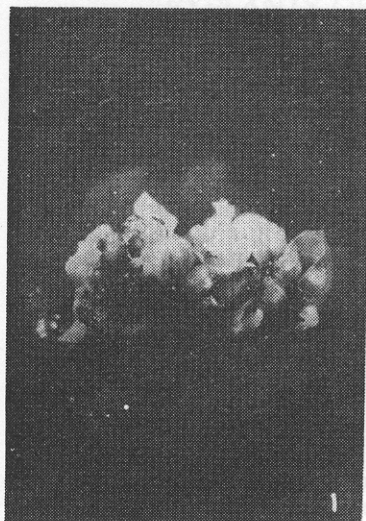


Fig. 1. Leaf explant with callus lining at the cut end.

Fig. 2. Embryoids developing from the callus lining.

Fig. 3. Single bipolar embryoid with shoot pole (s) and root pole (r).

Fig. 4. A tripolar embryoid with shoot (s), root (r) and haustorial (h) regions.

Fig. 5. Germination of the embryoid with shoot and root poles developing simultaneously.

Fig. 6. Plantlet transferred to mineral pot.

contrast to the meristemoid formation which essentially needs separate shooting and rooting treatments for developing the plantlets (Wooi, 1984), the method described here produces embryoids from the compact calli at the lower cut end of the explant, very similar to the sexual embryos and germinate with both shoot and root. The germination of the embryoids was found to be 75 to 80%. The time taken for the production of the plantlet of 5 cm height in tube from the leaf explant was only four months. This time was, however, varying with the plant used for the initiation of the culture.

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CALLUS INDUCTION AND RECOVERY OF PLANTLETS FROM SEEDLING EXPLANTS OF *EUCALYPTUS CAMALDULENSIS* DEHN

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ABSTRACT

Embryonal tissues of *Eucalyptus camaldulensis* Dehn. are callused on Murashige and Skoog (MS) medium supplemented with casein hydrolysate (CH) and 2, 4-dichloro phenoxyacetic acid (2,4-D). Subculturing of this calli to MS medium with 6-benzyl aminopurine adenine sulphate and sodium dihydrogen ortho phosphate formed numerous shoot buds, which on transfer to MS medium fortified with BAP and auxins (NAA, IAA & IBA) showed internodal elongation. Each of these elongated shoots, after isolation reared on MS medium (without hormones) formed roots. Plantlets thus derived are being hardened to the field conditions.

INTRODUCTION

Eucalyptus with about 445 species and 24 varieties covering a wide range of climate, soil and moisture conditions (Durand-Cresswell *et al.*, 1982, is an important genus in the afforestation programme to protect the deforested valleys from further erosion. Besides being planted as a shade tree in the cardamom plantations in southern India it is used as a source of pulp in paper production throughout the world (Chaturvedi, 1983). However, due to inefficient vegetative propagation methodology, the majority of the cultivations rely on seeds of unknown provenance (collected at random from existing forests), thereby throwing up a bewildering array of heterogenous seed-

ings and trees. Because of this, the technique of tissue and organ cultures has been advocated to generate superior and true-to-type progenies of eucalyptus (Durand-Cresswell *et al.*, 1982).

In vitro studies on this genus was taken up in our Institute as an integral part of the programme on tissue culture. Tissues from mature and juvenile plants of various species have been brought into culture and this report is the first in the series. We developed the tissue culture from *Eucalyptus camaldulensis* seedlings as a model system to serve as a basis to explore the role of various nutritional components in morphogenesis and organogenesis, and the problems encountered in rooting of adventitious buds.

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MATERIALS AND METHODS

Seeds of *Eucalyptus camaldulensis* Dehn. obtained from Eucalyptus Research Institute, Hyderabad, were washed under running tap water, overnight. They were then surface sterilized using 0.1% (W/V) aqueous mercuric chloride solution for 3 minutes followed by several rinses in sterile distilled water. Seeds were sown in 100 ml conical flasks containing 20 ml of an agar-sucrose media (agar 0.8%; sucrose 2%), which were earlier autoclaved, and incubated under artificial light of 150-200 ft. c., at $20 \pm 2^\circ\text{C}$ and 90% RH.

Cotyledonary nodes from seedlings in which cotyledons have expanded were excised and explanted on to various media. The basal media, hereafter referred to as BM, contains Murashige and Skoog's minerals, White's vitamins, inositol (100 mg/l) and sucrose (3%). This was supplemented with auxins, cytokinins and growth adjuvants as and when necessary, and this is discussed in the following pages. The media before gelling with 1.0% agar were adjusted to a pH of 5.6 ± 0.2 . They were dispensed into vials, tubes or conical flasks as the occasion demanded and were autoclaved at 1.05 kg/cm^2 for 20 minutes. All subsequent operations were performed under a laminar flow-hood. Cultures were incubated at $25 \pm 2^\circ\text{C}$ under continuous illumination (150-200 ft.c.) and high humidity.

The callus was routinely subcultured at 4 week intervals. Shoot buds, when they reached a height of about 2 mm were isolated and transferred to elongation media described later in the text. When they attained about 5 cm length they

were replanted to rooting media. After about one month in this rooting medium the seedlings were washed off the agar and transplanted to sterile soil before planted outside.

RESULTS

The minute seeds started swelling within 24 hours, and by the third day the radicle emerged out in agar-sucrose media. On an average about 60-80% of seeds germinated within 3-4 days. By 11 days, the seedlings elongated to a length of one cm with fully expanded cotyledons and shoot tips. When the first internode above the cotyledonary node grew to a length of one cm, cotyledonary nodes with the cotyledons intact were excised and planted on to either a proliferation/induction medium or a callus induction medium. The proliferation/induction medium contained BM, with BAP (5 mg/l), adenine sulphate (160 mg/l) and sodium dihydrogen orthophosphate (170 mg/l). In this medium a minimum of 3-6 shoot buds initiated from each axil and elongated into shoots within 20-30 days. It was apparent that the dormant axillary bud at the axil resumed its growth and this in turn triggered the initiation and development of axillary bud at the axils of leaves of the resumed cotyledonary bud. By this process 2-3 orders of axillary buds proceeded in their developmental pathway.

On the contrary, in the callus induction media (BM, with 2, 4-D 2 mg/l and casein hydrolysate 1 g/l), the explants started producing callus from cut ends within 7 days. By 20-30 days the whole explant was engulfed by a vigorously growing white friable callus (Fig. 1). These calli were subcultured on similar media at

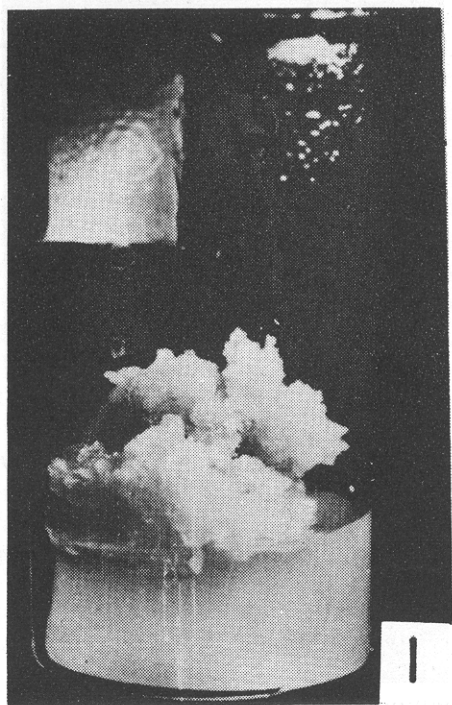


Fig. 1. A 3 week-old callus derived from cotyledonary node.

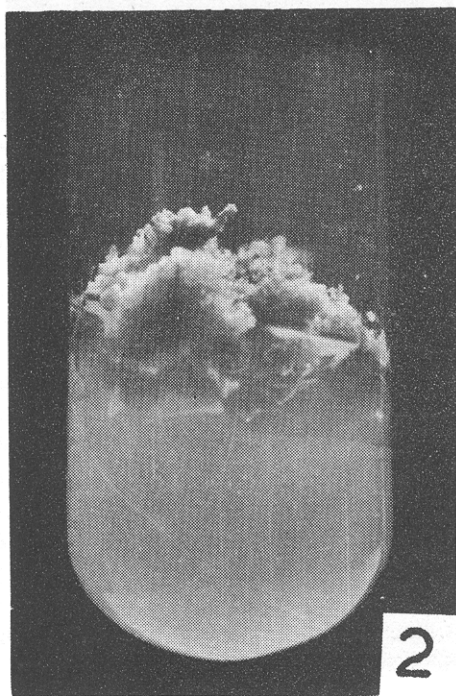


Fig. 2. Differentiation of minute shoot buds all over the callus on a shoot proliferation/induction medium.

monthly intervals. Every 10 days, the volume of callus increased by about two times in media of the above concentration. When these cultures were transferred to shoot proliferation/induction media, an altered morphogenetic pattern ensued. As the growth of the callus continued, the newly formed cells turned green and the white callus became completely chlorophyllous. On subculture to media of similar composition, numerous minute shoot buds arose within a month, which remained small (Fig. 2). Transferring these buds on to fresh media of similar composition did not help in improving their further growth and development. However, when these were transferred on to a medium containing BM, BAP (0.2 mg/l), NAA (1.8 mg/l), IAA

(1.0 mg/l) and IBA (0.5 mg/l) (shoot elongation media), these buds elongated to a length of 3-5 cm within 20-30 days (Fig. 3). In rare instances, the basal end of these produced small calli from which subsequently one or two thin, small roots emerged. However, these roots were weak and did not grow further. On isolation and culture of these elongated shoots on to a BM, they produced 6-8 healthy adventitious roots within 20 days. On a BM the axillary shoots reared in proliferation media (see earlier part) also initiated 6-8 roots from their basal ends (Fig. 4). After 30 days, the plantlets were washed off the agar and transplanted to a sterile soil before being transferred to the nursery. Attempts are now being made to harden them to field conditions.

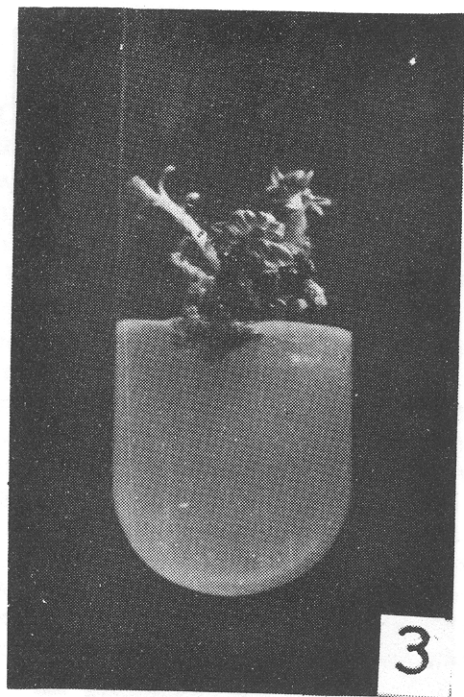


Fig. 3. A similar culture as in 2 on shoot elongation medium, after 20 days.

DISCUSSION

This report clearly brings out two alternative approaches for obtaining multiple plantlets from seedling tissues of *E. camaldulensis*. First, by the rapid production of numerous supernumerary buds from the existing axillary buds at the cotyledonary nodes and second by indirect morphogenesis through a callus which is subsequently induced to differentiate into shoot buds. Earlier, Lakshmi Sita and Vaidyanathan (1979), reported the multiple shoot production from seedling tissues of *Eucalyptus citriodora*. However, to our knowledge, no report is available on the production of shoot buds with the intervention of an intermediary callus from the *E. Camaldulensis*.

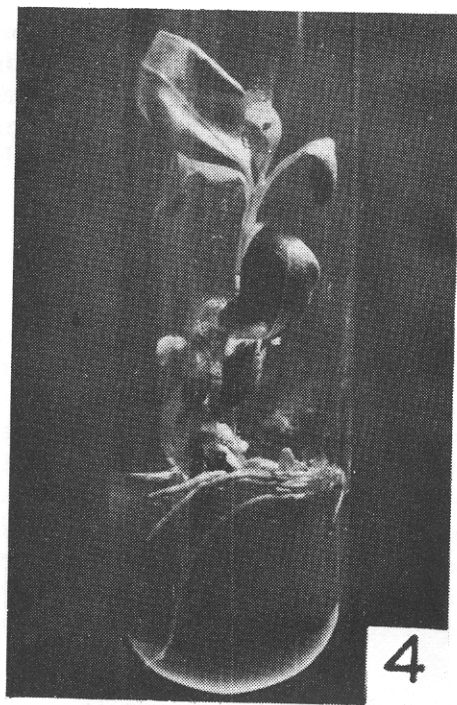


Fig. 4. An elongated shoot isolated and transferred to a BM, where profuse rooting be observed.

Eventhough the white friable callus was maintained by subcultures for several generations we did not observe any quantitative change either in its morphology or in its regenerative potential. Further, inspite of numerous shoot bud differentiation in several cultures, none exhibited any aberrant phenotypic characteristics. Eventhough we have not analysed the cytological components in these cultures, the high regenerative potential even in remarkably aged ones indicates that they are reasonably stable. However, literature abounds with instances where older cultures contain a high proportion of cells with cytological abnormalities leading to declining regenerative capacity (Cellarova *et al.*, 1984; D' Amato, 1978).

The hormonal requirements to the routes also varied, as was expected. Benzyladenine, a cytokinin, was found to promote axillary bud production as well as adventitious bud differentiation from callus cultures, while 2, 4-D promoted callus induction. The use of cytokinins in inducing shoot production from callus cultures of various *Eucalyptus* species has been a routine practice even earlier (Lakshmi Sita, 1981; Aneja and Atal, 1969). Benzyladenine at higher concentrations tended to encourage the production of several short and stumpy shoot bud which proved unsuitable for inducing rooting. Culturing these shoot buds in a BM where BAP concentration is reduced several folds and in addition enriched with 2 or 3 auxins, wherein they elongated appeared to be a *sine qua non* before they are being transferred to a BM where successful root initiation and development took place. Gupta *et al.*, (1983) observed that a charcoal based medium was necessary for root initiation in *in vitro* proliferated shoots from nodal explants of mature trees of *E. torelliana* and *E. camaldulensis*. We did not notice any beneficial effect with regard to either root initiation or its further development when activated charcoal was employed in the rooting medium. At present, we are not certain whether the differences in physiological studies (juvenile *versus* mature) of the tissues that we employed and used by Gupta *et al.*, (1983) or the pre-treatment of the cultures was responsible for these differential responses of the explants.

Thus, the experience gained from the responses of various tissue components to a variety of *in vitro milieu*, and the generally unique requirements for

different morphogenetic expressions observed in this study, will guide us in our future experiments with adult tissues of several other *Eucalyptus* species. However, at least in this species the seedlings can be employed to recover a large number of apparently uniform plants via tissue culture.

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EFFECT OF 'HORMONOL' AND 'FITOHORM', TWO COMMERCIAL GROWTH PROMOTORY FORMULATIONS ON PRODUCTIVITY IN MATURE SOUTH INDIAN SEEDLING TEAS

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ABSTRACT

Foliar applications of two commercial preparations, Hormonol and Fitohorm, enhanced the yield in mature seedling teas. The results indicated that the optimal dosage of Hormonol is somewhere between 250 to 500 ml ha⁻¹. Fitohorm sprays also boosted the yield in seedling teas. At 5 l ha⁻¹ the yield increased more than 12% while at higher concentration of 10 l ha⁻¹ the increase was more than 15%. Despite these increases, none of these chemicals was effective in altering the crop pattern.

INTRODUCTION

To reverse the trend in plateauing the yield that is fast approaching in some of the best and high-yielding South Indian tea plantations, a serious look into alternative avenues such as newly emergent biotechnology is warranted. The two simplest and less capital-intensive approaches seem to be the manipulation of the bush architecture, physiology and growth and development by the judicious application of plant growth regulators and the other, the use of plant tissue culture methods. While the latter may be a long term prospect, the former appears to have the potential to be exploited for beneficial purposes in the shorter time frame.

Though the use of plant growth regulators for productivity has been widespread in many annual agricultural and

vegetable crops, (Nickell, 1982) their employment in tea plantations is quite recent (Raman, 1981; 1982). Earlier publications indicated that triacontanol, triacontanol based formulations and gibberellic acid may prove useful to modulate either the productivity or the crop pattern in tea plantations. While individually, certain other plant growth regulators may have been attempted, the recent spurt in commercial formulations containing a mixture of several plant growth regulators and/or essential elements have not been fully experimented in tea plantations. This report represents a brief account on the effect of two commercial formulations, viz., Hormonol and Fitohorm on productivity in mature seedling teas.

MATERIALS AND METHODS

The trials were undertaken either in

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Table I. *Effect of 'Hormonol' on the monthly green leaf yield in a third year old (from pruning) mature seedling teas over a year.*

Plot size: 100 bushes Replication: 6 Sprays: 3 (Jan., June, Sept.)

Treatments	Yield (Adjusted) Green leaf weight kg.												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Control	59.97	71.18	113.99	87.39	165.92	57.71	19.25	81.09	96.17	109.77	71.40	75.96	1009.80
Hormonol (250 ml ha ⁻¹)	65.21	71.72	117.60	104.95	181.55	60.95	15.59	91.25	97.81	112.19	71.40	75.71	1065.93
	(8.7)	(0.9)	(3.2)	(17.6)	(9.4)	(5.6)	(-19.0)	(12.5)	(1.7)	(2.2)	(0)	(-0.3)	(5.6)
Hormonol (500 ml ha ⁻¹)	65.17	72.96	111.87	94.97	206.54	64.48	20.24	102.12	89.92	117.50	64.24	86.21	1096.25
	(8.8)	(2.5)	(-4.3)	(8.7)	(24.5)	(11.7)	(5.1)	(24.7)	(-6.5)	(7.9)	(-10.0)	(13.5)	(8.6)

(Figures in parentheses denote % $\pm$ over control)

the UPASI Tea Research Station experimental fields and/or in certain adjacent estate fields in the Anamallais on mature seedling teas. Aqueous solutions of the formulations in different concentrations were sprayed at a total volume of 200 l per ha using a Backpack sprayer. This volume was just enough to cover the top hamper. Plucking was done at weekly intervals in the Research Station trials, while the Estate schedules were followed in those conducted in the neighbouring estates.

RESULTS AND DISCUSSION

The crop pattern on a monthly basis following 'Hormonol' sprays of two concentrations on mature seedling teas is presented in Table I. The field planted in 1962 was last pruned in 1982. When this experiment was initiated it was in the third year from pruning. The crop typically reflects the pattern in a year where the rainfall is fairly distributed throughout and the other environmental conditions are reasonably favourable throughout. As is evident from Table I,

Hormonol treatment resulted in increased green leaf harvest. At 250 ml ha⁻¹, the fields yielded 5.6% more while at the higher rate (500 ml ha⁻¹) the increase amounted to 8.6%.

In a subsequent trial conducted in a neighbouring estate the 500 ml ha⁻¹ gave a boost to the tune of 5.1% while at 750 ml ha⁻¹, the increase was only 1.8% (Table II). Similarly in another trial in yet another estate the lower dosage rate of

Table II. *Effect of hormonol on green leaf yield of mature seedling teas in estates.*

Replications: 5 Plot size: 100	
Treatment	Green leaf yield Fr. Wt. Kg. Treatment ⁻¹
<i>Estate - A</i>	
T ₁ Control	606.50
T ₂ Hormonol 500 ml ha ⁻¹	636.50 (5.1)
T ₃ Hormonol 750 ml ha ⁻¹	617.00 (1.8)
<i>Estate - B</i>	
T ₄ Control	860.58
T ₅ Hormonol 200 ml ha ⁻¹	885.00 (2.8)
T ₆ Hormonol 500 ml ha ⁻¹	891.90 (3.6)

(Figures in parenthesis denote % over control)

Table III. *Effect of 'Fitohorm' on the monthly green leaf yield in a third year old (from pruning) mature seedling teas over a year.*

Plot size: 100 bushes Replication: 6 Sprays: 3; Jan., June, Sept.

Treatments	Yield (Adjusted) Green leaf Wt. Kg. Treatment ⁻¹												Total
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
Control	59.97	71.18	113.99	87.39	165.92	57.71	19.25	81.09	96.17	109.77	71.40	75.96	1009.80
Fitohorm	71.74	80.31	118.43	98.15	186.84	72.08	14.95	98.25	103.05	128.77	68.16	93.84	1134.57
5 lit ha ⁻¹	(19.6)	(12.8)	(3.9)	(12.3)	(12.6)	(24.9)	(-22.3)	(21.2)	(7.2)	(17.3)	(-4.5)	(23.5)	(12.4)
Fitohorm	73.59	85.02	135.86	104.55	198.44	61.35	19.28	95.73	99.09	123.06	78.74	93.43	1168.14
10 lit ha ⁻¹	(14.6)	(19.4)	(19.2)	(19.6)	(19.6)	(6.3)	(0.2)	(18.1)	(3.0)	(12.1)	(10.3)	(23.8)	(15.7)

(Figures in parenthesis denote % over control)

200 ml ha⁻¹, helped in increasing the crop by 2.8% while at 500 ml ha⁻¹ the increase was 3.6%. The crop showed increase following the Hormonol treatment in almost all the months except in July, November and December at the lower dosage. In fact only in July the crop showed a downward trend as a result of the spray. At the higher concentration the crop declined slightly, in March, September and November. In all the other months the treated plots registered increases over their respective yields in control plots.

The results obtained following the application of Fitohorm on mature seedling teas are presented in Table III. At lower levels of concentration, i.e., 5 l ha⁻¹ the yield increased by more than 12% while at the higher concentrations (i.e., 10 l ha⁻¹) the treated plots yielded 15.7% more than the untreated areas.

As in the case of the Hormonol treatment (lower concentrations) Fitohorm treatment also resulted in crop increase except in July and November. However, at the highest concentrations tried, the crop registered increase in all months of

the year, the least increase being observed in July.

The results presented above very clearly show that the two commercial formulations enhanced the productivity in mature South Indian seedling teas over a year. Hormonol, a preparation containing a mixture of auxins, cytokinins and gibberellic acid manufactured by Navele Brothers of Bangalore is reported to increase yield in coffee (Vasudeva, 1984). However, as far as the author is aware, this is the first report on the effect of this plant growth regulator mixture on South Indian teas. Unlike Hormonol, Fitohorm a Sandoz product, is a complex mixture of many essential elements, cytokinins and other growth promotory substances which is still at an experimental stage before being released.

Despite the fact that both the synthetic chemicals tried in this study enhanced the yield, none of them helped in altering the crop distribution. This is evident from Table IV. For example even though the yield increased more than 5% in July following Hormonol (500 ml ha⁻¹) treatment compared to control, still it was

Table IV. *Effect of Foliar sprays of Hormonol and Fitohorm on yield distribution (%) over a year in mature seedling teas (third year from purning).*

Treatments	Yield green leaf (Per cent distribution)											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Control	5.94	7.05	11.29	8.65	16.43	5.71	1.91	8.03	9.52	10.87	7.07	7.52
Hormonol (250 ml ha ⁻¹)	6.12	6.73	11.03	9.85	17.03	5.72	1.46	8.56	9.18	10.53	6.70	7.10
Hormonol (500 ml ha ⁻¹)	5.94	6.66	10.20	8.66	18.84	5.88	1.85	9.32	8.20	10.72	5.86	7.87
Fitohorm (5 lit ha ⁻¹)	6.32	7.08	10.44	8.65	16.47	6.35	1.32	8.66	9.08	11.35	6.01	8.27
Fitohorm (10 lit ha ⁻¹)	6.30	7.28	11.63	9.85	16.99	5.25	1.65	8.20	8.48	10.53	6.74	8.00

only less than 2% of the annual crop. Similarly in August the yield increase amounted to almost 25% more than the control; however, the percent distribution changed only 1%. A parallel situation also resulted following Fitohorm treatment. Even though the least crop increase of 0.2% was recorded in July, the crop share decreased from 1.9% to 1.6% compared to control, almost without any difference. In a similar way in May, treated plots outyielded the untreated ones by almost 20% without affecting the percent share of the annual yield distribution. Manivel *et al.* (1981) achieved a slight crop suppression for two/three weeks after foliar sprays of ethephon or chlormequat, which was compensated within 4 to 6 weeks.

While it can be reasonably concluded that a concentration range between 250

to 500 ml per hectare will be the optimal in the case of Hormonol, in the case of Fitohorm, it has to be ascertained as even at 10 l ha⁻¹, the yield has shown increase.

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EFFECT OF ZINC NUTRITION ON COCONUT YIELD IN A ZINC DEFICIENT SOIL

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ABSTRACT

An experiment conducted at the Coconut Research Station, Veppankulam, Tamil Nadu, representing East Coast belt indicated that application of 200 g $\text{ZnSO}_4 \cdot 7 \text{H}_2\text{O}$ tree/year was effective in ameliorating zinc deficiency besides increasing the nut yield of coconut palms to the extent of 49.7%. Nut characters were not altered by the treatment.

INTRODUCTION

In recent years, much emphasis is being given to micronutrient application for maintenance of good performance and quality produce in crop plants. The evolution of high yielding and fertilizer responsive varieties and increased use of inorganic major nutrients such as NPK are reported to aggravate the micronutrient problems of plants (Kamaladevi *et al.*, 1975). Though reports on effect of micronutrients on yield of annual crops are plenty, they are rare in this perennial crop. However, a few reports reviewed the literature on nutrient deficiencies in coconut palm (Joshi, 1959, Anon. 1969., Kamaladevi *et al.*, 1975 and Wahid *et al.*, 1981, Wahid, 1984). It was concluded that the most practical approach of diagnosis of deficiencies is through visible assessment for characteristic symptoms. An attempt was made to ameliorate the micronutrient deficiency of East Coast soil by applying the deficient trace element and studying its effect on the nut yield of coconut. The results are presented in this paper.

MATERIALS AND METHODS

The experiment was conducted at the Coconut Research Station, Veppankulam, representing East Coast belt of coconut growing region of Tamil Nadu. Soil and leaf samples collected from different blocks of the station were subjected to chemical analysis to understand the pretreatment status of micronutrients, *viz.*, Cu, Zn, Fe and Mn, for which the leaves were suspected to exhibit deficiency symptoms. As the leaves were found deficient in Zn and Cu, six treatments *viz.*, (i) 100 g $\text{ZnSO}_4 \cdot 7 \text{H}_2\text{O}$ (ii) 200 g $\text{ZnSO}_4 \cdot 7 \text{H}_2\text{O}$ (iii) 300 g of $\text{ZnSO}_4 \cdot 7 \text{H}_2\text{O}$ (iv) 100 g $\text{CuSO}_4 \cdot 5 \text{H}_2\text{O}$ (v) 200 g of $\text{CuSO}_4 \cdot 5 \text{H}_2\text{O}$ and (vi) Control were chosen. Each chemical treatment at the above rates per palm was applied on 2 palms of East Coast Tall. The palms were selected in such a way that their mean annual yield do not vary significantly among themselves. Each treatment was replicated five times. The micronutrient application was made over and above the recommended dose of 50 kg Green manure + 600 g N + 320 g

P_2O_5 + 1200 g K_2O per palm per year. While the major nutrients were applied in two splits July and January, the full dose of micronutrient was incorporated in soil along with the first dose of major nutrients in July. The experiment was initiated in 1981 and continued till 1985.

Data on cumulative yield of nuts, nut characters, whole nut weight, dehusked nut weight, kernel weight and thickness of kernel were recorded. Data on nut yield was subjected to covariance analysis, considering the pretreatment yield of eight years from 1974-1981 as the independent variable over which the post treatment yield (dependent variable) of 4 years from 1981-85 was regressed upon (Panse and Sukhatme, 1967). The leaf samples collected from the 14th leaf starting from the first fully opened one (Chapman, 1964) were oven dried and powdered. A portion of the homogenous powdered samples was digested with diacid and analysed for Zn, Cu, Fe and Mn by Atomic Absorption Spectrophotometer.

RESULTS AND DISCUSSION

The mean nut yield/palm and the nut

characters are presented in Table I. It is seen that application of 200 g $ZnSO_4 \cdot 7H_2O$ increased the nut yield of coconut significantly. This treatment has recorded mean annual yield of 103.82 nuts/palm which was 49.7% higher than that of control. The nut characters did not differ significantly between the treatments indicating that the application of Zn and Cu did not have any deleterious effect on the nut components studied. The micronutrient contents of the coconut prior to the treatment and also the post treatment period (Table II) revealed that the contents of Zn, Cu and Fe were increased substantially due to the treatment of Zn and Cu and on the other hand Mn contents have considerably reduced. The Fe contents have increased significantly due to the treatment of Zn which may be attributed to the possible synergistic effect of Zn on Fe. Bodin (1929) has reported that the application of iron salts increased the yield of palms growing in carol islands.

The improvement in yield is possibly due to the increase in Zn content in the palms which enhances favourable physio-

Table I. Mean nut yield and nut characters of palms under different treatments.

Treatment tree/year	Mean nut yield/ No./palm	Whole nut weight (g)	Dehusked nut weight (g)	Kernel weight (g)	Kernel thickness (cm)
100 g $ZnSO_4 \cdot 7H_2O$	84.67(122.1)	778	471	251	1.13
200 g $ZnSO_4 \cdot 7H_2O$	103.82(149.7)	678	417	245	1.09
300 g $ZnSO_4 \cdot 7H_2O$	93.06(134.2)	569	319	180	1.01
100 g $CuSO_4 \cdot 5H_2O$	76.47(110.2)	685	414	237	1.12
200 g $CuSO_4 \cdot 5H_2O$	84.02(121.1)	832	478	270	1.13
Control	69.37(100.0)	698	408	229	1.03
SE	13.40(19.3)	37	23	12	0.02
CD (P=0.05)	28.05(40.4)				

Values in parenthesis refer to percentage over control.

Table II. *Micronutrient content in leaf samples of coconut.*

Particulars	Micronutrient content (ppm)			
	Zn	Cu	Fe	Mn
Pretreatment	18.7	8.3	148.1	324.0
Post treatment Control	27.7	11.1	179.9	136.6
100 g ZnSO ₄ . 7 H ₂ O	30.5	13.3	227.7	127.9
200 g ZnSO ₄ . 7 H ₂ O	30.8	11.1	254.5	172.3
300 g ZnSO ₄ . 7 H ₂ O	36.1	11.1	239.8	193.2
100 g CuSO ₄ . 5 H ₂ O	27.4	13.3	202.6	156.6
200 g CuSO ₄ . 5 H ₂ O	25.2	12.2	201.9	113.1
SE	3.47	0.89	12.02	23.62
CD (P=0.05)	—	—	35.36	—

logical reactions. Kamala Devi *et al.*, (1979) reported that coconut palms tend to absorb more of Zn and Cu when increasing NPK. Continuous application of NPK fertilizers over the years without supplementing with micronutrients might have tended to lower the available Zn and Cu in the soil under study, which when amended, resulted in their increased availability with a consequent increase in nut yield. The element Cu although did not increase the nut yield, it increased its content in the leaves. Thus, the application of ZnSO₄. 7 H₂O at 200 g/palm/year would be useful in Zn deficient soil to overcome the deficiency and enhance the coconut yield.

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SOLUTE ACCUMULATION AND VARIETAL ADAPTABILITY TO DROUGHT IN COFFEE

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ABSTRACT

The differential behaviour of the coffee cultivars in making osmotic adjustments (osmo-regulation) by the accumulation of free proline, nitrogen, potassium, calcium, phosphorus and carbohydrates in similar condition under water deficit was investigated. Cultivars tolerant to drought have shown high osmotic adjustments by accumulating the solutes significantly. Among the seven arabica cultivars screened, Selections 10, 4 and 1 were found to be more drought tolerant than Selections 11, 5, 6 and 8.

INTRODUCTION

Osmotic adjustment occurs in some species and cultivars in response to water stress (Acevedo *et al.*, 1979; Cutler *et al.*, 1980; Morgan, 1980; Turner and Jones, 1980; Venkataramanan, 1985). Osmotic adjustment as defined by Turner and Jones (1980) refers to net accumulation of solutes, causing a lowering of osmotic or solute potential in response to water deficit or salinity. Generally a range of solutes accumulate during osmotic adjustment in both fully expanded and growing tissues, the solute can include inorganic ions, soluble carbohydrates and amino acids (Acevedo *et al.*, 1979; Boyer and Mayer, 1979; Munns *et al.*, 1979; Raven *et al.*, 1979; Jones *et al.*, 1980). In the present study, accumulation of these solutes in response to moisture stress was studied in seven cultivars of arabica coffee.

MATERIALS AND METHODS

About eleven months old seedlings of

Selection (Sln.) 1 (*Coffea arabica* Cv. S.288), Sln. 4 (*Coffea arabica* Cv. Tafari-kela), Sln. 5 (Devamachy $\times$ *C. arabica* Cv. S.881), Sln. 6 (*Coffea canephora* Cv. S.274 $\times$ *C. arabica* Cv. Kents), Sln. 8 (Hybrido de-Timor), Sln. 10 (*Caturra* $\times$ *Cioccie*) $\times$ (*Caturra* $\times$ S. 795) and Sln. 11 (*C. liberica* $\times$ *C. eugenioides*) were transplanted to a secondary bed containing a mixture of jungle soil and farm yard manure. The seedlings were planted 20 cm apart in groups of three to four cultivars, comprising one seedling from each cultivar to avoid the variation in soil condition. The beds were completely exposed to the full daylight. The seedlings were allowed to stabilize in the new condition for a month. The moisture level of the secondary beds was maintained to the field capacity by regular watering. During the experimental period the weather was completely dry.

Moisture stress was induced by withholding watering. Estimation of free pro-

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line content (Bates *et al.*, 1973) in leaf, stem and root was carried out in the fresh samples on the zero day and twenty days after imposing moisture stress. The bed was reirrigated to field capacity immediately after the second sampling and the moisture level was monitored. Fifteen days after alleviation of stress, the estimations were repeated. Soil moisture was determined at the time of all the samplings.

For estimations on the respective days, the samples were drawn around 9 AM. On the day of sampling, six seedlings from each cultivars were uprooted and two seedlings were pooled for each replication. Each cultivar was replicated thrice. The above experiment was conducted in a split plot design.

After the completion of estimations in

the fresh samples, remaining samples were dried in a hot air oven at 100°C for 72 hours. The dried samples were powdered in a powdering mill and used for analysis. Nitrogen was analysed by Micro-Kjeldahl method; estimation of potassium and calcium by using flame photometer, phosphorus and total carbohydrates by following the method of Watanabe and Olsen (1965) and Somogyi (1952) respectively were carried out. Statistical analyses were carried out following the method of Sundaraj *et al.* (1972).

RESULTS

Soil moisture:

Before imposing stress, the soil moisture was maintained at the field capacity (17.6%). Ten days after imposing moisture stress, the soil moisture decreased to 11% and at this moisture

Table I. Changes in proline content ($\mu\text{g g}^{-1}$ DW) at wilting and after alleviation of stress.

Cultivars	Samplings											
	Before stress				At Wilting				After Alleviation of Stress			
	Leaf	Stem	Root	Mean*	Leaf	Stem	Root	Mean*	Leaf	Stem	Root	Mean*
SLN.1	603	156	267	342	1177	471	473	707	384	23	43	150
SLN.4	426	153	211	263	938	414	284	545	277	71	76	142
SLN.5	739	236	378	451	1114	372	232	573	303	86	247	212
SLN.6	565	130	369	355	1004	572	415	664	604	144	235	327
SLN.8	803	186	459	483	1194	292	246	577	635	105	212	318
SLN.10	455	95	249	266	1166	362	207	578	303	111	178	197
SLN.11	809	232	376	472	1360	426	339	708	1207	390	429	675

*To compare the difference of means

	CDat	
	5%	1%
Between cultivars	97.65	136.90
Between samplings	61.13	82.47
Between samplings in a particular cultivar	161.72	218.18
Between cultivars in a particular or different samplings	164.10	224.11

level 50% of selections (Sln.) 5, 6 and 11 showed incipient wilting. Sln. 8 showed wilting symptoms twelve days after imposing the stress. When the soil moisture decreased to 7.8%, twenty days after imposing stress, Sln. 10, 4 and 1 showed wilting symptoms. By alleviating stress, the plants were brought back to normal condition.

Free proline accumulation:

Proline accumulation showed highly significant differences among cultivars, samplings and interactions in the seedlings. At the time of wilting, all the cultivars showed highly significant increase in proline in all the plant parts. In general, accumulation was found to be more in the leaves than in other parts. After alleviation of stress, proline content decreased significantly (Table I).

When the mean accumulation of proline per cultivar was considered from 0 to 20 days after stress, maximum accumulation was seen in Sln. 10 (2.17 fold), followed by Sln. 4 and 1 (2.07 fold). Minimum accumulation was observed in Sln. 8 (1.19 folds) (Table II).

Table II. *Increase in proline content* of the seedlings at wilting (from 0 to 20 days after stress).*

Cultivars	Number of folds
SLN.1	2.07
SLN.4	2.07
SLN.5	1.27
SLN.6	1.87
SLN.8	1.19
SLN.10	2.17
SLN.11	1.50

* $\mu\text{g g}^{-1}\text{DW}$

Nitrogen accumulation:

Nitrogen content was found to increase in all cultivars except in Sln. 6 (Table III). In general stem and leaf have shown more accumulation than the root.

Potassium accumulation:

Potassium content increased during stress in Sln. 4 and Sln. 5 (Table III). However leaf potassium was found to increase in Sln. 8 (0.33%), 10 (0.26%), 5 (0.20%), 4 (0.13%) and 6 (0.07%) (Table IV).

Calcium accumulation:

Calcium content increased during

Table III. *Changes in nitrogen, potassium, calcium, phosphorus and total carbohydrate content (%) of seedlings during moisture stress.*

Cultivars	Before Stress					At Wilting				
	N	K	Ca	P	T.C.*	N	K	Ca	P	T.C.*
SLN.1	2.15	2.38	0.30	0.17	8.10	2.38	2.22	0.36	0.17	9.43
SLN.4	2.39	1.51	0.23	0.15	6.70	2.61	1.56	0.43	0.13	7.87
SLN.5	2.16	1.33	0.27	0.14	8.96	2.23	1.44	0.47	0.13	7.42
SLN.6	2.53	1.60	0.21	0.14	7.88	2.40	1.31	0.36	0.16	7.21
SLN.8	2.46	1.62	0.75	0.18	10.32	2.50	1.53	0.83	0.19	10.63
SLN.10	2.66	1.60	0.72	0.17	11.01	2.68	1.47	0.87	0.20	10.41
SLN.11	2.37	1.58	0.64	0.18	11.17	2.49	1.13	0.82	0.17	10.46

*T.C.: Total Carbohydrates

Table IV. *Changes in solutes of leaves from 0 to 20 days after imposing moisture stress.*

Cultivars	Increase (+)/Decrease (-) of Solute at Wilting					
	Proline ($\mu\text{g g}^{-1}$ DW)	Nitrogen (%)	Potassium (%)	Calcium (%)	Phosphorus (%)	Total Carbo- hydrates (%)
SLN.1	+574	-0.06	-0.33	+0.13	-0.01	+2.16
SLN.4	+512	+0.17	+0.13	+0.40	-0.03	+2.13
SLN.5	+375	+0.23	+0.20	+0.52	Nil	-1.50
SLN.6	+439	-0.35	+0.07	+0.37	+0.01	-0.29
SLN.8	+391	0.24	+0.33	+0.26	Nil	+0.63
SLN.10	+711	+0.19	+0.26	+0.18	+0.01	-0.58
SLN.11	+551	+0.08	-0.26	+0.51	-0.01	Nil

stress in all the cultivars and particularly more in leaves than in stems and roots. Sln. 4 and 5 showed maximum increase of calcium content (0.20%), followed by Sln. 11 (0.18%) and 10 (0.15%) (Table III).

Phosphorus accumulation:

Mean phosphorus content per seedling increased more in Sln. 10 than in other cultivars (Table III). However significant accumulation of phosphorus could not be observed in leaves of all the cultivars.

Carbohydrates accumulation:

Accumulation of mean total carbohydrates was observed in Sln. 1 (1.33%), 4 (1.17%) and 8 (0.31%), whereas there was a decrease in carbohydrate content of Sln. 5 (1.54%), 11 (0.71%), 6 (0.67%) and 10 (0.60%). Initial content of carbohydrates was high in Sln. 11 and 10 (Table III).

Solute accumulation of leaves:

Table IV shows the pattern of accumulation of solutes in leaves of all the cultivars. More accumulation of solutes is seen in Sln. 10, 4 and 1 than in other cultivars.

DISCUSSION

Varieties of crop species or different crop species are known to show differential capability of tolerance to moisture stress conditions (Blum, 1974; Mehkri *et al.*, 1977).

The osmoregulatory role of proline accumulation under stress has been suggested by several workers (Stewart and Lee, 1974; Munns *et al.*, 1979). Plants with high proline accumulation are known to be drought tolerant; hence attempts have been made to evaluate the genotype of crop species based on their ability to accumulate free proline under moisture stress and to contain less proline on alleviation of stress (Blum and Ebercon, 1976; Mehkri *et al.*, 1977).

In the present study it is very interesting to note the differential behaviour of the cultivars in the accumulation of proline. Selections 10, 4 and 1 show more accumulation of free proline than other cultivars. Such differential accumulation among species and varieties are also reported earlier (Singh *et al.*, 1972; Richards, 1978; Venkataramanan, 1985).

In addition to the function of proline as hydrophylic colloid; its high solubility, ability to induce heat stability of enzymes (Paley *et al.*, 1981), serving as a respiratory substrate (Blum and Ebercon, 1976) and higher diffusivity (Chari *et al.* 1984) suggested that proline is a highly compatible solute.

All the cultivars except Sln. 6 showed nitrogen accumulation during stress. Hanson and Hitz (1981) have also observed accumulation of nitrogen to some extent in water stressed plants. Nitrogen acts as regulatory element along with potassium by influencing stomatal opening of coffee leaves (Kumar, 1979).

Selections 8, 10, 5, 4 and 6 accumulate potassium during stress. This can also contribute largely to the solute potential of the tissue (Munns *et al.*, 1979). Potassium content will provide better gradient for movement and uptake of water.

Calcium accumulation in Sln. 4, 5, 10, and 6 has the ability to maintain the integrity of the membrane (Stadelmann and Stadelmann Lee, 1974).

Sln. 10 accumulates phosphorus during stress. Phosphorus is reported to be capable of increasing drought resisting properties of plants (Stocker, 1960).

Eventhough Sln. 11 and Sln. 10 have higher initial carbohydrate content than other cultivars, these cultivars do not accumulate carbohydrates during stress. This may be due to the normal utilisation of photosynthates by these cultivars, and may help the proline synthesis by supplying needed precursors through oxidation

of sugars. Contrary to this, Sln. 1, 4 and 8 accumulate carbohydrates during stress. When water stress-adapted and non-adapted cotton plants were subjected to water stress, more accumulation of glucose and starch were observed in adapted plants than non-adapted plants (Ackerson, 1981). Similarly Acevedo *et al.* (1979) observed that soluble sugars mainly non-reducing sugars accounted for most of the observed decrease in leaf osmotic potential in sorghum.

Thus more accumulation of free proline, nitrogen, potassium, calcium, phosphorus and carbohydrates in Sln. 10, 4 and 1 may be due to the osmotic adjustments in these cultivars which have as a major consequence the maintenance of leaf turgor (Hanson and Hitz, 1982). Such osmotic adjustments are reported by Venkataramanan (1985) in arabica cultivars Sln. 9 and Sln. 7.3.

This study has indicated that Sln. 10, 4 and 1 are more tolerant to drought than selections 11, 5, 6 and 8.

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BIOCHEMICAL COMPOSITION OF VASCULAR SAP FROM THE INFLORESCENCE OF APPARENTLY HEALTHY AND ROOT (WILT) DISEASED COCONUT PALMS

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ABSTRACT

Vascular sap was collected from the inflorescences of apparently healthy and root (wilt) diseased coconut palms under aseptic conditions. The pH of the sap ranged from 6.8 to 7.5. Osmotic concentration was lower in the sap from the root (wilt) affected palms (540-620 m moles/kg) while apparently healthy palms showed higher values (790-850 m moles/kg). Direct analysis of the sap for the biochemical constituents, viz. sugars, protein, free amino acids, lipids and sterols showed discernible difference between the healthy and diseased palms. The major amino acids, sugars and organic acids were detected in the sap based on chromatographic studies. The possibility of utilising this data in preparing the media for culturing mycoplasma like organisms is discussed.

INTRODUCTION

Association of mycoplasma like organisms (MLOs) has been shown in root (wilt) disease of coconut (Solomon *et al.*, 1983) as is the case with lethal yellowing disease of coconut in Jamaica (Beakbane *et al.*, 1972). These organisms are restricted to the phloem sieve elements of sink areas such as rachilla of unopened inflorescence, apical meristem, petiole of developing leaves and root apices (Plavsin Benjac *et al.*, 1972; Solomon *et al.*, 1983). These fastidious organisms requiring special nutritional and environmental conditions are not readily amenable to cultivation in *in vitro* systems. Studies on the analysis of the sap were

carried out by earlier workers to understand the biochemical/nutritional requirement of the organisms (Stemmer *et al.*, 1982). In this study, an attempt has been made to determine the composition of the vascular sap and assess the physical and chemical parameters so that a medium akin to the sap could be synthesised for the culturing of the organisms.

MATERIALS AND METHODS

Seven healthy coconut palms (*Cocos nucifera* L. var. West Coast Tall) and seven root (wilt) diseased palms with disease index 11-20, grown in the Institute campus were selected for the collection of the vascular sap. Unfermented sap

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was collected from the inflorescence under aseptic conditions as per the method standardised earlier (Rajagopal, *et al.*, unpublished).

Frozen sap thus collected, was immediately brought to laboratory, thawed and the volume measured. The pH and osmotic concentration of the sap was measured, using a Beckman pH meter and Wescor vapour pressure osmometer respectively. Fermentation of the sap was judged by odour and determination of pH.

Aliquots from the fresh sap were used for the analysis of the biochemical constituents. Protein was estimated from the sap by Folin-Dennis method (Lowry *et al.*, 1951) after precipitating the protein in trichloroacetic acid and dissolving in dilute alkali. Total sugars were estimated directly by the phenol-sulphuric acid method (Dubois *et al.*, 1951) and reducing sugars by the modified method of Nelson (1944). The levels of free amino acids in the sap were determined by the method of Moore and Stain (1948). Modified Sakaguchi's method was used to estimate arginine levels in the sap (Mcpherson, 1942) and phenols by the Folin-Ciocalteu method (Bray and Thorpe, 1954.)

For the extraction of total lipids, the sap was treated with chloroform: methanol mixture (3:1) twice, pooled and evaporated to dryness. The lipids were estimated gravimetrically. The extracts were saponified by adding 3 KM KOH at 80°C for 2 hours. Sterols, which come under nonpolar saponified lipids were extracted with petroleum ether, volume decreased

by evaporation and estimated colorimetrically (Abell and Kendak, 1952).

The sap samples were fractionated through Dowex columns after concentrating them with insoluble polyvinyl pyrolidone (PVP). The resins - Dowex - 50 X₈ (H⁺, 200-400 mesh) and Dowex-1 X₈ (Cl⁻, 200-400 mesh) - were used for fractionation in 1×6 cm columns by a modification of the method of Canvin and Beevers (1961). Three fractions were collected, comprising aminoacids (basic fraction), sugars (neutral fraction) and organic acids (acidic fraction). The fractions were lyophilised and aliquots of the water extracts were used for further chromatographic studies.

Cellulose coated plates (1 mm thick) were used for the detection of aminoacids with solvent system Butanol:acetic acid: water (4:1:1). Sugars and organic acids were detected by paper chromatography using Whatman No. 1 filter paper. The solvent systems used were Butanol:Acetic acid:Water (4:1:1) and Ethanol:Water: Ammonia (100:12:16) respectively. The spots in all cases were identified based on the R_f values of authentic standards.

RESULTS

The pH and osmotic concentration of the sap from diseased and healthy palms are presented in Figs.1 and 2. The average value of the pH of the sap from healthy palms was always less (6.1-6.4) than that from diseased palms (6.9-7.2). In general, the pH of the sap collected during night in both diseased and healthy palms was less as compared to the day collections. Similar trend was also observed in the case of lethal yellowing in Jamaica (Milburn and Zimmermann,

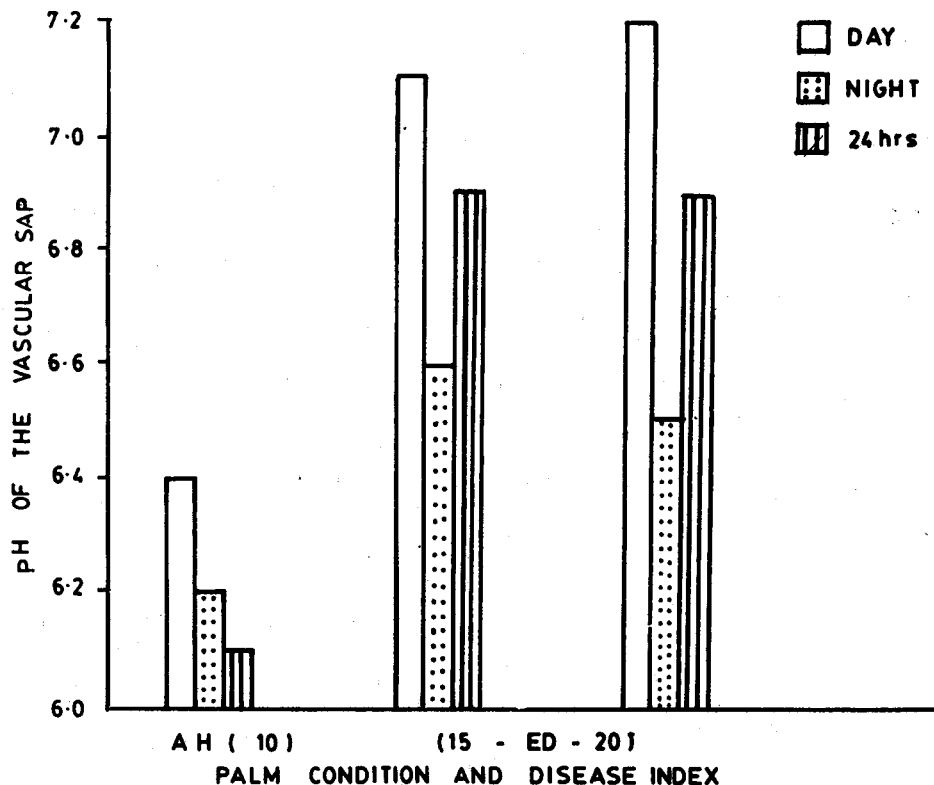


Fig. 1. pH of the vascular sap collected from the inflorescence of diseased and healthy coconut palms.

1977; Edengreen and Waters, 1982).

The osmotic concentration of the sap from healthy palms was higher than that from diseased palms both during day and night. (Fig. 2). Though the values for osmotic concentration of the sap from healthy palms differed between day and night, in diseased palms it was invariably higher during night.

Table I shows in detail the levels of the biochemical constituents present in the sap from healthy and diseased palms. Most of these constituents show marked differences between healthy and diseased palms. Thus proteins, phenols, reducing

Table. I. *Biochemical constituents of vascular sap.*

(Values expressed as mg. g⁻¹ sap solids)

Constituents	Apparently healthy	Diseased
Total sugars	299.50	286.20
Reducing sugars	98.10	65.90
Proteins	4.90	2.50
Free aminoacids	45.90	18.30
Arginine*	0.41	0.68
Phenols	0.60	0.20
Lipids	0.83	0.57
Sterols*	0.40	0.22

*Values expressed as mg. ml⁻¹ sap.

sugars, free amino acids, lipid components and sterols were found to be in

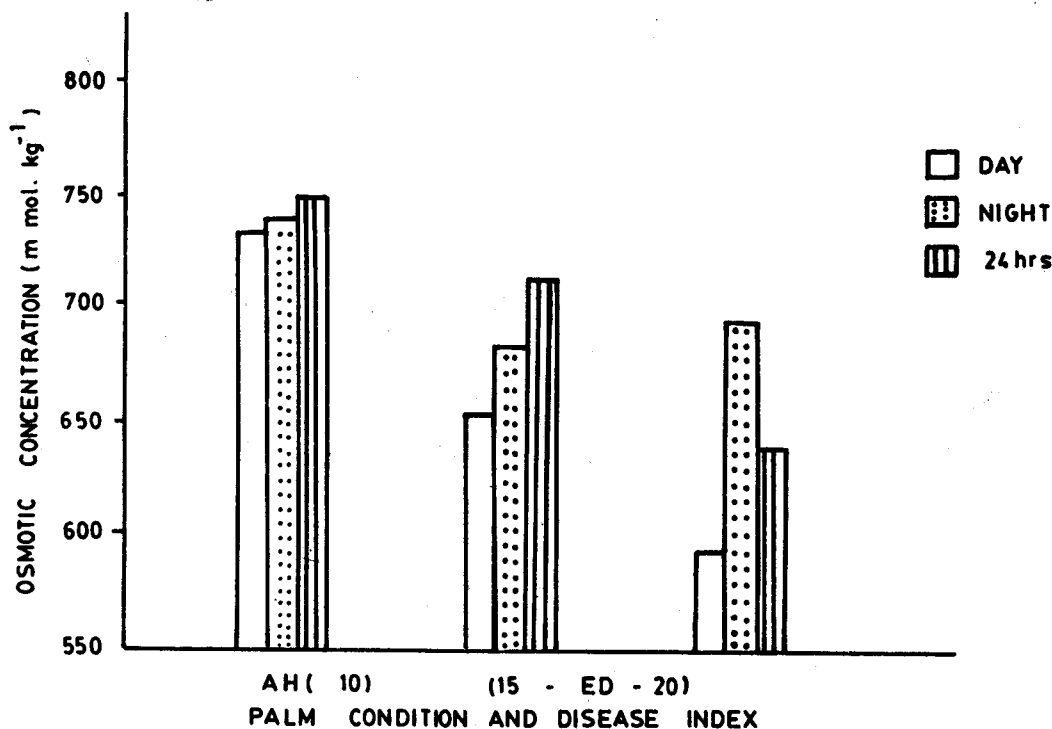


Fig. 2. *Osmotic concentration of the vascular sap collected from the inflorescence of diseased and healthy coconut palms.

lesser quantity in the sap of diseased palms as compared to healthy. Interestingly, arginine levels were found to be more in the sap from diseased palms even though the total free amino acids were less.

The following individual amino acids, organic acids and sugars could be detected in the sap from both healthy and diseased palms. The amino acids were: Cysteine, Cystine, Arginine, Serine, Alanine, Tyrosine, Glutamic acid, Aspartic acid, Methionine and Isoleucine. The organic acids were Malic acid, Fumaric acid, Succinic acid, Maleic acid and Lactic acid and sugars were Sucrose, Glucose, Fructose, Raffinose, Galactose and Lactose. On comparison, no qualita-

tive difference was seen between healthy and diseased palms. The quantification of these parameters is underway to arrive at a detailed account of the composition.

DISCUSSION

The lower osmotic pressure in the sap collected from diseased palms as compared to healthy indicates the concentration of the constituents like sugar fractions, organic and amino acids which contribute to solute concentration. This solute concentration is dependent on xylem pressure potential which showed difference between healthy and diseased (Rajagopal *et al*, unpublished). Similar trend in osmotic concentration was seen in lethal yellowing disease too (Eden-green and Waters, 1982).

The lower content of the major biochemical constituents in the sap from diseased palms might be possibly due to the higher rate of utilisation by MLOs associated with the disease, for their growth and multiplication. This lower solute concentration is reflected in the lower osmolarity of the sap from diseased palms. These observations assume significance in the light of the findings on the culturing of the citrus stubborn organism (*Spiroplasma citri*) which could be achieved by enhancing the osmolarity of the culture media with compounds like sorbitol and other sugars (Saglio *et al.*, 1971).

Mycoplasma like organisms do not possess a cell wall, unlike all other prokaryotes. Mostly, lipids especially glycolipids, phospholipids and lipopolysaccharides and proteins constitute the cell membrane (Razin, 1975; Kahane and Marchesi, 1973; Smith *et al.*, 1976). Since these organisms are phloem limited, the lipid and protein components, of the diseased sap may be utilised for constituting the plasma membrane, thereby resulting in the presence of lower quantities in the sap. In addition, the mycoplasmas and spiroplasmas have an absolute growth requirement of sterols (Stemmer *et al.*, 1982) in forming the lipid bilayer of the cell membrane (Rotham and Lenard, 1977). In the present case, the lower content of the sterols in the sap can be explained on the basis of higher utilisation by the MLOs for their cell membrane growth.

In contrast, arginine levels were high in the sap from diseased palms, as reported earlier (Pillai and Shanta, 1968). Arginine dihydrolase pathway has been pro-

posed as the major energy source for the growth of the organism, in some non-fermentative mycoplasmas (Schmike *et al.*, 1966) which has been confirmed by other workers too (Razin, 1969; Fenske and Kenny, 1976). In this case, the presence, of higher levels of arginine in the sap from diseased palms might provide a constant energy supply in the form of ATP, for the growth of MLOs, by entering the dihydrolase pathway. Further studies to substantiate the hypothesis are in progress.

Thus, the present study reveals an overall picture of the nature and composition of the vascular sap, which with further quantification will help in formulating appropriate media for *in vitro* culturing of MLOs associated with the disease.

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PHYSIOLOGICAL STUDIES ON ROOT(WILT) DISEASED COCONUT PALMS UNDER DIFFERENT MANAGEMENT PRACTICES

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ABSTRACT

Studies were undertaken in farmers' fields on root (wilt) diseased coconut palms maintained under well managed, moderately managed and poorly managed conditions. Physiomorphological characters and disease index were recorded at half yearly intervals for five years.

Diseased palms responded markedly to good management, as indicated by a decline in disease index (40% improvement over pre-treatment conditions). The overall improvement was brought about by decrease in the intensity of flaccidity symptom, enhanced greenness of leaves, reduction in leaf rot and necrosis and a fall in the rate of leaf senescence. There was only marginal improvement in palms under moderately managed conditions. while those under poor management had greater tendency of deterioration. The efficacy of scientific management practices in the root(wilt) affected garden is highlighted.

INTRODUCTION

In Kerala, one of the reasons attributed to the decline in the yield of coconut is the prevalence of root(wilt) disease in eight districts (Anonymous 1985). The disease is characterised by the flaccidity of leaflets of middle and outer whorl of leaves as the primary symptom, while yellowing and necrosis are the associated symptoms (Radha and Lal, 1972). Based on the intensity of symptoms the disease index was worked out and palms categorized as apparently healthy, diseased early, middle and advanced (George and Radha, 1973). Reduction in nut yield in the disease affected palms was found to be proportionate to the intensity of the disease (Anonymous, 1976).

In the absence of specific measures for control of the disease, adoption of management practices gains significance. The importance of fertilizer management, inter and mixed cropping with compatible crops and mixed farming in root(wilt) affected gardens to check the loss due to the disease was highlighted (Pillai *et al.*, 1981). While most of the studies were carried out in the Institute's Farm with known history of palms, recommended spacing, cultural operations and fertilizer application, there was no information on the response of palms in the farmers' plots to the management practices. As the farmers field conditions with various limitations of cultivation, offer ideal situations to study the efficacy of scientific management, investigations were

undertaken for five years (1981-1985) in small landholdings. The main objective of this pilot experiment was to compare the performance of palms under the recommended practices of management like irrigation fertilizer application, and prophylactic spray with that of palms under farmer's practices, as this comparison would help to know the extent to which the yield potential of diseased palms could be enhanced. It was also intended to be a demonstration experiment for educating the farmers. This paper offers physiological explanation for the changes in disease index under different management practices.

MATERIALS AND METHODS

Coconut palms were selected from four farmers' plots in Memana, Krishnapuram village, 4 km from the Institute. Sixty palms (27 apparently healthy and 33 diseased) were selected in two farmers' plots for summer irrigation (I_1F_1) and another sixty palms (14 and 46) in two other plots were maintained as rainfed (I_0F_1). Twenty palms (6 and 14) were selected to represent farmers' own management practices without imposing any treatment (I_0F_0). The palms were subjected to randomized selection for the treatments and indexed for the pre-treatment disease condition.

Irrigation schedule: Summer irrigation was given in the basins of sixty palms at weekly intervals at the rate of 250 litres per palm from January to May. Basins were covered with dry coconut leaves as much. Irrigation schedule was adjusted if there was rainfall during the period.

Fertilizer treatment: All the 120 palms (both irrigated and rainfed) received the

fertilizers at the rate of N:0.5 kg; P_2O_5 : 0.32 kg; K_2O : 1.2 kg; CaO: 1.0 kg and $MgSO_4$: 2.0 kg per palm as split doses during May-June and October-November. Cowdung was added at the rate of 50 kg per palm during October-November. Cultural operations like cleaning the basins and weeding were carried out at intervals. All the 120 experimental palms were given prophylactic spray with Bordeaux mixture twice a year (pre and post monsoon).

Physio-morphological observations: At half yearly intervals (December-January and June-July) following physio-morphological characters were recorded for all the 140 palms (including 20 palms under control I_0F_0); total number of leaves, rate of leaf production (by tagging first fully open leaf at each observation), number of flaccid leaves, number of yellow leaves, number of rotten leaves, number of senescent/dry leaves and condition of the spindle leaf.

Disease index of the palms was recorded at half yearly intervals based on flaccidity, yellowing and necrosis symptoms (George and Radha, 1973) for all the 140 palms. Data were statistically analysed using the 't' test.

As the paper deals with disease index, the results obtained with diseased palm (33, 46 and 14 respectively under the three treatments) alone are given in Table I. Since the preliminary analysis of data has shown that palms with disease index above 50% i.e. advanced stage of the disease did not respond to management practices, the index values for early and middle stages of disease are combined and the mean given in Table II.

Table I. *Effect of summer irrigation on the condition of root (wilt) diseased coconut palms (Final picture at the end of five years).*

Treatment	No. of palms observed	No. of palms showing		
		improvement*	deterioration**	No change
I ₁ F ₁	33	23(69.7)	5(15.1)	5(15.1)
I ₀ F ₁	46	14(30.4)	20(43.4)	12(26.2)
I ₀ F ₀	14	2(14.3)	11(78.5)	1(17.2)

Values in brackets indicate the percentage on total number of palms observed.

*Improvement refers to decline in disease index over pre-treatment.

**Deterioration means increase in disease index over pre-treatment.

RESULTS

The overall condition of the root(wilt) diseased coconut palms as a result of five years' irrigation treatment is given in Table I. It is evident that under well managed conditions (I₁F₁), 69% of the palms exhibited improvement in the health of the palm as indicated by a decline in disease index over pre-treated conditions. Even the fertilizer treatment alone (I₀F₁) brought about some improvement (30.4%), but it was less than that obtained when combined with irrigation. A natural improvement of 14.3% of palms was noticed even under farmers' practice of cultivation. That the adoption of

balanced management (I₁F₁) would ensure about five-fold improvement (69% as against 14%) in the condition of palms is evident. Deterioration of palms was more under farmers' practices (78.5%) than under fertilizer treatment alone (43.4%) and under well managed conditions (15.1%) treatments.

When the performance of palms under the three treatments was compared year-wise, it was clear that irrigation had brought about marked improvement of about 50% (i.e. decline in disease index from 22.1 in 1980 to 13.2 in 1985) from fourth year onwards, though there was

Table II. *Response of root (wilt) diseased coconut palms to management practices. (Comparison of disease index of palms between treatments over five years).*

Treatment	1980 Pre.	1981	1982	1983	1984	1985
I ₁ F ₁	22.1 (100%)	18.3 (82.8)	22.3 (100.9)	19.9 (90.0)	11.4 (51.6)	13.2 (59.7)
I ₀ F ₁	28.9 (100%)	26.5 (91.7%)	32.0 (110.7)	27.7 (95.8)	30.6 (105.9)	34.6 (119.7)
I ₀ F ₀	36.3 (100%)	40.8 (112.4)	40.4 (111.3)	36.8 (101.4)	35.8 (98.9)	41.0 (113.3)

tendency for improvement (10 to 20%) even earlier (Table II). Management of palms only with fertilizers resulted in marginal improvement in the initial stages, but that was not sustained, as the palms tended to show deterioration (i.e. increase in disease index from 28.9 in 1980 to 34.6 in 1985). Under farmers' own practices the palms exhibited either status quo or declined further (36.3 in 1980 to 41.0 in 1985).

Table III gives a critical analysis on the factors contributing to the marked improvement in palms with 1_1F_1 treatment *vis a vis* other treatments. Comparison of the pre and post-treatment values showed that in the irrigated plot there was significant reduction in the number of leaves showing flaccidity (42.9%) yellowing (40.5%) rotting (59.2%) and senescence (39.5%) whereas in the other two

treatments except in the case of flaccidity, there was no improvement in other characters studied (Table IIIa).

When the disease intensity was quantified (i.e. disease index score) and examined, it became apparent that irrigation had resulted in improving all the three disease symptoms namely flaccidity (68.1%) yellowing (70.0%) and necrosis (42.9%) (Table IIIb). It may be noted that under both 1_0F_1 and 1_0F_0 treatments, the palms suffered most with necrosis, followed by yellowing whereas flaccidity appeared to improve either naturally or even with only fertilizer application.

DISCUSSION

It is well established that coconut palms respond favourably to summer irrigation, in as much as the frequency and quantity of water markedly influence the

Table IIIa. *Effect of management practices on the leaf condition (Mean of 15 palms).*

Treatment	Stage	Number of leaves with			
		Flaccidity	Yellowing	Rot	Senescence
1_1F_1	Pre.trt.	13.3	11.6	4.9	4.3
	Post.trt.	5.7 (42.9)	4.7 (40.5)	2.9 (59.2)	1.7 (39.5)
	Diff.	7.7**	6.9**	2.0*	2.60**
1_0F_1	Pre.trt.	18.0	8.6	4.5	3.7
	Post.trt.	12.0 (66.7)	9.3 (108.1)	2.9 (64.4)	3.1 (83.8)
	Diff.	6.0**	-0.7	1.5	0.6
1_0F_0	Pre.trt.	20.4	12.3	5.7	5.1
	Post.trt.	16.0 (78.4)	12.7 (103.2)	5.3 (92.9)	5.7 (11.7)
	Diff.	4.4*	-0.4	0.4	-0.6

Values in brackets indicate percentage on pretreatment.

*Significant at 5%

**Significant at 1%

Table IIIb. *Effect of management practices on the disease intensity.*

Treatment	Stage	Disease index for		
		Flaccidity	Yellowing	Necrosis
I ₁ F ₁	Pre.trt.	6.9	5.0	2.1
	Post.trt.	2.2 (31.9)	1.5 (30.0)	1.2 (57.1)
	Diff.	4.7**	3.5**	0.9**
I ₀ F ₁	Pre.trt.	9.7	4.0	1.3
	Post.trt.	4.5 (46.4)	3.4 (85.0)	2.6 (101.6)
	Diff.	5.2*	0.6	-1.3*
I ₀ F ₀	Pre.trt.	11.3	6.3	1.7
	Post.trt.	9.0 (79.6)	6.4 (101.6)	3.5 (205.9)
	Diff.	2.3	-0.1	-0.8*

Values in brackets indicate percentage on pretreatment.

*Significant at 5%

**Significant at 1%

female flower production and nut yield (Marar, 1963; Venkitesan, 1973, Padmanabhan, 1973, Nelliath and Padmaja 1978 and Bhaskaran and Leela, 1978). As regards the management of root(wilt) diseased coconut palms, Menon and Nayar (1978) reported a slight decrease in the disease index and increase in the mean yield of diseased palms when elephant foot yam was grown as an intercrop. Adoption of mixed farming practice was shown to result in 28% increase in nut yield in disease affected coconut plot (Sahasranaman *et al.*, 1983). The present investigation, with the emphasis on summer irrigation was the first one to be launched in 1980 in farmers' plots afflicted with the diseased palms. In 1982, the scope of the experiments were widened and extended to more farmers' plots (Muraleedharan *et al.* 1986).

That the disease intensity could be drastically reduced by superimposing summer irrigation over the fertilizer application is evident from Tables II and III. This may be due to the fact that irrigation favours the uptake and/or utilization of nutrients. The efficacy of irrigation could be noticed by way of improved water uptake through the newly regenerated roots and lesser transpiration rate in diseased plants (Rajagopal *et al.* 1986a, b).

The fact that all the disease symptoms were brought down by irrigation revealed that the photosynthetic area was considerably enhanced (more greenness), as compared to the situation obtained with other treatments (Table IV). A marked decline in the number of yellow leaves from 11.6 to 4.7 between pre and post-treatment stages (59.5%) improvement

Table IV. *Effective photosynthetic area in root (wilt) diseased coconut palms under different management practices.*Leaf area, m² palm⁻¹

Treatment	Stage	Yellowing	Rot	Senescence	Average
1_1F_1	Pre-treatment	69.5	29.4	25.8	41.6
	Post treatment	28.6	17.4	10.2	18.6
	%	59.4	40.9	60.5	44.7
1_0F_1	Pre-treatment	51.5	27.0	22.2	33.6
	Post-treatment	55.7	17.4	18.6	30.6
	%	108.2	35.6	16.2	91.1
1_0F_0	Pre-treatment	73.7	34.1	30.6	46.1
	Post-treatment	76.1	31.8	34.1	47.3
	%	103.3	106.7	111.4	102.6

(Table IIIa) and a similar situation with rotten and senescent leaves would amount to an increase in all the components of photosynthesis namely chlorophyll content, CO₂ fixation and activities of enzymes. Table IV clearly reveals that there was about 55% improvement in the photosynthetic area between pre and post-treatment stages as a result of irrigation as against only about 10% in palms supplied only with fertilizers.

The persistence of yellowing and necrosis and also leaf rot in palms under 1_0F_1 and 1_0F_0 treatments over the years and their conspicuous decline with irrigation point out the fact that dry conditions probably weaken the tissues and expose them to attack by pathogens, while irrigation improves the health and vigour of palms and thus minimize their proneness to disease. In other words, prophylactic spray with Bordeaux mixture was more effective in controlling leaf rot/necrosis in palms which received summer irrigation than those exposed to rainfed conditions. Water deficit condition is known to be a

predisposing factor for certain of the plant diseases (Ayres, 1978).

It took four to five years for the transformation of whole canopy in diseased palms, as exemplified by steep reduction in the disease index (Table II). It would mean that until the disease-affected leaves complete the cycle of three years before shedding, the real impact of irrigation on the subsequently emerged leaves would not be fully revealed. Highlight of the study is the finding that yellowing and necrosis are the main culprits for the deterioration of the diseased palms and that they can be drastically reduced with suitable management practices (1_1F_1). The overall improvement in the diseased palms was reflected on the female flower production, fruit set (button retention) and nut yield (unpublished).

CONCLUSION

That the diseased palms responded significantly to well managed conditions (1_1F_1), as compared to those maintained

under farmers' practices (I_0F_0) point out clearly the urgent need to popularize among the farmers the scientific management of affected palms to enhance their yield potential and to realize good economic returns.

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AMMONIUM ENHANCES THE NITRATE INDUCED NITRATE REDUCTASE ACTIVITY IN COCONUT (*COCOS NUCIFERA* L.) LEAVES*

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ABSTRACT

Induction of nitrate reductase (NR) activity by nitrate in leaves of low and high yielding coconut palms was markedly different, requiring different levels of nitrate for optimum induction. Ammonium enhanced induction of NR activity by nitrate, under both light and dark conditions. Nitrate uptake was also enhanced in the presence of ammonium in the induction medium. It is postulated that ammonium might bring about the activation of NR by binding to an allosteric site on the enzyme in addition to its role in inducing NR synthesis.

INTRODUCTION

Nitrate reductase (NR) catalyzes the rate-limiting reaction in the reductive conversion of nitrate to ammonium in all higher plants. Nitrate has been shown to induce this enzyme in nearly all systems studied (Beevers and Hageman, 1969). Since ammonium is the end-product of the reaction sequence, it may be expected to exert inhibitory effect on NR. However, the effect of ammonium on NR activity is reported to vary widely ranging from no effect (Beevers *et al.*, 1965; Ingle *et al.*, 1966; Schrader and Hageman, 1967; Oaks *et al.*, 1977) to inhibition (Townsend, 1970; Smith and Thompson, 1971; Radin, 1975; Orebanjo and Stewart, 1975) and even stimulation (Bayley *et al.*, 1972; Mohanty and Fletcher, 1976).

The nitrogen requirement of the coconut palm is 500 g annually. This is given in the form of urea granules twice a

year. Urea undergoes rapid hydrolysis to ammonium in the soil, although the time required for the complete conversion to nitrate takes several days, depending upon the soil conditions. The coconut roots are, therefore, exposed to high concentrations of ammonium.

The present study was taken up to understand the effect of variable concentrations of ammonium on the NR activity and nitrate uptake in excised leaves of coconut.

MATERIALS AND METHODS

Leaf samples for the study were collected from adult palms of West Coast Tall cultivar (WCT) growing in the Institute campus under scientific management. Leaflets from the middle portion on either side of the rachis of leaf no. 14 were wiped clean and incubated with their cut ends dipped in various induction media under subdued light. Samples were

*CPCRI Contribution No. 373.

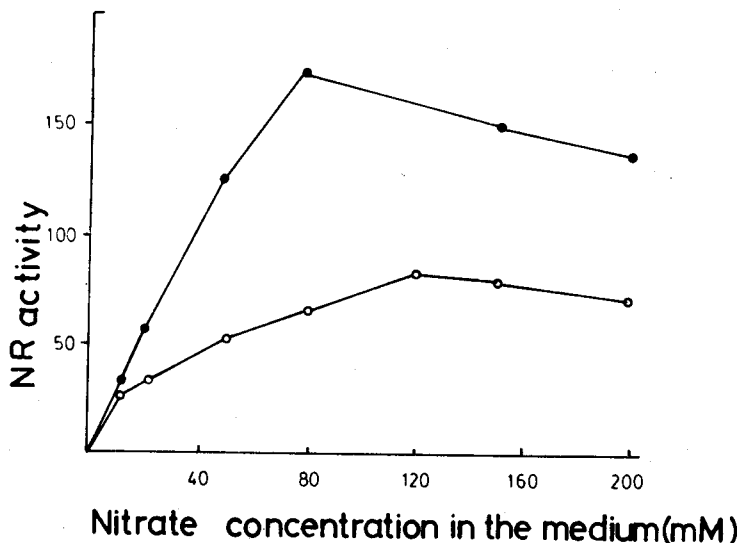


Fig. 1. Effect of increasing nitrate concentration on the leaf NR activity in high (●-●) and low (○-○) yielders.

drawn out at regular intervals for analysis.

Nitrate reductase was assayed *in vivo* by a modified method of Joworski (1971) as described by Shivashankar and Rajagopal (1983).

Nitrate uptake by leaves was determined by floating one gram of the leaf discs on medium containing nitrate for 24 h. The nitrate that disappeared from the medium was determined by spectrophotometry (Cawse, 1967).

RESULTS AND DISCUSSION

Effect of nitrate concentration: The course of enzyme induction at increasing levels of nitrate in the medium is presented in Fig. 1. The induction of NR activity by nitrate in the leaves of high yielders was markedly higher than that in low yielders. The nitrate concentration required for the maximum induction was

much less (80 mM) for high yielders than that for the low yielders (140 mM). Applying Michaelis-Menten postulates, it is found that the K_m for high yielders is relatively lower than that of low yielders. Since, the K_m is a measure of the affinity of the enzymes towards nitrate, it is obvious that the high yielders are able to utilize the available nitrate better than the low yielders. Although, the response of roots to similar conditions has not been studied and the existing soil nitrate levels may be different from the experimental conditions, the results do provide an important insight into the pattern of nitrate utilization, as the level of enzyme is dependent within limits, upon the concentration and rate of supply of the substrate to the tissue.

Effect of ammonium and benzyladenine (BA): Inclusion of ammonium in the induction medium containing nitrate enhanced NR activity up to 6 hours and

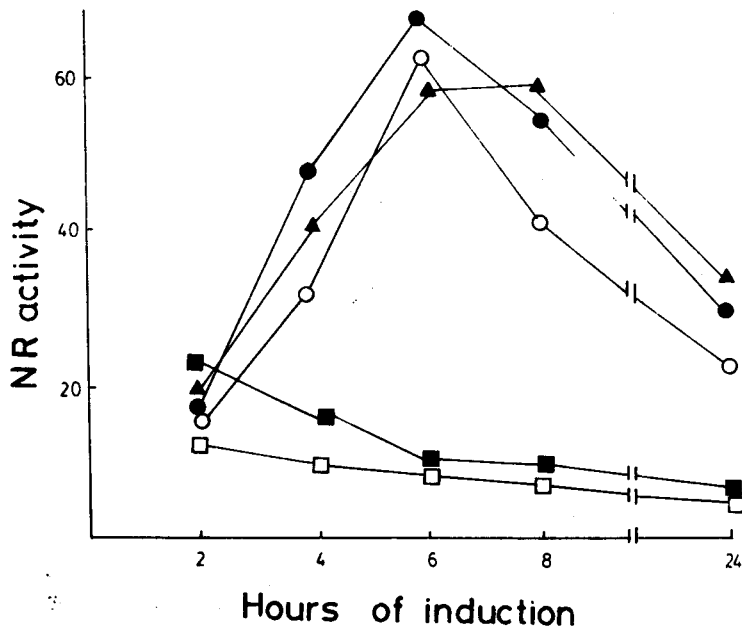


Fig. 2. Effect of ammonium on the induction of NR activity. Nitrate control (▲) Nitrate + 1 mM NH₄⁺ (○); Ammonium nitrate (●), Ammonium alone (□) and water (■).

reached levels higher than those obtainable by nitrate alone (Fig 2). The enhancement was greater with ammonium nitrate than that containing nitrate and 100 μ M ammonium. However, in the presence of only ammonium, the NR activity was far too low and declined continuously with lapse of time. The NR activity in others also was reduced at the end of 24h, as compared to the nitrate control.

BA also greatly enhanced the *in vivo* NR activity. The level of activity with nitrate was only marginally higher than that with BA alone. When BA was used along with nitrate, there was a further enhancement of enzyme activity, thus showing the additive effect of BA on NR activity (Fig 3).

The results show that ammonium

enhanced the induction of NR by nitrate. Hirschberg *et al.* (1972) showed that NR protein synthesized *de novo* in response to cytokinins. Subsequently Peterson and Miller (1976) demonstrated that exogenously supplied ammonium increases the biosynthesis of cytokinins in *Vinca rosea*. The present findings when viewed in the light of these reports show that ammonium might be stimulating NR activity by induction of synthesis of NR protein via the biosynthesis of cytokinins.

In another experiment in which graded levels of ammonium was used in the assay medium containing increasing concentrations of nitrate, it was found that NR activity measured at the end of one hour was considerably higher than those containing either nitrate or ammonium only. A Lineweaver Burk plot

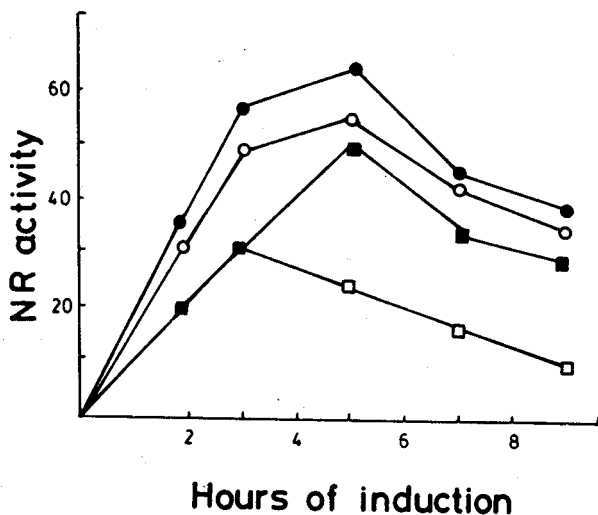


Fig. 3. Effect of benzyladenine on NR activity. (●) BA + Nitrate; (○) Nitrate (■) BA and (□) Transferred from BA medium to water.

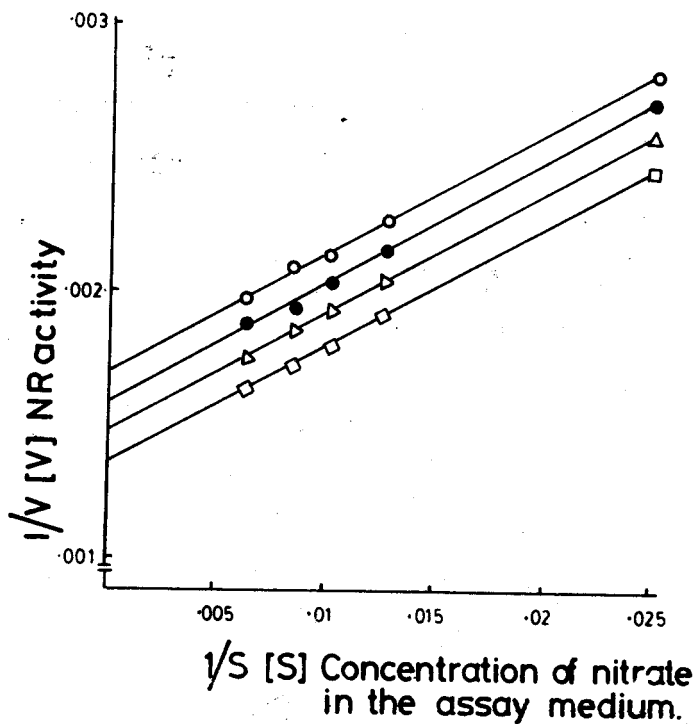


Fig. 4. Lineweaver-Burk plots for the activity measured in nitrate medium containing graded levels of ammonium. No ammonium (○), 40 μ M ammonium (●), 100 μ M ammonium (Δ) and 200 μ M ammonium (□).

Table I. Nitrate uptake by excised leaf discs.

Incubation medium	Nitrate taken up at the end of 24h. (μ moles. g^{-1} fresh wt.)
0.5 mM KNO_3	4.46
0.5 mM KNO_3 + μ M NH_4^+	6.82
0.5 mM KNO_3 + 100 μ M NH_4^+	6.89
0.5 mM KNO_3 + μ M NH_4^+	4.76

gave parallel lines with constant slope and increasing V_o . The degree of stimulation increased with increasing concentrations of ammonium in the medium. However, when only ammonium was used with no exogenously supplied nitrate, NR activity was less than half of that in the nitrate control. The lowered K_m in presence of both nitrate and ammonium (Fig. 4) indicates that ammonium might also bind to an allosteric site on the NR protein to bring about the activation.

Ammonium upto a concentration of 100 μ M in the medium also enhances the rate of nitrate uptake by excised leaves. (Table I). Thus, the results show that the induction of NR by low concentrations of ammonium and inhibition at higher levels thus provides the plant with an efficient mechanism to utilize both the predominant forms of soil nitrogen and also to regulate the input of reduced N in the cell.

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LIGHT PENETRATION PATTERNS THROUGH ARECANUT CANOPY AND LEAF PHYSIOLOGICAL CHARACTERISTICS OF INTERCROPS*

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ABSTRACT

The physiological performance of intercrops of arecanut was studied in relation to transmitted photosynthetically active radiation (PAR). Approximately 27% PAR passed through arecanut canopy. The leaves of shade-grown crop species were thinner having higher chlorophylls on unit fresh weight or leaf area basis. The crops, viz., banana, clove, cocoa, coffee and pepper were unaffected with respect to nitrate reduction (NR) activity showing their shade tolerance. The NR activity of pineapple leaf was less in shade. The distribution pattern of NR activity in roots and leaves showed that most of the crops except pepper and pineapple reduced NO_3^- in leaves substantially. Further there were no direct relationships of endogenous NO_3^- content to its reduction by NR. The reflectance characteristics of leaf surfaces in visible radiation range was also determined.

INTRODUCTION

The photosynthetically active radiation (PAR) which passes through canopy of trees is characterised by large temporal, spatial variability (Ross, 1960) and spectral qualities (Anderson, 1982). Tall palms of arecanut and coconut allow light penetration through their fixed canopies to an extent of around 30% (Nair and Balakrishnan, 1976). In such understorey environments different annual and perennial intercrops have been cultivated. However, there are no detailed studies on seasonal PAR profiles in arecanut plantation and physiological performance of intercrops. This paper deals with such a study on arecanut based high density multispecies cropping system.

MATERIALS AND METHODS

Six crop species viz., banana, clove, cocoa, coffee, pepper and pineapple were cultivated under 20-year-old arecanut palms with a spacing of $2.7 \times 2.7\text{m}$. The intercrops were planted as follows: banana planted at $5.4 \times 5.4\text{m}$, between arecanut and the inter space was planted with clove or cocoa in alternate rows. Pepper (var. Panniyur) vines were trained on every arecanut palm. Two pineapples were planted between two arecanut palms within a row. A single row of coffee at a distance of 1.35 m was planted after every 3 rows of arecanut. The general lay out of planting is shown in Fig. 1. The intercrops and monocrops received identical management practices.

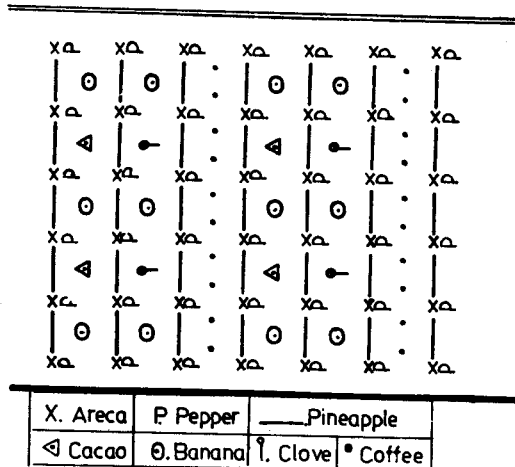


Fig. 1. Layout plan of arecanut based multi species cropping model (Vittal).

Leaves were sampled at 10.00 h for specific leaf weight (SLW), chlorophyll and nitrate reductase (NR) activity determinations. Leaf dry weights/leaf area was determined for specific leaf weight (SLW). Chlorophylls were extracted in 85% acetone (V/v) and estimated spectrophotometrically (AOAC, 1975). For NR activity, the leaves were washed with distilled water, dried with filter paper and cut into *ca* 5 mm discs. The *in vivo* NR assay procedures using 0.2g tissue were employed as described earlier (Jaworski, 1971). The reaction mixture contained 20 mM potassium phosphate buffer pH 7.5 and 100 mM potassium nitrate in a final volume of 5 ml and vacuum infiltrated for 3 min and incubated at 30°C in dark. NO_2^- liberated was estimated using sulphanilamide and N-1-naphthylethylene diamine diHCl. The colour developed was read after 15 min in a Hitachi Model 200-20 double beam spectrophotometer at 540 nm. Tissue NO_3^- was extracted and estimated with chromotropic acid reagent (Sims and Jackson, 1971). Solar radiation was

measured using LI-COR quantum radiometer.

RESULTS AND DISCUSSION

The PAR profile during the year showed that on an average 29.8% and 4.6% of full radiation was transmitted through arecanut and banana canopies respectively (Fig. 2). The understorey is interspersed with sunfleck areas and fully shaded areas which changed with the angle of sun and the above mean value was taken from values at noon time. The rainy season had only diffuse light through clouds and the PAR intensity was very low. The interception efficiency of arecanut canopy (i.e.

$$\frac{I \text{ full} - I \text{ through areca canopy}}{I \text{ Full}}$$

I Full

was calculated to be about 0.73. The banana canopy which occupied the next understorey allowed very little PAR to pass through.

Adaptation to shade varies among crop species. This involves modifications in leaf anatomy and morphology and how the available light is intercepted and utilised for photosynthesis. The leaves of all the crops studied here were thinner under shade as compared to sole crops. Season and light (shade or open) influenced SLW significantly in all species studied. Leaves of open crops showed significantly lower chlorophyll content than leaves in shaded crops (Table I). It is generally reported that leaves of plants grown in shade have lower SLW than sun leaves (Boardman, 1977; Fails *et al.*, 1982). The SLW is an important indicator of photosynthesis as it has been positively correlated with net photosynthesis (Barden, 1977). Although it was reported that shade plants contained a higher

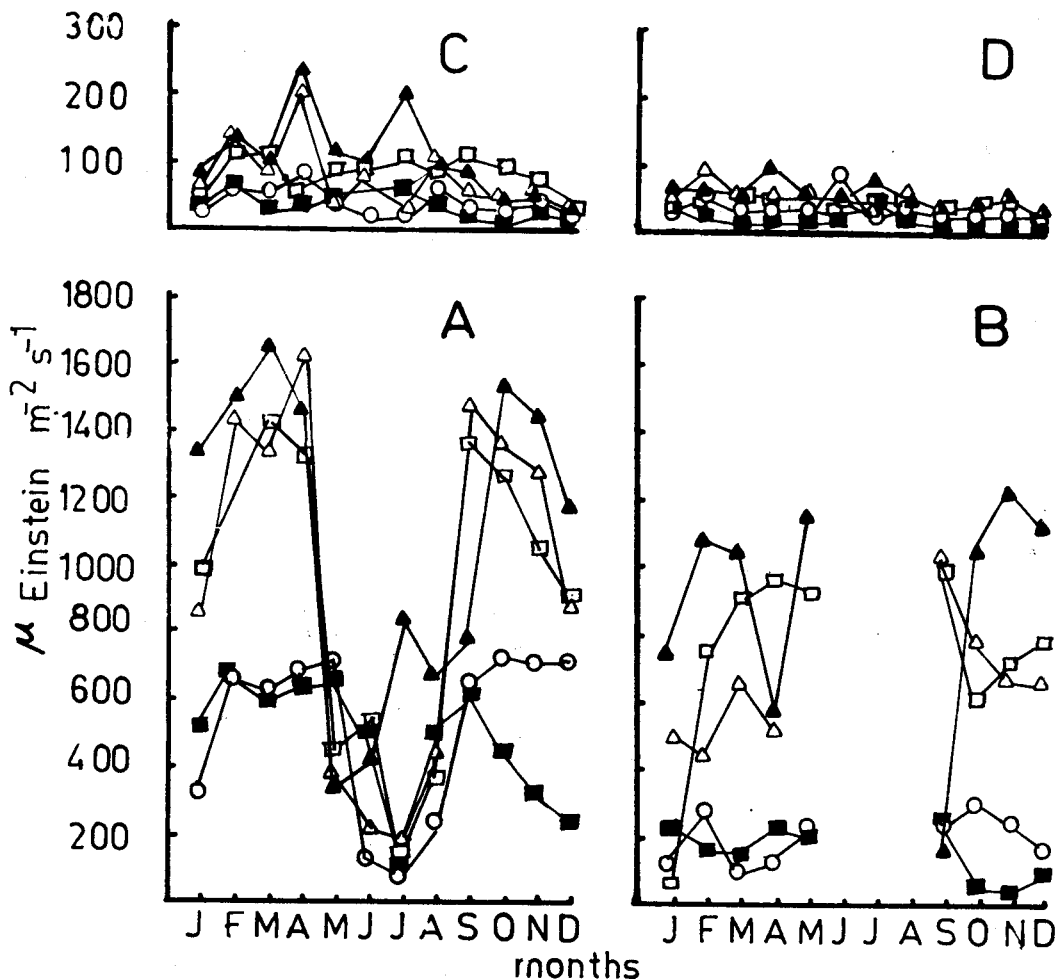


Fig. 2. Seasonal PAR profile under arecanut canopy, sunfleck area (B), arecanut canopy shade area (C), banana canopy shade area (D), and full radiation (A): At 8.00 h (O), 10.00 h (Δ), 12.00 h ($\blacktriangle$), 14.30 h ($\square$) and 16.30 h ($\blacksquare$); Mean transmission of PAR through arecanut and banana canopies were 29.8% and 4.6% respectively at 12.00 h.

proportion of Chl b relative to Chl a (Boardman, 1977), no such ratio could be observed in all the crops studied by us. The plants grown under limiting light conditions always recorded higher chlorophyll contents expressed on weight/area basis than did sun plants (Bjorkman, 1968; Boardman, 1977). This clearly demonstrates that shade leaves

invest more energy in the production of more light-harvesting systems than do sun plants. The NR activity was determined in leaves of intercrops and compared with sole crops except in case of clove which could not be grown in the open (Table I). In cocoa there was no appreciable change in open and shade conditions. However, since PAR was

Table I. Means for leaf characteristics of intercrops.

Crop	Seasons					C.D. for compar- ing seasons	Shade	Open	C.D. for comparing shade and open
	Jan	Apr	Jun	Sep	Dec				
<i>Specific leaf weight (mg cm⁻²)</i>									
Banana	6.29	7.08	9.28	8.67	—	1.03	6.93	8.69	0.73
Cocoa	7.15	5.96	5.81	5.32	5.36	0.73	5.49	6.34	0.46
Coffee	6.24	6.67	5.6	5.39	5.39	0.66	5.09	6.63	0.42
Pineapple	17.50	18.52	18.23	16.36	16.54	1.56	15.17	19.70	0.99
Clove* (Shade)	6.64	—	6.99	8.36	—				
Pepper*									
(Border)	—	5.78	—	7.59	—				
Pepper*									
(Interior)	5.52	4.43	—	6.56	—				
<i>Chlorophyll content (mg g⁻¹ fresh weight)</i>									
Banana	1.47	1.11	1.33	1.41	—	0.24	1.55	1.11	0.17
Cocoa	1.14	1.49	1.23	1.24	1.67	0.25	1.58	1.13	0.16
Coffee	1.70	1.48	1.05	1.30	1.89	0.24	1.94	1.02	0.15
Pineapple	0.19	0.21	0.16	0.30	0.24	0.05	0.29	0.15	0.03
Clove* (Shade)	1.76	—	1.26	1.24	—				
Pepper*									
(Border)	—	1.51	—	1.18	—				
Pepper*									
(Interior)	2.05	1.31	—	1.27	—				
<i>NR activity (n moles g⁻¹ fresh wt. h⁻¹)</i>									
Banana	369	221	131	128	—	72	206	219	NS
Cocoa	431	273	241	258	212	88	290	276	NS
Coffee	360	388	147	225	277	90	414	145	57
Pineapple	45	85	32	57	26	20	39	59	12
Clove* (Shade)	99	—	28	38	—				
Pepper*									
(Border)	—	78	—	90	—				
Pepper*									
(Interior)	231	115	—	84	—				

CD (P = 0.05)

*Statistical analysis not performed

relatively high during April the activity of enzyme decreased. Cocoa is a shade loving crop and excessive PAR can cause inhibition of enzyme and photo-bleaching (Balasimha, 1982). The NR activity in coffee adversely inhibited in sole crop. In pepper, there was no significant variation between the border and interior plants. Pineapple and clove showed very low NR

activity as compared to other crops and in the former it was more in sole crop. In banana, although the activity was unaffected under shade in initial period of growth, it decreased towards later part of growth in both varieties.

Seasonal trends in NR activity has been reported in several field grown crops

Table II. *Distribution of nitrate reductase activity and nitrate content in leaves and roots of intercrop species.*

	Without induction		Induction with nitrate*	
	Leaf	Root	Leaf	Root
<i>Nitrate reductase (n moles g⁻¹ fresh wt. h⁻¹)</i>				
Banana	50.5 ± 17.2	23.7 ± 2.2		
Clove	58.6 ± 1.8	16.7 ± 4.7	108.3 ± 24.8	27.0 ± 11.0
Cocoa	177.0 ± 6.9	33.5 ± 14.9	484.0 ± 175.0	69.0 ± 15.0
Coffee	381.0 ± 27.1	145.3 ± 13.6	783.7 ± 278.8	99.0 ± 34.0
Pepper	44.3 ± 7.4	122.3 ± 25.4	503.7 ± 126.1	256.0 ± 39.8
Pineapple	29.2 ± 3.9	61.6 ± 16.7		—
<i>Nitrate content (µg/g dry weight)</i>				
Banana	865 ± 315	610 ± 110	—	
Clove	120 ± 20	148 ± 42	513 ± 220	365 ± 185
Cocoa	470 ± 60	687 ± 74	430 ± 122	843 ± 342
Coffee	643 ± 338	1740 ± 615	3430 ± 250	5573 ± 1140
Pepper	293 ± 143	186 ± 112	2440 ± 876	621 ± 112
Pineapple	1431 ± 240	453 ± 253	—	—

*Seedlings were treated with 20 mM KNO₃ for 3 days and sampled

(Harper *et al.*, 1972; Teare *et al.*, 1974) and in cocoa (Balasimha, 1982). The NR activity was generally higher when the PAR received by leaves was more. It is interesting to note that in banana the capacity to reduce NO₃⁻ declined gradually with maturity. This was more pronounced in shade plants and showed shade tolerance of banana varied depending on the plant's ontogenetic stage. Canopy variations of NR activity in cocoa plants have been reported (Balasimha, 1982). Canopy variations in pepper and banana were determined. The activity was always reported to be less in shaded leaves (Balasimha, 1982; Harper *et al.*, 1972; Teare *et al.*, 1974) in crops studied. The same trend was noticed in pepper. The NR activity (n moles g⁻¹ h⁻¹) was 114.5 and 77.8 in upper and lower canopy levels of border plants respectively. However, in banana the middle and lower leaf positions recorded higher NR activity; 1st-740,

2nd-440, 3rd-430, 5th-460, 7th-680 nmoles g⁻¹ h⁻¹ respectively.

In order to determine whether the NO₃⁻ assimilation occurs in either of two sites among these crop species, NR was assayed in leaves and roots (Table II). In banana, clove, cocoa and coffee the major reduction occurred in leaves. This became more evident when the plants were substrate induced with NO₃⁻ solution. In pepper and pineapple however, roots took a major part in reducing NO₃⁻. Under non-inductive conditions pineapple accumulated maximum NO₃⁻ but did not show any corresponding increases in NR activity. No direct relationship could be ascribed to NR activity and NO₃⁻ content in either leaf or root (Table II). But external supply of NO₃⁻ enhanced NR activity in leaves only remarkably except in pepper where it was enhanced in roots also substantially. Comparisons of rates of NO₃⁻ reduction

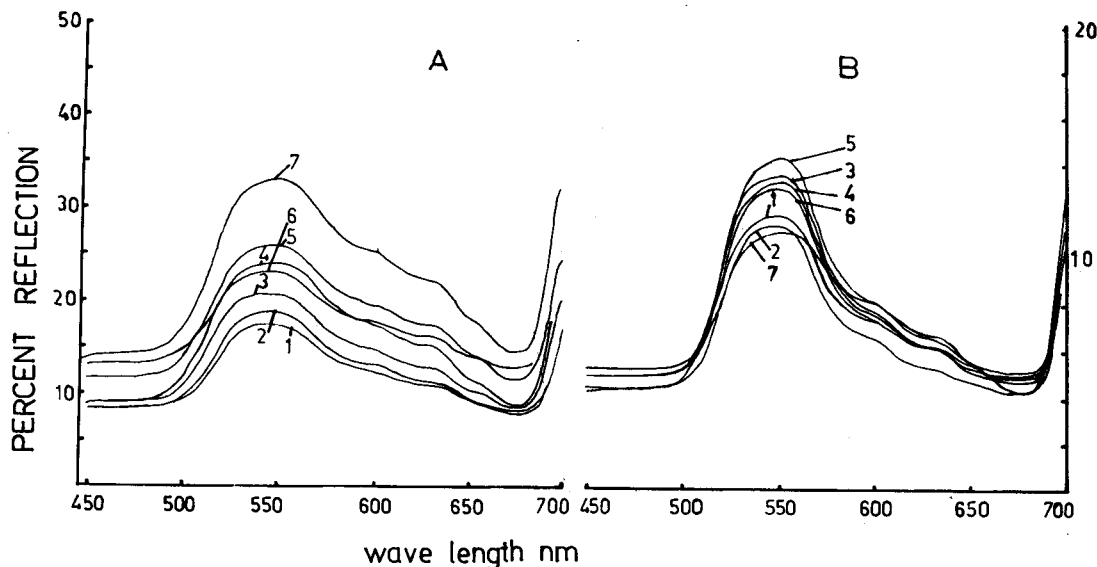


Fig. 3. Leaf reflection of leaf back (A) and front (B) surfaces; Pineapple reflection alone in B has full scale of 50% R; Numbers on curves represent arecanut (1) banana (2), cocoa (3), clove (4), coffee (5), pepper (6) and pineapple (7).

among species have shown that some species reduced considerably more in roots than in leaves (Olday *et al.*, 1976; Radin, 1978). This difference in distribution could be correlated with amounts of NO_3^- accumulated by plant parts. But in the crops studied by us no such relationship could be found. It can be argued that nitrate reduction cannot be totally influenced by the presence of NO_3^- and the potential NR activity in plants is considerably higher than that actually required. This is clearly discernible as NR activity was considerably lower under natural environment but increased under inductive conditions.

Reflectance of leaf surfaces of these crops was measured as a function of wavelength in visible range with a Hitachi double beam model 200-20 Spec-

trophotometer fitted with an integrating sphere (Fig. 3). In the wavelength band 400-700 nm major portion of radiation is absorbed and the reflection curve showed a peak at 550 nm. The leaves of pineapple showed highest reflection which may be due to the thick leaf structure. The valuable detailed study of the directional and spectral reflectance properties of various plant genera have been studied by Woolley (1971) who also showed that thick leaves reflected more in 400-700 nm wave band. Leaves however, reflect as much as 96% of light in infra-red range i.e. 800-1100 nm (Woolley, 1971). the significance of such data have to be viewed in as much as intercropping under taller trees are considered. Since, the shade cast by trees and transmitted light will be richer in non-PAR it is essential that the intercrop species should be able to adapt to such an environment.

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SESSION I : DISCUSSIONS

Dr. P. Mohan Kumar: I would like to know from Sri CR Raju the exact time he has experienced from the start of the experiments to the stage when seedlings go into the field.

Shri CR Raju: In case of oil palm I started the work in February 1985 and came out with the first plant in December 1985. That is almost one year. First plant was established in soil; thus I could get the plant in a four month's time.

Dr. P. Mohan Kumar: What was the dose of BAP? I think that you mentioned as 1 mg per litre.

Shri CK Raju: No, it is 0.1 mg per litre.

Dr. M.R. Sethuraj: I have great appreciation for the Nationalist in him and we always should strive for self reliance, but then there is a matter of priorities; we have the expertise and then we do not have the chemicals. So give them that first.

Dr. K.U.K. Nampoothiri: There is some apprehension from the work outside whether we can get as much yield increase in oil palm through tissue culture. So we would like to hear from Sri. Raju how to go ahead with the optimism on this particular line of work. What is our policy? What is our line of approach against these variations and yield predictions which we get from oil palm?

Shri CR Raju: Regarding the multiplica-

tion of oilpalm, my experience is not very much in favour. While discussing the matter with people who are working in this field, I could find that because of the high commercial interest they were going actually not for the high yielding plants. But they go through the embryo, callus induction, callus multiplication. We do not expect too much of variation because we have not passed through an elaborate callus stage and the explant itself is not exposed to 2, 4-D which is known to produce any variation for a long period.

Dr. KV Ahamed Bavappa: The issue has been raised by Dr. Nampoothiri regarding the potential of the tissue culture in some of these crops. It is important that the genetic stability of the material should be understood when you go through a micropropagation technique. Now the method has been debated as far as oil palm is concerned at length the variability factor that has brought down the yield performance in oil palm is still not very clear. May be that the basic material that was handled was not of the type that the breeders really wanted and that there exists a high genetic and environment interaction. There are quite a few areas in which the breeders would like to get information prior to a commercial application of the micro-propagation or tissue culture in the plantation crop side.

Mr. K. Sudhakar: Dr. Rajagopal's paper on 'Physiological studies on root (wilt) disease of coconut palms' mentions that under well managed conditions the

yield of coconut palm can be improved. Recently a survey was conducted in Cannanore by CPCRI and root(wilt) was found in that region and the farmers were compelled to cut and remove those coconut palms. Similarly, cutting and removing the palms and replanting is being recommended in the southern parts of Kerala also to prevent the further spread of this disease to the neighbouring districts. In my opinion these are contradictory. You can manage the palms very well and get good yields while the other recommendation is that you cut and remove the palms followed by replanting. The farmers are very reluctant to cut and remove the palms. So please clarify this.

Dr. V. Rajagopal: The palms in the early stages and middle stages of the disease do respond to these management practices, whereas when the palms reach the advanced stage of the disease (above 50% of the disease index) they are not responding to any of the treatments, and this was shown in our experimental farm. This recommendation for removing the palm also pertains only to the advanced diseased stage of the palm, where the economical yield is very low.

Dr. P.K. Ramaiah: You say it is responding continuously; that means no replanting is necessary after 5 years. Suppose you see that the management practices are intensive, do you think that once again the disease will take an intensive form after some time?

Dr. V. Rajagopal: No, as far as we have seen, the early and middle stage of the diseased palms, respond to some of these management conditions. But once the disease reaches the advanced stage

whatever management you give, they are not going to improve. The main concept of removing these palms revolves only in that direction.

Dr. P. Rethinam: We have two clear strategies for the management of root (wilt) disease in Kerala. For Trivandrum to Trichur the disease incidence is contiguous, and nearly 23.6 millions of palms are affected by this disease. In the northern districts of Kerala (Trichur), from Karuvannur river upto Kasaragod only about 4000 palms have been affected. We have been operating a field station at Trichur and 1000 palms have been cut and removed 3 years before. By this process we are able to keep the area north of Karuvannur river free of the disease. So any diseased palm located north of Trichur should be cut and removed. The strategy of management holds good only for the area between Trivandrum and South of Karuvannur river. Our strategy is not to leave a single root(wilt) diseased palm in Tamil Nadu or Karnataka or between Trichur and Kasaragod in Kerala.

Mr. A. Periakaruppan: Dr. Raman in his paper mentioned that there has been an yield increase of 5 to 8%. How it has been achieved? Is it due to the increase in fresh shoots or higher percentage of shoots or due to the vigorous growth and closer rounds? If it is really going to be the increased weight of the shoots probably the comparison should be only on made tea and not on green leaf. Has there been anything on quality, assessed?

Dr. K. Raman: Answering to the first question it is basically from the increased number of shoot generation and secondly

from that point of view there would not be any increase in the outturn and we have not looked into any quality parameter separately.

Mr. Jacob Pothan: How many sprays were done per annum and also whether cost benefit ratio has been worked out?

Dr. K. Raman: Three sprays were done per annum and only for the first chemical cost-benefit ratio has been worked out. The other chemical is not yet available in the market.

Mr. H. Vijayaraghavan: What is the pH of the hormonal spray fluid and whether it is compatible with pesticides commonly used in tea estates?

Dr. K. Raman: We have not looked into this matter since this is a new chemical. There are so many questions to be looked into.

Mr. P. Asokan: What is the chemical constituent of Harmonol and Fitohorm?

Dr. K. Raman: Manufacturers say that, Harmonol is a mixture of auxins, cytokinins and gibberellins.

Mr. P. Asokan: Are these chemicals

carcinogenic?

Dr. K. Raman: These hormones, auxins and cytokins are naturally occurring within the plant.

Mr. P. Asokan: Most of the synthetic hormones are carcinogenic. This is a well established fact.

Dr. P.K. Ramalah: As far as carcinogenic properties are concerned most of the products are synthesised and there is a system of data development and that takes care of it and the data have to be developed on human and animal population. I do not think that these products are coming without screening at that level.

Dr. K.S. Krishna Sastri: I had one time privilege of getting a paper for review which showed that 2,4-D at 2 ppm, when coming into direct contact with the cell causes abnormalities. But many of these growth regulators are used in low concentration and they are metabolised in the plants and on metabolism they produce the desired effect. No doubt when the concentration is high many abnormalities do appear. So the most important thing is the concentration at which it is used.

CHAPTER II

PROCESSING, PRODUCT DIVERSIFICATION AND EQUIPMENT

Chairman : Dr. M. R. SETHURAJ
Rapporteurs : Dr. N. M. MATHEW
: Dr. S. RAMASWAMY

PROCESSING, PRODUCT DIVERSIFICATION AND EQUIPMENT DEVELOPMENT

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From time immemorial India has been a producer and exporter of raw spices. However, in recent years, spices are being converted into value added products for export.

Solvent extraction followed by concentration results in oleoresin. It will contain both the volatile aroma and non volatile pungent principles, colour etc. In most major spices, non volatile principles, especially pungent principles are important. They include piperine in pepper, capsaicin in chilli, gingerol in ginger and curcumin in turmeric. Spice oils represent only the volatile aroma compounds which are obtained by steam distillation. Major technological needs in a successful technology is the selection of various process parameters, employment of minimum solvent by use of counter current extraction, and retention of aroma and quality when solvent is removed. The crucial operation in the processing is the removal of last traces of solvent so that the product conforms to regulation of importing countries (Table I). It will be advantageous to remove the volatile oil first and then solvent extract the residue. This way it is possible to protect the aroma and it will not interfere in the desolventisation if vacuum is applied.

Indigenous technology for oleoresin developed by CSIR was released in early

Table I. *Level of solvent residue allowed in oleoresin*.*

Solvent	Maximum allowed (ppm)
Acetone	30
Methanol	50
Hexane	25
Isopropyl alcohol	50
All chlorinated solvents	30

*As per US Food Additive Regulations

70s. This has resulted in the export of spices oleoresins from the country (Table II). In 1984-85 the quantity of oil and oleoresin exported has amounted to 331 tonnes earning a foreign exchange representing nearly 10 crores of rupees. India has thus emerged as the leading

Table II. *Export of spice oils and oleoresins from India.*

Year	Spice oils		Spice oleoresins	
	Quantity (tonnes)	Value (Rs. crores)	Quantity (tonnes)	Value (Rs. crores)
1973-74	0.94	0.027	25.16	0.185
1976-77	5.18	0.118	122.54	1.466
1979-80	19.66	0.823	181.61	2.442
1980-81	12.93	0.482	148.87	2.176
1981-82	16.59	0.495	166.76	2.626
1982-83	24.24	0.862	214.27	3.546
1983-84	21.62	1.134	197.19	3.707
1984-85	37.66	2.308	303.32	7.396

manufacturer of oleoresin in the world. Another encouraging feature of oleoresin industry in India is the wide base of raw materials.

While chilli is well liked as a flavour in India, its main export potential is for use as a counter irritant in pharmaceutical and cosmetic purposes. Indian chilli have the disadvantage of inadequate capsaicin content and excessive colour. As against a heat value of over 1 million Scoville unit, Indian chilli oleoresin gives only less than half a million units. Besides the colour value is much higher than 20000 units. By making use of liquid - liquid extraction, it has been possible to fractionate Indian chilli oleoresin into a high pungency fraction and a colour fraction. With the introduction of the technology, the country has been able to boost the export of chilli oleoresin. During the last year, we have been able to export over 20 tonnes of high pungency oleoresin and about 2 tonnes colour fraction. This is a clear case where research oriented technology has created an exportable product of high value. During the same year about 50 to 60 tonnes of celery oleoresin was also exported. This is in addition to continued export of oleoresins from pepper and to lesser extent from turmeric and ginger.

Further value addition is expected to boost export of value added spice oleoresins. It has been possible to produce from fresh ginger, oleoresin with fresh ginger flavour. If the Westerners are shown the superiority of the flavour of fresh ginger over dried ginger, there is possibility of production of this type of oleoresin. Similarly industry with the help of research institutions should

develop blended, modified and micro encapsuled spice flavours.

Significant increase has been achieved in the export of spice oils also. The export for spice oils during the 84-85 touched 26.66 tonnes valued at Rs.2.3 crores. The main flavour ingredients of spice essential oils are the oxygenated compounds. Efforts are made to get a hydrocarbon free, deterpenated spice oils. It will be more stable and better dispersable in water. The hydrocarbons with inferior flavour can be chemically modified to increase the flavour value.

European countries like France and Germany like the fresh green flavour of green pepper. Normally the harvested green pepper, on keeping turns black. This is because of an enzyme catalised blackening reaction. If this can be controlled, then we can get a green coloured product. Canning used to be one of the ways in which green colour of the product is maintained. Pickling in acid-brine solution also used to control the blackening.

In the earlier days, the European demand of green pepper used to be met by a French Company which has processing plants in Madagascar. In India improved canning process has been developed. It is possible to get unruptured berries and clear drain liquid. It was also shown that by introduction of a drop of pepper oil, fresh peppery note can be introduced. Many Indian processors are now doing canning and bottling of green pepper.

In 1971-72 the export of canned green pepper was only 10.7 tonnes with a

foreign exchange earning of Rs.2.9 lakhs. The figure showed increase to 64 tonnes and Rs.12 lakhs in 1972-73 and to 97 tonnes and Rs.16.65 lakhs in 1975-76. By 1981 the quantity had more than doubled to about 200 tonnes and value of about Rs.20 lakhs.

India introduced for the first time in the world, dehydrated green pepper. In this processing, the blackening is controlled by checking the enzyme action. The enzyme is inactivated by blackening for 10-15 minutes in boiling water. The dehydrated green pepper is produced by artificial drying to reduce the loss of chlorophyll by sun's radiation. The product has good green colour and "green" flavour. The packaging cost has been reduced considerably. The weight of the product is only about 10% of canned green pepper. India has been exporting about 100 tonnes of this product valued at about Rs.4.5 to 5 crores.

Dehydrated green pepper has, however, one disadvantage of having a hard core compared to canned green pepper. Recently a product known as dry packed green pepper has been developed. In this moist treated berries are packed in flexible packages without covering liquid.

The demand for white pepper in the world is believed to be about 10 to 15 thousand tonnes. The major part of the export is shared by Indonesia, Malaysia and Brazil, with India being a negligible contributor. In 1979-80, India exported only 6.2 tonnes of white pepper valued at Rs.2 lakhs. During the last 2 years the export was respectively 2 and 11 tonnes only. White pepper is liked for its mellow flavour, high pungency, low fibre, high

starch content and above all for the white colour.

Traditional method of preparing white pepper is by retting either ripe berries for 3 to 4 days or black pepper for 7 to 12 days. The loosened skin is then scrubbed off. Indian farmers are unwilling to leave the berries to ripen for fear of picking by birds and dropping to the ground. The processors also feel that loss of skin amounting to about 25% off-sets the increase in price of white pepper partially.

Recently a new technology has been developed for producing white pepper from black pepper by a dry and quick process. The process is based on the difference in chemical composition of black skin and white inner core and consequent difference in structure. This results in difference in the resistance when compressive force is applied. Under special grinding technique using a roller mill, white core powders to a fine size compared to the skin, so much so that an easy separation is possible by selective screening. Although, the product is obtainable in powdered form only, the skin is not wasted and can be used for oleoresin extraction.

India is the third largest producer of coconut in the world, the first two being Philippines and Indonesia. The major producing state in India is Kerala State accounting for 60%. Due to root (wilt) disease, there has been some decline in production in recent past. Also other States, especially Tamil Nadu and Andhra Pradesh, have increased their production. In India slightly less than 60% is used for culinary, religious and similar uses. About 8% are believed to be

Table III. *Composition of coconut products.*

Material	Moisture %	Protein %	Fat %	Carbohydrate (by diff. %)	Crude fibre %	Ash %
Kernel from ripe nuts	46.3	4.08	37.29	11.29	3.39	1.03
Kernel from unripe nuts	90.8	0.9	1.4	6.3	—	0.6
Water from ripe nuts	91.23	0.29	0.15	7.27	0.0	1.06
Water from Unripe nuts	95.01	0.13	0.12	4.11	0.0	0.63
Copra	5.8	8.9	67.0	16.5	4.1	1.8
Desiccated coconut	3.5	6.3	57.4	31.5	7.5	1.3

used as edible copra, and about 3.5% as tender coconuts. On an average, 28% is represented by shell, 55% kernel and 17% water. Wet kernel from ripe coconut contains 46% moisture, 4% protein and 37% fat. The chemical composition of coconut and coconut products are presented in Table III.

Desiccated coconut is probably the only major manufactured product from coconut. In future there could be need for a convenience food for which purpose desiccated coconut may be very expensive. With this in view a new process has been standardised, wherein defatted gratings are produced for food use, after a portion of the fat has been recovered. As much as 3/4 of the oil can be removed leaving the residue as a white powder containing enough oil required for palatability. Products containing different levels of oil can be prepared according to end use. Even for desiccated coconut use a defatting of 5 to 10% will give added stability to the product, because of the possibility of oil oozing out on storage. By recovering oil as a valuable byproduct, the product can be prepared at a reduced price. With the increasing price of coconut, it is hoped that defatted coconut gratings will be in high demand in institu-

tional catering, and in non traditional areas as a convenience food. The various operations in the processing includes breaking and scooping of kernel, disintegration of kernel, drying and pressing out the oil. A pin disc type mechanical disintegrator does the job of size reduction satisfactorily. A forced draft mechanical drier is required. A venetian type tilting drier as was originally used in tea industry and later in desiccated coconut industry will give satisfactory result. A hydraulic press will give adequate pressure without shearing action. If spearing action is given as in an expeller, then there will be generation of considerable heat resulting in discolouration and denaturation of the residue.

It is estimated that as much as 270 million litres of ripe coconut water is available in the country. In desiccated and partially defatted grating units, coconut water can be a disposal problem. A process for upgrading the flavour of the ripe coconut water and preserving by bottling has been released for commercial exploitation. Essentially, the process consists of upgrading the flavour of ripe coconut water to the level of tender coconut water by supplementation with additives including sugar and preserving

by a judicious combination of heat sterilization and permitted chemical like sulphur dioxide.

A considerable quantity of coconut milk is used in Indian cookery. If a stable product with satisfactory shelf life is available it can be a good commercial idea. A product is being standardised for this purpose. It can also be produced in dry form later.

In India, palm oil has a great relevance as an oil seed. Country is chronically short of vegetable oil since against the demand of 4.7 million tonnes, India produces only 3.5 million tonnes. The import bill of oils is as much as Rs.1200 crores. During 1985, country has imported 5 lakh tonnes of palmoil. The oil is well accepted by the consumer.

Cultivation of oil palm as a commercial proposition was started in Kerala (about 3700 ha) and in Andaman Nicobar Islands (about 1000 ha). CPCRI has been engaged in research in agricultural aspects and a large area is likely to come under oil palm cultivation.

Palm oil is derived from the mesocarp of the palm fruit. The kernel has also an oil known as palm kernel oil, however, it is the former which is a major source. One of the major problems of palm oils is the high lipase activity, and there is considerable fat spitting resulting in free fatty acids. The fruits are also rather difficult to separate. The major unit operations include harvesting, sterilization, stripping, digestion, pressing and clarification. A plant to process 500 kg of raw palm oil in a 8 hr. shift is being finalised.

Other special feature of palm oil is a high carotene content of about 800 ppm. It has also a fairly high tocopherol content of about 700 ppm. To obtain an ISI standard refined oil, bleaching using 3% bleaching earth containing active carbon at 150°C for 1 hour was found to give satisfactory result. The characteristics of crude and refined palm oil is given in Table IV. Another feature of palm oil is the presence of high percentage saturated fatty acids notably palmitic acid. This requires winterization to separate palmolein.

Table IV. *Chemical and physical characteristics of crude, neutralised and bleached palm oil.*

Characteristics	Crude	Neutralised	*Bleached
Colour (Lovibond unit, 1 cm cell)	26Y + 18R	28Y + 11R	16Y + 3.1R
Free fatty acids (%)	5.7	0.25	0.22
Iodine value	56.3	55.5	55.3
Sapon value	197	196	196
Unsapon matter %	0.421	0.407	0.354
Moisture (%)	0.20	0.25	0.07
Melting point	35.5	35.5	35.5
Peroxide value (me. eq. O ₂ /Kg fat)	2.0	2.5	Nil
Iron (ppm)	4.29	—	2.64
Copper (ppm)	0.08	—	0.052

*3% bleaching materials; 150°C; 1 hr.

India has been doing export of cashew kernel and CNSL (cashewnut shell liquid) for quite some time (Table V). So far India has been exporting CNSL in raw form only. With the level of technology available in the country we must do better by exporting value added products.

Table V. *Trends in export of cashew kernels and CNSL from India.*

Year	Cashew kernels		CNSL	
	Quantity (tonnes)	Value (Rs.) crores)	Quantity (tonnes)	Value (Rs.) crores)
1956-57	31,275	14.53	-	-
1960-61	43,625	18.91	-	-
1964-65	55,676	27.06	14,400	-
1968-69	63,661	60.93	10,500	-
1972-73	66,278	68.82	3,253	0.38
1976-77	51,565	105.99	6,055	1.29
1980-81	32,265	140.13	10,699	9.43
1983-84	35,729	137.86	3,176	1.20
1984-85	31,142	174.21	3,677	1.77

The major user of CNSL is the brake lining industry. CNSL resins have the property of absorbing heat generated by friction in the braking action, while retaining their efficiency longer. Surface coating materials also represent a major outlet for CNSL. It is imperative that country should strive to export CNSL in as processed a form as possible.

India has also become a significant producer of cocoa. India has acquired the necessary technology of processing the cocoa. For small scale operation the procedure for making cocoa mass is also available.

DESIGN AND DEVELOPMENT OF A NATURAL CONVECTION TYPE LOW COST DRYER FOR MEDIUM HOLDINGS*

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ABSTRACT

A simple and cheaper dryer working on indirect heating and natural convection principle using dry agricultural waste as fuel has been designed and developed to suit medium sized plantation crop holdings and processing units. The dryer consists of a drying chamber, burning cum heat exchanging unit and chimney. The dryer can hold 1000-1200 coconuts or 375 kg of ripe arecanuts per batch and the drying time required is about 33-37 hrs for copra and about 87 hrs for arecanut. As a preliminary study, the dryer was tested for drying 75 kg green cardamom in trays but slight discolouration of the product after drying was observed. The thermal efficiency of the dryer was 18.7-23.4%. The dryer costs about Rs.4000/- only and it requires an area of 7 m² for housing. Economic analysis has shown that this dryer can be profitably used during monsoon months.

INTRODUCTION

Drying is an important operation in plantation commodities. Fresh coconut meat which contains 45-55% moisture (wet basis) has to be dried to 6% moisture level and fresh arecanut has to be dried from 80% moisture to 9% moisture (w.b) for safe storage and further processing.

During rainy season, when conventional practice of open sun drying is not possible, drying by artificial method is the only possible solution for processing the produce. The existing direct type Kiln dryers are not desirable as the products become inferior in quality due to smoking and improper drying (Grimwood, 1975).

The other indirect type dryers using electricity or oil or firewood as fuel are either uneconomical propositions or having very low thermal efficiency. Patil (1982) developed a dryer using agricultural waste as fuel suitable for small holders. Based on this dryer, larger version of a natural convection type low cost dryer suitable for medium plantation holdings (>5 ha) and processing units was designed and fabricated at Central Plantation Crops Research Institute, Kasaragod.

MATERIALS AND METHODS

Design of the dryer

The various dryer parameters like size of the drying chamber, plenum chamber,

CPCRI Contribution No. 557

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area of heat exchanging unit, air flow required, etc. were worked out based on psychrometric and heat transfer principles. The width of the dryer in relation with the diameter of the burning cylinder has been standardised and it was found that the dryer width, burning cylinder diameter ratio should be of the ratio 3:1 for better performance.

Any dry agricultural waste can be used as fuel and the burning cum heat exchanger unit and chimney have been designed accordingly. The dryer is designed to hold 1000-1200 coconuts or 375 kg of arecanut per batch. The estimated air flow received through the system for drying copra worked out to 1.6 m³/min. at an air velocity of about 2 m/min.

Description

The dryer consists of drying chamber, plenum chamber, burning cum heat exchanging unit, chimney with regulators and support frames. The dryer was fabricated from locally available materials such as AC sheet, GI sheet and MS

Angle. The list of materials required is given in Table I. Asbestos cement sheets are used for structural use as well as for thermal insulation.

The details of the dryer are shown in Figures 1,2 and 3. The overall dimensions of the dryer are 2.5 m(L) × 1.2 m(B) × 1.75 m(H) and it requires a housing shed of 7 m² area. The drying chamber has an area of 3 m² and volume of 1.2 m³. Three doors on hinges are provided on one side of the chamber to facilitate easier loading and unloading of the produce. The plenum chamber is just below the drying chamber. It has a trapezoidal vertical cross section. Vertical area of cross section of this chamber is 1.06 m² and the volume of the chamber is 2.25 m³. On either side of the plenum chamber, 15 cm wide opening is provided at the bottom along the length with baffles on hinges for fresh air flow into the dryer. The burning cum heat exchanging unit is housed at the centre of the plenum chamber longitudinally. It is a 45 cm diameter cylinder made of 22 gauge galvanised iron sheet. The volume of the cylinder is 0.40 m³ and the surface area is 3.5 m². GI sheet fins

Table I. *List of materials required for fabricating the dryer*

S.No.	Material	Size	Quantity
1.	M.S. Angle	32 × 32 × 6 mm	129 kg
2.	- do -	25 × 25 × 6 mm	24 kg
3.	M.S. Flat	32 × 6 mm	35 kg
4.	- do -	25 × 6 mm	12 kg
5.	M.S. Rod	6 mm	1 kg
6.	Weld Mesh	50 × 25 mm	4.5 Sq. m.
7.	Corrugated G.I. Sheet	18G, 2 × 1 m. size	2 Nos.
8.	Plain G.I. Sheet	- do -	1 No.
9.	M.S. Sheet	18 G	1.2 sq. m.
10.	A.C. Sheet	2 × 1 M	7 Nos.
11.	Hinges (M.S.)	75 mm, 50 mm	6 Nos.
12.	G.I. Bolt nuts	25 × 6 mm	2 kg

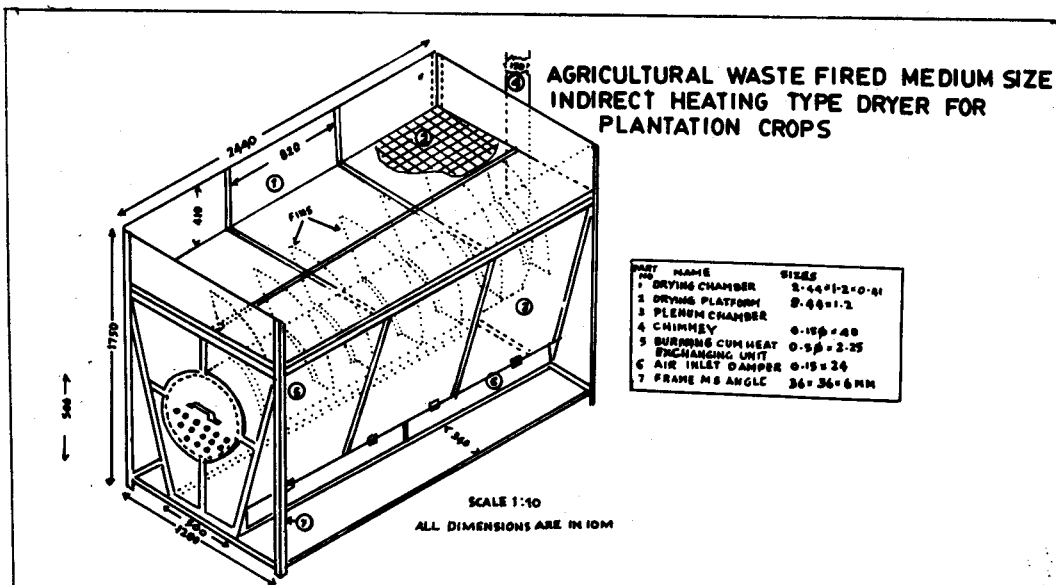


Fig. 1

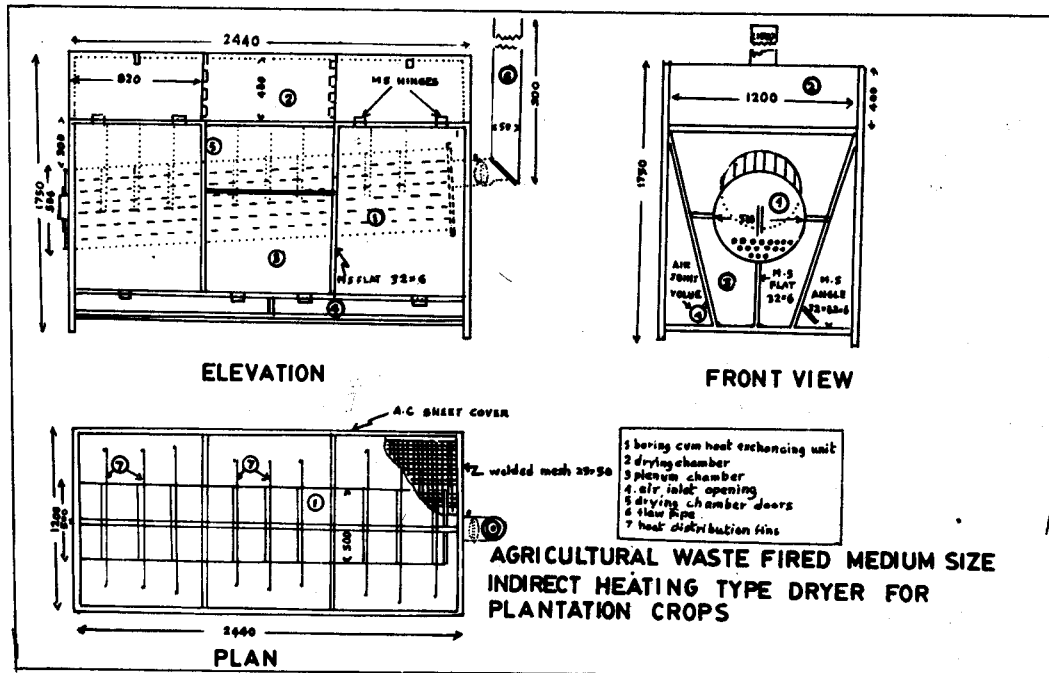


Fig. 2

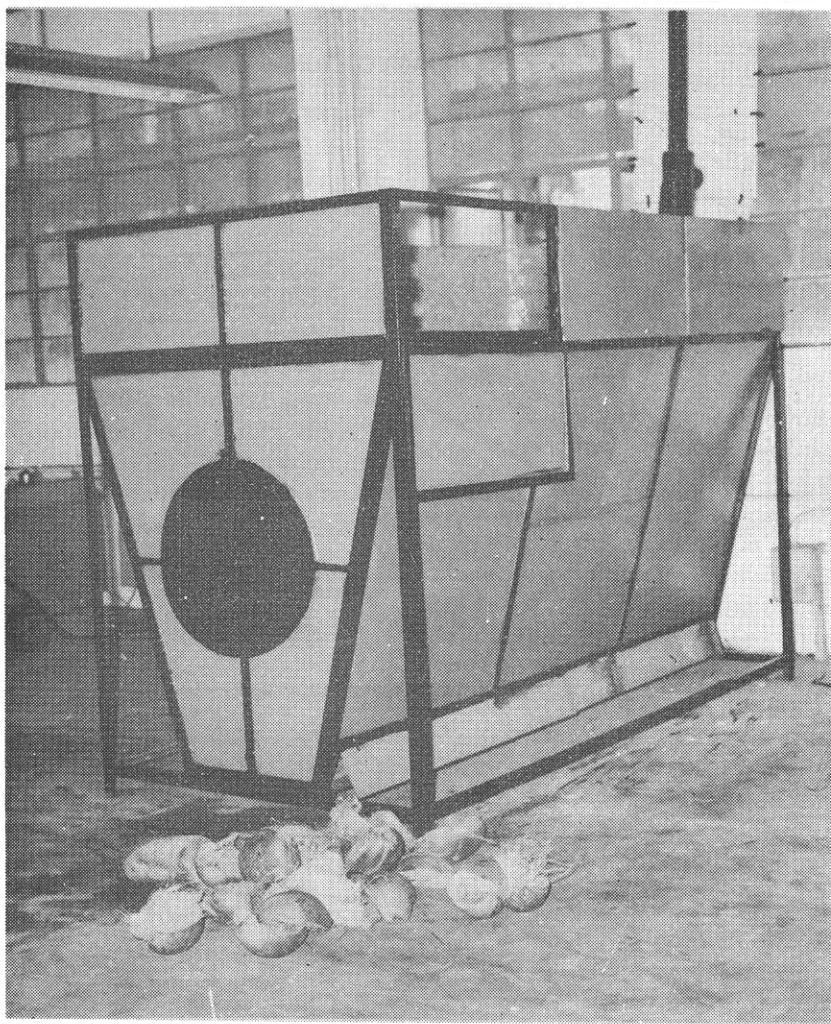


Fig. 3a. Overall view

have been provided on the upper half of the cylinder for better heat transfer. The cylinder is placed at a vertical inclination of 4°C for smooth flow of flue gases to the chimney. The lower end of the cylinder is fixed on plenum chamber wall with a damper having holes for entry of air required for combustion of fuel. The other end is connected to a 15 cm diameter chimney which lets out flue gases after

combustion. The chimney is provided to a height of 3 meters for better draught. The fuel is burnt inside the cylinder in a M.S. flat tray of size $100 \times 43 \times 15$ cm. Two butterfly valves are provided in the chimney to regulate the escape of flue gases. This in turn regulates the entry of air for combustion and thus controls the rate of combustion of fuel and the drying air temperature.

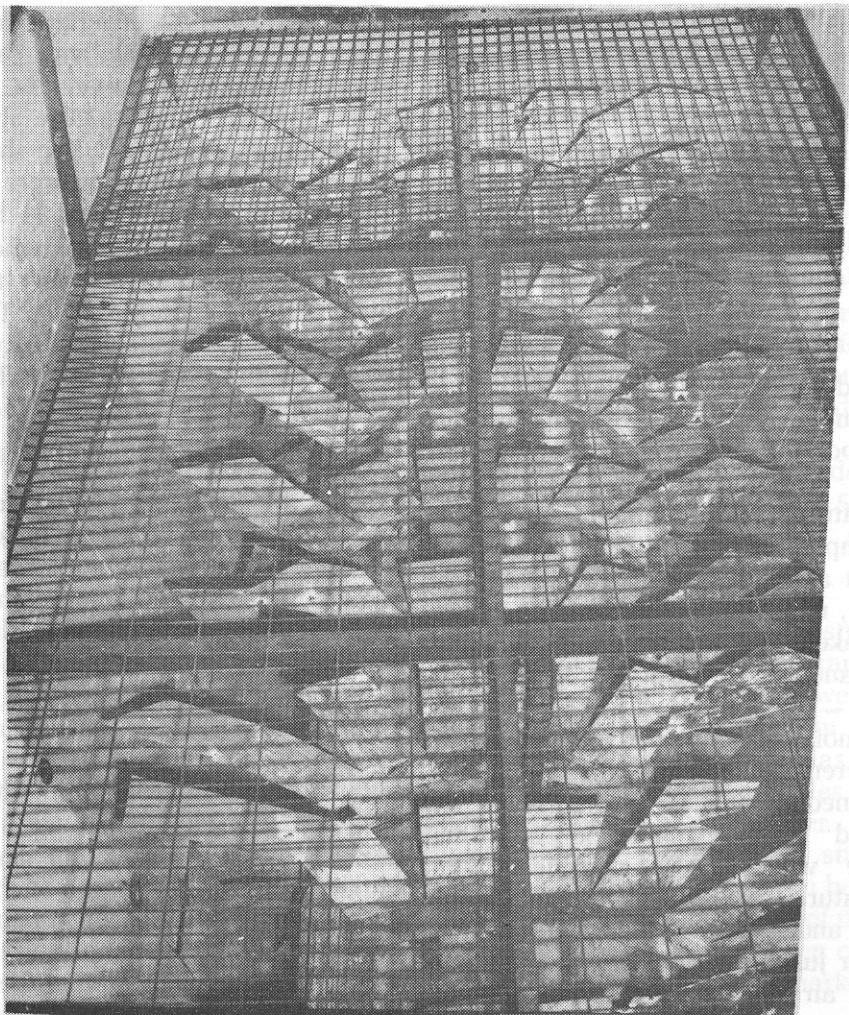


Fig. 3b. Internal view showing fins

Operation of the dryer

The fuel is burnt in the firing tray inside the burning cylinder. The temperature of the flue gases is about 180-190°C. The heat from the GI sheet surface which is at 100°C, is transferred by radiation to the surrounding fresh air entering from the bottom of the plenum chamber and this heat transfer generates a convection air current. The hot air moves up through

the wet produce kept in the drying chamber and the hot air laden with moisture escapes from the top of the drying chamber. This phenomenon helps in the natural convection of the air through the drying bed.

Copra and arecanuts were dried in this dryer by bulk drying as a thin bed (bed thickness of 30 cms). The dryer was tried for cardamom drying also as a prelimi-

nary study. To facilitate the drying of cardamom in thin layers in trays, angle iron runners at four levels have been provided in the drying chamber so that 12 numbers of aluminium wire mesh trays of size $120 \times 80 \times 3$ cm could be kept in 4 layers. The top of the drying chamber is covered with a GI sheet hood with exhaust air outlet.

Testing the dryer

The dryer was intensively tested for copra and arecanut drying during August-November 1985. Hourly observations on various parameters like drying air temperature at different zones, exhaust air temperature, relative humidity of ambient air and exhaust air, velocity of air flow, moisture content of the produce were taken and the drying parameters were standardised for drying copra.

The moisture content of the samples at six different zones during the drying was determined at $105 \pm 2^\circ\text{C}$ for 8 hrs by standard air oven method and the average values were recorded. The temperatures of ambient air, drying air at corners and middle region in the plenum chamber just below the drying chamber, exhaust air and flue gas were measured by mercury thermometer. The relative humidity was measured with Barigos hygrometer. The air velocity was measured with Ota Anemometer. Detailed studies on drying parameters were carried out for copra only. Coconut husk and shells were used as fuel and total fuel consumption for each batch of drying was found out.

For copra drying, coconuts broken into two halves were stacked with first two layers facing up and the remaining cups

were arranged in inverted position in brick fashion. Drying was carried out intermittently giving overnight tempering after 12 hrs of drying. The shells were removed after 8-10 hrs. The shells found difficult for shell removal were placed at the bottom. By the end of 16 hrs, shells from all the cups could be removed. The copra cups were mixed every two hours after that for uniform drying. The drying was continued till the moisture content of copra reached below 6% level. The drying air temperature was maintained at $60-70^\circ\text{C}$.

For arecanut drying, fresh ripe arecanuts were loaded in bulk into the drying chamber and drying was carried out intermittently with overnight tempering of the produce. The drying air temperature was kept at $60-70^\circ\text{C}$. Frequent mixing of the produce was done for uniform drying.

For drying cardamom, the green capsules were loaded in trays into the drying chamber and the drying was carried out continuously. The doors of the drying chamber were opened every one hour to exhaust the moist air. The trays were interchanged and the capsules were raked every hour for uniform drying.

The temperature of drying air was kept at $45-55^\circ\text{C}$. The trials for cardamom were conducted as a preliminary study.

The thermal efficiency of the drying was calculated by using the formula:

$$\eta_t = \frac{Q_L (M_o - M_f) \times 100}{WC (100 - M_o)}$$

Where η_t = thermal efficiency of the dryer in %

- Mo = Initial moisture content per cent, wet basis
 Mf = Final moisture content per cent, wet basis
 Q = Quantity of the final dried product at Mf moisture content in kg
 λ = Latent heat of Vapourization in Kcal/Kg.
 W = Quantity of fuel used in kg
 C = Calorific value of fuel used in Kcal/kg.

RESULTS AND DISCUSSION

The drying performance data of the experiments are given in Table II. 1000-1200 coconuts could be dried from 43-51% moisture to 5-6% moisture (w.b) in 33-37 hr using about 110 kg of fuel. 350 kg of fresh ripe arecanuts could be dried from 71% moisture to 8% moisture (w.b) in 87 hr (11 days) using about 240 kg of fuel. In the preliminary experiments on cardamom, 75 kg of fresh capsules were dried in 23-28 hours using 34-37 kg of fuel. The thermal efficiency of drying was 18.7% for copra, 19.2% for arecanut and 23.4% for cardamom respectively (the calorific value of the fuel was assumed 4500 Kcal/Kg).

The reduction in moisture content of the produce during drying is shown in Fig. 4. It can be seen that rate of drying of arecanut is slow as the migration of moisture from the kernel to the husk is slow. Normally by the conventional method of sun drying, the ripe arecanuts require about 45 days for drying and hence very often it is noticed that sudden intermittent rains during the process of sun drying accelerates fungal infection in the kernel. The drying of arecanuts in this dryer resulted in uniformly dried product of good quality, free of fungal infection with percentage of cracks developed during drying being less than 5%. Very rapid drying of arecanut may result in cracking of the nuts.

The rate of removal of moisture from cardamom was found to be rapid as it can be seen in Fig. 4. However, the quality of the dried cardamom was not satisfactory as there was slight discolouration of the capsules due to condensation of moist vapour. Since it was only a preliminary study for cardamom, the dryer needs to be slightly modified for quicker removal of the moist exhaust air to retain the green colour as desired in the international markets.

Table II. *Dryer performance data.*

S. No.	Produce	Qty.	Drying air temp. °C	Initial m.c. %	Final m.c. %	Total drying time hrs.	Qty. of final product kg	Fuel used	Qty of fuel used kg	Thermal efficiency
1.	Copra	1000-1200 coconuts	60-70	43-51	5-6	33-37 (3 days)	145-160	Coconut husk + shell	110	18.70
2.	Arecanut	350 kg	60-70	71.0	8.0	87 (11 days)	170	-do-	240	19.20
3.	Cardamom	75 kg	45-55	82	7.8	23-28	14.5	-do-	34-37	23.40

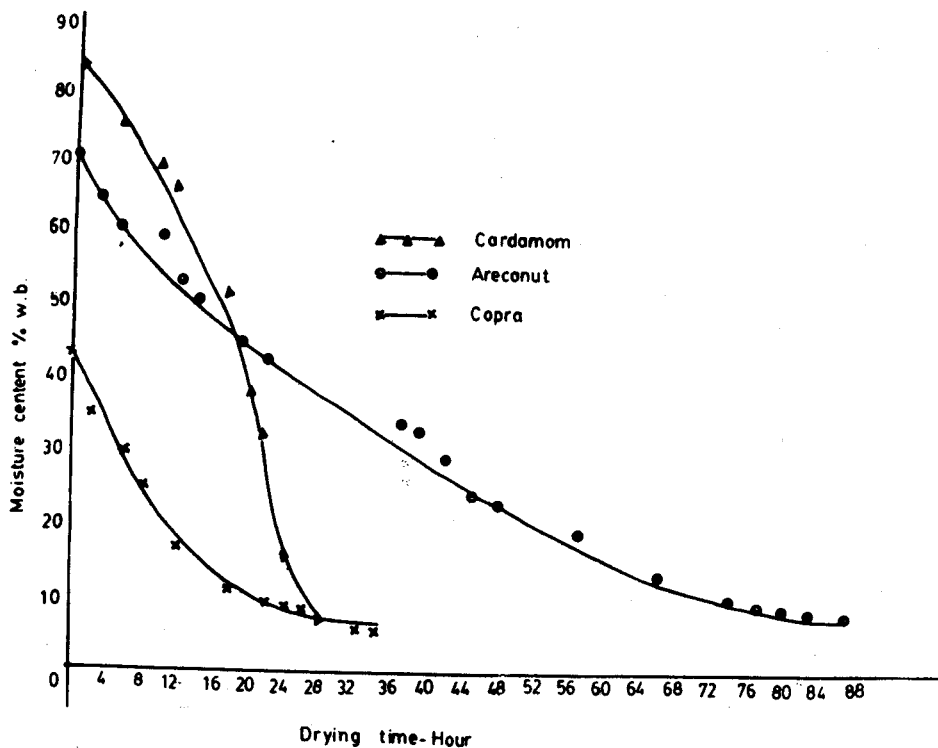


Fig. 4. Drying curves for produces in the dryer

The rate of removal of moisture from copra is found to be rapid in the initial 10 hrs due to the free moisture available in the produce and subsequently the moisture removal is found to be slow. The quality of copra dried in this dryer was very good with 70-85% of the produce as I grade copra, free of any microbial infestation.

The temperature and relative humidity of the air during copra drying are shown in Fig. 5. The temperature of drying air in the central region just below the drying chamber was about 60-75°C while the temperature of air in the corners was 50-60°C. There is a variation of about 10°C temperature between corners and the central region and hence frequent mixing

of the produce was required to effect uniform drying. These variations did not affect the drying process much. The temperature of the exhaust air was about 40°C initially and later on it rose to 55-58°C. The relative humidity of the exhaust air was high initially due to the quicker removal of moisture and after 10 hr, the relative humidity was about 70% while the ambient air relative humidity was 90%. The velocity of exhaust air was ranging from 3-10 m/min.

Economic analysis of the dryer for copra drying

The cost of the dryer was estimated as Rs.4000/- and the expected life of the dryer is 10 years. The use of the dryer for copra and other crops can be at a mini-

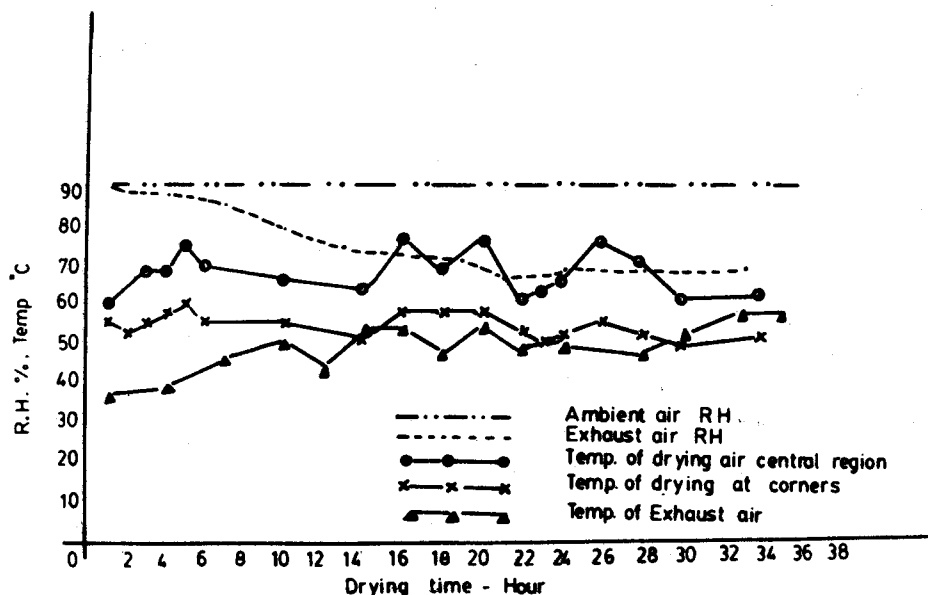


Fig. 5. Temperature and relative humidity variations of drying air and exhaust air during copra drying

Table III. *Economic analysis of the dryer for copra drying.*

Cost of the dryer	: Rs.	4000.00
Fixed cost:		
Annual Depreciation	: Rs.	400.00
Interest at 10% per annum	: Rs.	400.00
Maintenance cost per annum	: Rs.	100.00
Fixed cost per annum	: Rs.	900.00
Fixed cost per batch	: Rs.	18.00
Variable cost per batch:		
Average cost of coconuts during March-May '85:	Rs.	1650.00
		per 1000 coconuts
(including handling & transportation)		
Dehusking charges	: Rs.	35.00
Labour charges for 4 mandays @ Rs.25/ per day		
(For splitting, loading, fueling, bagging etc.)	: Rs.	100.00
Cost of fuel at 0.50 per kg for 110 kg	: Rs.	55.00
Total variable cost	: Rs.	1840.00
Total cost (Fixed cost + variable cost) per batch	: Rs.	1858.00

Returns

A. Gross revenue from sale of 160 kg of copra at Rs. 12 per kg	: Rs.	1920.00
Value of husk and shell	: Rs.	150.00
Total revenue	: Rs.	2070.00
Net income	: Rs.	2070 - Rs.1858 = Rs.212
∴ Nett additional revenue obtained by copra drying per batch	: Rs.	212.00
Cost of drying per kg of copra (excluding cost of coconut)	: Rs.	1.30 per kg
Nett additional revenue that can be realised in a year	: Rs.	10,600.00
Minimum area of holding required	:	5 ha

imum of 150 days per year especially during monsoon months. Accordingly 50 batches of 1000 coconuts each can be dried in a year. The straight line method of depreciation was adopted for calculating annual depreciation. The interest rate was assumed as 10% per annum and the maintenance cost was assumed as Rs.100.00 every year.

With the above considerations the cost analysis of copra drying in this dryer was done as shown in Table III. The cost of drying per kg of copra worked out to Rs.1.30. Additional revenue realised per batch by processing coconuts into copra instead of selling coconuts as such was Rs.212.00 and even by processing 20,000 coconuts, the investment on the dryer can be realised back. Hence use of this dryer during monsoon months is economically profitable proposition.

ACKNOWLEDGEMENTS

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MODIFIED PULPER CUM WASHER FOR PROCESSING COFFEE

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ABSTRACT

In a comparative trial a modified dry pulper cum washer was evaluated against a conventional washer to determine water required to produce one tonne of clean coffee. Percentage cut beans produced and quality of processed coffee were also assessed. The experimental results showed that water consumption was less by 80-90 per cent in dry pulper cum washer. Quality of coffee processed by these two machines remained same. Advantages of using dry pulper are discussed.

INTRODUCTION

Generally, coffee fruits are processed by one of the two methods: the wet process which produces mild or washed coffee; and the dry method to produce natural coffee or cherry coffee. In the former process large quantity of water is consumed to produce parchment coffee – a high value product, fetching higher price than cherry coffee. About 70 per cent of arabica coffee produced in India is processed by wet method (Anon. 1986). Studies have revealed that 400 to 450 litres of water is consumed to process one forlit (25 kg) of fruits. Forlit is an unit to measure coffee in terms of volume.

More water consumption results in coffee pulp house effluents which causes pollution in natural water bodies. In order to reduce the quantum of water used for processing of coffee, several manufacturers of coffee pulpers in consultation with Central Coffee Research Institute (C.C.R.I.) attempted to bring about modifications in the existing machinaries. One firm was successful in developing a

new machinery, a modified washer (dry pulper cum washer) involving less water consumption per unit weight of coffee processed. Therefore, a comparative trial against a conventional washer was conducted to evaluate the water requirement and the quality of coffee produced. The experimental results of this comparative trial are presented in this paper.

MATERIALS AND METHODS

Dry pulper cum washer (new machinery) developed by M/s. Adams Engineering Works, Mercara and Henstchel – an old German model washer in use at C.C.R.I were evaluated in the experiment.

Conventional washer had the capacity to wash/process 35-40 forlits of fruits per hour while the new machinery had the capacity to process 80-90 forlits of fruits per hour.

The new machinery differed from the one in use only in one respect; that is to say the pulping was being done dry in the

absence of water and the water was being used only to convey the fruits to the pulper. Water carrying the fruits will trickle down from the screen and flow down to recycling tank from where it is recycled to syphon tank with the help of a sump pump. The recycled water amounted to 1365 litres.

In pulper the pulp or exocarp (fruit skin) is removed by the rotating disc. First the fruit is squeezed between the roughened surface of the disc and a stationary member called a breast with a smooth surface, sometimes lined with rubber.

In aqua washer the mucilaginous layer (0.5-2.0 mm thick) is removed by attrition or scrubbing. The washer consists essentially of a rotating horizontal cylinder inside a fixed cylinder with a slightly ribbed surface. The inner cylinder is fitted with cleats, both longitudinal and traverse, to assure the positive, partial rotation of the coffee. At the feed end, a few turns of screw conveyor ribs feed the coffee through the machine at a uniform rate. Some resistance and pressure is built up within the machine by a partially throttled and adjustable outlet. Small slots are provided in the bottom for the escape of water, mucilage and finely ground pulps with retention of coffee.

The machine is usually set with just enough clearance to avoid bruising of coffee beans i.e., to avoid cuts and bits of coffee. Washers have usually been used as a simple scrubber for coffee that has already been pulped in standard pulpers.

The waste waters let out from the general coffee pulping and processing

unit using aqua pulper include wash water along with skins from the pulper, wash water from the aqua washer and seed wash water after the aqua pulper.

Arabica coffee harvested daily at CCRI was processed by using both these machines separately. Observations on quantum of water used in different lots and also the percentage cut and naked beans produced were recorded for two seasons. Handful of washed coffee was taken to determine the total number of beans and number of cut beans. The quantum of fruit processed per day and time taken were also noted. The waste water flow was measured using bucket method (Trivedy and Goel, 1984). Buckets of 5 l and 10 l capacity were used to measure the water at the end of the sewer and the time taken in filling was noted. Flow of water per minute was calculated using the following formula.

$$\text{Flow (in litres/min)} = \frac{\text{Litres in bucket} \times 60}{\text{time in sec.}}$$

RESULTS

The quantity of waste water as measured by fill and draw method from individual sections from the conventional washer and new machinery is given in Table I.

The washed parchment obtained from the two machineries was dried on a tiled drying yard to the prescribed standard test weight (15.5 kg/forlit). Clean coffee samples were processed and 'A' grade samples (6 each) were sent for cup evaluation at Bangalore cup tasting centre. The cup taste results with respect to raw, roast and liquor characteristics

Table I. Flow measurements of waste water from coffee pulping units using conventional aqua washer and new machinery on different occasions processing arabica fruits.

(Waste water production in litres)

Section	Henstchel washer			New washer		
	1	2	3	1	2	3
Pulper	5500	5500	9000	1365 litres of water recycled		
Aqua pulper	8000	8100	14000	1375	875	1200
Seed wash	550	540	1300	733	656	600
Total Quantity	14050	14140	24300	2108	1531	1800
Fruits processed in forlits per day	35*	36*	60*	68*	55*	55*
Time taken for processing (minutes)	60	62	102	55	35	40
Water consumed or waste water produced per forlit (in litres)	401	393	405	31	28	33
Mean of 3 occasions	—	400 l	—	—	31 l	—
Quantum of water consumed for processing one tonne of clean coffee		80,000 l			6,100 l	
Percentage cut beans		3.4%			3.0-4.2%	

*One forlit of arabica fruits weighs 25-26 kg

and the scores awarded are presented in Table II.

It is seen from the data (Table I) that the quantity of water consumed to produce one tonne of clean coffee (approx-

mately to process 200-210 forlits of fruits) in case of conventional washer as computed works out to 80,000 l of water (no recycling), while in case of dry pulper, 7500 l of waste water is produced per tonne of clean coffee processed, which included water recycled.

Table II. Mean scores awarded to raw, roast and liquor characteristics of coffee processed by conventional washer and new machinery.

Washer	Scores* awarded			Total
	Mean of 6 replications			
	Raw	Roast	Liquor	
Conventional Washer	2	3	3	8
New washer	2	3	3	8

*Higher the score lower the quality.

Observations recorded on percentage naked and cut beans produced revealed that it varied between 3 and 4.2% which falls in the permissible limits and compares with that of conventional washer (4.0% naked and cut beans).

The overall quality of coffee processed by these two machines remained same.

DISCUSSION

The water requirement in case of con-

ventional washer works out to 80,000 l per 200-210 forlits of fruits processed and this is in agreement with earlier studies (Anon., 1980).

In respect of quantum of water consumed evaluated with sufficient number of replications using dry pulper the data indicated the total waste water production would be 7,500-8,000 l (including the recycled water from syphon tank to pulper) for processing 200 to 210 forlits of fruits. Keeping the maximum water consumption at 8,000 l it is worthwhile to note that the water used is 90% less than that of conventional washer.

Percentage naked beans, cuts and bits produced in new machinery did not vary much as compared to conventional washer.

The over all quality of coffee processed by these two machines also remained same indicating that use of new machinery had no adverse effect on quality of coffee.

Considering the benefit that accrues by the use of dry pulper cum washer particularly with regard to quantum of water

it may be concluded that by the use of this new machinery the volume of effluents produced, the size and dimensions of the treatment units such as anaerobic and aerated lagoons is reduced and in turn less capital costs on effluent treatment. It would be advantageous to use this washer in coffee growing zones where water is scarce. Treatability studies on effluents produced from dry pulper unit are contemplated.

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MODIFICATIONS IN CTC RECONDITIONING PROCESS FOR THE IMPROVEMENT OF BLACK TEA QUALITY

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ABSTRACT

Methods for preparation of reconditioning dusts by suitably modifying the CTC process of black tea manufacture were suggested. Black teas obtained from green leaf using three kinds of reconditioning dusts were evaluated for their liquor quality by chemical analysis. Keeping quality of these teas was also determined.

INTRODUCTION

The reconditioning process in CTC (crush, tear and curl) tea manufacture in southern India has been established with a view to improving blackness, graininess and bulk density of tea (Stephen Thanaraj and Ramaswamy, 1980). The powdery stuff, known as reconditioning dust (RC) which improves the desirable attributes of CTC tea, is obtained generally by grinding unremunerative larger grade of tea, spills and stalky teas to a fine powder in a pulveriser. However, no standard exists at present in any factory on the physico-chemical properties of the raw materials that produce RC. Quality of RC is also ambiguous in this context. In order to understand the influence of different kind of RCs on the quality of mode tea, experiments were carried out by making modifications in the CTC reconditioning process.

MATERIALS AND METHODS

Mixed jat green leaves were used for the manufacture of RCs as well as black tea samples. The quantity of RC incorporation at rotorvane stage was such that

the crushed dhool contained moisture content of 50%. Wherever withering and fermentation were required, they were carried out to 75% and one hour respectively. All the RCs and black tea samples were manufactured on factory scale at UPASI Tea Research Manufacturing Unit. Three kind of RCs designated as RC-1, RC-2 and RC-3 were prepared and incorporated in the manufacture of black teas by following CTC process.

As illustrated in Fig. 1, RC-1 is the pulverised stuff withered, crushed, fermented and dried tea by the process P-1. The RC-2 was prepared in the same manner as RC-1 but leaving the fermentation stage in accordance with the process P-2. The RC-3 is again the ground material of unwithered, crushed and immediately dried tea as shown in the process P-3. Teas produced using RC-1, RC-2 and RC-3 were labelled as T-1, T-2 and T-3 respectively. Of these T-1 corresponds to the conventional reconditioned CTC tea.

Broken Orange Pekoe (BOP, sieved between 12 and 18 mesh), Red Dust (RD,

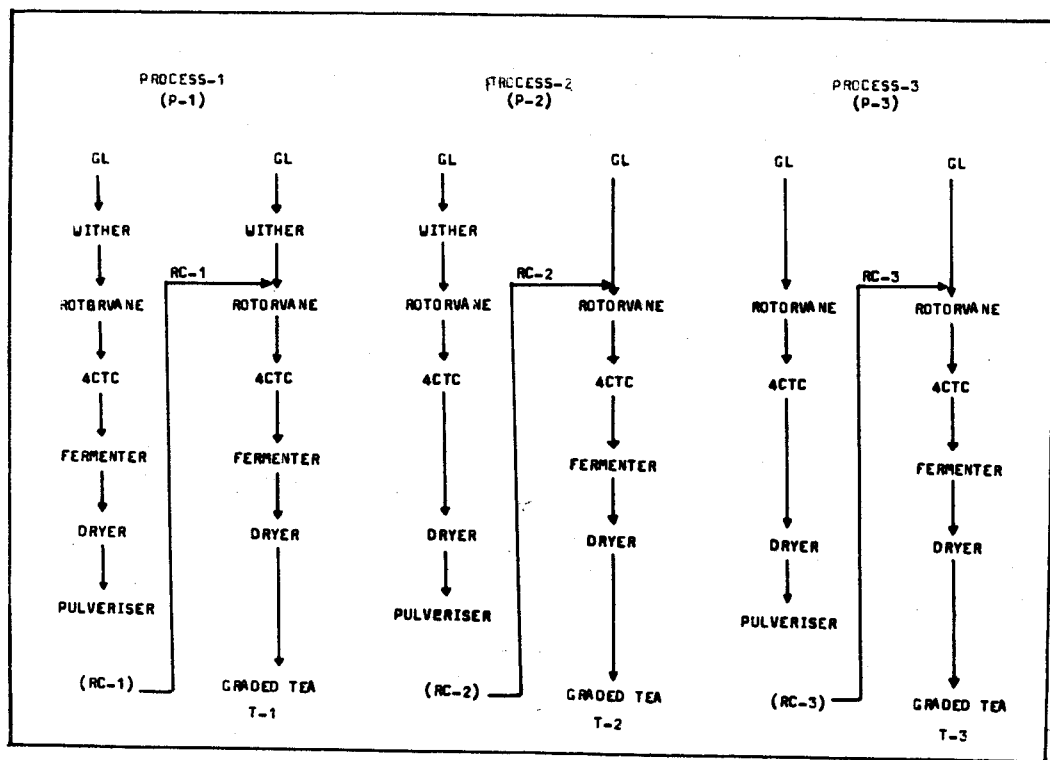


Fig. 1. Various types of CTC-reconditioning processes.

- GL - Green leaf
 CTC - Crush, Tear and Curl Process
 RC - Reconditioning dust

sieved between 30 and 40 mesh) representing the leaf, and dust grades, respectively, were collected for chemical analysis. The percentage of each grade was determined by following the established practice of grading. To study the keeping quality of manufactured teas, samples were stored in aluminium containers.

Moisture content of withered leaf, dhool, made tea and RC was determined by the oven method (I.S.I., 1973). Black tea samples were analysed for the contents of thea-flavins (Takeo and

Oosawa, 1976), caffeine (Egon et al., 1981) and total chlorophylls (Harborne, 1973).

RESULTS AND DISCUSSION

Table I shows the grade ratio of teas made using the three kinds of RCs. It is observed that the percentage of total dust grades (including Red Dust, Super Red Dust and Super Fine Dust) was 44 and 48 for teas T-2 and T-3, respectively, when compared to 43.8 for T-1. The percentage of total leaf grade, which consists of Pekoe and Broken Orange Pekoe, in T-1, T-2 and T-3 is 19, 23.9 and 19.2 respec-

Table I. *Grade ratio of teas made using three kinds of reconditioning dusts.*

Grade	Process - 1 (P - 1)	Process - 2 (P - 2)	Process - 3 (P - 3)
Pekoe	8.0	6.7	8.2
Broken Orange Pekoe	11.0	17.2	11.0
Broken Orange Pekoe Fanning	31.5	19.8	23.8
Red Dust	10.8	14.6	14.0
Super Red Dust	9.0	20.2	21.8
Super Fine Dust	24.0	9.2	12.2
Residue	5.7	12.3	9.0
Total	100.0	100.0	100.0

tively. The decrease in leaf grade percentage in T-3 is compensated by an increase in dust grade, when compared to other teas. This indicates that the disintegration of leaf and the rate of oxidation in P-3 are higher than that in P-1 and P-2. Among the various grades of teas produced by CTC manufacture in southern India, dust grades get premium for appearance, density and cuppage value compared to leaf grades (Stephen Thanaraj and Ramaswamy, 1980). Observations from Table I confirm that modified processes P-2 and P-3 produced larger percentage of dust grades com-

pared to the conventional process, P-1.

Table II show the level of theaflavins,

$\frac{\text{TF}}{\text{TR} + \text{HPS}} \times 100$ and total chlorophylls of

BOP, and RD grades of teas, respectively, obtained from P-1, P-2, and P-3. Ellis and Cloughley (1981) reported that the theaflavin is known to contribute to the liquor quality and it has a positive correlation with price realisation. Modified reconditioning processes have produced black teas with improved liquor quality as indicated by higher levels of theaflavins in T-2 and T-3 (Table II). The

Table II. *Chemical analysis of tea samples manufactured by three different CTC Reconditioning processes P-1, P-2 and P-3.*

Process	Theaflavins %		TF $\frac{\text{TF}}{\text{TR} + \text{HPS}} \times 100$		Caffeine %		Chlorophylls ppm	
			BOP	RD				
P-1	0.51	0.69	3.52	4.51	3.64	3.79	2100	2080
P-2	0.78	0.87	5.95	5.76	3.81	3.59	1890	1950
P-3	0.74	0.90	5.98	6.16	3.49	3.48	2040	1980

Analysis carried out after 10 days of manufacture.

TF: Theaflavins TR: Thearubigins HPS: High polymerised substances.

Table III. *Chemical analysis of tea samples after six months of storage*

Process	Theaflavins %		TF × 100		Caffeine %		Chlorophylls ppm	
			TR+HPS					
	BOP	RD	BOP	RD	BOP	RD	BOP	RD
P-1	0.55	0.55	3.60	3.74	3.74	3.65	1990	2130
P-2	0.74	0.90	5.52	6.12	3.27	3.40	1850	1840
P-3	0.80	0.95	6.20	6.55	3.47	3.36	1930	2100

TF: Theaflavins TR: Thearubigins HPS: High polymerised substances.

possible reason for the increased level of theaflavins in such teas could be due to the addition of reconditioning material RC-3. It has been reported earlier that the ratio, between TF and TR + HPS is an indication of overall black tea liquor quality (Stephen Thanaraj and Ramaswamy, 1981). In the case of tea produced from modified process, the ratio is higher when compared to the conventional process.

As far as the caffeine content is concerned all the teas maintained sufficient levels of caffeine which is desirable in the context of briskness. With regard to chlorophyll content of tea, T-2 and T-3 exhibited a decrease when compared to T-1. According to Wickremasinghe (1966), the chlorophylls and their degradation products present in black tea are responsible for different shade of blackness of made tea. Also, it is known that higher levels of chlorophylls in black tea will impart greenness to infused leaf colour. Table III shows the chemical analysis of teas T-1, T-2 and T-3 after 6 months storage. It is clearly seen that the general trend is maintained in all three types of teas even after 6 months of

storage. It is also observed that there was no deterioration in quality.

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INFLUENCE OF HIGH TEMPERATURE DYING ON GALLIC ACID FORMATION IN BLACK TEA

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ABSTRACT

The role of gallic acid on blackness of tea was investigated. The effect of high temperature drying and clonal variation on the blackness of tea was also studied. The quality of black tea dried by fluid bed drying was compared with that by conventional drying, with respect to blackness and gallic acid and theaflavins contents. This study indicated that fluid bed drying increased the gallic acid content with an improvement in the blackness of tea, also showing an improvement in theaflavins levels.

INTRODUCTION

In the case of South Indian CTC (Crush, Tear and Curl) teas, blackness is one of the important characteristics which is highly preferable and is intimately associated in our minds with a quality product. Blackness of tea has been positively correlated with gallic acid content of made tea (Ramaswamy and Stephen Thanaraj, 1981). Gallic acid (3, 4, 5-trihydroxybenzoic acid) is present in tea shoots mostly in the form of esters with catechins, (-) epicatechin-3-gallate, (-) epigallocatechin-3-gallate and (-) epigallocatechin-3, 5-digallate as well as in the free form (Saijo, 1983).

Gallic acid content of made tea has been found to be greatly influenced by manufacturing conditions. It has been reported earlier that gallic acid content decreases during fermentation stage of black tea manufacture due to its conversion into eip-theaflavic acid and its gallate (Berkowitz, *et al.*, 1971). A modified split CTC process involving two

stages of fermentation and mixing of re-conditioning dust after first stage of fermentation resulted in teas with high levels of gallic acid (Ramaswamy and Stephen Thanaraj, 1981). However, there is no information available on the effect of drying conditions on the gallic acid content of made tea. The present investigation was, therefore, designed to study the effect of high temperature drying and clonal variation on the gallic acid content of made tea during manufacture.

MATERIALS AND METHODS

Tea manufacture was carried out in the mini-manufacturing unit of UPASI Tea Research Institute. Freshly plucked clonal tea (UPASI-3, UPASI-10, UPASI-15 and UPASI-17) leaves collected from UPASI Tea Experimental Farm were spread out at the rate of 10 kg m⁻² on a withering trough and allowed to wither artificially by means of ambient air for 16 hours. The withered leaves were passed through a CTC machine four times to bring about adequate maceration. A portion of CTC

processed leaves (dhool) was allowed to ferment for appropriate time in an air-conditioned cabinet at 25°C and 95% RH. The fermented 'dhool' was dried in a miniature drier using hot air at 80, 100 and 125°C to a final moisture content of 3%. During fermentation and drying, samples were collected periodically for analysis. The Broken Orange Pekoe Fannings (BOPF) grade of tea collected between 18 and 24 mesh sieves was used for chemical analysis. Tea samples dried in Endless Chain Pressure drier (ECP) and Fluid Bed Drier (FBD) were collected from one of the tea estates in Anamalais.

Estimation of theaflavins (TF) content of black teas was carried out by following the modified Roberts' spectrophotometric method (Takeo and Oosawa, 1976; Ramaswamy, 1977). The gallic acid content of tea was determined by paper chromatographic technique (Ramaswamy and Stephen Thanaraj, 1981). Scores offered by professional tasters on blackness of made tea were also recorded.

RESULTS AND DISCUSSION

Gallic acid profile of CTC processed 'dhool' of clones UPASI-15 and UPASI-17 during fermentation and drying is shown in Fig. 1. Gallic acid content of both the clones was found to decrease during fermentation. The decrease in gallic acid during fermentation could have resulted in the formation of epi-theaflavic acid which in turn could have been oxidized into thearubigins as reported earlier by Berkowitz, *et al.* (1971). Between the two clones, UPASI-17 showed greater decrease in gallic acid during fermentation than UPASI-15 (Fig. 1). It is also observed that gallic acid content of

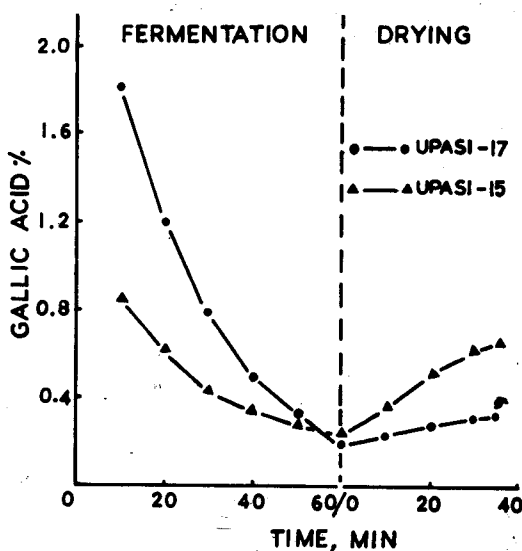


Fig. 1. Gallic acid profile of processed tea clones.

optimum fermented 'dhool' increased as drying advances and the increase is more pronounced in the case of clone UPASI-15 than UPASI-17; after 35 minutes of drying, the former showed an increase of 0.44%, whereas the latter showed only an increase of 0.12%. Between the two clones, UPASI-15 is known to produce blacker teas than UPASI-17. It has been reported that blacker teas contain more gallic acid than the browner teas (Ramaswamy and Stephen Thanaraj, 1981) and the present study confirms the earlier findings. From Fig. 1, it is also observed that UPASI-17 had higher level of gallic acid in green leaf than that of UPASI-15; but, the trend is reversed in the finished product. These data suggest that the release of gallic acid during drying is one of the important factors in the context of blackness of teas. The increase in the level of gallic acid during drying might be due to the hydrolysis of gallated catechins, theaflavin gallates and gallated epi-theaflavic acid. The difference in the

Table I. *Effect of temperature during drying (ECP) on gallic acid and theaflavins contents and blackness of made tea from different clones.*

Clone	80°C		100°C	125°C					
	GA %	TF %	Blackness score	GA %	TF %	Blackness score	GA %	TF %	Blackness score
UPSAI-17	0.50	1.35	2	0.59	1.46	3	0.78	1.25	5
UPSAI-3	0.60	1.61	3	0.75	1.68	5	0.79	1.52	6
UPSAI-15	0.72	0.95	6	0.94	1.00	7	0.99	0.83	8
UPSAI-10	1.02	0.80	8	1.30	0.88	9	1.42	0.70	10

GA: Gallic acid; TF: Theaflavins

amount of increase in gallic acid content during drying with respect to the two clones indicate that the level of gallated polyphenols and the rate of hydrolysis might be markedly different in two clones which may be attributed to the clonal character.

Table I shows the effect of drying at various temperatures on gallic acid and TF contents and blackness of made tea from four clones. It is observed that among the four clones analysed, those which gave blacker teas had higher levels of gallic acid. The gallic acid content of teas dried at 125°C was found to be more than those dried either at 100°C or at 80°C. As the temperature of drying is increased, the gallic acid content of made tea also increased which ultimately indicates that hydrolysis of gallated polyphenols during drying is temperature-dependent.

As TF content of black teas has been found to be positively correlated with briskness and colour of the liquor (Roberts, 1962) as well as with the price realisation of the product (Ellis and Cloughley, 1981), it is all the more important to look into the change in the

TF content of made teas dried at different temperature, in addition to the gallic acid content. It is also observed from Table I that the clones which produced blacker teas had less amount of TF. The sample dried at 100°C had higher amount of TF than that at 80°C, but too high a temperature (125°C) in the ECP was found to reduce the amount of TF significantly.

It is well established in the tea industry that FBD improves the blackness and bloom of made tea. Table II shows the influence of types of drying on gallic acid and TF contents and blackness of tea. It is observed that teas dried in FBD resulted in higher levels of gallic acid in all the grades of teas than those dried in ECP. Even though FBD drying is done at a high temperature (125°C) compared to ECP drying the TF content of tea is not affected probably because of the fact that the individual tea particle is freely suspended on a cushion of hot air during fluidisation which results in more uniform and rapid drying.

This study shows that the galic acid content of tea increases during drying stage of black tea manufacture, and the

Table II. *Effect of types of drying on gallic acid and theaflavins contents and blackness of made tea.*

Grade	ECP drying (at 95°C)			FBD drying (at 125°C)		
	GA %	TF %	Blackness score	GA %	TF %	Blackness score
Red dust	0.84	0.54	7	1.24	0.63	9
Fine dust	0.90	0.59	8	1.30	0.64	10
Super fine dust	0.92	0.53	8	1.50	0.61	10

GA: Gallic acid; TF: Theaflavins

ECP drying: Endless chain pressure drying

FBD drying: Fluid bed drying

level of gallic acid in made tea is dependent on the temperature of drying. Also, the clonal character of tea influences the blackness of made tea. The FBD drying increases the gallic acid content of made tea with a consequent improvement in the blackness without affecting the TF content.

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CURCUMIN FROM TURMERIC OLEORESINS

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ABSTRACT

A process for the isolation of volatile oil and curcumin from turmeric powder is described. Curcumin assay extracted by this process is estimated to be >95%. Economic viability of this process indicated that multiple recovery of curcumin and essential oil should be attempted by the enterpreneur.

INTRODUCTION

The main colouring principles in turmeric rhizomes are curcumin and its analogues. Curcumin belonging to dicinnomyl methane class bears an empirical formula $C_{12}H_{20}O_6$, is 1,7 bis (4-hydroxy 3 methoxy phenyl) 1,6 dione 3,5 dione. Its melting point is in the order of 184-186°C. It is insoluble in hexane but readily soluble in alcohol. Curcumin is synthesised by two stage condensation reaction between carbomethoxy feruloyl chloride and ethyl acetoacetate (Mayer, 1943). Besides synthesis many workers (Srinivasan, 1953, Khalique and Amin, 1967; Janaki and Bose, 1967; Sair and Klee, 1967 and Sastri, 1978) resorted to the retrieval of curcumins from its native spices *Curcuma longa* L. Each of these above processes were either uneconomical or contained solvents prohibited for use as food additives. Lead salt precipitation of this pigment (Perkin and Philps, 1943) is also not suitable, due to the stringent conditions laid down by WHO and FAO (Anon., 1961) on the levels of lead in food products.

Due to increased tendency to change over from synthetic colours to natural ones, the utility value of natural colouring principles of turmeric is gaining ground. Curcuminoids besides being safe possess an added advantage of anti-oxidant property, (Hirhara, 1975, Sethi and Agarwal, 1950).

In the present paper a new approach has been attempted towards recovering curcumin from deoiled turmeric oleoresin (>95% assay ratings). The price of this product is adjusted as \$68 per Kg by local trade representative (personal communication).

MATERIALS AND METHODS

Turmeric powder preferably ground to pass through 200 mesh is depleted by its volatile oil by steam distillation. The deoiled spices is air dried and filled in a column and alcohol is percolated. After a contact time of 12 hours, this percolate is desolventized and alcohol free resinous mass is added with equal quantities of hexane and decanted out to remove fats

*CPCRI contribution No. 526.

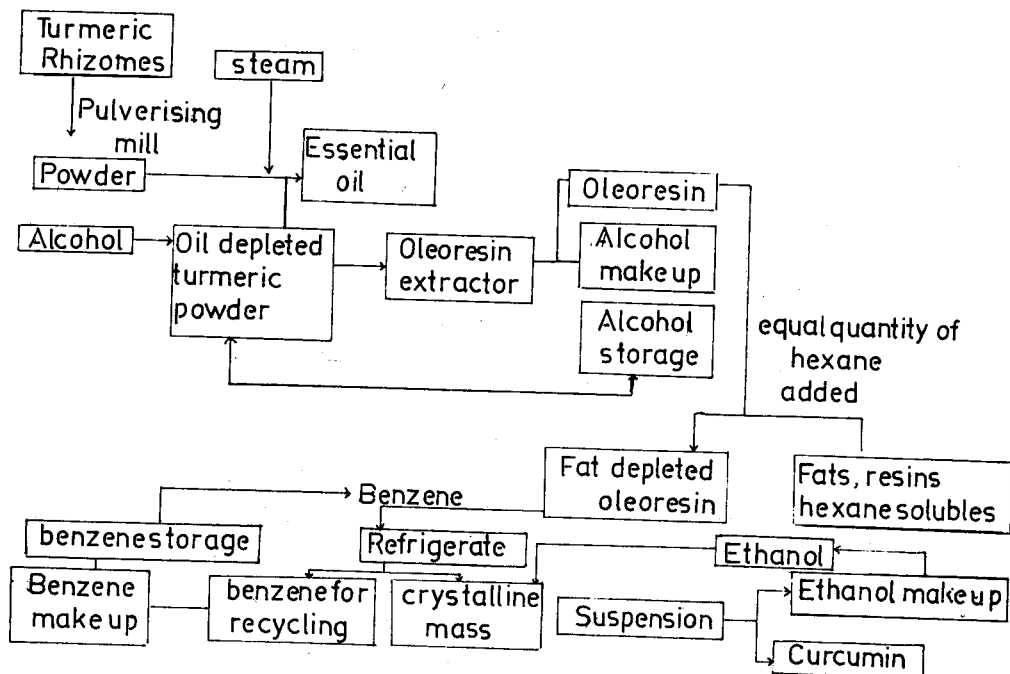


Fig. 1. Process for the isolation of curcumin from Turmeric oleoresin

and other hexane solubles (Fig. 1). The hexane extracted oleoresin is now treated with equal volumes of benzene and thoroughly mixed. The contents are positioned in a refrigerator at 4°C for facilitating crystallization. The crystallization mass is cold centrifuged and purified further by suspending the centrifuged mass in limited quantity of ethanol. The ethanolic suspension is vacuum concentrated by removing ethanol resulting in yellow crystal mass with curcumin assay ratings of 95%. Curcumin is estimated by spectrophotometry as per the method of ASTA (1978). Thin layer chromatography is used to monitor the presence of oxidation products of curcumin. TLC plates (0.25 mm thickness) are developed with a solvent system containing benzene and

ethyl acetate (7:3 v/v) and analogues are estimated by spectrophotometry.

RESULTS AND DISCUSSION

Two batches of deoiled turmeric oleoresin having two levels of curcumin content (Table I) have been processed for the isolation of pure curcumin (>95% assay). The unprocessed oleoresin had 36% curcumin. The yield percentage is around 15% with a recovery of the chemical during hexane and benzene extraction. When the curcumin recovery at the intermediate stages is also taken into account, the process appears to be more economical. Attempts have been made to avoid hexane extraction but abundant quantities of resinous matter in the oleoresin warrants the use of a high

Table I. *Curcumin recovery from turmeric oleoresin.*

Batch No.	Turmeric oleoresin	Curcumin content	Curcuminoid concentrate	% Yield	% recovery of chemical
			Quantity % Curcumin content		
1	80	36	15 96	18.75	52.08
2	500	34	78 95	15.60	45.88

polar solvent like hexane and benzene. Benzene extraction facilitates an easy removal of fatty acids, resin acids and other resinoids.

An important limitation of this extraction process is the loss of appreciable quantities of curcuminoids in benzene and alcoholic extracts. Assay of solvent depleted benzene and alcohol extracts contained 60-70% curcumin content. The loss of active ingredient during this process is negligible if this quantity is also taken into account, vice its commercial value. Thin layer chromatography of different solvent extracts and pure curcumin sample indicated

that these extracts gave three distinct yellow coloured spots along with appreciable quantities of base material.

Srinivasan (1953) extracted curcuminoids from *Curcume longa* L. with light petroleum ether followed by boiling benzene extraction. The subsequent chromatographic resolution makes the process too cumbersome for industrial adoption. The process outlined by Janaki and Bose (1967) used a soxhlet extraction for initial extraction. Sastry (1970) suggested throwing the alcohol extract into pure kerosene and later recovering the ethanol by crystallisation. The use of kerosene does not appear to be a suitable

Table II. *Tentative cost benefit estimate for curcumin recovery process.*

Basic treatment of 100 kg of turmeric oleoresin and production of 90 kg volatile oil and 15 kg of curcumin.

Raw material cost	Quantity	Rate Rs.	Cost Rs.
Turmeric rhizomes	15000 kg	1550/ton	23250
Alcohol (industrial grade)	1500 l	9.50/l	14250
Hexane	250 l	7.50/l	1875
Benzene	200 l	8.0/l	1600
		Total	40975
			or 41000
Sale price of the products			
Curcumin concentrate of 95% assay ratings	15 kg	\$68/kg	12780.6
Volatile oil	90 kg	360/kg	34280.0
		Total	46,980
			or 47,000

process for the end product is to be used as a food additive.

Economic viability of this process depends upon the multiple recovery of solvents and essential oil components. Tentative cost benefit estimates of this process are presented in Table II. On the basis of the recovery of curcumin and volatile oil the cost benefit implications appear to be attractive. The difference between the costs of raw material and proceeds of the sale is substantial to absorb other overhead expenses like service, labour, maintenance of equipment and return on capital etc. leaving large margin of profit.

Any solvent extractor can easily adopt the process provided supply of essential raw material i.e. turmeric rhizomes is ensured. An extension of refrigeration plant is necessary for recovering the curcumin with high assay ratings.

ACKNOWLEDGEMENTS

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*Original not seen.

LIPOPHILIC PROFILE OF EXTRACTABLE FAT FROM NUTMEG *MYRISTICA FRAGRANS* L.

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ABSTRACT

A simple scheme for extraction of nutmeg fat from nutmeg *Myristica fragrans* L is described. The variation in this fat was 24-30% in the accessions evaluated. Thin layer chromatography of saturated lipids in the fat indicated the presence of mono, di and tripalmitins. The triglyceride content varied from 86.2 to 97.4% within the accessions and may serve as a useful quality index in nutmeg. The other triacylglycerols are found to be absent. The glyco, neutral and phospholipids were found to be 33, 28 and 10% respectively. Large variation is observed in the case of fatty acid profile. The suitability of this fat in perfumery and confectionary is described.

INTRODUCTION

Nutmeg *Myristica fragrans* L is a source of two spices viz. nut and the mace. Analytical characteristics of mace fat (Pishawikar and Pishawikar, 1953) and its lipid composition studies (Prakashchandra and Chandrasekharappa, 1984) confirm its suitability for perfumery. Even though nut is reported to contain 28.35% of solvent/fat, reports about its analytical characteristics and lipophilic profile are scanty. In the present paper a simple scheme for solvent extractable fat is presented and its analytical characteristics and lipid composition are studied.

MATERIALS AND METHODS

Nutmeg nuts were obtained from marked accessions (from CPCRI Research Centre, Kannara) and shade dried,

ground fine to pass 40 mesh and fat extracted as per the flow sheet (Fig. 1). For obtaining the total fats hexane extract was desolvent and quantified by gravimetry.

Lipid separation

The chloroform solubles were resolved by stepwise elution into neutral, glyco and phospholipids as per the method of Prakashchandra and Chandrasekharappa (1984) and respective fractions were quantified by gravimetry.

TLC of lipids

Known quantity of nutmeg fat from each accession was dissolved in chloroform alongwith lipid standards containing mono, di and tripalmitins (Sigma Chemicals) in equiproportions on a pre-activated silica gel G (0.25 mm thickness)

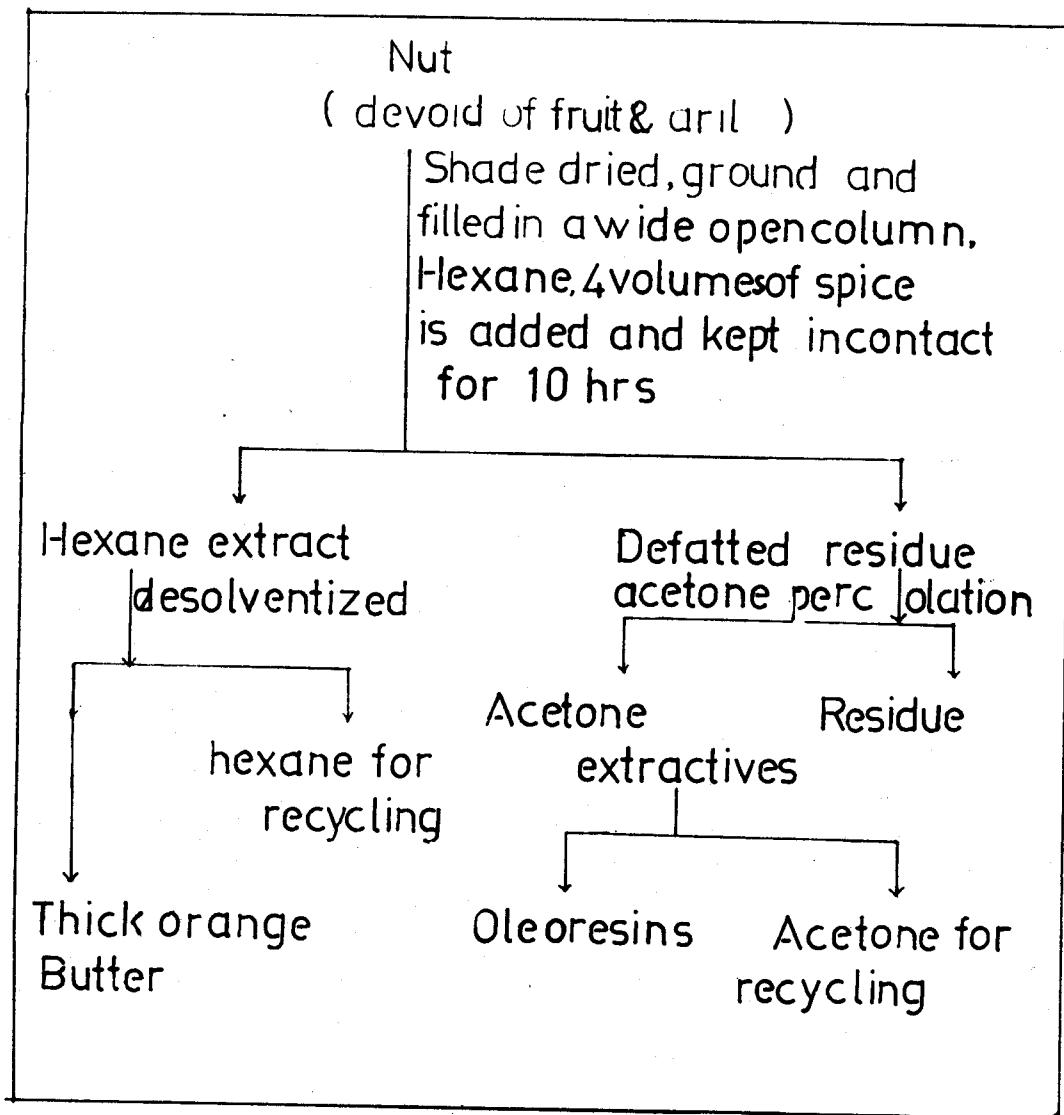


Fig. 1. Flowsheet for the extraction of nutmeg butter and oleoresins

plate and developed in a solvent system containing petroleum ether (60-80°C), diethyl ether and acetic acid (90:10:1 v/v) and exposed to iodine vapours for visualisation. Another plate was developed and sprayed with 0.5% Bromothymol blue in aqueous ethanol and exposed to

ammonia vapour to confirm the above results.

TLC of fatty acids

Fatty acids in nutmeg fat was separated by TLC with a linoleic acid as a marker standard as per the method of Morrison *et al.* (1980).

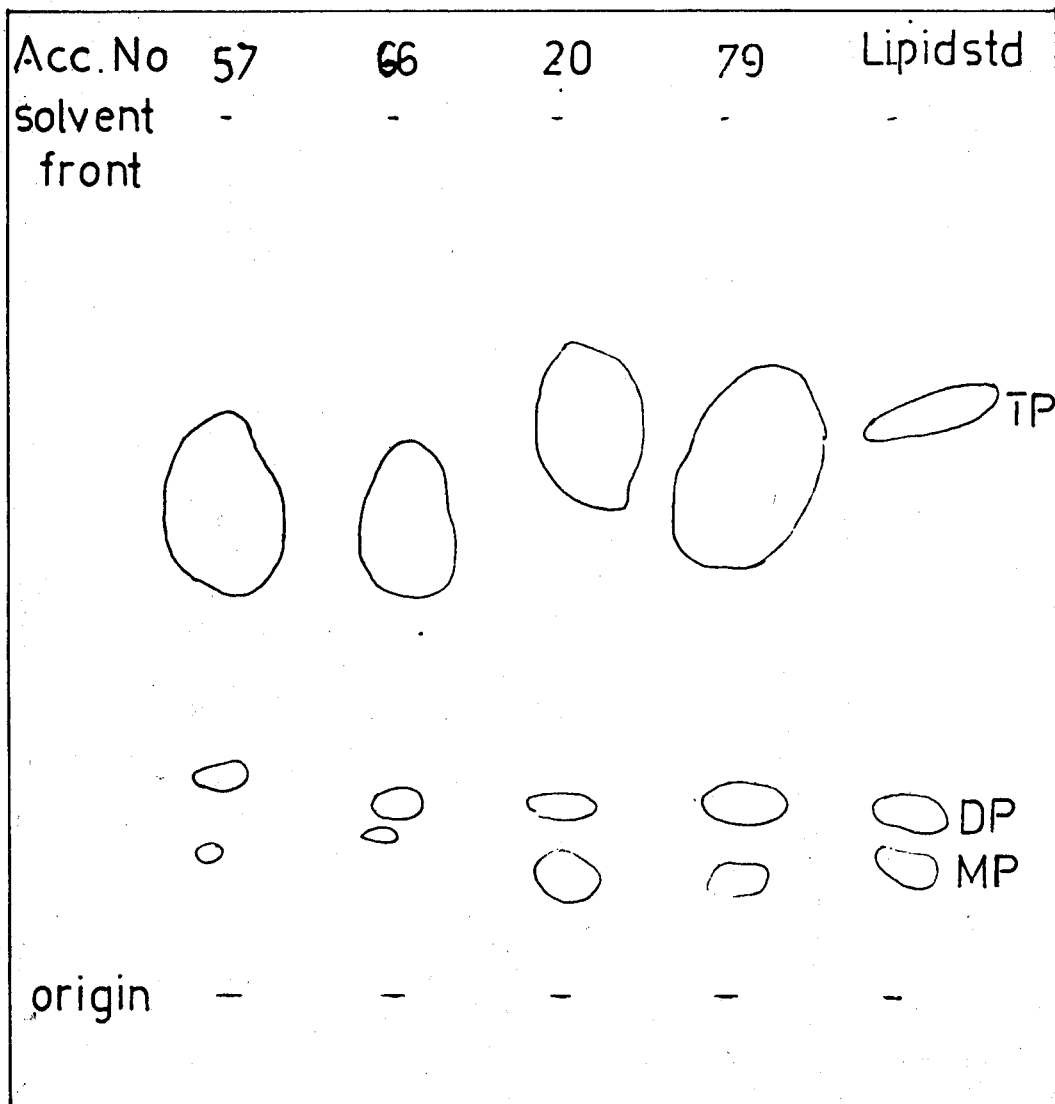


Fig. 2. TLC trace diagram of saturated lipids in
 Fat extracted from nutmeg solvent system: Pet: ether:
 Diethylether: Acetic acid 90:19:1(v/v)
 TP: Tripalmitin. DP: Dipalmitin.
 MP: Monopalmitin

Gas liquid chromatography of fatty acids

GLC of representative sample of the (methylated) fat was accomplished by using Hewlett pachard 5730 A GC inter-

faced with varian Techtron recorder as per the method of Marta I. Aveldans and Lioyd Horrecks (1983). Individual fatty acids were quantified and presented as the b% total of the acids.

Table I. Variation in nut weight, total extractable fat and lipid profile in the selected accessions.

Accession No	Nut weight	%** Fat	Lipid profile		
			Mono	di palmitins	tri
20	17	26.04	0.6	1.9	97.4
57	27	30.50	6.8	6.8	86.2
66	15	24.00	4.7	5.0	89.3
79	13	25.78	0.8	5.4	93.8

*Average of two determinations

**Hexane extraction

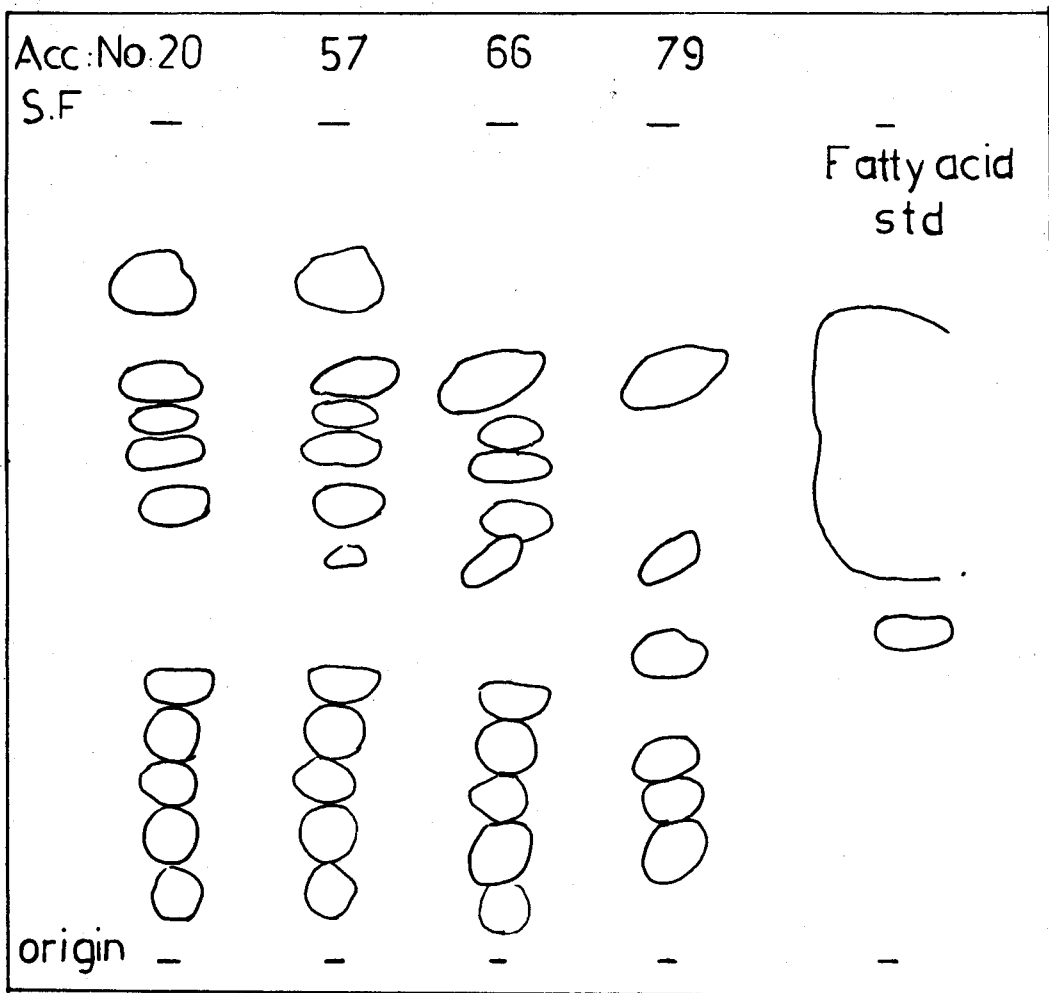
RESULTS AND DISCUSSION

A simple scheme for the extraction of nutmeg fat is presented in Fig. 1. It is necessary to use wide open column in place of ordinary glass columns since the hexane extract during the elution blocks the column by the formation of semi solid fat. However, by using a wide open column such a difficulty could be overcome, the extraction of 200 g nut flour yields about 60 g of nutmeg fat. Analysis for the residual solvents in the extractable fat indicate the presence of spice fat only. A wide variation in the total extractable fat was observed in different accessions. Variation in per cent nut weights, extractable fat and lipid profile in selected accession are presented in Table I. It is generally observed that the fat content depends on the per cent nut weight, and varied from 24-30%. A preliminary TLC after dissolving nutmeg fat in chloroform and visualized by iodine vapour exposure has revealed besides fatty acids, some saturated and unsaturated lipids. Hence a selective TLC was conducted for lipids and fatty acids. TLC profile for saturated lipids is presented in Fig. 2. It is observed that alongwith the saturated lipids, the unsaturated counter-

parts are totally absent, which indicates that rancidity of this fat is negligible. As linear relationship is observed between concentration and the area, the unknown lipids could be extrapolated. Mono, di and triglyceride content in different accessions indicate that triglycerides vary from 86.2 to 97.4 whereas mono and diglycerides vary from 0.6 to 6.8 and 1.9 to 6.8 respectively. Out of three triacyl glycerols only tri-myristicin was present in nutmeg while triolein and tripalmitin were absent.

Fractionation of nutmeg fat, into neutral, glyco and phospholipid resulted in 33% of glycolipids, followed by neutral lipids (28%) and phospholipids (10%). The unaccounted lipid fraction may be a lipoprotein. As neutral lipid portion is considerably high a detailed estimation on the fatty acid composition was taken up to understand the lipophilic profile of this fat.

TLC profile of fatty acids is presented in Fig. 3. Due to the paucity of fatty acid standards, linoleic acid standard alone was co-chromatographed and the unknowns were identified on the basis of Rf values of Morrison, *et al.* (1980) and



3. TLC Trace diagram of fatty acids from Nutmeg fat solvent system: Pet: ether: Diethylether: Acetic acid. 70:30:1

Table II. Variation in % fatty acids in different accessions.

Fatty acids	% of total fatty acids
Caproic	2.8-3.6
Caprylic	4.2-5.2
Capric	3.6-4.1
Lauric	3.6
Myristic	5.2
Palmitic	2.6-3.6
Stearic	4.1
Oleic	0.2-2.4
Linoleic	4.3-6.7
Linolenic	0.9

presented in Table II. Gas liquid chromatography of the fatty acids, trimethylsilyl derivatives confirm the results of TLC. A typical gas chromatogram is presented in Fig. 4. The acid value and the saponification value of the hexane extractable fat was found to be 8.98 and 196 respectively.

High saponification value and low acid value indicate its suitability in perfumery. In spite of its easy extractability and

desirable physical and chemical characteristic, reports on the use of this fat either in perfumery or in confectionery are scanty. High glycolipid content (Finlay Macrutchie, 1977) makes the fat desirable for confectionery and low lipolysis of triglycerides (Ahuja *et al.*, 1979) confirm the suitability of this fat for bread making.

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DESIGN AND DEVELOPMENT OF COPRA MOISTURE METER

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ABSTRACT

For safe storage copra its moisture content should be less than 6 per cent. At about 10 per cent level serious mould damage occurs and the product is more subject to attack of insect pests. For a rapid and accurate estimation of moisture content, an electronic moisture meter was developed on the principle of electric conductivity. The instrument is calibrated against standard air oven method. It can read moisture content from 5% to 40%. The instrument is handy and useful to copra processors.

INTRODUCTION

In the field, moisture content of copra is often estimated subjectively by observation of the texture, appearance or by observing how fast the copra piece picks up flames.

A direct method of determining moisture content is to place weighed samples in an oven for a few hours till the water is completely evaporated. The sample is again weighed from which the original moisture content of the sample can be calculated (air oven method). This is standard method of determining the moisture content and is used as a basis for calibrating the moisture meters. However, the oven method is too slow, costly and cannot be adopted by farmers.

Indirect methods have in general replaced direct methods because of their rapidity of measurement, easiness of

operation and less cost involvement. Indirect methods measure a property of the product viz., the electrical conductivity, dielectric property which depends on the moisture content. This paper deals with the design and development of a copra moisture meter based on the principle of electrical conductivity.

MATERIALS AND METHODS

Design details

The copra Moisture Meter consists of a square wave oscillator, sensor, rectifier bridge and a 100 μ A out put meter (Fig. 1). The instrument requires a 6 V stable supply which is derived from a 9 V Eveready 216 battery or through an Eliminator. The sensor consists of a pair of steel rods of 0.2 cm diameter fixed 0.6 cm apart. The sensor is fabricated in such a way that it can probe coconut kernel to a depth of 0.8 cm only. This value is selected because the average thickness of copra is about 0.8 cm and the sensor

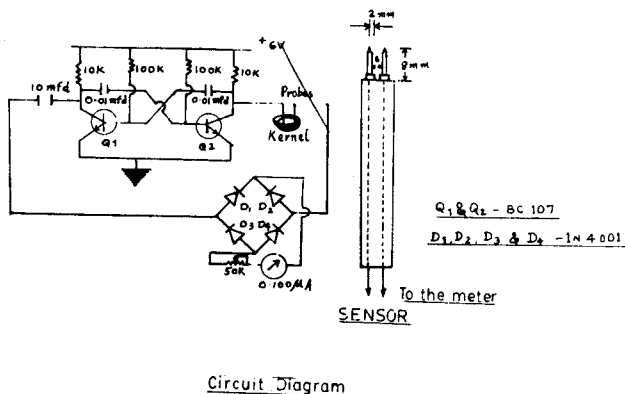


Fig. 1. Copra moisture meter

must be probed fully into the kernel (Fig. 1).

When the sensor is pressed into the kernel the a.c. signal generated by the oscillator is passed through the copra and after rectification read in the 0-100 UA ammeter. As the sensor rods are kept separated by 0.6 cm, the current measured on the meter gives the conductivity/moisture content of $0.6 \times 0.2 \times 0.8$ cm of copra (approximately). So the sensors are to be probed at different points in the same sample to have the average reading. This is often very much necessary as the drying of copra may not be uniform.

Calibration of the meter:

The moisture meter is calibrated against standard air oven method. Samples were collected at different stages of drying and their conductivity in UA is noted in the moisture meter. The moisture content of the same samples were also determined by oven method. A graph was plotted showing the per cent moisture content on wet basis estimated by oven method and the corresponding UA reading read on the moisture meter (Fig. 2). The readings were statistically analysed and suitable equation formulated. As the scatter of the points in the graph showed steep increase beyond 12%

Table I. Equations used for calibration of moisture meter

Type of equation	No. of samples used	Equation	r^2 value	Limits in variables
$Y = a + bX$	53	$Y = 2.932 + 0.1482X$	.82	14 X 65
	40	$Y = -72.29 + 1.2509X$	.83	70 X 90

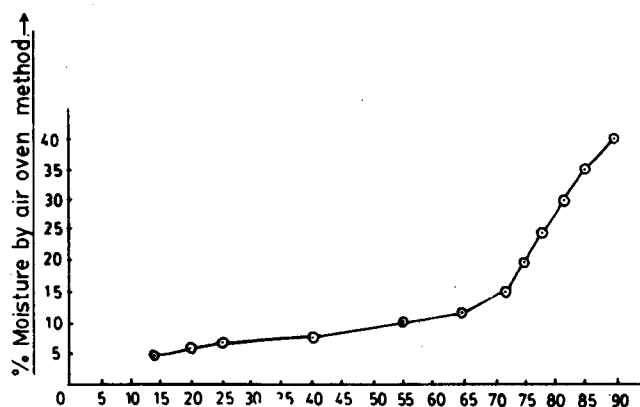


Fig. 2. % Moisture-meter reading in Micro amps →

moisture, two separate straight lines are fitted between the limits ($X = 14$ to $X = 65$) and ($X = 70$ to $X = 90$). The equations are given in Table I. The observed and predicted values of percent moisture corresponding to UA readings (X) and the deviation from the standard air oven readings are given in Table II. The instrument was calibrated from 5% to 40% moisture content.

RESULTS AND DISCUSSIONS

From Table II it can be seen that the per cent error is nil at 5% M.C and 0.11 at 6% M.C increasing upto 0.58. So the accuracy is more than 94% in the lower moisture level observations which is actually required by the copra processors and farmers.

The moisture estimation by this instrument is non-destructive as the samples of copra do not get damaged by the introduction of sensor in to the

Table II. *Observed and predicted moisture values of copra*

Moisture Meter Reading μA	Observed Moisture by air oven Method	Predicted Moisture values %	Deviation from observed reading
14	5.00	5.00	Nil
20	6.00	5.89	0.11
25	7.00	6.64	0.36
40	8.00	8.26	0.26
55	10.00	10.58	0.58
65	12	12.56	0.56
72	15	17.77	2.77
75	20	21.52	2.52
78	25	25.27	0.27
82	30	30.28	0.28
85	35	34.03	0.97
88	38	37.78	0.23
90	40	40.28	0.28

kernel. Unlike other moisture meters the operation is simple and rapid. The instrument can be fabricated very easily and the cost per unit will be less than Rs. 450.

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CHAPTER III

MARKETING, EXTENSION AND COST OF PRODUCTION

Chairman : Dr. P. RETHINAM
Rapporteurs : Mr. P. SWAMINATHAN
: Dr. S. RADHAKRISHNAN

PRODUCTION TRENDS, MARKET INSTABILITY AND REMEDIAL MEASURES IN BEVERAGE CROPS

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ABSTRACT

This paper essentially dwells on the present status of India's major beverage crops in respect of their production, export and prices. It is concerned with stability, viability and growth; and those activities contemplated in the immediate future. Stress has been laid on rejuvenation and replanting programmes. This paper also suggests that the most effective way to reduce the uncertainties and to increase the profit margins of the smallholders would be to encourage multispecies cropping systems. Futuristic projections are beyond its purview.

INTRODUCTION

Beverage crops, namely, tea and coffee are the most vital segments of the plantation industry in India. They make significant contributions to the Indian economy and the welfare of its people. It is a matter of great satisfaction that the key role played by the beverage crops was recognised quite early in the post-independent period at the policy planning level of the Government of India. As a result, a host of promotional schemes have been implemented through successive Five Year Plans in order to support and strengthen the beverage crops sector. Both tea and coffee have shown considerable growth by offering large supplies to the Society. While the recent R&D efforts put India ahead of most of the beverage crops producing countries, here still exists a considerable demand-supply gap because of too many impediments. We shall be briefly reviewing the situation in this paper.

analyses are: (i) Government of India (Directorate of Economics and Statistics, Ministry of Agriculture) for area, production and yield of tea and coffee; (ii) Tea Board and (iii) Coffee Board for export earnings and unit value, current prices and working force for respective crops.

THE STATE OF ART

Production trend in tea:

Although tea cultivation in India is hardly 150 years old, it is remarkable that this country is the largest producer of tea in the world. Among the five major tea producing countries, currently India's share in the world production is somewhere around 30 per cent followed by China (21 per cent), Sri Lanka (9 per cent), the USSR (7 per cent) and Kenya (6 per cent).

The production of Indian tea has registered an increase from about 275,000 t in 1950-51 to the record output of some 657,000 t in 1985-86. This phenomenal

The sources of data used for the

growth in Indian tea sector is however the combined effect of the area and yield expansions during the period under reference. It is observed that while the tea area rose from nearly 314,000 ha to around 400,000 ha, the average productivity of Indian tea plantations almost doubled from 876 kg to 1643 kg per ha (Table I). The compound growth rates (CGR) in respect of the area, yield and production of tea during 1950-51 to 1985-86 are estimated at 0.72 per cent, 1.81 per cent and 2.54 per cent, per annum respectively.

The relative contribution of area and yield improvements to output growth is studied with the help of the Minhas-Vaidyanathan decomposition technique* for decennial ending 1959-60, 1969-70

Table I. *Trend in area, production and yield of tea in India during 1950-51 to 1985-86.*

Year	Area (000 ha)	Production (000 t)	Yield (kg/ha)
1950-51	314	275	876
1960-61	331	321	971
1970-71	354	419	1182
1980-81	382	570	1491
1981-82	384	560	1458
1982-83	395	561	1420
1983-84	396	581	1467
1984-85	398	640	1608
1985-86	400	657	1643
CGR (%)	0.72	2.54	1.81

$$* P_n - P_o = A_o (Y_n - Y_o) + Y_o (A_n - A_o) + (A_n - A_o) (Y_n - Y_o)$$

where:

P_n = Level of output in the terminal year n
 P_o = Level of output in the year o
 A_n = Area under the crop in the year n

and 1979-80. The analysis reveals that the relative shares of area and productivity to the growth in production of Indian tea during the fifties and sixties were more or less of similar order, but there was a departure during the seventies. While the yield effect, for example, has shown an improvement from around 66 per cent to 74 per cent, the area effect has taken a downward trend from 29 per cent to 19 per cent, during later period. The interaction effect is however observed to be marginal in all the three periods (Table II). It is evident that land availability for tea plantations is now tending to become scarce and the yield improvement programmes are assuming greater importance for maintaining a steady growth in tea industry. Even the smallholders are now adopting drought tolerant, pest and disease resistant, high yielding and high quality clones in their replanting, infilling as well as new planting schemes. (Sharma, and Ranganathan, 1985).

Export trend in tea:

India also continues to maintain its position throughout as the world's largest exporter of tea. During the year 1950-51, the export of Indian tea was of the order of 183,000 t and it was 215,000 t in the year 1985-86. The CGR of tea export from this country is estimated at 0.15 per cent per annum during the period under reference. It is however noticed that

A_o = Area under the crop in the year o
 Y_n = Productivity per unit area in the year n
 Y_o = Productivity per unit area in the year o

unlike the production trend in tea, its export growth is not at all steady. It has fluctuated between 167,000 t and 238,000 t during the last 35 years and the record export was in the year 1956-57. In other words, the export figure of Indian tea is hovering around 200,000 t. On the other hand, the growth in the export earnings from tea was more or less stable because of the impressive growth in the unit value realisation during the same period. The unit value is observed to rise from Rs. 3.93/kg in 1950-51 to Rs. 30.49/kg in 1985-86 and as a result, the export earnings have gone up to Rs. 6560 million in 1985-86 from Rs. 719 million in 1950-51 (Table III).

While the world tea trade has been

Table II. *Percentage contribution of area, yield and their interaction to the growth of tea production in India.*

Period	Area Effect	Yield Effect	Interaction Effect	Total
1950-51 to 1959-60	29.20	67.11	3.69	100.00
1960-61 to 1969-70	29.26	65.75	4.99	100.00
1970-71 to 1979-80	19.07	74.48	6.45	100.00

Table III. *Trend in export, export earnings and unit value of Indian tea during 1950-51 to 1985-86.*

Year	Export (000 t)	Export earnings (Million Rs.)	Unit value (Rs/kg)
1950-51	183	719	3.93
1960-61	193	1199	6.21
1970-71	199	1482	7.44
1980-81	232	4353	18.78
1981-82	224	4068	18.15
1982-83	194	3694	19.03
1983-84	202	5575	27.56
1984-85	217	7404	34.12
1985-86	215	6560	30.49
CGR%	0.15	5.48	3.32

rising at the rate of 3 per cent per annum during these years, it is a matter of great concern that Indian tea exports in quantitative term is more or less stagnating. As a result of this, India's share in the export market is rapidly declining. During 1950-51, for instance, India's export amounted to 45 per cent of world export. In the year 1968 it was reduced to 33.5 per cent and by 1982 further declined to 23 per cent. Despite higher levels of production, a strong demand for tea in the domestic front kept export prospect down. (Fig. 1).

In the first half of the sixties, India's exports as percentage of production was little over 60 and it was reduced to 50 in the second half of the sixties. The share

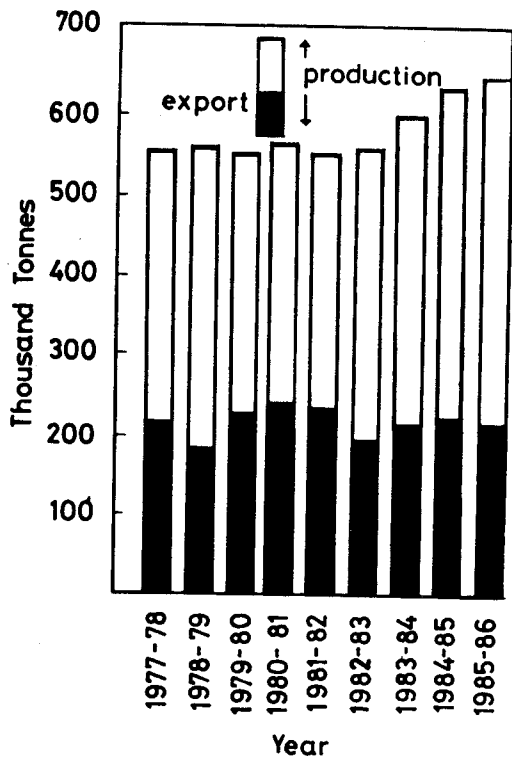


Fig.1 Production & export of tea

of export to total production continued to fall due to growing internal market and in the first half of the eighties it accounted for 36.5 per cent (Table IV). In other words, about two-thirds of India's tea output is now being consumed in the domestic market. The growth in India's internal tea trade is estimated to

be around 6 per cent per annum. In order to cope up with the demand from the home market, India's output growth needs to be further accelerated very fast. It may be mentioned here that the Government of India resorted to ban on the export of CTC tea in December 1983 with a view to avoid a possible shortage of common type tea in domestic market. Though this ban was fully lifted from May 1984 the Government fixed a quota of 215,000 t for export as an unpleasant compromise with the situation.

Besides the widening of the demand-supply gap in the internal tea trade, Indian tea industry is being subject to stiff competition in the international market. The most important competitors are the East African tea growing countries, namely, Kenya, Tanzania and Malawi. Moreover, China, a traditional exporter of green tea has now-a-days stepped up its export of black tea. On account of these factors, India's export base is gradually getting eroded.

Price trend in tea:

Indian tea prices show a highly unstable and violent trend. During the fifties, average wholesale prices of tea fluctuated between Rs. 3870 and Rs. 5970

Table IV. India's average production and export of tea during 1960-61 to 1984-85.

Period	Production (000 t)	Export (000 t)	Export as % of production
1960-61 to 1964-65	348	210	60.3
1965-66 to 1969-70	384	193	50.2
1970-71 to 1974-75	454	204	45.0
1975-76 to 1979-80	533	212	40.0
1980-81 to 1984-85	582	213	36.5

per tonne. In the next decade it ranged between Rs. 4480 and Rs. 5910 and in the seventies it moved between Rs. 5990 and Rs. 16300. During the first half of the eighties, price behaviour was equally erratic as it ruled between Rs. 12660 and Rs. 26970 per tonne.

It is observed that the current price of tea in Indian market is largely influenced by the overall supply position of this

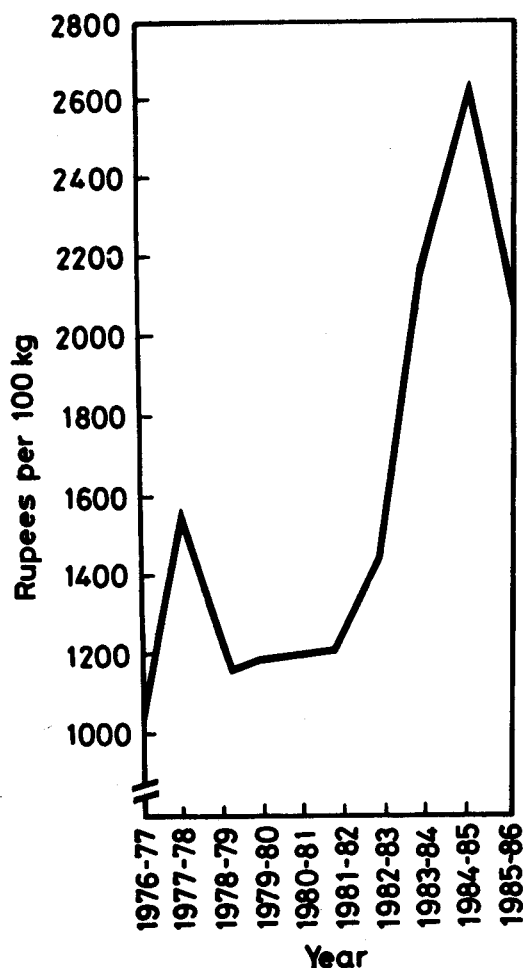


Fig.2 Wholesale price of tea

commodity in world market rather than India's output position in the corresponding period. For instance, in spite of a bigger crop of Indian tea in the year 1974-75 its current price in home market suddenly made a quantum jump. Similar things were repeated during the period 1977-78, 1983-84 and 1984-85. The unprecedented price rise in those years was because of the narrowing of total supply in world tea trade and Indian tea being an export oriented crop, this sort of behaviour in prices is quite understandable. The general improvement in the current prices of tea in Indian domestic market is however a combined effect of growing internal and external demands for this beverage. (Fig. 2).

But when we look to the price trend of tea in real term the picture appears to be altogether different from that of the current prices. The relative price index which is the indicator for the real price, reveals that Indian tea prices have rather declined in five out of 10 years covering the period 1976-77 to 1985-86 (Table V). In other words, tea industry has failed to maintain the parity with the general inflationary trend of the country. (Fig. 3).

Production trend in Coffee :

Indian coffee industry registered remarkable progress between 1945 and 1975. During this period, the area under coffee was doubled, its productivity improved by three times and there was a seven fold increase in the production. Today India occupies tenth position among the leading producers of coffee in the world.

According to the official statistics, the

Table V. *Average wholesale price and relative price indices of tea in India.*

Year	Wholesale price		Wholesale price Index of all comodities	Relative price indices
	Rs./100 kg	Index Number (Base: 1970-71)		
1976-77	1117	186	177	105
1977-78	1630	271	186	146
1978-79	1232	205	186	110
1979-80	1255	208	218	95
1980-81	1266	210	257	82
1981-82	1282	213	281	76
1982-83	1539	256	289	88
1983-84	2288	380	315	121
1984-85	2697	448	337	133
1985-86	2144	356	357	99

area under coffee has gone up steadily from about 91,000 ha in 1950-51 to

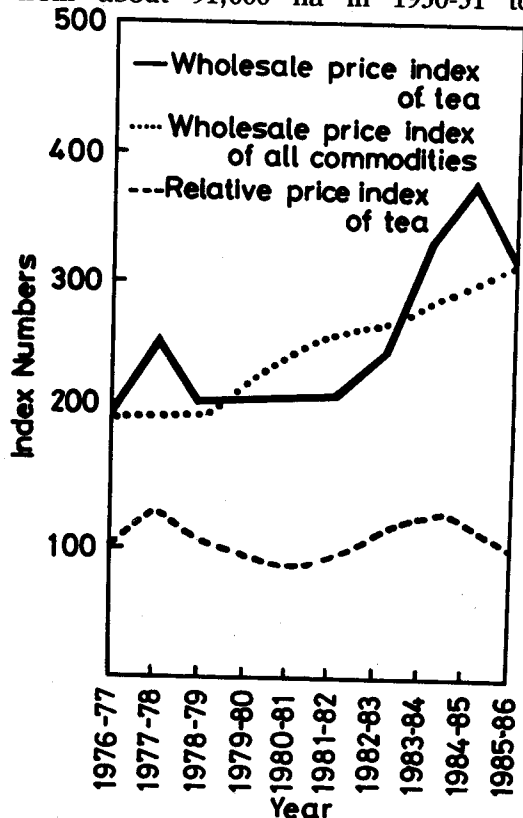


Fig.3 Relative price indices of tea

235,000 ha in 1985-86. The productivity also has improved from 275 kg/ha to 518 kg/ha during the same period. As a result, India's coffee production has reached the level of 172,000 t from a small 25,000 t some 35 years ago. However, the production in recent years is not showing any stability. The violent fluctuations in the yield rate and resultant instability in coffee production could be attributed to adverse weather condition. The CGR for area, yield and

Table VI. *Trend in area, production and yield of coffee in India during 1950-51 to 1985-86.*

Year	Area (000 ha)	Production (000 t)	Yield (kg/ha)
1950-51	91	25	274
1960-61	114	43	377
1970-71	135	110	814
1980-81	208	118	567
1981-82	211	105	497
1982-83	227	130	573
1983-84	232	105	452
1984-85	234	197	842
1985-86	235	122	518
CGR (%)	2.93	5.49	2.50

Table VII. *Percentage contribution of area, yield and their interaction to the growth in coffee production in India.*

Period	Area effect	Yield effect	Interaction effect	Total
1950-51 to 1959-60	26.10	60.67	13.24	100.00
1960-61 to 1969-70	30.52	60.26	9.22	100.00
1970-71 to 1979-80	132.28	(-)21.60	(-)10.68	100.00

production of Indian coffee for the period 1950-51 to 1985-86 was worked out as 2.93 per cent, 2.50 per cent and 5.49 per cent, respectively, per annum (Table VI).

The relative contribution of area and productivity to output growth is studied. The result indicates that the relative shares of area and yield to the production of Indian coffee during the fifties and sixties were, by and large, similar in nature. The yield effect was very strong and more than double that of area effect in those two decades. Interaction effect was very weak. This analysis, however highlights that during the seventies both the yield effect and interaction effect were negative, while the area effect was phenomenal (Table VII). It is clear from this study that the production growth in coffee in recent years has taken a different path and it is also very different strategy wise from tea sector. However, the factors contributing to the negative yield effect needs an indepth investigation.

Export trend in Coffee:

Like tea, historically coffee is an important export oriented crop for India. From a small 2,700 t export in 1950-51 the figure has gone up to 99,300 t in 1985-86. But the growth was rather uneven because of the unstable produc-

tion. When one looks at the unit value realisation one could find that it had during the fifties stabilised around Rs. 6 per kg of coffee export from India. In the following decade, instead of any improvement, it exhibited a sign of decline. In the first half of the seventies there was a marginal increase in unit value and it was in the neighbourhood of Rs. 8, but in the second half of the seventies it was stepped up considerably and fluctuated between Rs. 24 and Rs. 39. In the first half of the eighties the unit value crashed to certain extent.

As far as the growth in export earnings from coffee is concerned it was really phenomenal despite year to year fluctuations. From Rs. 13.4 million in 1950-51 the figure went up to Rs. 72.2 million in 1960-61, to Rs. 251.1 million in 1970-71 and to Rs. 2150.0 million in 1980-81. Thereafter, though it was adversely affected during 1981-82 to 1984-85 because of the shrinkage in the volume of exports on the one hand and lowering in the unit value of export on the other, the year 1985-86 however experienced an unprecedented record export earnings of Rs. 2749.8 million from this beverage crop due to a sizeable enhancement in the volume of export. The estimated CGRs for export volumes unit value and export earnings of Indian coffee during

Table VIII. *Trend in export, export earnings and unit value of Indian coffee during 1950-51 to 1985-86.*

Year	Export (000 t)	Export earnings (Million Rs.)	Unit value (Rs./Kg)
1950-51	2.7	13.4	4.96
1960-61	19.7	72.2	3.66
1970-71	32.2	251.1	7.80
1980-81	89.0	2150.0	24.16
1981-82	83.8	1668.8	19.91
1982-83	76.7	1871.2	24.40
1983-84	71.2	1750.5	24.59
1984-85	68.9	2096.8	30.43
1985-86	99.3	2749.8	27.69
CGR (%)	10.60	17.08	5.90

the period 1950-51 to 1985-86 were estimated at 10.60 per cent, 5.90 per cent and 17.08 per cent respectively per annum (Table VIII).

India's export of coffee as percentage of production during the first half of the sixties amounted to 57.4. Then for a decade long time the share of export to the country's total production declined to the level of 43 per cent even though both the production and export rose in their absolute terms. In other words, the increase in the volume of exports was

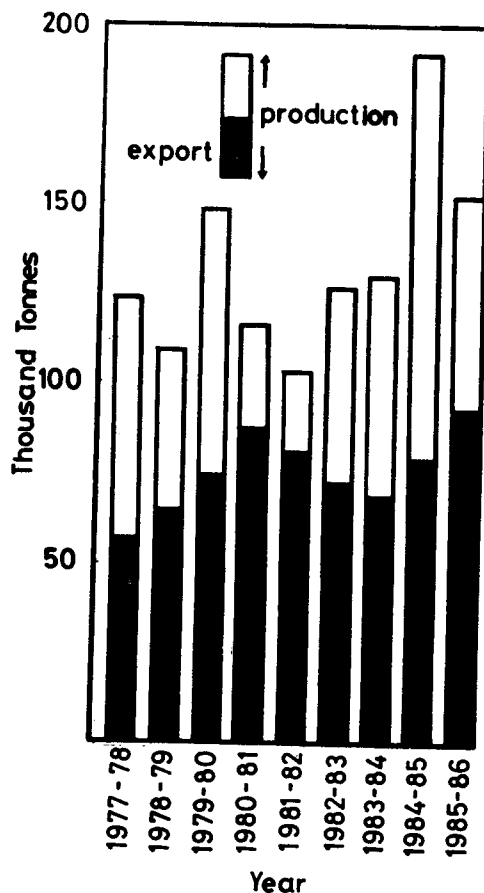


Fig.4 Production & export of coffee less than proportionate to the enhancement in the level of production between 1965-66 and 1974-75. Thereafter, the size of exports showed considerable improve-

Table IX. *India's average production and export of coffee during 1960-61 to 1984-85.*

Period	Production ('000 t)	Export ('000 t)	Export as % of production
1960-61 to 1964-65	43	24.7	57.4
1965-66 to 1969-70	67	29.4	43.8
1970-71 to 1974-75	89	37.7	42.3
1975-76 to 1979-80	114	58.8	51.5
1980-81 to 1984-85	131	77.9	59.5

ment along with the impressive growth in the production and the share of exports to production stood at the level of 59.5 per cent during the first part of the eighties (Table IX). In other words nearly 4 kg of coffee out of every 10 kg of its production is presently consumed in home market and the remaining goes to global market. Inspite of the fact that the demand for coffee in the international market has nearly stagnated because of the growth in the shares of other beverages India's export performance in recent years is a unique achievement. (Fig. 4).

Price trend in Coffee:

Current prices of Indian coffee per

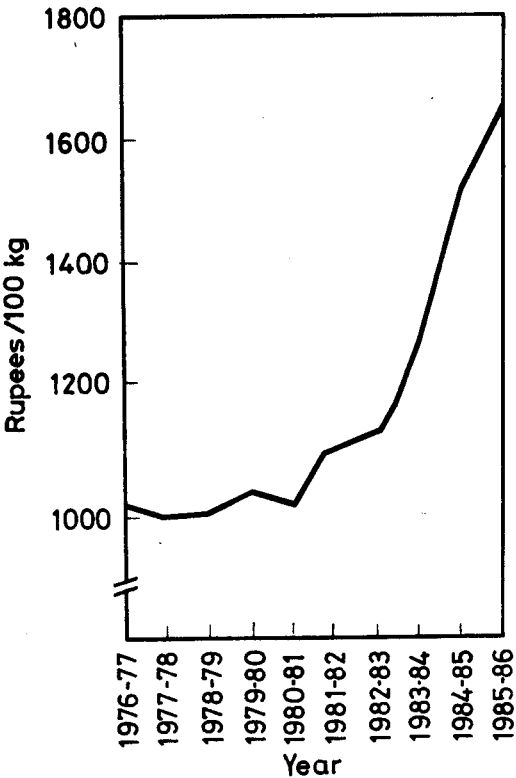


Fig.5 Wholesale price of coffee

tonne in domestic market ruled between Rs. 3680 and Rs. 4950 during the fifties, between Rs. 4460 and Rs. 7080 in the sixties, between Rs. 6870 and Rs. 10,440 in the seventies and between Rs. 10,460 and Rs. 17,020 in the first half of the eighties. Price trend of Indian coffee seems to be relatively stable as compared to tea eventhough it is an important export oriented crop. This price stability was the result of export controls established within the framework of the International Coffee Agreements of 1962, 1968, 1976 and 1982.

An unprecedented price rise in domestic market during the period 1984-85 and 1985-86 could be attributed

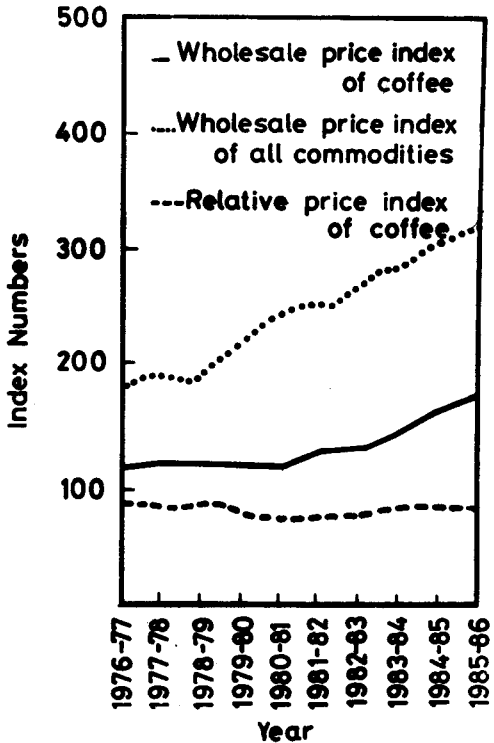


Fig.6 Relative price indices of coffee

Table X. *Average wholesale prices and relative price indices of coffee in India.*

Year	Wholesale price		Wholesale price Index of all comodities	Relative price indices
	Rs./100 kg	Index Number (Base: 1970-71)		
1976-77	1035	130	177	73
1977-78	1025	128	186	69
1978-79	1023	128	186	69
1979-80	1044	131	218	60
1980-81	1046	131	257	51
1981-82	1168	146	281	52
1982-83	1195	150	289	52
1983-84	1366	171	315	54
1984-85	1571	197	337	58
1985-86	1702	213	357	60

to the drastic reduction in world coffee stocks on account of the drought effect on Brazilian crop. (Fig. 5) Since Brazil alone accounts for nearly 30 per cent of the world output of coffee, the adverse weather conditions such as frost and drought are bound to affect the export and price trends elsewhere.

Though current prices in domestic market showed an upward trend, it is surprising to notice that the prices in real term during the last 10 years followed a declining trend (Table X). As far as the real prices are concerned, Indian coffee position seems to be worse than Indian tea. (Fig. 6).

Prospects and challenges

In India, coffee is dominated by small and medium sized plantations. Similarly, as far as South Indian tea is concerned, it is predominately dominated by the small holders, whereas the tea gardens in the Eastern and North-Eastern regions of the country are mostly larger plantations.

The annual turnover of the beverage crops in current prices is of the order of some Rs. 18,250 million (about Rs. 15670 million from tea and Rs. 2580 million from coffee). The export earnings from them now amount to nearly Rs. 9400 million annually and it is in the increasing order.

The production sector in tea provides direct and regular employment to nearly 800,000 agricultural labourers, 50 per cent of which are women workers. The processing sector in tea industry again provides direct employment to another 100,000 workers in factories throughout the year. In the case of coffee, around 250,000 agricultural labour force gets regular employment in the production sector, of which one-third are women. Another 10,000 labour force finds gainful employment in coffee processing sector and 80 per cent of them are women. In total approximately 1,160,000 field and factory labourers, besides a sizeable other categories of workers are absorbed in production, processing of tea and

coffee. These field and factory labourers are, by and large, landless tribals who are located in remote hill areas and who do not have alternate source of employment near their habitats. They are fortunate in the sense that their welfare is well protected through various legislative measures unlike nonplantation workers.

Apart from these aspects, the production of beverage crops is characterised by lower requirement of capital machinery. The planters in general and small-holders in particular, gain comparative advantage when they choose these crops in preference to other competing crops. The relevance of tea and coffee plantations in hill-terrain further stems from their inherent capability to sustain the fragile ecosystem of the region. Primary beverage sectors also promote a number of secondary and tertiary sectors in the economy.

Indian market for beverage commodities is fast growing because of the increase in population; rise in per capita income and disposable income and overall improvement in the standard of living of our people. It is a general apprehension that if each person drinks one more cup of tea or coffee per day, India may have nothing left to export (Mahanti, 1986). When we realise that in coming years more and more people will be involved with the production, processing and marketing of beverage produces, we also realise the challenges. They are concerned with stability, viability and growth of beverage sector.

The rising cost of energy inputs is a major threat. The input/output price ratio under the prevailing situation has become

unfavourable as far as the economic sustainability is concerned. Indian beverage industry is in a cross road. On the one hand we are interested in keeping the production sector free from mechanisation to provide gainful employment to the socially handicapped and economically disabled people. On the other hand, we are overburdened with the mounting wage bills. The solution certainly does not lie with the mechanisation as India cannot afford to go for a compromise which would necessitate the displacement of labour. However, the challenge can be met through appropriate R&D efforts that will push up the existing productivity levels substantially without involving much of the energy inputs. New production technologies in tea and coffee which have been developed and tested by the premier Institutions namely, the United Planters' Association of South India, Tea Research Association, Tocklai, and Central Coffee Research Institute offer great promise.

One could see a considerable tendency towards traditional approach, particularly in the case of smallholders. Technology transfer should therefore, assume priority. However, one thing we may keep in our mind that the traditional approach followed by the smallholders is not because of their lack of progressive mind, but mainly due to their financial constraints. Since capital cost of replanting is very high, most of the small sized plantations are overaged and their productivity is severely affected for obvious reason. The financial disabilities of the smallholders are also found to be the major cause for the poor upkeep of their plantations as the recurrent costs are becoming formidable for them. The

planters are stifled with the heavy dose of taxations and are therefore unable to build up the finance for rejuvenation and replanting programmes from internal sources. At the same time, the small-holders are also having internal credit aversion because of the vulnerability of the beverage crops to price uncertainties. Besides the instability, the threat has come from the declining price trends in real term. The Government should therefore take note of the emerging danger to the beverage industry while formulating the fiscal policies from time to time and should provide corrective measures that will go a long way in motivating the planters for adopting new technologies; and undertaking rejuvenation and timely replanting programmes aimed towards increasing the productivity and reducing the cost of production per unit output.

Since it is extremely difficult to make the Indian beverage sectors free from the vulnerability to external market forces, we strongly feel that the monocropping approach in plantations should be substituted by the multispecies cropping system approach. It is a matter of great satisfaction that most of the coffee plantations are now switching over to mixed cropping patterns with training of black pepper on the shade trees, and planting orange and lime in between the rows of coffee. Similarly, when coffee is planted in valley, cardamom is grown in alternate rows with an objective of diversifying the income source as a measure to reduce the onfarm income uncertainty. However, tea based cropping systems have so far not taken root excepting in a few cases here and there. But casual observation suggests that tea based cropping systems with black pepper on the live standards

that are already present to provide shade to the plantation could enhance the profitability of the planter, while reducing the dependence on a single crop. Some of the fruit crops namely pear, orange and lemon wherever they are found compatible also can be raised in tea plantations for generating income besides providing shade to the main crop (Bavappa, 1987).

These strategies are expected to bring about stability, viability and desired growth in the beverage sectors.

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IMPACT OF THE TRAINING PROGRAMMES ON V.P. TEA NURSERY MANAGEMENT IN THE NILGIRIS

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ABSTRACT

The results of a survey conducted to study the impact of the training programmes on the v.p. tea nursery management in the Nilgiris are reported in the paper. The study has compared the performance of the nurseries raised by trained with untrained personnel. There are 136 nurseries with an annual capacity of over 10 million plants, raised by the small farmers, both trained and untrained. The training has resulted in the better utilization of resources and inputs and also has attracted self employment opportunity to most of the educated unemployed youth in the District.

INTRODUCTION

India is the largest producer, exporter and consumer of tea in the world with an annual production of nearly 660 million kilograms, export of nearly 220 million kilograms and domestic consumption of 440 million kilograms. Tea earns about Rs.750 crores in foreign exchange and contributes considerable revenue to the central and state Governments by way of taxes. South India has the distinction of possessing the highest productivity in the world and Nilgiris is the largest tea growing district in the South, accounting for as much as 32,000 hectares of the total 82,000 hectares of tea in the region. With over 65 per cent of the tea small gardens situated in Nilgiris, tea is essentially a small grower enterprise here, whose number is estimated to be above 20,000 with an average extent of less than one hectare. The small tea gardens harvest a deplorably low yield of 1000 kg per

hectare as against the average yield of around 2,400 kg per hectare in the large grower sector principally due to traditional, subsistence culture and large vacancies.

As there were running counter to the scope for improvements, the UPASI, in collaboration with the Tea Board, laid stress on educating the growers on improved and scientific methods of cultivation and infilling the vacancies with suitable clonal teas. In reaching this objective, the UPASI-Tea Board schemes depend on imparting training and demonstrations. Subsequently with the ICAR granting a Krishi Vigyan Kendra to the UPASI in 1982, the activities in this objective were strengthened.

The KVK also laid emphasis on diversification of vegetable crops into tea in steep slopes. This novel scheme coupled with the boom in tea prices that prevailed

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between 1983 and 1985 has resulted in the tremendous horizontal expansion of the tea areas which in turn resulted in the acute shortage in the availability of planting materials.

METHODOLOGY

At this juncture, the Kendra also decided to encourage the small growers, especially the unemployed youth, to take up commercial vegetatively propagated tea nurseries to serve triple benefits of meeting the demand for supply of the required plants, generating employment opportunity and improving living standards of the farmers in the district. With these objectives, training programmes on v.p. tea nursery management were organised for the small farmers (Table IA) besides offering assistance in availing the loan from the nationalised and co-operative banks. Detailed project reports were also prepared and given to those interested in this regard.

Suitable areas available in the district with easy accessibility, having perennial water source with gentle terrain and free from wind, frost and damage by wild animals were identified. From these

Table IA. *Particulars on the training programmes organised on v.p. tea nursery management*

Year	No. of courses	No. of beneficiaries
1983	11	297
1984	5	106
1985	3	73
1986 – refresher course	2	62
	21	538

areas, the farmers were motivated to take up raising v.p. nurseries. Periodical advisory visits were also undertaken to these nurseries to ensure good results.

The performance of these nurseries has also influenced the other farmers in the vicinity to start such tea nurseries. Thus, the efforts taken by the Kendra had resulted in the establishment of 136 nurseries by the small farmers, both trained and untrained.

The Kendra undertook a study to evaluate the impact of the training programmes organised on the v.p. tea nursery management. The main thrusts were on the following:

- i) To identify the socio-economic status of trained and untrained nursery farmers.
- ii) To assess the efficiency of adoption of scientific practices by the trained and untrained farmers.
- iii) To find out the consequences of the training on the resources management.
- iv) To suggest suitable strategies for selection of respondents for training and to modify the training programme, if necessary.

Ninety respondents were selected by random sampling technique from twenty villages in Coonoor, Kotagiri and Udhamandalam taluks in the Nilgiris. Out of them 45 trained and 45 untrained were interviewed with a constructed pre-tested questionnaire.

RESULTS AND DISCUSSIONS

I. Socio-economic characters of the tea nursery growers:

The socio-economic characters of the tea nursery growers in the Nilgiris both trained and untrained are discussed in this chapter.

(a) Age:

The classification of age group for trained and untrained are presented in Table IB.

It is noted from this that majority of the trained farmers fall under young age group as against middle aged in the case of untrained. This indicates that the younger age group is more amenable to accept new outlook and is fairly free from ingrained prejudices and inhibitions of middle and old age group.

Another interesting feature was that most of the trainees were unemployed youth who carried the message to their neighbours propagating the techniques learned by them.

(b) Educational classification:

The educational classification is given in Table IC:

Table IB. *Classification of age group:*

Age group	Trained	Untrained
Young (upto 30 years)	23 (51%)	17 (38%)
Middle (30 to 45 years)	17 (38%)	22 (49%)
Old (above 45 years)	5 (11%)	6 (13%)
Total	45 (100%)	45 (100%)

Table IC. *Educational classification:*

Education	Trained	Untrained
Illiterate	3 (7%)	11 (24%)
Upto Higher Secondary	9 (20%)	26 (58%)
Collegiate	33 (73%)	8 (18%)
Total	45 (100%)	45 (100%)

From Table IC, it is seen that, over 70 per cent of the trainees had college education as against less than 20 per cent in the case of untrained. Our main aim was to provide self employment opportunities for educated rural youth, which was given due consideration while selecting the participants for the training programme. Also the educated youth could appreciate the scientific approach to new self employment avenues.

II. Relationship between trained and untrained in the adoption of recommended practices:**(a) Selection of site and lay out of the nursery**

The percentage of adoption has been interpreted by giving scores from 1 to 7 and the results on the nursery site selection and lay out are given in the Table ID.

It is clear from the above that more than 85 per cent of the trained farmers are well aware of all the criteria for site selection and proper lay out of the nursery, which is so essential for the successful raising of plants. In the case of untrained, majority of them selected the site without proper assessment even with regard to the suitability of the area which is responsible for the poor performance of

Table ID. *Results on the nursery site selection and lay out*

Extension	Trained	Untrained
7 score	28 (62%)	Nil
6 score	11 (25%)	2 (4%)
5 score	5 (11%)	7 (16%)
4 score	1 (2%)	21 (47%)
3 and below	Nil	15 (33%)

the nurseries both in quality and net sales.

(b) Testing of the soil:

The particulars on the testing of the media by the trained and untrained is given in Table II.

All the trained farmers have taken keen interest in testing the media, since they are well aware of its contribution to the successful raising of plants. The soil testing facilities available, free of cost, with UPASI at Coonoor for small growers, have been fully utilised by the trained farmers. With regard to the untrained nearly 70 per cent of them have ignored the testing, since most of them are unaware of the necessity for testing the media.

(c) Number of plants produced and percentage success:

The details on the number of plants produced and the percentage success for the trained and untrained are given in Table III.

This reveals that the trained farmers have produced a total of 62.3 lakh plants with 86 per cent success as against 53% success in the case of untrained farmers. The high percentage of success achieved by

Table II. *Testing of the media*

Soil testing for	Trained	Untrained
pH, texture & eelworm	27 (60%)	6 (13%)
pH and texture	15 (33%)	8 (18%)
pH	3 (7%)	Nil
Not tested	Nil	31 (69%)
Total	45 (100%)	45 (100%)

the trained farmers is due to the proper adoption of the departmental recommendations right from the selections of site, testing the media, use of proper overhead shade etc. The nursery capacity of the trained farmers is also high – double that of the untrained.

(d) Quality of plants produced:

The success in the transfer of technology is always governed by the quality of the produce. Table IV deals with the quality of plants produced by the trained and untrained, based on the root development, growth of plants, girth of the stem, health and vigour of the plants, incidence of pests and diseases etc.

It is thus noted that 80 per cent of the trainees have produced good plants when compared to the untrained, where more than 70% of them have produced poor

Table III. *Number of plants produced and percentage success*

Particulars	Trained	Untrained
Number of plants produced (in lakhs)	62.3	31.7
Average number of plants produced per grower (lakhs)	1.4	0.7
Percentage success	86	53

Table IV. *Quality of plants produced*

Quality of plants	Trained	Untrained
Very good	17 (38%)	4 (9%)
Good	19 (42%)	8 (18%)
Poor	6 (13%)	15 (33%)
Very poor	3 (7%)	18 (40%)
Total	45 (100%)	45 (100%)

quality plants. The good quality of plants produced by the trainees does not pose any marketing problems. Most of the buyers prefer these plants to those produced by the untrained.

(e) Cost of production:

The cost involved is presented in Table V. It is, therefore, evident that 80 per cent of the trained farmers have produced their plants at a cost less than 70 paise. This is mainly achieved with the greater percentage of success due to adoption of scientific methods. The cost of plant produced by the untrained is more than 70 paise mainly because of high casualty.

(f) Source of finance:

The most important requirement for the success of any developmental programme is the availability of financial assistance.

Table V. *Cost of production*

Cost of production	Trained	Untrained
Less than 50 paise	7 (16%)	Nil
51 to 70 paise	29 (64%)	8 (18%)
71 to 90 paise	9 (20%)	17 (38%)
above 90 paise	Nil	20 (44%)
Total	45 (100%)	45 (100%)

Table VI. *Trend of availing finance by the trained and untrained*

Source of finance	Trained	Untrained
Self	16 (36%)	38 (84%)
Banks	28 (62%)	4 (9%)
Money lenders	1 (2%)	3 (7%)
Total	45 (100%)	45 (100%)

The trend of availing finance by the trained and untrained is given in Table VI.

It is observed here that most of the trained farmers availed the loan facilities from nationalised banks, whereas in the case of untrained, self financing was the major trend (84%). This is mainly because the trainees are provided with information on the financial institutions besides certificates and project reports which enable them to avail the loan from banks easily.

III. Consequences of adoption:

These are detailed in Table VII.

It is evident from here that most of the trained (91%) as well as untrained (85%)

Table VII. *Consequences of adoption*

Consequences	Trained	Untrained
1. Switched over to clones	91	85
2. Increase in nursery capacity	53	9
3. Profitability	57	18
4. Invested on land	73	42
5. Vehicle purchased	20	4
6. Developed contact extension agencies	80	42
7. Developed contact with UPASI	100	49

have switched over to clonal plants from their traditional seedlings. This itself is the greatest achievement in educating the farming community towards the use of new high yielding planting materials. Over 50 per cent of the trained have increased their nursery capacity in view of the good demand for the plants produced and also to reduce the cost per plant. With regard to the profitability there is a mean increase of 57% in the case of trained and only 18% in the case of untrained. Around 75% of the trained have ploughed back, their profits by investing on the purchase of land while it is only 42 per cent in the case of untrained. It is interesting to note that 20 per cent of the trained have procured new vehicles (mostly two wheelers) who were depending on the public conveyance for transport before starting the nursery. The purchase of vehicle in the case of untrained is only 4 per cent. Eighty per cent of trainees have developed contacts with the extension workers and cent per cent contact with UPASI, while half of the untrained have no contacts either with government agencies or UPASI and do not have adequate knowledge on the recent developments in scientific research.

IV. Suggestion of new strategies for trainee selection:

A major outcome of the study was the highlight of the fact that the methodology and norms adopted by the Kendra so far in respect of selection of trainees, the imparting of the training and the course contents are adequate to yield results. In view of this, the study could not identify much scope for modification of the norms governing these aspects. Nevertheless, this study shows that the training given to young and educated is more effective and

profitable in the sense that they are enthusiastic and relay the message to the neighbours. However, the Kendra is open to receive newer concepts to incorporate the latest developments concerning the scientific aspects.

CONCLUSION

The training programme offered by the UPASI Krishi Vigyan Kendra is mainly focussed on the weaker sections of the community. Results of the training are also more effective in terms of promoting the adoption of new technologies, recommended in the training programme. Consequent on this, the living style and outlook of the individual farmers have undergone changes as reflected by the acquisition of wealth through the construction of new houses, purchase of land and possession of transport means. There has also been a marked and welcome diversification of cropping pattern from annual vegetables to perennial crop like tea. There has been a widening of their contact with other agencies and also in their awareness to utilize their services. The trainee has become an opinion leader in the society with respect to agricultural technology.

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RUBBER WOOD MARKET IN INDIA : EMERGING CHANGES

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ABSTRACT

This paper tries to evaluate the contribution of rubber wood to the wood based industry in Kerala and Kanyakumari district of Tamilnadu. The main consumer of rubber wood is the packing case manufacturing industry, accounting for about 13.6 million cft. The present study has attempted to evaluate the consumption of rubber wood in other sectors of wood based industry viz. plywood, splinters, veneers, accessories to textile mills and furniture. These industries consumed about 93000 cmt of rubber wood. The main conclusion of the study is that the rubber wood is supplying about 68 per cent of the requirements of small scale wood based industry in Kerala.

INTRODUCTION

Until three decades ago, rubber wood was used only as firewood in India. In the sixties it began to be used for manufacturing packing cases. With the rapid industrialisation of the country and the exhaustion of low-priced wood sources, more and more people turned to rubber wood for a number of uses. Packing case manufacturing industry however continues to be the most important consumer of rubber wood in India. The present study attempts to evaluate the use of rubber wood in other sectors of wood-based industry.

MATERIALS AND METHODS

The data required for the study were collected by visiting the units consuming rubber wood. In the first stage the lists of factories producing plywood, veneers, splinters etc. were collected from the Industries Department of Kerala and the Kanyakumari District Industries Centre, Nagercoil. Making use of the lists, visits were made to the factories in 1985-86. A

total of 273 units could be covered for this study.

RESULTS AND DISCUSSIONS

Table I shows the distribution of units in Kerala and Kanyakumari District of Tamil Nadu. The total quantity of rubber wood consumed by the 273 units was 3.27 million cft. (92.7 thousand cmt.) in 1984-85. Of this quantity, 98.5 per cent was accounted for by the units in Kerala.

Table II shows the units producing plywood and the quantity of rubber wood consumed by them. It will be seen that 35 per cent of the total consumption of rubber wood in the plywood sector was in Calicut district. Some plywood units in the district also produced veneers and splinters as well. The largest number of units was also in the same district. There was no plywood unit in Kanyakumari district of Tamil Nadu.

Excepting five units, the plywood produced by all was mainly used for manufacturing tea chest and the size of

Table I. *Districtwise distribution of units using rubber wood.*

District	No. of units	Total quantity (in Cmt)
Alleppey	16	909.09 (0.98%)
Kottayam	27	9597.85 (10.36%)
Ernakulam	18	5700.93 (6.15%)
Trichur	41	12399.89 (13.38%)
Palghat	18	4604.93 (4.97%)
Malappuram	5	1515.15 (1.63%)
Calicut	69	20101.95 (21.69%)
Cannanore	11	12772.59 (13.78%)
Quilon	42	21580.99 (23.29%)
Pathanamthitta	4	1416.03 (1.53%)
Idukky	5	730.67 (0.79%)
Total Kerala	256	91330.07 (98.55%) – 3224865 Cft
Kanyakumari	17	1342.40 (1.45%)
Grand total	273	92672.47 (100%) – 3272265 Cft

Table II. *Districtwise consumption of rubber wood in Plywood Industry (in Cmt).*

District	No. of units	Plywood	Plywood & Veneer	Plywood & Splinters
Alleppey	2	178.42 (0.37%)		
Kottayam	7	5392.24 (11.04%)		
Ernakulam	9	4384.03 (8.97%)		
Trichur	16	6737.47 (13.79%)		
Palghat	1	283.20 (0.58%)		
Malappuram	2	552.25 (1.13%)		
Calicut	54	17170.77 (35.25%)	382.33 (100%)	637.21 (100%)
Cannanore	6	11781.37 (24.12%)		
Quilon	12	1008.21 (2.07%)		
Pathanamthitta	2	1359.39 (2.78%)		
Idukky	–	–		
Kanyakumari	–	–		
Total	111	48847.35 (100%) (1724800 Cft)	382.33 (100%) (13500 Cft)	637.21 (100%) (22500 Cft)

Table III. *Districtwise consumption of rubber wood (in Cmt).*
(Veneers & Splinters)

District	No. of units	Veneers	Splinters	Veneers & Splinters
Aleppey	14	—	314.36 (6.54%)	416.31 (1.52%)
Kottayam	18	2480.88 (32.33%)	934.58 (19.46%)	382.33 (1.40%)
Ernakulam	9	288.87 (3.76%)	722.18 (15.04%)	305.86 (1.12%)
Trichur	14	3797.79 (49.48%)	—	373.83 (1.37%)
Palghat	16	—	—	4236.76 (15.51%)
Malappuram	3	—	962.90 (20.05%)	—
Calicut	15	410.65 (5.35%)	1246.11 (25.94%)	254.89 (0.93%)
Cannanore	5	—	566.41 (11.79%)	424.81 (1.56%)
Quilon	28	—	—	19541.21 (71.55%)
Pathanamthitta	2	—	56.64 (1.18%)	—
Idukky	5	169.92 (2.22%)	—	560.75 (2.05%)
Total Kerala	129	7148.11 (93.14%) (252400 Cft)	4803.18 (100%) (169600 Cft)	26496.75 (97.01%) (935600 Cft)
Kanyakumari	17	527.76 (6.86%)	—	815.63 (2.99%)
Grand total	146	7674.87 (100%) (271000 Cft)	4803.18 (100%) (169600 Cft)	27312.38 (100%) (964400 Cft)

the plywood was usually around 75 × 75 cm with three plys of wood (around 3 mm thickness). Some units also produced plywood for seat and back of chairs. The plywood produced by the units also found use in the manufacture of suit cases. Other five units were fairly large ones and they produced ply wood of different sizes and qualities. They were found

using some form of chemical treatment for rubber wood. They used rubber wood for inside ply of commercial plywood when quality wood was in short supply. Three of the five units also occasionally used rubber wood as block-board for flush doors. No plywood factory was found using the chemical impregnation method for treating rubber wood.

Table IV. *Districtwise consumption of rubber wood (in Cmt).*
(Other than Plywood, Veneers & Splinters)

District	No. of units	Quantity
Alleppey	-	-
Kottayam	2	407.82 (13.53%)
Ernakulam	-	-
Trichur	11	1490.80 (49.45%)
Palghat	1	84.96 (2.82%)
Malappuram	-	-
Calicut	-	-
Cannanore	-	-
Quilon	2	1030.87 (34.20%)
Pathanamthitta	-	-
Idukky	-	-
Kanyakumari	-	-
Grand total	16	3014.45 (100%) (106440 Cft)

Table III shows the units producing veneers and splinters for safety matches. Although rubber wood is not ideal for veneers and splinters, due to nonavailability of soft wood in adequate quantity it is being used by the industry. Quilon district has the largest share of consumption in this sector followed by Palghat district.

Table IV shows the details of the rubber wood consumption in other spheres of the industry. There were only 16 units in this sector. The main items they produced were bobbins and shuttles for textile mills. In Kottayam district one unit produced door and window frames and shutters and also furniture, after chemical impregnation treatment of

Table V. *Estimated soft-wood registered with the government department of Kerala.*
(256 units)

Department	Quantity in cmt.			
	Plywood	Veneers Splinters	Others	Total
Industries Department				
(Installed capacity	60000	53000	23000	136000
Forest Department	9000	5600	4200	18800
(Allotted)	(15.00%)	(10.56%)	(18.26%)	(13.82%)
Rubber wood consumption according	49867.00	38448.03	3014.44	91329.07
to the study of Rubber Board	(83.52%)	(73.06%)	(13.28%)	(67.63%)

(SSI Registration)

rubber wood. In the same district another unit was producing panelling material after treating rubber wood. But the unit discontinued that line of operation recently.

Table V shows the installed capacity and the quantity of wood distributed to the units in Kerala. The Table shows that only about 14% of installed capacity was met from the supply of wood from the Forest Department. It also shows that around 68 per cent of the capacity was

met by rubber wood purchased from the open market.

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CHAPTER IV

PEST MANAGEMENT

Chairman : Dr. K. JAYARATHNAM
Rapporteurs : Dr. R. VARATHARAJAN
: Mr. P. KRISHNAMOORTHY BHAT

PEST MANAGEMENT IN PLANTATION CROPS

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ABSTRACT

The paramount importance of pest control and the increasing public concern on the adverse effects of synthetic pesticides demand newer approaches to pest management. Critical studies on crop loss due to pests and establishment of economic threshold levels of major pest species are pre-requisites for minimising the use of pesticides. Though life history and symptoms of most of the pests of plantation crops are known, there exists a big lacuna in the knowledge of the ecology of even the key pests of these crops. Biocontrol programmes have been initiated and to a certain extent practised in crops like coffee and coconut; but serious studies in this line are lacking in other plantation crops. Cultural control measures such as crop sanitation, crop pattern and density, manipulation or destruction of alternate hosts and selection of pest resistant/tolerant varieties need to be given more importance in our research programmes on pest management. Since pesticides will continue to play a vital role in the management of pests of plantation crops, urgent investigations need to be taken up on the effect of pesticides on bees, predators and parasites active in the plantation ecosystem, on pesticide residues in plantation crop products and also on the newer technologies of pesticide application. There also exists considerable scope for research on the use of pheromones and insect growth regulators for pest management programmes in plantation crops. Application of system analysis in IPM would greatly help in understanding the ways in which factors such as weather, age, structure and density of pest population interact to effect the yield and also to aid in the decision making process, thereby increasing the chances of success in pest control.

INTRODUCTION

Ecological conditions of the tropics which are conducive for plant growth and productivity also favour colonisation and build up of phytophagous insects and mites. When some of the plantation crops like tea, coffee and rubber were introduced into South India, they either replaced the natural forests or other crops and in all probability some of the insect and mite species of these ecosystems readily accepted and adjusted to these new crops. Moreover, the ever increasing host range of polyphagous herbivores and the adaptations of oligophagous species also contributed to the abundance of insects and mites on the plantation crops. The richness and diversity of insect communities inhabiting the plantation ecosystem are determined

by the interaction of crop(s) with the cultivation practices and the physical and biological environment.

Considerable literature is available on the descriptive aspects of plantation crop pests, especially their nature of damage and chemical control measures. Our knowledge on the pests of tea (*Camellia sinensis* L.) and their control relates to the major contributions of Watt and Mann (1963) Das (1965) and Rao (1970). A recent review (Muraleedharan, 1983) gave details on tea pest complex and various measures adopted for their control. The monograph by LePelley (1968) deals with the pests of coffee throughout the world. Brief accounts on the pests of coffee in India have also been published by Vasudevan and Narayanan

(1958) and Sekhar (1964). A comprehensive volume on the pests of cocoa is also available (Entwistle, 1972). The pest situations in cardamom (*Elettaria cardamomum* Maton.) had been reviewed by several authors (Nair, 1967; Nambiar *et al.*, 1975; Kumaresan and George, 1979; Butani, 1984a). The perennial, evergreen climbing vine, *Piper nigrum* L., is infested by a few insects, of which the pollu beetle, *Longitarsus nigripennis* is the most important (Visalakshy, 1970; Pillai, 1978). In ginger (*Zingiber officinale* Rosc.) shoot borers cause substantial crop loss (Butani, 1984b) in South India. Arecanut palm (*Areca catechu* L.) is infested by the spider mite, spindle bug etc. (Nair and Menon, 1963; Daniel and Premkumar, 1976). The pests of coconut palm (*Cocos nucifera* L.) have been reviewed by Nirula (1955, 1956), Menon and Pandalai (1957), Lever (1969) and Kurian *et al.* (1979).

Important pests of cashew *Anacardium occidentale* L. have been described by Pillai *et al.* (1979), Pillai (1979, 1980), Butani (1981) and Haribabu *et al.* (1983). There is practically no pest problem in rubber (*Hevea brasiliensis* Mull. Arg. The biology of important pests of cinnamon (*Cinnamomum zeylanicum* Breyn.) was studied by Sing *et al.* (1978).

Crop Loss

Qualification of losses due to pests is an integral part of the studies on pest management. A very conservative estimate shows that pest damage results in crop loss amounting to Rs. 15,000 crores in agriculture alone (Rangaswamy, 1983). The magnitude of losses in plantation crops is rather high despite the normal

Table I. Crops loss in tea due to pest attack

Species	% loss	References
<i>Biston suppressaria</i>	30-35%	(Das, 1961)
Termites	10-15%	(Das, 1962; Sen & Chakraborty, 1964)
Eriophyid mites	8-17%	(Rao & Subramanian, 1968)
<i>Oligonychus coffeae</i>	25%	(Das, 1963)
<i>Xyleborus fornicatus</i>	7-18%	(Rao, 1976)
<i>Scirtothrips bispinosus</i>	13-56%	(Rao, 1976)

plant protection measures. Cramer (1967) estimated that the losses due to pests in coffee, tea and rubber in Asia were 10% 8% and 5% respectively. The loss in tea due to pests was estimated at 6-14% (Banerjee, 1976) or 29 million kg of made tea (Glover *et al.*, 1961). Crop loss studies due to different pests in tea have also been made by various workers (Table-I).

Nambiar *et al.* (1975) noted that thrips can damage upto 80-90% of the cardamom crop. In pepper, the pollu beetle, *Longitarsus nigripennis*, is reported to cause about 30% crop loss (Premkumar 1980). The tea mosquito, thrips and fruit borer in cashew are responsible for fruit droop resulting in more than 30% loss (Pillai & Pillai, 1975; Sathiamma, 1979). An early study on damage due to *Oryctes rhinoceros* in coconut had shown a crop loss of 4-9% (Ramachandran, 1961). There is an urgent need for critical studies on crop loss due to pests in plantation crops which will aid in evolving an Integrated Pest Management Programme (IPM) for these crops.

Pest Management Strategies

Integrated Pest Management (IPM)

programmes require joint, interdisciplinary scientific efforts to assemble sound information on (i) ecological basis of the pest problem, (ii) factors in the agrosystem that can be manipulated to make the crop environment unfavourable for the pest, (iii) population trends of pests and their natural enemies to determine the timing of pesticide applications and (iv) the benefits and risks of IPM strategy for agriculture and society (Pimental, 1982). The tactics for developing an overall strategy for IPM, consists of (A) Direct control tactics and (B) Supportive control tactics. The former involves the use of (i) crop plant resistance (ii) bio-control agents (iii) cultural control measures (iv) attractants and (v) pesticides.

A. Direct Control

1. *Crop plant resistance*: In plant breeding or selection programmes, there has always been a tendency to develop or select high yielding crop varieties with almost total disregard to characters for tolerance of resistance to pests. In the clonal selection programmes for tea in Sri Lanka, resistance/tolerance to *Xyleborus fornicatus* is now being seriously considered and recommendations have also been released on planting of tolerant tea clones in areas infested with this pest. In Southern India, recently there has been some preliminary attempts to study the reaction of UPASI released tea clones to shot-hole borer (Unpublished data).

High yielding pepper cultivars like Karimunda and Panniyur I suffer greatly from pollu beetle attack, the infestation percentage ranging from 40.1 to 56.8 (Pillai & Abraham 1979). Relative

susceptibility of different cashew types to infestation by *Helopeltis antonii* was also studied. (Ambika *et al.*, 1979; Sathiamma, 1979).

In our plant breeding programmes, trait for resistance or tolerance to the key pests has to be seriously considered, especially when it is known that the introduction of new varieties may lead to outbreak of pests immediately or within 3-4 years after release (Mehrotra, 1986).

2. *Biocontrol agents*: Among all the prospective tactics used in integrated control of insect pests, biological control has excelled all others, with the possible exception of cultural control (DeBach, 1974). Several species of parasites and predators have been recorded on the pests of plantation crops. Nevertheless, special efforts are needed to survey and identify the natural enemy complex of most of the plantation crop pests in our country. Considerable progress has been made in the biological control of some pests of coconut and coffee. Biocontrol programmes of *Opisina arenosella*, the blackheaded caterpillar of coconut, have been receiving attention for the last several years and the larval and pupal parasites are being mass multiplied and released for the control of this caterpillar. Nagarkatti and Jayanth (1981) were successful in mass rearing of the more host specific parasites such as *Elasmus nephantides* on artificial diet. One of the serious defects of the parasite rearing programme for the control of *O. arenosella* is that efforts are made only to mass multiply the parasites which can be reared easily (Nagarkatti, 1973). Generally, the larval parasitoids of this pest are few and the extent of natural pest suppression by them is also low. In

Southern Kerala, regulation of this pest has been mostly due to pupal parasites like *Brachymeria nosatoi* and *B. nephantides* (Joy and Joseph, 1977, 1978, Pillai and Ramachandran Nair, 1981). In these areas, parasitism by *T. pupivora* is low since part of *T. pupivora* population in the field aestivates in the pupal stage during March-May. The low searching and dispersal ability, low preference for non-optimal temperature, poor sense of discrimination between parasitised and non-parasitised hosts and inability to compete with other pupal parasites such as *Brachymeria* sp. are the major factors that contribute to its low efficiency and low incidence in the field (Pillai and Ramachandran Nair, 1982). Several species of biocontrol agents of coffee pests are recorded from India and they play an important role in the natural suppression of many of these pests, especially scale insects and mealy bugs (Chacko, 1977; Chacko *et al.*, 1977; Chacko *et al.*, 1978a, 1978b, Chacko and Deepak Singh, 1980). Recently, a parasite *Leptomastix dactylopii* has been introduced for the control of *Planococcus* spp. on coffee and the progress is being monitored (Krishnamoorthy Bhat, 1985). Many of the tea pests are naturally controlled by several parasites and predators and one such tea pest under natural control is the scale, *Fiorinia theae* in north east India. Surveys on the natural enemies of phytophagous mites and flushworms of tea have revealed the presence of several beneficial arthropods (Rao *et al.*, 1970) and more recently Sarma (1976) listed the important bio-control agents of the tea pests in our country.

Among the success stories on biological

control throughout the world, predators have always an edge over the parasites. Introduction of the exotic predator, *Platyeris laevicollis* for the control of adults of *Oryctes rhinoceros* is worth mentioning because encouraging results were obtained in certain field studies (Antony *et al.*, 1979). The coccinellid *Cryptolaemus montrouzieri*, a predator of coffee mealy bugs, has been able to establish in some pockets in Wynad, Coorg and the Nilgiris (Chacko, 1978; Chaco *et al.*, 1978c). The aphid, *Toxoptera aurantii*, attacking tea, is checked by a few species of syrphid predators (Muraleedharan and Radhakrishnan, 1986). On arecanut, phytophagous mites are preyed upon by several species of predatory insects and phytoseiid mites (Daniel, 1979).

Our knowledge on the pathogens of the insect pests of plantation crops is rather poor. Recently, a baculovirus disease of *Oryctes rhinoceros* was reported from Kerala, and since then it had been confirmed to be the same disease that was responsible for the successful biological control of this pest in the South Pacific Islands (Mohan *et al.*, 1983). The fungus, *Verticillium leucanii* was found useful in the control of *Coccus viridis* (Easwaramoorthy and Jayaraj, 1978) and its efficacy was further increased by the addition of sublethal doses of fenthion (Easwaramoorthy *et al.*, 1978). Similarly *Metarhizium anisopliae* may be useful against the grubs of *Oryctes rhinoceros*. In cardamom, large scale mortality of the whitefly, *Dialeurodes cardamomi* caused by *Aschersonia placenta* was recently reported (Muraleedharan, 1985). This aspect of biological control of pests needs intensified studies.

3. *Cultural control*: This, apparently is the most economical and widely applicable method of pest control. In crops like tea, coffee and cardamom shade regulation plays a predominant role in pest suppression. Infestation by mites and thrips is seen more in tea fields devoid of shade. Adults of the coffee white stem borer, *Xylotrechus quadripes* are active, lay more number of eggs and cause more damage in thinly shaded areas rather than in well shaded regions. Mealy bugs and scale insects also thrive well on unshaded coffee. Thin shade and good drainage help to reduce the incidence of the coffee shothole borer, *Xylosandrus compactus*. Regulation of shade is also known to help in cardamom thrips control.

Crop sanitation, especially tracing and removal of infested plants, plays a vital role in the control of white stem borer of coffee and coconut palm weevil. Phyto-sanitary measures are very effective for the control of the cashew stem borer, *Plocaederus ferrugineus* as well. Manual removal of infested shoots during plucking reduces the incidence of flushworms in tea fields. Destruction of alternate hosts is a measure by which the population of cardamom stem borer, *Dichocrocis punctiferalis*, can be reduced. Application of higher dose of potassium in shot hole borer infested fields of tea in the pruned year was useful in reducing its infestation (Ranganathan *et al.*, 1985).

4. *Attractants*: Logs of tender coconut palms treated with coconut toddy, yeast and acetic acid were found to be very helpful in trapping adults of *Rhynchophorus ferrugineus* (Kurian *et al.*, 1982).

Research on pheromones of plantation crop pests is yet to commence in India though in Japan sex pheromones have been used for the management of the caterpillar pests of tea (Tamaki, 1980). More work on a collaborative basis in this line especially in the control of lepidopterous pests like *Dichocrocis punctiferalis* and *Opisina arenosella* is needed.

Insect growth regulators can play a predominant role in integrated pest management programmes. The chitin inhibitor, diflubenzuron had been field tested for the management of *Opisina arenosella* of coconut (Sundaramoorthy, 1980) and *Cydia leucostoma* of tea (Muraleedharan and Varatharajan, 1985).

5. *Pesticides*: Though continuous use of pesticides poses problems of environmental contamination, they remain still the most immediate solution to a pest problem in hand and will continue to influence our pest control programmes in future also. Insecticides ranging from DDT to the most recent synthetic pyrethroids do find a place in the schedule of pest control programmes in plantation crops. While BHC swabbing continues to be an integral part of coffee white stem borer control programme, application of the synthetic pyrethroid fenvalerate is being presently recommended for the mid cycle control of *Xyleborus fornicatus*, attacking tea (Muraleedharan, 1986).

Investigations on the effect of pesticides on beneficial insects have already been made especially in relation to *Cryptolaemus montrouzieri* (Chacko *et al.*, 1979b) and *Coccophagus cowperi*

(Chacko and Deepak Singh, 1979; Chacko *et al.*, 1979a.) Effect of pesticides on bees assumes special significance in crops like cardamom where pollination by bees is of tremendous importance. Some attention has been paid to this (Crane and Walker, 1983), but a lot more needs to be done.

Most of our plantation crop products are exported and pesticide residues on these will continue to be strictly monitored by the importing countries. Intensification of research on the fate of pesticide residues in plantation crop products should be taken up on a priority basis.

Rapid strides have been made in the field of pesticide application technology, but in plantation crops we still rely mostly on the conventional sprayers, requiring large volumes of water, enormous manpower and incurring loss of pesticides. Changes in nozzle design can produce sprays with a narrower droplet spectrum and the introduction of electrostatically charged sprays can provide greater control of droplet trajectories to increase deposition and reduce downward drift (Mathews, 1982). Aerial application of chemicals has been tried for mite control in tea, but the undulating terrain and tall shade trees pose a problem for the successful implementation of this programme (Venkata Ram, 1978a, 1978b). Moreover, environmental contamination will be an added disadvantage. Aerial application of insecticides has also been tried for *Helopeltis* control in cashew.

B. Supportive Control Tactics

For evolving successful IPM programme, supportive control tactics

play a major part. Mention has already been made on the need for generating basic data on bioecology and population dynamics of pest species and for assessing the loss of crop incurred by the attack of these noxious organisms. It is known that establishment of economic threshold levels empirically, as a function of several factors such as weather, vigour and maturity of crop, time of pest infestation, age structure of pest population, size of the population of beneficial organisms etc. require large number of field trials – many more than economically feasible to make (Shoemaker, 1980). Mathematical models can greatly help us to understand the ways in which the above factors interact to affect the yield and also on the success of different control strategies. Systems analysis can ultimately help us to guide in decision making on the combination and timing of pest control practices to be adopted.

CONCLUSION

- i) Our present knowledge on the ecology of most of the pests of plantation crops and their natural enemies is insufficient. Efforts are needed to obtain the necessary information on the ecology of the pests as well their biocontrol agents.
- ii) Long term studies are required to generate data on the economic threshold levels of pest species and a beginning has to be made at least in the case of key pests of plantation crops.
- iii) A good pest surveillance system has to be developed for each of the major plantation crops.

- iv) Research programmes on IPM need increased funds and more personnel for generating basic data and for training.
- v) IPM is a sophisticated technology and has certain associated risks. Often, the seriousness of pest problems is disproportionately magnified, endangering IPM programmes.
- vi) IPM will not be able to provide an immediate solution to the problem of sudden outbreak of pests in a severe form. Moreover, it may not be possible to incorporate IPM programmes universally.

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INTEGRATED MANAGEMENT OF RED PALM WEEVIL (*RHYNCHOPHORUS FERRUGINEUS* F.) IN COCONUT GARDENS*

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ABSTRACT

The red palm weevil, *Rhynchophorus ferrugineus* F., is a dreaded pest of the coconut palm, capable of killing the palm outright. Though different methods of management have been recommended against this pest, any single method has not been proved to be effective in combating the pest infestation. Timely adoption of curative chemical control can protect the palms from pest infestation. But being a tissue borer, the infestation is quite often detected at later stages only and as such it would be difficult to save the palm with the curative treatment. Hence, an integrated method of pest management system was developed and tested in cultivators' gardens in Alleppey District. The schedules included adoption of plant and field sanitation, prophylactic method of filling all the leaf axils of palms with BHC + sand, curative chemical treatment, prevention of pest entry through cut ends of petioles and wounds and use of attractants. Sixty nine out of a total of 1005 young experimental palms were infested by the pest at the time of commencement of the experiment during 1970. By adoption of all the proven methods of weevil control in an integrated manner the pest infestation could be brought down near to zero level and the gardens could be maintained free of fresh infestation.

INTRODUCTION

The red palm weevil *Rhynchophorus ferrugineus* F. (Coleoptera: Curculionidae) is a dreaded tissue borer pest of the coconut palm capable of killing the palms outright. Grubs of the weevil tunnel into the palm trunk/crown and feed on the soft tissues of the growing point viz., the 'heart' or the cabbage portion, which results in death of the infested palm. Though different methods of management have been recommended against this pest, no single method has been proved to be quite effective in

combating the pest infestation. Coconut being a monocot, if the growing point of the palm is damaged, curative treatment with insecticides will not be able to save the palm. Thus, an analysis of the nature of the crop and the nature of damage done by the pest (a tissue borer) would reveal that sole dependence on any single method will not be feasible for combating this pest. Hence an integrated pest management system was developed and tested in large scale plots in farmers' fields. The results of the experiment are discussed in this paper.

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MATERIALS AND METHODS

One thousand and five coconut palms of the age group of 3 to 20 years were selected in a contiguous area of coconut gardens at Kurathicadu near Mavelikkara, Alleppey Dist., Kerala, during 1970. A thorough combing of all the palms was made for detection of red weevil infestation. Pest infested palms which were beyond the stage of recovery/dead palms were removed and all the stages of the pest present in the palm trunks were destroyed as a measure of preventing further spread of the pest and bringing down the population. Thereafter all the proven schedules for suppressing the coconut weevil were adopted in the area in an integrated manner. These schedules included, maintaining plant and field sanitation, prophylactic method of filling all the leaf axils of palms with BHC 5 per cent dust + sand (Mathen and Kurian, 1966), dressing of wounds caused on the palm with BHC + tar for preventing egg laying by weevils on such wounds (Abraham, 1971 a, 1971 b), treating the leaf rot/bud rot disease affected palms with Dithane M-45 and insecticide to prevent pest entry through decayed tissues and prevention of pest entry through the cut ends of leaf stalks by discouraging cutting of leaf stalk near the stem (Abraham, 1971 a) and curative treatment of weevil infested palms with Pyrethrins-piperonyl butoxide/carbaryl at one per cent concentration (Nirula 1956, Mathen and Kurian, 1970). During the year 1977 trapping and killing the floating population of weevils was also introduced. The weevils were caught using traps prepared out of coconut log + toddy + yeast (Abraham and Kurian, 1975).

The palms were examined regularly at monthly intervals for the detection of fresh incidence of the pest, if any, and the curative treatment was resorted to. Those palms which received the curative treatment earlier were also examined periodically and curative treatment given as and when reinfestations detected. The experiment was continued up to 1982.

RESULTS AND DISCUSSION

Pretreatment observations of the experimental palms (1005 nos.) enabled detection of 69 palms harbouring red palm weevil in varying degrees of intensity (Table I). Thus the initial pre-treatment incidence was 6.86 per cent. Out of these, 36 palms were either dead or at a stage beyond recovery even before the commencement of the trial. These palms were cut open and all the stages of the pest destroyed. The stem and other

Table I. *Red weevil infestation in the integrated pest management garden at Kurathicadu.*

Year	Palms infested by red weevil	Palms died
1970	69	36*
1971	43	4
1972	14	2
1973	13	—
1974	12	—
1975	8	—
1976	8	—
1977	3	—
1978	1	—
1979	0	—
1980	1	—
1981	1	—
1982	0	—
Total	173	42

*Died before the commencement of the experiment

parts were burnt. This operation helped in reducing the pest population in the field. If these palms were not removed they would have served as natural reservoirs for multiplication of the pest in the field. Remaining 33 palms were given curative injection treatment with pyrethrins-piperonyl butoxide/carbaryl 1 per cent suspension. These palms recovered from the infestation. During 1971, there were 43 fresh incidence and after treatment 39 were cured and four died. From 1972 onwards there was considerable decline in fresh infestation. There were only 14 fresh infestation of which two palms died in spite of the curative treatment. During 1973 and 1974 also the infestation remained almost at the small level with 13 and 12 palms, respectively, showing fresh infestation. All of them were cured after treatment. The infestation came down to eight during 1975 and the same trend continued during the subsequent year also. The results of these two years indicated that it was rather difficult to bring down the infestation any further with the treatment schedules adopted. This could perhaps be due to the migration of the floating population of weevils from the adjoining gardens. Hence, the trapping of floating population of weevils was also incorporated as an additional tool.

Coconut log splits treated with toddy and yeast were maintained in the gardens. These traps attracted 18 weevils during 1976. In subsequent years also trapping helped in catching the weevils. During 1977 the infestation has come down to three while during 1978 and 1979 the infestation was one and nil, respectively. The experiment continued for another period of three years and the

infestation was one or nil. Thus, by adoption of the integrated management practices the gardens could be maintained at a very low level of red weevil infestation.

The total expenditure for carrying out the above operations worked out to Rs.22,315/- towards the cost of insecticides, fungicides etc. and labour charges for 13 years. Thus the average expenditure per palm per year worked out to Rs. 1.72. With this expenditure a total of 131 palms could be saved from the red weevil infestation. Only six palms which received treatments could not be saved. This treatment also drastically reduced the population of red palm weevil in the field.

The above results clearly proved that integration of the different methods of red palm weevil management was quite successful in coconut gardens. The coconut log traps helped to bring down the pest population to a very negligible level. This is because the floating population of weevils migrating from the adjoining gardens of the experimental area could also be trapped, thus denying chances for their multiplication in the gardens.

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BIOLOGICAL SUPPRESSION OF COCONUT RHINOCEROS BEETLE *ORYCTES RHINOCEROS* (L.) IN MINICOY, LAKSHADWEEP BY *ORYCTES* BACULOVIRUS – IMPACT ON PEST POPULATION AND DAMAGE*

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ABSTRACT

The population of *Oryctes rhinoceros* (L.), one of the key pests of coconut palm, has been substantially reduced in Minicoy Island, Lakshadweep, through the use of a virus disease of the pest. *O. rhinoceros* beetles were infected with *Oryctes baculovirus* (30 LD₅₀ dose/ml. of inoculum) and released into the pest population in Minicoy Island in April, 1983. The virus was previously isolated from field-collected, diseased *O. rhinoceros* beetles from Kayangulam in Alleppey District, Kerala. Pre-release observations at Minicoy in April, 1983 revealed high incidence of pest damage to coconut and the absence of the viral disease in the pest population. Post-release observations recorded after two years revealed spread of the virus disease to the subsequent generations of beetles and larvae in breeding sites. The resultant epizootic in the pest population drastically reduced the larval population in breeding sites, leading to a substantial reduction in the damage to coconut palms in experimental plots.

INTRODUCTION

Oryctes baculovirus, a viral pathogen of the coconut rhinoceros beetle, *Oryctes rhinoceros* (L.) has been successfully used to suppress the pest population of *O. rhinoceros* in the South Pacific Islands, Fiji, Mauritius, Seychelles and Papua New Guinea (Marschall, 1970; Hammes, 1971; Young, 1974; Bedford, 1977; Gorick, 1980). Wherever the virus was introduced into the habitat of the pest, an initial epizootic decimated the larval and beetle populations resulting in drastic reduction in crop damage. The easy and rapid transmission of the virus disease could maintain the pest at low

levels for many years in some islands. Young and Longworth (1981) reported the successful control of *O. rhinoceros* by baculovirus in Tonga for seven years after its first and only release in 1970, whereas in Western Samoa, a resurgence of the pest was noticed at low levels of virus incidence, four years after the viral epizootic. Subsequent re-release of a small number of diseased beetles brought about substantial reduction in pest population and crop damage (Marschall and Ioane, 1982). Taking into account both the extremes, an ideal schedule should include minimum three spaced releases of virus-infected beetles. The experiences of successful biological

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control of *O. rhinoceros* unambiguously points to the potential of the virus (Malaysian isolate) for long-term control of the coconut pest in island habitats.

In addition to Malayasia, where the virus was first discovered by Huger (1966) it has been reported to occur in the wild populations of the pest in the Philippines, Indonesia and India (Zelazny, 1977b; Mohan *et al.* 1983). This paper describes the biological suppression of *O. rhinoceros* by *Oryctes* baculovirus (Kerala isolate) in the island of Minicoy, Lakshadweep.

MATERIALS AND METHODS

a) *Screening of beetles and larvae in Minicoy*: Prior to the release of virus – infected beetles it was necessary to screen the wild pest population for the incidence of baculovirus disease. Accordingly, one hundred *O. rhinoceros* beetles were collected from the crowns of

infested palms and breeding sites (fallen coconut trunks, decaying coconut stumps etc.) from all over the Island, and screened for symptoms of baculovirus disease by (1) visual examination of midgut and its contents, (2) Giemsa stained smear of midgut cells, (3) immuno-osmophoresis of the midgut aspirate (Zelazny 1978; Mohan *et al.* 1983). An equal number of breeding sites were raked up and three grubs collected from each site were kept in a box, containing organic matter from the same site, and observed in the laboratory for two weeks, for the appearance of symptoms of baculovirus disease.

b) *Experimental fields*: Fig. 1 depicts the map of Minicoy Island. The farm of the Central Plantation Crops Research Institute (CPCRI) of area of 6 ha almost in the centre of the Island, was one of the experimental plots. Eight hundred coconut palms falling in the age

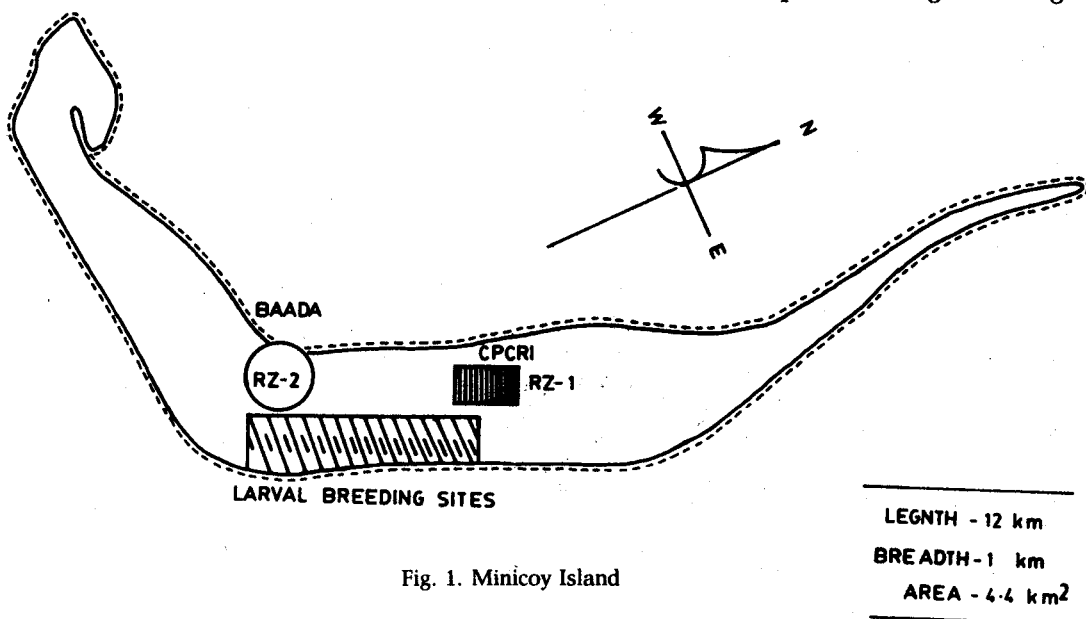


Fig. 1. Minicoy Island

group for 5-50 years were taken and among them 80 palms (10% sample size) were randomly picked for detailed observations relating to the condition of the opened leaves, spathes and spindles. The CPCRI plot also constituted the first Release Zone (RZ-1) since virus-infected *O. rhinoceros* beetles were first released here. The second experimental plot constituted village lands of Baada, Rammid I and II, Boduvathiri, Sidalwalo, Ahamuge, Phunhilol and RBBS (Radio Broadcasting and Ranging Station) on the south-western part of the Island. The second release of diseased beetles was made in Baada plot (RZ-2), about 3 Km from RZ-1. The number of palms taken up for the study was 420 in Baada and adjoining plots, 460 in Ahamuge and adjoining plots and 170 in the RBBS plot. The sample palms for detailed observations consisted of 10% of the above number. Capture of beetles was recorded in all palms, whereas the condition of every opened leaf (damaged/healthy), spathe and the central spindle of only sample palms was recorded. The percentage of pest damage was calculated by computing the proportion of damaged leaves/spathes to the total leaves/spathes which had emerged since the last observation. The data were analysed by randomised block design.

For studying the impact of the virus disease on the population level of beetles/larvae, an experimental plot was chosen on the south-eastern part of the Island of area approximately 80 ha ($\sim 0.9 \text{ Km}^2$) consisting of the lands of villages of Allody, Funhilol and Pallisery. The area contained maximum density of breeding sites of the pest in the form of rotting coconut stumps and fallen logs. The area

was divided into five zones for the convenience of enumeration of breeding sites and the larvae within. The following observations were recorded per site: i) No. of larvae (instar wise), pupae and live beetles (ii) Cadavers of larvae and beetles. Only sites considered suitable for the breeding of *O. rhinoceros* were raked up for taking observations and the larvae were put back into the sites after enumeration. If there was a wide variation between the larval stages within a single site, it was presumed to have come from more than one brood. A breeding site was deemed to contain infective virus if morbid larvae with striking external symptoms of virus disease were found or if the samples larvae developed the disease in the laboratory, later on.

c) *Method of infection and release:* Field-collected *O. rhinoceros* beetles were allowed to wade through virus inoculum contained in a basin for 30 min. The inoculum contained 1 g of infected larval tissue in 1 l of phosphate buffer (0.05 M, pH 8.0) which amounted to 31.6 LD 50 dose and 3% sucrose. After the swim treatment the beetles were confined together in a box containing rotting coconut wood powder mixed with virus inoculum, used before for 24 h. The treated beetles were removed the following day and confined in a box with fresh coconut petiole pieces as feed for a week, since infected beetles begin excreting baculovirus only after a week post-infection. The beetles were liberated after dusk in the experimental plots.

RESULTS

Pre-release screening of approximately one hundred beetles and an equal

number of larval breeding sites from all over the Island in January and April, 1983, revealed the total absence of the virus disease.

Detailed observations of palms in experimental plots recorded before the introduction of virus disease showed high incidence of leaf (60%), spathe (30%) in CPCRI farm and plots of Ahamuge Village in 10% of the palms examined.

The release of 130 infected *O. rhinoceros* beetles in April, 1983 in the CPCRI farm resulted in a significant reduction in crop damage (Fig. 2) in all the four experimental plots. There was a steady decline in the leaf damage with time in all the plots consequent to the introduction of the virus disease, excepting in Baada. The means (leaf damage) of the four plots showed significant differences between the observations at different times (Table I). The leaf and spindle damage at Baada did not decline till Jan. '84 viz., ten months after the introduction of the virus disease, but did so subsequently. This is the site of the second release of 35 infected beetles in Jan. 1984.

The reduction in spathe damage in the four plots described a steeper concerted decline and the mean values were significantly different between observations, excepting the last two in November '84 and September '85 since the values had reached the lowest levels in November '84 itself. Again the rate of decline of spathe damage in Baada was much slower as compared to that in CPCRI and Ahamuge. The reduction in spindle damage was also drastic in all barring Baada. Spindle damage reached its nadir

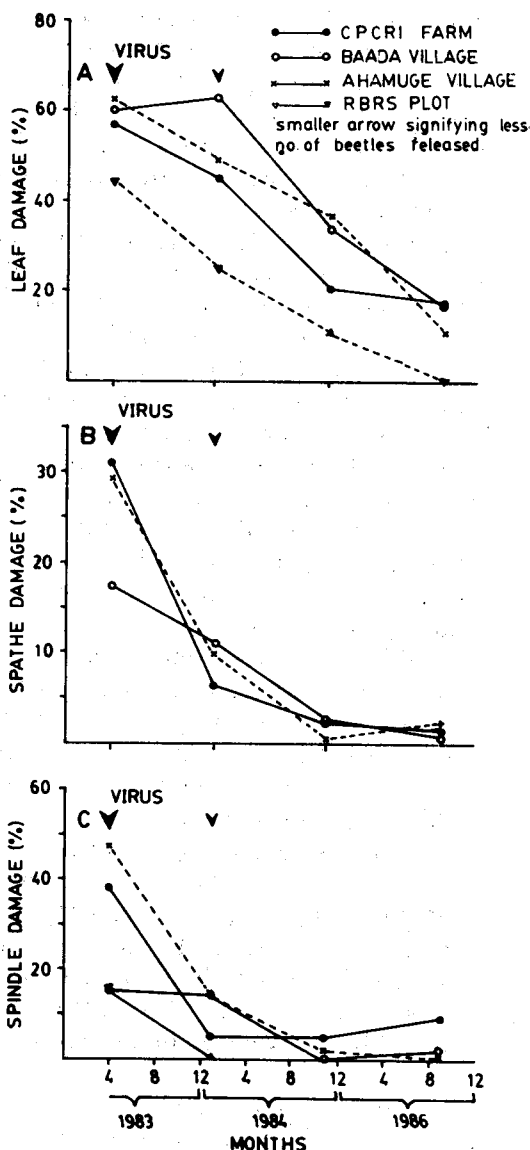


Fig. 2. Effect of the release of Baculovirus-infected *O. rhinoceros* beetles on damage to leaves (A), spathes (B) and spindles (C) in the experimental plots in Minicoy

in CPCRI soon after the introduction of the virus disease and thereafter remained stabilised at low levels around 5%. The

Table I. *Impact of the introduction of baculovirus disease into O. rhinoceros population in Minicoy, on crop damage in experimental plots*

	Means (%) of experimental plots		
	Leaf damage	Spathe damage	Spindle damage
Pre-release:			
April, '83	55.83 (46.66)d	25.90 (30.75)c	29.56 (32.62)b
Post-release:			
January '84	45.43 (42.52)c	8.86 (17.73)b	8.27 (15.61)a
November '84	25.57 (30.18)b	1.95 (8.84)a	1.84 (7.85)a
September '85	12.89 (20.26)a	1.61 (8.27)a	2.90 (9.01)a

(Figures in parentheses denote angular transformed values)

C.D (5%) 5.40 6.14 9.72

C.V. (%) 9.36 16.73 31.32

SEM 1.75 1.88 3.16

Means in the same column with letters in common are not significantly different.

mean spindle damage values after January '84 were not significantly different at 5% level, nevertheless they are significantly different from the pre-release observations in April, '83.

In brief, the mean reductions in leaf damage after 9, 19 and 29 months after the release of virus-infected beetles were 18.63, 54.20 and 76.91%, respectively. Similarly, the mean reductions in spathe and spindle damage during the same time intervals were 65.79, 72.02, 92.47, 93.77, 93.78 and 90.19% respectively.

The virus disease seemed to have a marked effect on the larval population in breeding sites. Immediately after the introduction of the virus disease in April

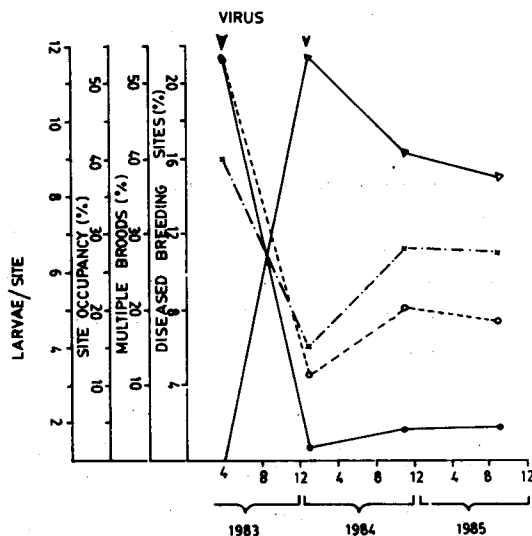


Fig. 3. Effect of the Release of Baculovirus - infected *O. rhinoceros* beetles on larval population in breeding sites in minicoy

Larval population —●—, Site occupancy —○—, Breeding sites with diseased larvae —▲—, Incidence of multiple broods —○—.

'83 a steep decline was recorded in the larval population in breeding sites (Fig. 3) and the associated site occupancy percentage (SOP) which is the ratio of breeding sites in the experimental plots occupied by larval stages to the total sites screened.

Thereafter the larval population was maintained at a low level due to the suppressive effect of the virus disease albeit a small increase after the initial epizootic. SOP almost followed a similar trend to that of the larval population and showed an increase in November '84 in spite of the release of a small number of virus infected beetles (35) in January '84. Similarly the percentage of sites containing one brood also drastically declined establishing a relationship between incidence of multiple broods and virus disease transmission. On the same

count the % of breeding sites which diseased larvae rose sharply to 22.

DISCUSSION

The absence of baculovirus disease in the natural population of *O. rhinoceros* in Minicoy coupled with the medium to high incidence of pest damage to coconut palms prompted us to test the efficacy of the Indian isolate of *Oryctes* baculovirus in Minicoy, Lakshadweep.

The foremost inference which could be drawn was that the virus-infected beetles released from CPCRI farm in Arpil '83 had transmitted the disease to the next or even second generation beetles and to larvae in breeding sites within a span of nine months (January '84). The mode of transmission of *Oryctes* baculovirus disease in nature has been worked out based on the trials which the Malaysian isolate of *Oryctes* baculovirus in the South Pacific Island (Zelazny, 1976). The rapid spread of the virus disease in Minicoy had presumably triggered an epizootic resulting in the crash of larval population in breeding sites (Fig. 3) and free flying adults (data not presented) and culminated in the reduction of crop damage by pest in all the experimental plots. Past experience with the field trials of *Oryctes* baculovirus in South Pacific Island and other places also indicates rapid spread of the virus disease causing epizootics and improvement in the condition of palms (Bedford, 1980).

The reduction in leaf damage consequent to the release of virus-infected beetles had been much slower (but statistically significant) as compared to the rapid decline in spathe and spindle

damage. This could be due to the fact that in a coconut palm, damage to the fronds is generally the heaviest as compared to spathes (which are also few in number) and the spindle leaf. Hence, any reduction in the pest population is reflected by a sharp drop in spathe damage (being few in number) as against a slow decline, in reduction of leaf damage due to the gradual replacement of damaged leaves by healthy.

The slower response of palms in Baada plot in reflecting the reduction in pest population could be due to its close proximity to the area of maximum density of breeding sites on the south-eastern side of the plot. Hence the nearness to innumerable breeding sites kept up the supply of beetles from sites not affected by disease and thus leaf and spindle damage in Baada did not decline till January '84 in the face of the initial epizootic. Subsequently as these 'escaped' breeding sites also became infected, the beetle population in Baada declined leading to the improvement in the conditions of palms from January '84 onwards.

It may be noted that there was a fall in spathe damage (mean) by 65.8 and 92.5% in 9 and 19 months time respectively after the introduction of the virus disease, since spathe damage is economically the most serious.

The first direct evidence of the transmission of baculovirus disease in Minicoy was the dramatic fall in the larval population in breeding sites and SOP. Young and Longworth (1981) reported a reduction in larval population (Larvae/site) by $\sim 43\%$ soon after the first

virus epizootic in Tonga and remarkably the reduction was found to be 47% after another seven years with no further release of virus infected beetles whereas the reduction in larvae/site in Minicoy after the epizootic was by $\approx 94\%$ and a level of 86% was maintained thereafter. Moreover the number of breeding sites examined in Minicoy was 720, as against 69 by Young and Longworth (1981). A strong negative correlation is evident between the incidence of multiple broods and disease in breeding sites, an observation corroborated by Zelazny (1976), since high incidence of multiple broods in a site increases the probability of virus contamination of the site by visiting females. The incidence of disease in breeding sites would probably be maintained around 15% and thus is on par with the level of 9.3% recorded in Philippines (Zelazny, 1977b), 7.3 to 8.4% in Western Samoa (Zelazny, 1977a).

Areas having high density of breeding sites are expected to have low incidence of disease due to the reduced chances of multiple visits by beetles to the same site, hence the disease incidence observed in the 80 ha experimental plot of Minicoy (high density of breeding sites) could possibly be the lower limit.

Taking an overview of the experiment, the introduction of the Kerala isolate of *Oryctes* baculovirus disease into Minicoy to effect biological suppression of *O. rhinoceros* seems to have been achieved, though the long-term suppression has to be studied. This also seems to be on par with the South Pacific trials with the Malaysian isolate of *Oryctes* baculovirus.

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STUDIES ON THE INTEGRATED MANAGEMENT OF COCONUT BLACK-HEADED CATERPILLAR, *OPISINA ARENOSELLA* IN TAMIL NADU*

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ABSTRACT

Investigations were made to assess the role of three parasites, viz., *Bracon brevicornis*, *Parasierola nephantidis* and *Trichospilus pupivora* in the control of coconut black-headed caterpillar under field conditions in Tamil Nadu. It was observed that *P. nephantidis* was better than the other two species in checking the pest population. The total number of progenies per *P. nephantidis* female was increased markedly by treatment with Altosid. Studies were also made to develop mass production techniques for the pupal parasite, *Tetrastichus israelis* under laboratory conditions for field release.

All the species of parasites were not able to establish and check the pest population effectively during peak summer conditions in Tamil Nadu. Hence successful attempts were made to control the pest by trunk injection with certain systemic insecticides as a one-time measure during summer. The results of the integrated control trials are discussed in this paper.

OBSERVATIONS ON *XANTHOPIMPLA PUNCTATA PUNCTATA* F. (HYMENOPTERA: ICHNEUMONIDAE), A PUPAL PARASITOID OF *OPISINA ARENOSELLA* WLK.*

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ABSTRACT

Xanthopimpla punctata F. the solitary, polyphagous, pupal parasitoid has been so far considered as an insignificant species in the biological suppression of the coconut leaf eating caterpillar, *Opisina arenosella* Wlk. (Lepidoptera: Cryptophasidae). Recent observations carried out in Tamil Nadu and Kerala revealed that *X. punctata* breeds in *O. arenosella* during July to December with a peak period of activity during September – October. Without uniformly dispersing in all the *Opisina* – infested coconut gardens, the adult parasitoids congregated in some localised tracts close to the sea, back waters or other water ways or in irrigated coconut plantations and effected a high degree of parasitism, suppressing even the dominant species of pupal parasitoids like *Brachymeria nosatoi* Habu. Other ichneumonid parasitoids such as *Zanthopimpla* sp. and *X. nana nana* Schulz. were not found to build up their populations in the territory occupied by *X. punctata*. Host feeding is present prior to oviposition, which is continued in every one to three days, through out the long life span of the female parasitoid. A method for rearing this parasitoid in the laboratory, its mating behaviour life history, intensity of natural parasitism etc. are also discussed.

INTRODUCTION

Opisina arenosella Wlk. (= *Nephantis serinopa* Meyr.) (Lepidoptera: Cryptophasidae), the leaf eating caterpillar, is an economically important pest of coconut palms in India and Sri Lanka. The months migrate to distant places and establish there causing severe damage to coconut plantations. More than fifty species of parasitoids and predators are now known to be associated with this pest, among which the pupal parasitoids are more important (Pillai and Nair, 1981). *Xanthopimpla punctata* F.,

Xanthopimpla sp. and *X. nana nana* Schulz. (Pillai and Nair, 1983) are the recorded ichneumonid pupal parasitoids of *O. arenosella* in Kerala State.

X. punctata F. (Hymenoptera: Ichneumonidae) occurs in China, Formosa, India, Nigeria etc. parasitising host insects infesting Jasmine, tea, cotton, paddy, snake gourd, soybean etc. Its hosts include the European corn borer, *Ostrinia nubilalis* Hb. the *Lasiocampid* *Metanastria punctata* Wlk. the leaf roller *Sylepta derogata* F., the *Lymantrids* *Olene mendosa* Hb. and

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Notolophus posticus Wlk. and *Nausinoe geometralis* Guen., *Anadevidea peponis* (F.) etc. Significant level of parasitism by *X. punctata* has not been reported so far. Soman (1927) observed two to three per cent parasitism on *N. posticus* on tea in Formosa. Pillai and Nair (1981) recorded only 1.36% incidence of it on *O. arenosella* in Kerala. In this paper, we furnish the results of our observations carried out at Salem (Tamil Nadu) and Ayiramthengu, Quilon district, Kerala State. A method for rearing *X. punctata* in the laboratory and details of its mating habits and life history are also furnished to enable the parasite breeding laboratories to take up multiplication of this parasitoid also for biological suppression of *O. arenosella*.

MATERIALS AND METHODS

The method used by Pillai and Nair (1983) for rearing *X. nana nana* was used for laboratory multiplication of *X. punctata*. Mating habits of the parasitoid were studied under a stereoscopic microscope and in laboratory cages. The virgin female was transferred to a clean glass vial, 7.5cm × 2.5cm, containing three to four-day-old males. Biology of the parasitoid was studied at a temperature range of 22-30°C and 45-80% RH in the insectary.

To study the intensity of natural parasitism, pupal cases from which the moths and parasitoids emerged and the live pupae were collected from Salem during September, 1981 and brought to the laboratory at the Central Plantation Crops Research Institute, Regional Station, Kayangulam. The live pupae were transferred to glass bottles, 18cm × 9cm, for recording the emergence of

moths and parasitoids, from which the intensity of natural parasitism was computed. Empty pupal cases were examined and the extent of pupal parasitism by different parasitoids recorded as per the method adopted by Pillai and Nair (1982), in which the nature, size and position of the emergence holes are taken into consideration. At the time of emerging *X. punctata* makes a characteristic operculum like opening at the cephalic and of the host pupa, which is retained intact in the pupal case.

Intensity of parasitism by *X. punctata* at Ayiramthengu was recorded during 1983 and 1984 by observing the live pupae collected from the field and reared in the laboratory.

RESULTS AND DISCUSSION

Laboratory rearing of X. punctata:

Five to six mated females and two to three male parasitoids were released in a glass bottle. Undiluted honey was provided as minute droplets on a piece of wax-coated paper. The mouth of the jar was closed with a piece of mosquito net fastened with rubber bands. Over the net a piece of snake gourd leaf was kept on which several pupae of *O. arenosella* or *A. peponis* were placed. The pupae were held tight to the bottle with a piece of muslin cloth and rubber bands. The glass bottle was kept horizontally.

The female parasitoid thrust her ovipositor into the host pupa, contracted her abdomen, disorganised the pupal contents with the clockwise and anticlockwise rotatory movements of the ovipositor and fanned her wings in slow

or high speed during oviposition. When *A. peoponis* pupae were used for rearing the parasitoid, the female parasitoids fed on the host's haemolymph after puncturing, in every one to three days, during their long life span. They were removed every day and fresh pupae offered for parasitisation. Upto six host pupae were parasitised by a female parasitoid a day. The parasitised pupae were transferred to a similar glass bottle, covered with a muslin cloth and kept undisturbed for emergence of the parasitoids.

Mating habits:

The females mated immediately on emergence with the earlier emerged males. An unmated female may mate any time during its long life span. The females are polyandrous. On recognition of the female, the male waves his antennae and touches her with them. Vibrating the wings he mounts on the female, assumes a parallel position and holds her wings with the first pair of legs. The abdomen of the female is held firmly with the meso and metathoracic legs of the male in three ways.

1. Holds the ventral side of the female's abdomen firmly with the claws.
2. Locks the abdomen of the female between the legs with the firm claw to claw hold of all the four legs.
3. Locks the female between the meso-and metathoracic legs of one side and the metathoracic leg of the other side with claw to claw hold.

The male alternately vibrates the wings in high speed, four to fifteen times, during

mating, each lasting 3 to 20 seconds. The time lag between wing fannings is one to eleven seconds. Mating lasts for 35-61 seconds. The male terminates mating. The female may mate four times in 30 minutes with different males.

Life history

First host feeding: Fifth day of emergence; Preoviposition period: Six to seven days; Egg period: one day; Larval period: 4 to 10 days; Pupal period: 5 to 10 days; Egg to adult stages: 10 to 20 days; Longevity of females: one to five months.

Female progeny produced in *O. arenosella* in the field during 1983 and 1984 was 44.36% and 46.12% respectively.

Intensity of incidence of X. punctata at Salem:

Infestation by *O. arenosella* was very severe at Salem during 1981. By September, the pest had completed three to four generations and excepting the unopened spear leaves all the remaining leaves were heavily infested in majority of coconut palms and palmyra palms growing in the hedges of coconut gardens. Several hundred of adults of *X. punctata* were observed hovering in the coconut gardens and a large number of female parasitoids were noticed in the act of oviposition in the pupae of *O. arenosella*. However, it could not suppress the outbreak of the pest.

One hundred and sixteen emerged pupal cases were collected from the infested field and examined. The results of examination of empty pupal cases are summarised below.

No. of emerged pupal cases of <i>O. arenosella</i> examined	: 116
No. of pupal cases from which months emerged	: 79
No. of pupal cases from which parasitoids emerged	: 37
Percentage of total parasitism	: 31.9
No. of pupal cases from which <i>X. punctata</i> emerged	: 31
Percentage parasitism by <i>X. punctata</i>	: 26.72
No. of pupal cases from which <i>Brachymeria</i> spp. emerged	: 4
Percentage parasitism by <i>Brachymeria</i> spp.	: 3.45
No. of pupal cases from which	

the hyperparasitoid (<i>Eurytoma albotibialis</i>) emerged	: 2
Percentage parasitism by the hyperparasitoid	: 1.72

Other parasitoids such as *Trichospilus pupivora* Ferr., *B. nosatoi*, *Xanthopimpla* sp. and *X. nana nana* were totally absent at Salem area.

The intensity of incidence of *X. punctata* recorded from the rearings of live pupae (351 nos.) collected from Salem area is furnished in Table-I. Of the total parasitism, the contribution of *X. punctata* was to the extent of 53.77%.

Table I. Intensity of parasitism by *X. punctata* F. and other parasitoids in *O. arenosella* Wlk. at Salem and at Ayiramthengu.

Locality of collection of sample pupae year of observation	No. of pupae from which months and parasitoids emerged	No. of parasitoids emerged	Percentage parasitism	<i>X. punctata</i>	<i>B. nosatoi</i>	<i>B. nephantidis</i>	<i>B. lasus</i>	<i>B. himeae-hakonen-ttevae</i>	<i>Antrocephalus</i>	Hyper-parasitoid <i>Eurytoma albotibialis</i>
SALEM										
1981	351	173	49.27	26.5 (93)	Absent	10.82 (38)	Absent	7.12 (25)	0.57 (2)	4.27 (15)
AYIRAMTHENGU										
1983	355	204	57.46	37.46 (133) Male: 74 Female: 59 44.36%	10.70 (38)	8.17 (29)	0.56 (2)	Absent	Absent	0.56 (2)
1984	562	363	64.59	43.59 (245) Male: 132 Female: 113 46.12%	10.32 (58)	8.90 (50)	0.71 (4)	0.35 (2)	ABSENT	0.71 (4)

*Figures in parantheses indicate the actual number of parasitised pupae

Intensity of parasitism by X. punctata at Ayiramthengu:

Ayiramthengu is an area close to the sea where congregation of *X. punctata* was observed during September 1983 and 1984. The data on the extent of parasitism are summarised in Table I. This data reveal the remarkable degree of activity of *X. punctata*. Of the total parasitism, the contribution by *X. punctata* ranged from 65.2% to 67.5% during 1983-84. Another important result emerged from this study was that *B. nosatoi*, which is the most dominant species of pupal parasitoid of the pest in southern Kerala was unable to compete with *X. punctata*. The other two allied species of ichneumonid pupal parasitoid viz. *Xanthopimpla* sp. and *X. nana nana* also totally absent in the territory occupied by *X. punctata*.

A few other breeding sites of *X. punctata* were also located at Kayankulam Kayal Farm and nearby areas of Alleppey district during 1983 and 1984.

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MID-CYCLE CHEMICAL CONTROL OF *XYLEBORUS FORNICATUS* EICHHOFF (SCOLYTIDAE:COLEOPTERA), THE SHOT-HOLE BORER OF TEA

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ABSTRACT

Extensive field studies were carried out in the different tea areas of Southern India, on mid-cycle chemical control of *Xyleborus fornicatus*, the shot-hole borer of tea. Chlorpyrifos, quinalphos and fenvalerate were found to be effective in suppressing the populations of this beetle. Among field study indicated that application of highly persistent organochlorine compounds at the time of pruning need not necessarily help in reducing the infestation of shot-hole borer either on the old wood or on the new stems formed after pruning.

INTRODUCTION

Xyleborus fornicatus Eichhoff, the shot-hole borer (SHB), is a perennial pest of tea inflicting severe damage to the bushes in certain mid and low elevation tea plantations of southern India. Though the presence of this scolytid beetle had been reported as early as in 1930, it was thought to be of minor importance even in the sixties (Ananda Rau, 1956). During the last two decades, this species has come to be recognised as an important pest of tea in South India.

Extensive field investigations had been conducted in the past on the chemical control of shot-hole borer (Rao, 1971). Spraying of dieldrin, at the time of pruning, was considered an effective method for controlling SHB. Son, dieldrin was replaced with heptachlor and the application of this chemical was recommended at 8.5 l/ha in 675 litres of water. In the beginning, mid-cycle

chemical application with dieldrin and heptachlor was also practised for controlling this pest. However, spraying of highly persistent organochlorine compounds was discouraged owing to the resurgence of secondary pests. Soon, the organophosphate insecticides were field tested for mid-cycle control (Rao, 1971; Murthy & Rao, 1979). Very recently, a combination of endosulfan and dichlorvos was suggested as an interim measure for the control of SHB in fields under plucking (Muraleedharan *et al.*, 1982). This report presents the results of studies on the efficacy of synthetic pyrethroid, organophosphate insecticides against *X. fornicatus*.

MATERIALS AND METHODS

Four field experiments were conducted on mid-cycle chemical control of shot-hole borer and details of the experiments are given below. In this paper, year of the tea field refers to its age from the time of last pruning.

*Names of authors are given in alphabetical order

Experiment-1, carried out in randomised block design in a second year tea field at Vandiperiyar, consisted of four treatments with six replications, each plot having 100 tea bushes. The treatments included organophosphate insecticides like chlorpyrifos (Coroban 20 EC), quinalphos (Ekalux 25 EC), synthetic pyrethroid like fenvalerate (Sumicidin 20 EC) and untreated control. Chemicals were applied once in every two months. Spraying was carried out with a power sprayer, using a spray volume of 350 l/ha. Care was taken to direct the spray on to the bush frames. Infestation level of SHB was monitored every month by examining 8 infested stem cuttings of 1-1.5 cm diameter and 20 cm long selected at random from each plot. The stem samples were split open in the laboratory to record the number of different life stages of the beetle and also the position and number of borer galleries.

Experiments 2, 3 & 4 were conducted at the Anamallais (Coimbatore District) as large scale, non-replicated field trials with two treatments only. Experiment-2 was initiated in a second year field, consisting of 1100 tea bushes per treatment. Chemical treatment was given once in two months, alternating with the application of fenvalerate (Sumicidin 20 EC @ 500 ml/ha) and quinalphos (Ekalux 25 EC @ 1 l/ha). Chemicals were applied with a motorised sprayer at the rate of 350 l/ha. The spray was directed on to the stems of the tea bushes. Post treatment assessments were made at an interval of two months by random sampling of 100 stem cuttings from each block.

Experiment-3 was carried out in a third

year field and for each treatment a plot having 2000 tea bushes was selected. Fenvalerate was applied @ 500 ml/ha, every alternate month. Care was taken to direct the spray to bush frames. Population of SHB was assessed every month by random sampling of 20 infested cuttings from each block.

Experiment-4 was initiated in a second year field and the two experimental blocks had 1500 bushes each. Agrofen 20 EC another brand formulation of fenvalerate, was sprayed once in two months @ 500 ml/ha. Mode of application and volume of spray fluid were the same as those employed in Experiments 2 and 3. Samples of 25 infested cuttings were collected at random, every month, to determine the efficacy of chemical treatment against the beetle.

Besides these experiments on mid-cycle chemical control, yet another field trial (Experiment-5) was laid out in Wynad during October 1983 to assess the feasibility of replacing organochlorine chemicals which are commonly used for SHB control in pruned tea fields. The field experiment was laid out in randomised block design with five treatments and seven replications, each plot consisting of 100 tea bushes. Chemical treatments were imposed immediately after pruning. Though heptachlor is recommended for application at the time of pruning, aldrin was used in the present experiment, due to the non-availability of heptachlor during 1983. A thorough drenching spray with aldrin was given to the frames and prunings employing a hand operated knapsack sprayer, using a spray volume

Table I. *Efficacy of mid-cycle chemical application against the shot-hole borer (Expt. 1)*

Sl. Treatments No	Dosage beetles/8 infested cuttings ml/ha	Mean number of	
		1984	1985
		Jan - Dec	Jan - Dec
1. Chlorpyrifos	1000	23.98 a	13.47 a
2. Fenvalerate	500	24.00 a	14.24 a
3. Quinalphos	1000	25.14 a	11.90 a
4. Untreated control	-	36.48 b	18.88 b

Numbers followed by the same letter in column are not significantly different ($P = 0.05$) (Duncan's multiple range test)

of 675 l/ha. Assessment of SHB infestation in the old wood was made by counting the number of infested bushes. For evaluating borer attack on the new wood formed after pruning, 10 stem cuttings were collected at random from each plot.

RESULTS AND DISCUSSIONS

Results of Experiment-1 on mid-cycle chemical control (Table I) revealed that beetle population in plots treated with chlorpyrifos, fenvalerate and quinalphos

were significantly less when compared to untreated control ($P = 0.05$). Observations over a period of two years indicated a drastic reduction in SHB population in the tested plots.

Laboratory studies of *X. fornicatus* had shown that fenvalerate application resulted in 100% mortality of the beetle (Rao, 1978). Preliminary field studies on the efficacy of fenvalerate had also shown encouraging results (unpublished data). Results of Experiment-2 showed that the population of beetles in the plots sprayed with insecticides was significantly less ($P = 0.05$) with an average of 0.93 beetles/cutting while the stem samples collected from the untreated control block had a mean of 1.93 beetles/cutting (Table II).

Similarly, in Experiment-3 and 4, significant reduction in the number of beetles was observed in blocks treated with fenvalerate ($P = 0.05$). These experiments clearly established the field efficacy of fenvalerate for mid-cycle control of SHB.

Experiment-5 on the effect of insecticide application at the time of pruning showed that chemical treatments

Table II. *Efficacy of chemicals for mid-cycle control of X. fornicatus*

Experiment number	Treatments	Dosage ml/ha	Mean number of beetles/cutting		Calculated t - value*
			Chemical treated block	Control block	
Expt. 2	Fenvalerate and Quinalphos alternate spray	500			
		1000	0.93	1.93	4.97
Expt. 3	Fenvalerate (Sumicidin 20 EC)	500	2.43	3.94	5.38
Expt. 4	Fenvalerate (Agrofen 20 EC)	500	1.7	3.5	8.65

*Values given in the last column are significant at $P = 0.05$ (Student's t test)

Table III. *Effect of different chemicals applied at pruning time on fresh infestation of shot-hole borer on old and new wood (Expt. 5)*

Treatments	Dosage l/ha	Pre-treatment assessment (% of infested bushes)	Post treatment observation			
			% of infestation on the old wood 7 months after spray	% of infestation on the tea new wood		
				10 months after spray	12 months after spray	18 months after spray
Aldrin (Aldrex 30 ED)	5	44.00	6.60	1.40	1.43	4.3
Fenvalerate (Sumicidin 20 EC)	0.5	48.7	2.97	1.18	5.71	5.7
Quinalphos (Ekalux 25 EC)	2	42.6	3.86	0.19	7.14	7.1
Chlorphyrifos (Coroban 20 EC)	2	48.7	4.11	0.56	2.86	4.3
Untreated control	—	42.3	7.42	0.18	5.71	10.0
		NS	NS	NS	NS	NS

The data represent mean of 7 replications NS: Nonsignificant at $P = 0.05$

immediately after pruning did not result in any significant reduction in borer infestation. Incidence of beetles in the control blocks was almost on par with that observed in chemical treatment blocks (Table III). Insecticides with long residual action were considered essential for suppressing the infestation of SHB (Danthanarayana *et al.*, 1968). However, recent studies showed that the reduction in sap flow after pruning and the reduced levels of spinasterol in the pruned bushes create unfavourable conditions for the beetles for several months after pruning (Sivapalan and Delucchi, 1975; Wickremasinghe *et al.*, 1976). Consequent to these studies, Sri Lanka withdrew the recommendation of heptachlor application for SHB control (Anon., 1975). The results of the present experiment also point to the fact that application of persistent organochlorine compounds need not necessarily help in preventing the attack of SHB either on the old wood or on the new stems formed

after pruning. Nevertheless, chemical application at the time of pruning may be of some use in preventing the migration of beetles from the infested bushes and prunings to the neighbouring fields. This aspect of beetle migration from pruned fields needs further study.

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OBSERVATIONS ON THE LARVAL PARASITIDS OF *HOMONA COFFEARIA* (NIETNER) (TORTRICIDAE:LEPIDOPTERA) IN A TEA GARDEN AT THE ANAMALLAIS

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ABSTRACT

The tea tortrix, *Homona coffearia* is commonly found in the tea fields of South India, especially in young fields and those recovering from pruning. Recent surveys conducted in the different tea growing areas showed the presence of one egg, five larval and four pupal parasites of *H. coffearia*. In the Anamallais (Coimbatore District), two larval parasitoids, viz., *Phytodietus* sp. and *Palexorista solennis* (Walker) were found to be more prevalent. Field studies showed that parasitism by *P. solennis* ranged from 14.2 to 53.12% as against 6.6 to 61.01% by *Phytodietus* sp. Overall larval parasitism of the caterpillar observed during this study was 54.96%. Population trends of the parasitoids in the experimental field almost closely followed the numerical fluctuations of the tea tortrix larvae.

INTRODUCTION

In South India, the leaf rolling caterpillars *Cydia leucostoma* (Tortricidae), *Caloptilia theivora* (Gracillariidae) and *Homona coffearia* (Tortricidae) infest the harvestable tea shoots. Larvae of *H. coffearia* are seen in appreciable numbers in South Indian tea plantations, especially in young tea fields and those recovering from pruning. This species has also been reported from other tea growing areas like North-East India, China, Indonesia and Taiwan. In Sri Lanka, it was considered a serious pest of tea till 1936 when a braconid parasite, *Macrocentrus homonae* (Nixon) introduced from Indonesia brought the pest under control (Sivapalan and Delucchi, 1975). The larva of tea tortrix makes leaf nests by webbing the leaves, often one above the other, using silken threads and feed from inside. The young caterpillars prefer tender leaves, while

the mature ones are seen more in the leaf cases made of slightly mature foliage.

Herein we report the findings of our surveys on the natural enemies of *H. coffearia* from the tea gardens of South India and the seasonal abundance of the two important larval parasitoids, *Phytodietus* sp. (Ichneumonidae: Hymenoptera) and *Palexorista solennis* (Walker) (Tachinidae:Diptera) in the Anamallais (Coimbatore District), Tamil Nadu.

MATERIALS AND METHODS

Extensive surveys on the parasites of tea tortrix were carried out at irregular intervals in the tea areas of the Anamallais, Vandiperiyar, Peermade, Munnar, Wynad and the Nilgiris during 1983-86.

Studies on species composition and seasonal abundance of parasites were

conducted in a tea field in the UPASI experimental farm between November 1984 and March 1986. Regular samplings were made at fortnightly interval by delayed counting technique (Irwin and Yeargan, 1980). To assess the incidence of the host as well as the parasitoids, all the infested shoots were removed from 10 bushes, selected at random.

The field collected host larvae were examined under stereo binocular microscope and categorised according to the nature of parasitism. The parasitised larvae were reared singly in petridishes under laboratory conditions. Host larvae were checked daily and provided with fresh, tea leaves. The parasitoids, once pupated, were transferred to separate plastic rearing containers of 7 cm wide and 9 cm long. Adult parasitoids were identified and percentage of parasitism effected by each species was recorded. The larvae of *Phytodietus* sp. could be seen on the second or third segment of the caterpillar, whereas the host larvae affected by endoparasitic *P. solennis*

were distinguished by the presence of ovipositional punctures and consequent colour changes.

RESULTS AND DISCUSSION

Surveys conducted in the different tea districts revealed the presence of one egg, five larval and four pupal parasites of *H. coffearia* (Table I). Species composition of parasites varied in the different tea growing areas. *Phytodietus* sp. and *P. solennis* were found in all the regions surveyed, but their incidence was comparatively high in the Anamallais. Similarly, braconids (*Apanteles* sp.) were also widely distributed in all the tea regions of South India. The pupal parasites, *Triclistus* sp. and *Ascogaster* sp. were recorded only from the Anamallais. The other two pupal parasites, *Brachymeria excarinata* and *B. lasus* were collected in large numbers from tea fields in the Peermade area (Idukki District, Kerala State) where more than 30% of the tortrix pupae were found parasitised by these two chalcid

Table I. *Parasites of the Tea tortrix, Homona coffearia, in South India*

Type of parasites	Species	Family	Order
Egg parasite	<i>Telenomus</i> sp.	Scelionidae	Hymenoptera
Larval parasite	<i>Phytodietus</i> sp.	Ichneumonidae	"
	<i>Palexorista solennis</i>	Tachinidae	Diptera
	<i>Apanteles</i> sp.	Braconidae	Hymenoptera
	(<i>Glomeratus</i> group)		
	<i>Apanteles</i> sp.	"	"
Pupal parasite	(<i>ater</i> group)		
	<i>Apophua</i> sp.	Ichneumonidae	"
	<i>Ascogaster</i> sp.	Braconidae	"
	<i>Triclistus</i> sp.	Ichneumonidae	"
	<i>Brachymeria lasus</i>	Chalcidae	"
	<i>Brachymeria excarinata</i>	Chalcidae	"

species. In Sri Lanka, about 20 species of parasites were recorded on tea tortrix, though most of them have been squeezed out by the introduced braconid, *Macrocentrus homonae* (Cranham, 1966).

H. coffearia is a seasonal pest of tea and its infestation in the experimental block gradually increased from September/October reaching a peak in December/January and declined by March/April. *Phytodietus* sp. and *P. solennis* were the two common species reared from *H. coffearia*. The ichneumonid was found to parasitise the host larvae and highly active in the early season (October-December) and the incidence of parasitism ranged from 6.6 to 61.01%. Parasitism by *Phytodietus* sp.

reached its maximum in December. During these months, tortrix larvae were found to be more and subsequently its population showed a declining trend. Reduction in larval numbers of *H. coffearia* continued with the appearance of the second parasitoid, *P. solennis*. Larvae of the tea tortrix were almost absent by April/May.

The tachinid, *P. solennis* is known to be an efficient larval parasitoid of several insect pests. Incidence of parasitism by *P. solennis* on *H. coffearia* was high during January to March, ranging from 14.2 to 53.2% in the different months, and reach the peak in February. Larval parasitism of *H. coffearia* by both the parasitoids ranged from 14.25 to 86.30%.

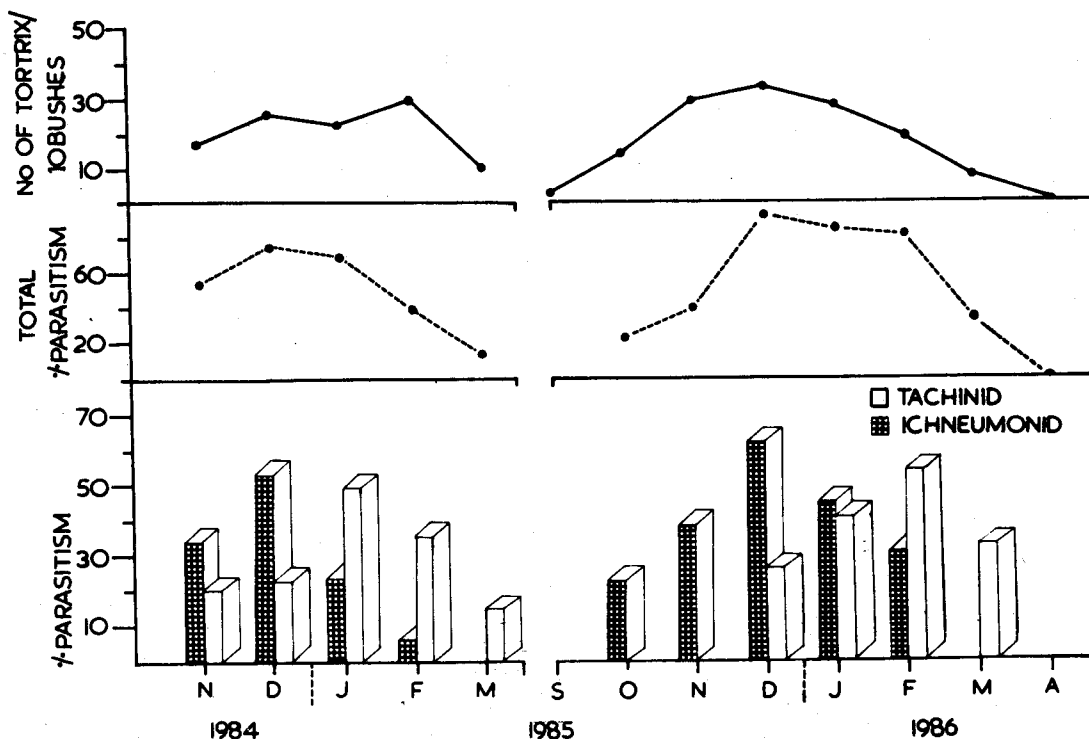


Fig. 1. Seasonal abundance of tea tortrix and percentage parasitism by *Phytodietus* sp. and *P. solennis*.

Both *Phytodietus* sp. and *P. solennis* attack the same host and there appears to be some sort of a competitive exclusion between these two larval parasitoids. Incidence of parasitism by *P. solennis* was found to be high during January to March, whereas attack by *Phytodietus* sp. was more in October to December (Fig. 1).

Instances of multiparasitism by both the parasitoids was also noted, especially during January when both *P. solennis* and *Phytodietus* sp. had almost an equal distribution in the tea fields. When tortrix larvae with multiparasitism were reared, only adults of *P. solennis* emerged and mortality of *Phytodietus* sp. was near total.

Among the several larval parasitoids recorded by us, *Phytodietus* sp. and *Palexorista solennis* are more widespread, capable of naturally regulating the populations of the tea tortrix and never allowing it to become a serious pest of tea.

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LIFE HISTORY AND POPULATION DYNAMICS OF *MICROMUS TIMIDUS* HAGEN A PREDATOR OF THE TEA APHID, *TOXOPTERA AURANTII* (BOYER DE FONSCOLOMBE)

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ABSTRACT

Investigations were carried out on the life history and population dynamics of the lace wing predator, *Micromus timidus* Hagen (Hemerobiidae: Neuroptera) feeding on the tea aphid, *Toxoptera aurantii*. At $26 \pm 2^\circ\text{C}$ and $85 \pm 5\%$ R.H., developmental period of this predator from egg to adult emergence was 19 ± 0.54 days. There were three larval instars and both larvae and adults preyed on aphids. A gradual increase in the rate of aphid consumption was observed from the first to the sixth day of larval period, and the feeding rate started declining after the seventh day. Maximum consumption of aphids was seen on the sixth and the seventh days and a total of 309 ± 49.17 aphids were consumed during the life time of the predator. Larval populations of the predator were more in September/October and April. These peaks almost coincided with the periods of abundance of aphids in tea fields.

INTRODUCTION

The tea aphid, *Toxoptera aurantii* (Boyer de Fonscolombe) is commonly observed on tender tea shoots and the incidence of this pest is more on bushes recovering from pruning. Both nymphs and adults suck the sap leading to retarded shoot growth and delayed recovery of plants after pruning. In tea fields, *T. aurantii* is attacked by several natural enemies, such as Coccinellid, Syrphid and Neuropteran predators and Hymenopteran parasites (Das 1974; Muraleedharan 1983; Muraleedharan & Radhakrishnan, 1986). A list of parasites and predators of *T. aurantii*, recorded during our survey in S. Indian tea plantations is given in Table I.

Micromus timidus Hagen has been recorded as a predator of aphids from all the tea plantations of South India.

Information pertaining to the biology and population dynamics of this species in India is rather scanty. In the present paper, we report the findings of our laboratory and field investigations on the biology, predatory efficiency and population fluctuations of *M. timidus*.

MATERIALS AND METHODS

Eggs and larvae of *M. timidus*, collected from tea fields in the Anamallais were reared in the laboratory to obtain adults. Immediately after emergence, the adult Hemerobiids were kept in 20×15 cm glass jars and were regularly provided with aphid infested tea shoots, kept in small vials containing water. The neonate predators, emerging from the eggs, were introduced individually into petridishes containing a moistened filter paper and a specific number of second and third instar aphids.

Table I. *Parasites and predators of T. aurantii recorded from South Indian tea fields*

Species	Family	Order
<i>Episyrphus balteatus</i>	Syrphidae	Diptera
<i>Paragus tibialis</i>	"	"
<i>Dideopsis aegrota</i>	"	"
<i>Betasyrphus serarius</i>	"	"
<i>Ischiodon scutellaris</i>	"	"
<i>Allobaccha nubilipennis</i>	"	"
<i>Menochilus sexmaculatus</i>	Coccinellidae	Coleoptera
<i>Jauravia pubescens</i>	"	"
<i>Trioxys</i> sp.	Braconidae	Hymenoptera
<i>Aphidius</i> sp.	Aphidiidae	"
<i>Aphidius colemani</i>	"	"

*Parasites

The number of aphids provided in the petridishes were enough to satiate the predators as determined by preliminary observations. Number of aphids consumed by the larval and adult Hemerobiids were counted every day. Duration of developmental stages was recorded and the predatory efficiency of larvae and adults determined.

Observations on the numerical changes in the larval populations were made from April 1984 to June 1986 in a clonal (UPASI-3) tea field at the UPASI Tea Experimental Farm (Anamallais; Coimbatore Dt.), situated at an altitude of 1035 m above MSL. The experimental area consisted of 2500 bushes and had been kept free from any pesticide application since pruning.

For studying the seasonal abundance of *T. aurantii* and its neuropteran predator

all the aphid infested shoots from 25 randomly selected plants were removed at fortnightly intervals. The samples were analysed by delayed counting method developed by Irwin and Yeargan, (1980). Aphid infested shoots were brought to the laboratory in polythene bags and the number of aphids and the life stages of the predator from each shoot were examined and counted.

RESULTS AND DISCUSSION

Females started laying eggs near the aphid colonies after a pre-oviposition period of 2-3 days. Eggs, laid in batches of 2-5, were light yellow initially but their colour changed to brown before hatching. Number of eggs laid by a female per day in the laboratory varied from 11-22. Under field conditions, a maximum of only four eggs were observed on an aphid infested shoot. Eggs were ovoid, measured $803.33 \pm 0.87\mu$ length and $362.5 \pm 0.97\mu$ in width. They were seen attached to the leaves by the dorsal axis. Incubation period ranged from 4-5 days and larvae, immediately after emergence, started feeding on aphids. Raychaudhuri *et al.* (1981) observed an incubation period of 6-7 days for *M. timidus* preying on aphid species such as *Lipaphis erysimi* (Kalt.) and *Aphis craccivora* Koch.

Three larval instars were recognised for *M. timidus* and the duration of the three instars is given in Table-II. Total larval period varied from 7-9 days. Liao *et al.* (1983) observed a mean developmental time of 8-9 days for *Micromus posticus* preying on the aphid, *Monellia caryella* (Fitch). In the present study, the highest larval mortality was observed in the first instar stage.

Table II. *Biology of Micromus timidus fed on T. aurantii at 25 ± 5°C and 80 ± 5% R.H.*

Period/Stage in life history	Duration in days (mean ± SE)
Pre oviposition period	2.8 ± 0.23
Oviposition period	8.25 ± 1.19
Incubation period	4.5 ± 0.41
Duration of I Instar larva	2.36 ± 0.48
"II "	2.45 ± 0.15
"III "	3.18 ± 0.25
Pre pupal period	1.75 ± 0.29
Pupal period	8.28 ± 0.26
Adult longevity :	
Males	24.9 ± 6.33
Females	35.67 ± 6.78

*Average of eleven replications

Prior to pupation, full grown larvae searched the petridishes to locate a suitable substratum for pupation, usually a little away from the aphid colonies. Immediately after selecting a place, the larvae stopped feeding, started spinning

a loose white cocoon and pupated inside. The pupal cases were seen attached to the walls of petridishes in the laboratory, but in fields *M. timidus* mostly pupated on the lower margins of older leaves. Pupal stage lasted for 8-10 days.

Adults emerged by splitting the cocoon on the middorsal side. Development of *M. timidus* from egg to adult was completed in 18-22 days. Interestingly, in temperate species such as *M. posticus* and *M. subanticus*, developmental period was found to be shorter, ranging from 15-18 days (Selhime and Kanavel, 1968). The present study confirms the observations of Raychaudhuri *et al.* (1981) on the developmental period of this species in North East India.

Sex ratio was highly disproportionate and in the laboratory a male:female ratio of 1:9 was observed. Details on the

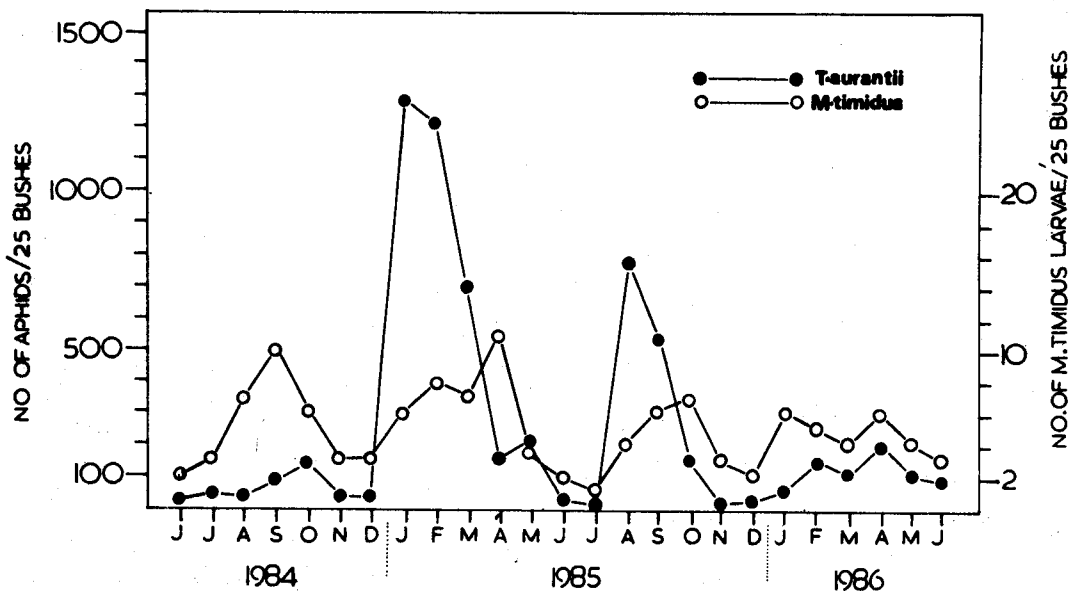


Fig. 1. Feeding rates of *Micromus timidus*

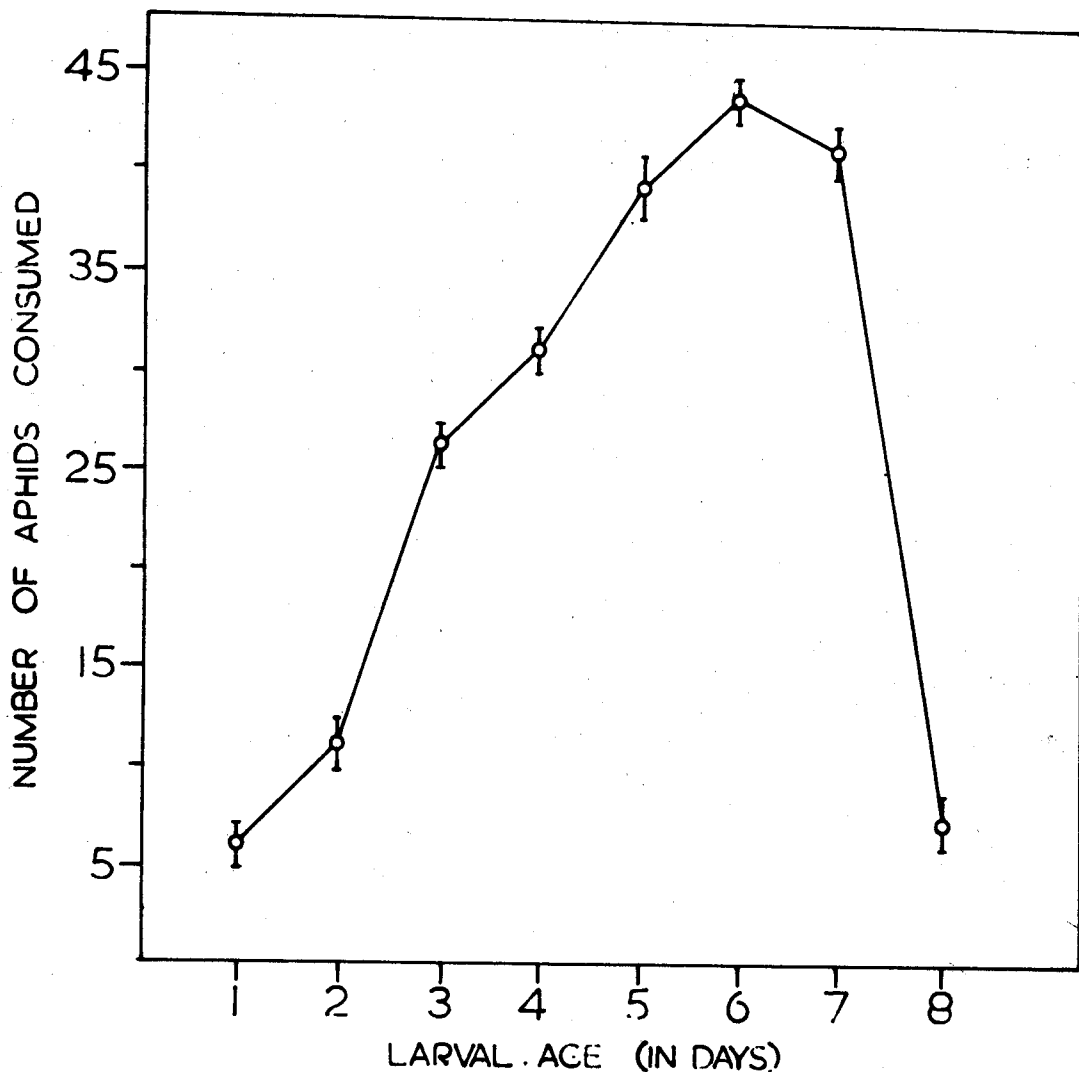


Fig. 2. Population Dynamics of *Micromus timidus* in relation to its prey *Toxoptera aurantii*

biology of *M. timidus* are shown in Table-II.

Average time, taken to consume a single aphid by the neuropteran varied from 6-7 minutes. A gradual increase in the rate of prey consumption was observed from the first to the sixth day, and the feeding rate declined sharply after the seventh day (Fig. 1). Maximum

number of aphids were consumed on the 6th and the 7th day of larval development and the mean number of aphids consumed during the entire larval period was 203 ± 5.09 . Predatory efficiency of the third instar larva was maximum and this instar alone fed on more than 50% of the total number of aphids consumed during the entire larval period.

Regular field sampling of aphid infested shoots provided data on the seasonal abundance of the larvae of *M. timidus*. They were observed throughout the year. Larval populations of the predator gradually increased from July, reached a peak in September/October and started declining from November onwards. A smaller second peak was observed in April (Fig-2). Population fluctuations of *M. timidus* almost closely followed that of *T. aurantii* populations. Aphid populations reached maximum numbers in January/February and started declining from May onwards. Again, a second peak was observed in August. Aphids are abundant in fields recovering from pruning and this is probably due to the preponderance of succulent, actively growing buds which are preferred by this pest. As the age of the bush advances from pruning, there is reduction in the quantity of vascular supply to the growing buds due to the multiplicity of shoots and this appears to be the reason for the comparatively low incidence of aphids in older fields. In North-East India, populations of *T. aurantii* begin to build up from mid January and a peak is reached during March-April. In May, the populations start declining with the appearance of alates and a second small peak is observed in August (Anon, 1973). Heavy rains received in Anamallais during the months of June and July (108.9 cm in 1984 and 107.9 cm in 1985) seems to wash off and kill a large number of mobile forms of the predators and aphids from tea shoots and this could be a possible reason for the sudden decline in the populations of aphids and Hemerobiids during these months.

Thus, populations of *T. aurantii* in tea

fields, to a very large extent, are controlled by weather, age of the bushes from pruning and the biocontrol agents like predators and parasites. Consequently, pesticide applications are seldom needed for the control of tea aphids.

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INTEGRATED MANAGEMENT OF COFFEE GREEN SCALE *COCCUS VIRIDIS* (GREEN) (HOMOPTERA, COCCIDAE)

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ABSTRACT

Detailed studies were made on the control of coffee green scale on Lower Palney hills, Tamil Nadu using the white halo fungus, *Verticillium lecanii* Zimm. The fungus at a dosage of 16×10^6 spores/ml caused high mortality of the pest under field conditions. It effected the fungus twice at fortnightly applications. The effectiveness was increased to 97.6 per cent when the surfactant Tween 20 was added to the spore suspension. High volume spray was found to be better than low volume application. Addition of the humectant glycerol 0.1 per cent enhanced the efficacy of the insect pathogen. During summer months, addition of subtoxic level of the insecticide fenthion (0.025%) to a lower dose of spore suspension (4×10^6 spores/ml) reduced the pest population markedly. Application of the insect pathogen one or two weeks after Bordeaux mixture spray could restore the inoculum level of *V. lecanii* under field conditions. Techniques for mass production and field use, methods of increasing the virulence, and safety of the insect pathogen are discussed.

INTRODUCTION

In recent years, control of pests through conventional methods has been found to be often difficult in view of intensive cultivation. Emphasis has, therefore, been given on developing sound pest management practices based on the ecology of the pests. The green scale, *Coccus viridis* (Green) is one of the serious pests of coffee in different parts of South India. The pest becomes very severe, particularly during summer months, causing extensive reduction in yield. In addition to the direct damage caused by desapping, the pest indirectly affects the physiology of the plant by encouraging the development of black sooty mould fungus on the honeydew on leaf surface. The existing method of chemical control is not quite effective and, in addition, is often not economical. Hence studies were made on the Lower Palney hills, Tamil Nadu on the inte-

grated management of the pest utilising the naturally occurring biocontrol agent, viz., white halo fungus *Verticillium lecanii* Zimm. and insecticides compatible with the entomopathogenic fungus.

Ecology of coffee green scale

Under field conditions, the green bug population was positively correlated and the infection by the fungus, *V. lecanii* negatively so with mean maximum most and minimum most temperatures recorded at 8 a.m. and 4 p.m. (Table I). While maximum most relative humidity (afternoon) showed negative correlation with the pest population, forenoon and after noon mean humidity and maximum most humidity (afternoon) showed positive correlation with the fungus infection. Total rainfall one and two weeks prior to the observation was negatively correlated with the pest

Table I. *Correlation between weather elements and the population of green bug and its natural infection by the fungus*

Weather elements	Population of green bug	Natural infection by the fungus
Maximum-most temperature °C (8 a.m.)	0.609**	-0.900**
Maximum-most temperature °C (4 p.m.)	0.753**	-0.873**
Maximum-most temperature °C (8 a.m.)	0.615**	-0.809**
Minimum-most temperature °C (4 p.m.)	0.765**	-0.854**
Fore-noon relative humidity % (Mean)	-0.242NS	0.507**
After-noon relative humidity % (Mean)	-0.395NS	0.620**
Fore-noon relative humidity % (Maximum-most)	-0.052NS	0.095NS
After-noon relative humidity % (Maximum-most)	-0.542**	0.604**
Total rainfall one week prior (mm)	-0.407**	0.350**
Total rainfall two weeks prior (mm)	-0.405**	0.488**

*Significant at 5% level

**Significant at 1% level

NS not significant

population and positively with the fungus infection. The multiple correlation showed the greater influence of temperature than humidity on the pest population as well as on the fungus infection. There existed a negative correlation between the pest population

and the natural infection of the fungus (Eswaramoorthy and Jayaraj, 1976).

Use of white Halo Fungus

Symptomatology: The adult healthy green bugs is bright pale green with an irregular but distinct black spot on the middle of the dorsum, while the nymph is pale green. The earliest symptom of disease was the development of dark brown spots which appeared 3 to 5 days after inoculation and spread over the rest of the body. In the case of the nymph the entire body became brown on the third day. Soon after death, which occurred in 3 to 10 days after infection, the body became stiff and mummified. The external mycelial growth was at first white but later turned to pale yellow. The dead bugs were anchored firmly on the leaf surface by the mycelium which helped in the further spread of the fungus.

Pathogenicity: Under laboratory conditions, it was evident that the green bug was highly susceptible to fungus infection. The mortality of bugs was observed from third day onwards. Nymphs were more susceptible than adults. A rapid and increased mortality of coccids was observed when the post-treatment temperature was 25°C followed by 30°C compared to 20°C or 40°C indicating the importance of temperature under field conditions.

Five species of aphids, the scale insects viz., *Pulvinaria psidii* Mask. and *Saissetia coffeae* Wlk., mealy bug, *Centroccocus insolitus* Gr., rice brown planthopper *Nilaparvata lugens* (Stal.) and the coccinellid beetle grub, *Hemosepilachna vigintiocto-punctata* (Fabr.) were found susceptible to the fungus to

Table II. *Effect of media on the growth of Cephalosporium lecanii*^a

Medium	Mean diameter of growth circle (mm)	Mean mycelial dry weight (mg)
Sorghum	36.5	403.1
Finger millet	27.8	291.0
Maize	28.8	390.8
Pearl millet	41.1	499.5
Potato	40.8	482.5
Carrot	34.5	358.4
Tapioca	40.4	272.7
Sweet potato	37.3	224.6
C.D. (P = 0.05) ^b	2.2	68.7
Asthana-Hawker solution	—	152.8
Benecke's solution (modified)	—	187.0
Czapek's solution	—	154.0
Potato dextrose broth	—	482.9
Richard's solution	—	243.6
Sabouraud's fluid medium	—	651.4
C.C. (P = 0.05) ^b	—	28.8

a Mean of four replications.

b Critical difference (L.S.D.).

Table III. *Spore production on V. lecanii on broken jack seeds and whole sorghum grains (Mean of 3 observations)*

Treatment	Mean No. of spores produced (X 10 ⁹ spores/40 g)
Broken jack seeds (5 mm dia)	7.05
Broken jack seeds + 1% glucose	3.06
Broken jack seeds + 1% sucrose	2.64
Broken jack seeds (16 mm dia)	4.52
Broken jack seeds + 1% glucose	3.37
Broken jack seeds + 1% sucrose	1.16
Sorghum whole grains	5.81
S.E.	0.66**
C.D. (P = 0.05)	2.03

**Significant at 1% probability level

varying degree (Easwaramoorthy and Jayaraj, 1979).

Mass culture: The fungus isolated

Table IV. *Effect of temperature on the growth of Cephalosporium lecanii*^a

Temperature (°C)	Mean diameter of growth circle (mm)	Mean mycelial dry weight (mg)
15	25.6	487.0
20	47.4	512.5
25	56.9	701.6
30	54.3	674.2
35	20.6	516.5
C.D. (P = 0.05) ^b	0.82	23.9

a Mean of three replications.

b C.D.: Critical difference (L.S.D.).

Table V. *Effect of storage and temperature on the infectivity of the fungus C. lecanii on coffee green bug*

Storage Period	Mortality of bug* (mean of 3 observations)		Mortality of bug* (mean of 6 observations)
	Room temperature	5°C	
6 months	39.14 (38.53)	69.15 (56.50)	54.14 (47.52)
5 months	52.07 (46.26)	78.15 (61.73)	65.11 (54.00)
4 months	82.39 (65.61)	79.96 (64.48)	81.18 (65.05)
3 months	81.48 (64.67)	68.28 (48.61)	74.88 (56.64)
2 months	70.51 (57.14)	71.36 (51.06)	70.93 (54.10)
1 month	70.83 (57.49)	70.59 (50.81)	70.71 (54.15)
Mean	66.08 (54.96)	67.33 (55.54)	
	SE		CD (P=0.05)
Period	(2.28)**		(6.68)
Temperature	N.S.		—
Interaction	(3.22)**		(9.44)

*Per cent dead bugs (P); figures in parenthesis are the values of arc since P

**Significant at 1% level

N.S. — Not Significant

from field-collected green bugs grew best on Sabouraud's liquid medium and potato dextrose broth. Since loose rather than solid substrates like agar yielded more spores per unit area, in the attempts made to develop a medium based on locally available grains and tubers, pearl millet, potato and sorghum were found to be more suitable (Table II) (Eswaramoorthy and Jayaraj, 1977). About 100 g of sorghum grains yielded on an average 13.5×10^9 spores 21 days after seeding. Recent attempts showed that jack seeds, a bye product in coffee plantations, can also be effectively utilized for the production of the fungus (17.6×10^9 spores/ 100 g brokeden seeds) (Table III). The optimum temperature and pH were 25°C and 6.5 , respectively (Table IV). A slow reduction in the virulence was noted when repeated sub-culturing on artificial media was undertaken. The viability of spores decreased as indicated by reduced pathogenicity when stored at room

temperature ($32\text{--}38^\circ\text{C}$) for 6 months, but storage at reduced temperature of 4°C showed no adverse effect on the spore viability (Table V).

Field evaluation: The fungus, when sprayed, caused increased mortality of green bugs in all the field tests. Among the five different dosages tried, 16×10^6 spores/ml was found adequate to cause high mortality (Easwaramoorthy and Jayaraj, 1978). With two fortnightly applications of 16×10^6 spores/ml, it effected maximum mortality of 73.1 per cent two weeks after application. The effectiveness of the pathogen was increased by the addition of different surfactants. The maximum mortality of bus (97.6%) was observed when the surfactant Tween 20 was added to the spore suspension (Table VI, VII). The pathogen, as low volume spray, caused significantly less mortality compared to high volume probably due to inadequate moisture on leaf surface, for better spore

Table VI. *Effect of Verticillium lecanii with certain surfactants on the percentage mortality of coffee green bug*

Treatments	Period in weeks after spraying		
	1	2	3
Fungus alone	49.2	68.1	67.1
Fungus + Tween 20 0.05%	88.0	96.7	95.4
Fungus + Methyl cellulose 0.05%	40.0	80.8	72.9
Fungus + Starch 0.05%	60.8	94.2	92.8
Fungus + Lerolat 0.05%	71.5	96.6	92.0
Fungus + Erkentrol 0.05%	62.7	85.1	74.3
Fungus + Wannin 0.05%	50.4	77.8	81.2
	SE	LSD ($P = 0.05$) ^a	
Between treatments	0.4**		1.3
Interaction between Treatments and periods	1.2**		3.4

a For data transformed by arcsin (percentage) $\frac{1}{2}$

**Significant at 1 % level.

Table VII. *Effect of fungus and certain insecticides on the percentage mortality of coffee green bug*

Treatments	Period in weeks after spraying		
	1	2	3
Fungus alone	49.2	68.1	67.1
Fungus + Tween 20, 0.05%	88.0	96.7	95.4
Fungus + Tween 20, 0.05% + DDT 0.1%	80.6	92.0	89.9
Fungus + Tween 20, 0.05 + B.H.C. 0.1%	45.9	66.5	67.3
Fungus + Tween 20, 0.05% + Acephate 0.225%	74.6	93.1	98.5
DDT 0.1%	46.4	44.3	41.5
B.H.C. 0.1%	27.9	38.5	29.1
Acephate 0.225%	75.0	97.7	98.1
	SE	LSD	(P= 0.05) ^a
Between treatments	1.4*		4.6
Interaction between Treatments and periods	2.8*		8.8

a For data transformed by $\arcsin(\text{percentage})^{\frac{1}{2}}$

*Significant at 5% level.

germination. Fungus when tested in drought period was comparatively less effective and addition of humectant glycerol 0.1 per cent probably by way of altering the micro-climate increased the susceptibility of bugs slightly. In another experiment conducted during summer, addition of the wetting agent, Triton X 100 at 0.05 per cent increased the pathogenicity of the fungus greatly.

There was considerable variation in the mean mortality caused by the fungus in different experiments. This is mainly attributable to the influence of weather factors. Greater mortality of bugs was observed in the tests conducted during north-east monsoon and cold weather seasons in 1974-75 during which time there were intermittent rains (27.6 mm mean total rainfall/week) with low mean temperature ($26.4 \pm 2.4^\circ\text{C}$). In contrast, in the tests conducted during summer 1975, when there was no rainfall and

mean temperature was high ($32.0 \pm 3.6^\circ\text{C}$), the mycosis was very low. The increase in population of the bugs a fortnight after fungus spray suggests the need for repeated sprays in the initial stages to have a short term control of the bugs.

Integrated control

Under laboratory conditions vegetative growth of the fungus was restricted to varying degree by 12 insecticides that are commonly used for pest control. While dichlorvos was highly inhibitory, acephate, DDT and phosphamidon showed the least effect on the vegetative growth. Under field conditions, acephate and DDT were compatible with the pathogen even at their normal field dose. This is of much practical significance since the insecticides can be added to the fungus to check multiple infestations of green bugs and other pests and also phoretic ants. During summer months,

Table VIII. *Effect of Verticillium lecanii and insecticides on the mortality of coffee green bug (Mean of 3 observations)*

Treatments	Mortality*	
	7 days	14 days
Fungus (Spores/ml)		
16 × 10 ⁶	24.6(27.4)	28.4(31.0)
Fenthion 0.05%	48.1(43.5)	49.9(45.2)
Phosphamidon 0.05%	13.5(21.4)	28.6(32.0)
Fungus +		
Phosphamidon 0.05%	85.3(67.8)	91.7(73.9)
Fungus + Fenthion 0.05%	83.3(66.2)	88.8(72.0)
S.E.	(6.0)**	(5.1)**
C.D. (P=0.05)	(17.4)	(14.7)

*Percent of dead scales P., in parenthesis are the values of arc sin/√P.

**Significant at 1% level

Table IX. *Inhibition of fungal growth by different fungicides at three concentrations (Mean of 9 observations)*

(Figures in parenthesis represent transformed values)

Fungicides	% inhibition of radial growth concentrations			
	1500 ppm	2000 ppm	2500 ppm	Mean
Bordeaux mixture	69.71 (56.68)	78.70 (62.67)	85.07 (67.59)	77.82 (62.31)
Dithane Z 78	66.99 (54.95)	74.12 (59.83)	84.47 (67.10)	75.19 (60.63)
Dithane M 45	68.87 (56.10)	76.64 (61.22)	85.13 (67.62)	76.88 (61.65)
Sulphur	3.95 (11.32)	5.35 (13.09)	13.53 (21.56)	7.61 (15.32)
Mean	52.38 (44.76)	58.70 (49.20)	67.05 (55.97)	

C.D. (P = 0.05)

- i. Between concentrations
- ii. Interaction between fungicides and concentrations

0.53

1.60

when green bug population was high and fungus was less active, additions of reduced dose of fenthion (0.025%) to a lower dose of spore suspension (4×10^6 spore/ml) brought down the green bug population appreciably (Easwaramoorthy *et al.*, 1978). There existed supplemental synergism in all fungus-fenthion combinations (Table VIII) and the magnitude was greater when the dose of fenthion was reduced to 0.025 than 0.05 per cent with either of the doses of the fungus/viz., 8×10^6 spores/ml. In the fungus-phosphamidon combinations, supplemental synergism was maximum when the dose of phosphamidon was 0.05 per cent and that of fungus 8×10^6 spores/ml. When both the toxicant and the fungus were at their lower doses there occurred only a sub-additive synergism. The fungicide like Bordeaux mixture commonly used in coffee plantations for the control of red rust and other diseases inhibited the growth of the fungus under laboratory conditions (Table IX). Application of the pathogen one to two weeks after Bordeaux spray mixture can prevent the increase of green bug by way of restoring the inoculum level of *V. lecanii* in the field.

Safety test: In a preliminary oral feeding test, a massive dose of the fungus failed to show any adverse effect on poultry birds. Since the fungus could not grow at temperatures above 35°C, it is unlikely that it will infect higher animals.

CONCLUSION

For the overall management of coffee green bug (a) artificial inoculation of *V. lecanii* for initiating epizootics before their natural occurrence, (b) maintenance

of medium cover shade in coffee plantations which facilitated epizootics, (c) selection of pesticides which were less harmful to the entomopathogenic fungus, and (d) restoration of inoculum potential after fungicide sprays were found helpful.

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INSECTICIDE APPLICATION METHODS AGAINST THE GREEN SCALE ON COFFEE

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ABSTRACT

The bio-efficacy of monocrotophos and dimethoate by 'Stem-implantation' method in the control of *Coccus viridis* (Green) varied greatly with the age and size of coffee plants. Studies on the efficacy of monocrotophos at different dosages by 'stem-implantation' method have shown that there was no significant increase in the percentage reduction of scales with the increase in quantity of the insecticide. Though this method effected appreciable reduction of scales on young coffee plants, severe phytotoxic symptoms were noticed on monocrotophos treated plants. Both the insecticides by 'stem-implantation' method were found not effective in the control of green scale on older coffee plants. Spraying method was superior to 'stem-implantation' method for the control of this pest on older coffee plants.

INTRODUCTION

The green scale, *Coccus viridis* (Green) (Homoptera: Coccidae) is one of the important pests of coffee in South India. In nature, some enemies exert a great degree of natural control of this pest during favourable conditions. However, it becomes inevitable to resort to chemical control to keep this pest under check during prolonged dry periods when the population of the pest reaches its peak. Systemic insecticides like monocrotophos and dimethoate were found effective and economical at 0.025% a.i. by high volume spraying for the control of this pest on coffee (Chacko *et al.*, 1977, Anon., 1985).

An essential aspect of 'Integrated Pest Management' is to ensure that when insecticides have to be used, they should have the minimum effect on beneficial insects and environment and maximum effect on target pests. To achieve this objective, systemic insecticides can be exploited by selective methods of application. In the present studies carried

at the Central Coffee Research Institute (CCRI) the efficacy of 'stem-implantation' method for the control of *C. viridis* on coffee plants of different age groups was evaluated by using two systemic insecticides, viz., monocrotophos 36 EC and dimethoate 30 EC and also compared with conventional spraying method at the concentration found effective for the control of this pest on coffee (Chacko *et al.*, 1977).

MATERIALS AND METHODS

Laboratory experiment

Three year old potted arabica coffee plants infested with green scale were used to study the efficacy of monocrotophos 36 EC and dimethoate 30 EC in the control of green scale by 'stem-implantation' method. There were three treatments including check, and five replications with one plant per replication. In each plant, five green scale infested twigs were marked and green scale population was recorded on the marked twigs. A slant downward cut was

then made on the stem just 30 cm above the soil level. A thin layer of absorbent cotton was placed in the cut portion and 1 ml of diluted insecticide solution (the ratio of insecticide to water was 1:1) per plant was administrated drop by drop with the help of a syringe. A strip of polythene was wrapped around the stem covering the cut portion and secured fast. Counts of live scales were taken at definite interval to find out the percentage mortality of scales due to the treatments.

Field experiment 1: A field trial was laid out at the CCRI farm to find out the efficacy of monocrotophos by 'stem-implantation' method. Monocrotophos 36 EC was diluted with water at the ratio of 1:1 and the diluted insecticide solution was applied at the rate of 1,2 and 3 ml per plant as described above. There were four treatments including check, and five replications with two arabica coffee plants (about 18-year old) per replication. Green scale infested twigs and leaves on each plant were marked and initial scale population was recorded. Counts of live scales were taken at 5 days interval upto

20th day after imposing the treatments. The percentage of efficacy due to treatments was calculated using the formula of Henderson and Tilton (1955).

$$\text{Percent efficacy} = 1 - \frac{T_a \cdot C_b}{T_b \cdot C_a} \cdot 100$$

Where T_b : is the number counted per sample unit before treatment.

T_a : the number counted after treatment;

C_b : the number counted from the control plant before treatment

C_a : the number counted from the control plant after treatment;

The percentage reduction of scales was transformed to angular values and statistically analysed. The data are presented in Table I.

Field experiment 2: This trial was laid out in Netrakonda Estate to compare the efficacy of 'stem-implantation' with

Table I. *Evaluation of monocrotophos by 'stem-implantation' method for the control of Coccus viridis on coffee*

Treatments	Mean percentage reduction of scales in transformed figures on			
	5th day	10th day	15th day	20th day
50% diluted monocrotophos/plant				
1 ml	39.13	61.75	66.23	69.64
2 ml	47.09	65.34	69.48	72.65
3 ml	51.40	66.31	72.98	74.28
Mean	45.87	69.47	69.56	72.19
Significance	NS	NS	NS	NS

NS: Not significant

Table II. *Evaluation of monocrotophos and dimethoate by spraying and stem-implantation methods for the control of Coccus viridis on coffee*

Treatments	% a.i. dosage	Percentage reduction of green scale in transformed figures on		
		7th day	14th day	21st day
1. Monocrotophos (spraying)	0.025	60.57	77.30	79.53
2. 50% diluted monocrotophos (stem-implantation)	1 ml/plant	43.19	48.50	45.85
3. Dimethoate (spraying)	0.025	55.59	64.15	65.93
4. 50% diluted Dimethoate (stem-implantation)	1 ml/plant	36.35	38.44	41.50
Mean	48.93	57.10	58.20	
C.D. (p = 0.05)		6.73	11.10	15.46
(p = 0.01)		9.41	15.52	21.62

spraying. The insecticides used were monocrotophos 36 EC and dimethoate 30 EC. For stem implantation, 1 ml of 50 per cent diluted insecticide was used per plant, and spraying was done with the chemicals at 0.025% a.i. concentration. There were five treatments including check. Each treatment consisted of five replications with three plants per replication. Arabica coffee plants (about 24-year-old) heavily infested with green scale were selected and three infested branches were marked on each plant for recording the initial population of living scales. In 'stem-implantation' method the insecticides were applied adopting the same procedure as described earlier. A gator rocking sprayer was used to spray the insecticides. Post treatment population count was made at an interval of 7 days upto 21st day after treatment. The per cent efficacy due to treatments was calculated using the formula of Henderson and Tilton (1955). The percentage reduction of scales was transformed to angular values and analysed statistically (Table II).

RESULTS AND DISCUSSION

In the laboratory experiment about 90 per cent reduction of scales was noticed on the 10th day in monocrotophos treated plants and on the 14th day in dimethoate treated plants. However, severe phytotoxic symptoms were noticed in monocrotophos treated plants. In case of dimethoate treated plants only a few dark spots were noticed on the foliage. In untreated plants, there was gradual increase in green scale population.

The data presented in Table I show that there was no significant increase in the percentage reduction of green scale population with the increase in quantity of insecticide.

The data in Table II show that on the 7th day, spraying with monocrotophos and dimethoate was superior to 'stem-implantation' of the two chemicals in controlling the pests. Dimethoate spraying was on par with monocrotophos spraying. On the 14th day, spraying with

monocrotophos was superior to 'stem-implantation' method by the two insecticides, and was also superior to dimethoate spraying in the percentage reduction of scales ($p = 0.05$). A similar trend was observed in the case of dimethoate spraying. The same trend was continued on the 21st day also. However, there was no significant difference in the percentage of reduction of scales between monocrotophos and dimethoate in the spraying method.

The present observations on the efficacy of monocrotophos and dimethoate as spray for the control of green scale corroborate with the findings of Chacko *et al.* (1977). Efficacy of certain systemic insecticides for the control of green scale on coffee by 'stem-application method' viz. 'Banding technique' was also studied earlier (Anon., 1957), and it was reported that with systemic insecticides like Metasystox, 60 to 90 per cent mortality of scales was observed on 2 to 3 year old arabica coffee plants. However, the results were not promising on older coffee plants (Anon., 1957). In the present studies also the same trend was observed with regard to the efficacy

of 'stem-implantation' of systemic insecticides in the control of green scale.

The above studies indicate that efficacy of monocrotophos and dimethoate by 'stem-implantation' method in the control of green scale greatly varies with the age of coffee plants. The method was not effective on older plants. Spraying was found superior to 'stem-implantation' method in the control of this pest on older coffee plants.

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EVALUATION OF HERBICIDE APPLICATORS

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ABSTRACT

A field trial was laid out in rubber to test the relative efficacies of ULV spraying with HV spraying on weed control with 4 herbicides. The sprayers were LOCDA, BOCDA, and LOK with 30, 15 and 400-500 litres of spray volume per hectare respectively. The herbicides were Gramaxone (@ 2.5 l/ha), Gramaxone + Fernoxone (@ 2.5 l + 1.25 kg/ha), Dalapon (@ 5 kg/ha) and Glycel (@ 2 l/ha). There were 12 treatment combinations replicated thrice. A significant difference in weed control was observed due to herbicide applicator interaction. It indicated that Dalapon and Glycel sprayed with LOCDA and LOK gave similar narrow leaf control. While with BOCDA, the effect was similar with Glycel, but with Dalapon the duration of control was lower. Further Glycel sprayed by LOCDA gave significantly better prolonged overall weed control. With Gramaxone, LOK and LOCDA produced equivalent overall weed control up to 30 DAS whereas BOCDA gave lower level of control. However, Gramaxone + Fernoxone combination sprayed with LOK was significantly better than both the CDA's. The experimental results justify the substitution of conventional LOK sprayers with LOCDA sprayers for spraying Glycel, Dalapon and Gramaxone with considerable saving in the spray volume and mandays, thus making spraying herbicides easier and cheaper.

INTRODUCTION

The current weed control measures have high energy requirements in terms of mandays. The increasing labour costs and scarcity will render the manual control measures unviable in the near future. Further the manual clean weeding will expose soils to erosion and degradation as the climate is humid tropical and terrain undulating in the rubber growing tracts. Previous experiments of Rubber Research Institute of India (Mathew *et al.*, 1984) have shown that herbicidal weed management was economical. Herbicidal weed management may also decrease soil exposure by providing a dry mulch, thus conserving soil and moisture. Conventional lever operated kanapsack (LOK) sprayers currently used in herbicidal application require high spray volumes and energy. Herbicide application with controlled droplet applicators (CDAs) has shown savings in volume of

spray, application time, and easier application in difficult terrain (Jollands *et al.*, 1983; Mathew, 1979; Sin Liu and Alif, 1981).

Therefore a field experiment was conducted to test the relative efficacy of low volume (LV) spraying with CDAs and high volume (HV) spraying with LOK sprayers using four herbicides.

MATERIALS AND METHODS

A field experiment with 12 treatments and 3 replications in R.B.D. was laid out in the inter-row spaces of a mature stand of rubber at Boyce Estate, Harrison Malayalam Ltd., Mundakayam in 1985-86. The individual plot size was 100 m². The treatments consisted of four herbicides sprayed by 3 different herbicide applicators. The four herbicides Gramaxone (@ 2.5 l/ha), Gramaxone + Fernoxone (@ 2.4 l/ha +

Table I. *List of herbicides used.*

S.No.	Trade Name	Common Name	Chemical Name	Formulation & Concentration
1.	Glycel	Isophosphyl Amine Salt of Glyphosphate	N-(Phosphonomethyl) Glycine	Liquid-41% W/W
2.	Dalapon	Na & Mg. Salt of Dalapon	2, 2-Dichloro Propionic Acid	WP 74% AE
3.	Fernoxone	Na Salt of 2, 4-d	(2, 4 Dichloro phenoxy) Acetic Acid	WP 80% W/W
4.	Gramaxone	Paraquat Dichloride	1, 1-Dimethyl 4, 4' Bypiridium	Liquid 24% W/W

1.25 kg/ha), Dalapon (@ 5 kg/ha) and Glycel (@ 2 l/ha) (Table I). The dosages used were of the commercial products. The sprayers used were conventional Lever Operated Knapsack sprayer (LOK), Lever Operated Controlled Droplet Applicator (LOCDA) and Battery Operated Controlled Droplet Applicator (BOCDA) (Tables II, III).

Description of sprayers

Lever Operated Knapsack Sprayer (Aspee, code SRP/19): The sprayer was equipped with a pressure regulator and pressure gauge. A flood jet nozzle WFN 40 was used. The spray tank was of 13 litre capacity (Tables II, III).

Table II. *Technical data of sprayers used.*

Data	Birky (LOCDA)	Aspee-CDA (BOCDA)	Aspee Backpack sprayer (LOK)
Weight	4.5 kg	1 kg with 11 container 3 kg with 101 container	5.4 kg
Spray Tank Capacity	5 l	11-101 (modified)	13 l
Nozzle	Plastic colour coded Yellow-1.3mm (orifice Dia) Flowrate-290ml/Min Red-1.6mm (Orifice Dia) Flowrate-190ml/min	Steel Disc Discharge rate CDA75-75cc/min	Brass-flood jet WFN 40
Atomizer	Rotary type	Rotary type	Impact type
Droplet size	Flowables & EC 270-320 UM VMD WP-330-380 UM VMD	VMD-100-160 UM	VMD - 5-500 UM
Delivery Rate/ha	20 l to 30 l	15 l	200-1000 l
Swath width	1.6 M	1.2 M	30cm-60cm upto 2.1M with WFN 78
R.P.M.	1600	4000-5000	
Droplet formation	Centrifugal	Centrifugal	Hydraulic
Energy Source	Manual	Battery Powered	Manual.

Table III. *Comparative study of applicators*

	LOK	LOCDA	BOCDA
No. of Fills required to spray per effective hectare	30 – 77	Δ 6	Δ 2
*Mandays required to spray 1 hectare	2 to $3\frac{1}{4}$	$\frac{1}{2}$ Less Physical Effort Than LOK	With modified 10 Litre Tank $\frac{1}{2}$ Less Physical effort than LOK and LOCDA
**Cost of spraying/ha	Rs. 50 – 81.25	Rs. 12.50/-	Rs. 14/- (including Rs. 1.50/- for recharging battery)
Volume of Diluent (Water)	High Hence impure water may have to be used 400 l/ha	Ultra-Low Hence clean water can be used 30 litre/ha	Ultra Low Hence clean water can be used 15 l/ha
Herbicide concentration	low	High	High
Energy source	Manually operated	Manually operated hence low maintainance	D.C. Battery has to be recharged in 2 hours.
Herbicide specificity and formulation	Weed kill good with contact and traslocated herbicides (W.P. and) Flowables	Weed kill relatively lower with contact but equivalent or better with translocated herbicides especially flowables.	

*Mandays were calculated with the formula based on the following observations and assumptions.

The time required for actual spraying of 100 m² of area in this trial were 4, 1, 1 & 1.5 minutes for LOK, LOCDA & BOCDA respectively. Time taken for the fills is assumed to be 10 minutes. In actual situations, it may vary widely.

$$M = \frac{(t(100 \times 100) + (f \times n))}{60 \times 6} \quad \text{where } M = \text{Mandays (6 hr) for spraying 1 hectare;}$$

^t100 = time in minutes for spraying 100 m²; ^f = time in minutes for each fill;

ⁿf = No. of fills required for spraying 1 ha.

**C = M × W^M, where C = Cost of spraying 1 ha in Rupees

M = Manday (6 hr) for spraying 1 ha

W^M = Wages per manday multiplied by No. of mandays

Assumption: Wages per manday = Rs. 25/-

Battery Operated Controlled Droplet Applicator (Aspee-CDA, Code UL-I): The sprayer was a hand-held type with a spray head consisting of a rotary atomizer driven by a 3 watt DC motor powered by a 6V rechargeable dry battery. The power pack consisting of the battery and charger unit could be shoulder-slung. Droplet formation is by centrifugal energy generated by the

spinning disc. A modified backpack spray container of 10 litre capacity was used. The spray solution is fed to the rotary atomizer by gravity flow.

Lever operated Controlled Droplet Applicator (Birky-Ciba-Geigy): The sprayer was a manual lever operated CDA with the rotary atomizer driven by air supplied to a turbine by a pneumatic

pump. The pneumatic pump and 5 litre capacity spray container are housed in a backpack. The spray solution is fed by gravity through a flow rate control nozzle into the rotary atomizer. The spray head is situated behind the operator.

Calibration: The CDA sprayers were calibrated as per the instruction manuals for the respective sprayers. The LOK sprayer was calibrated as per set procedures (Fisher and Sabio, 1984). The LOCDA was calibrated to deliver 30 litres of total spray volume per hectare and the BOCDA was calibrated to deliver 15 litres. The LOK was calibrated to deliver 400 l of total spray volume with Glycel and 500 l of total spray volume with the other 3 herbicides. All the spray volumes were inclusive of the dose of herbicides and were on par hectare basis.

Spraying technique

LOK: The area to be sprayed was demarcated into plots of 2 m × 50 m size. The spraying was done at a constant speed with the nozzle kept at 30 cm height from the ground level as far as possible. The effective swath width was 50 cm. The pressure was maintained at 15 PSI. Four passes were required to cover the area of one plot.

LOCDA: The area to be sprayed was demarcated into plots of 1.6 m × 62.5 m size. The spray head housing the spinning disc was kept at 50 cm height from the ground level. As the spray head is behind the sprayer, the operator walked away from the sprayed area. The effective swath width was 1.6 m. Spraying of each plot was completed in one pass.

BOCDA: The area to be sprayed

was demarcated into plots of 1.2 m × 83.3 m size. The operator held the spray lance across and in front of his body with the spray head about 75 cm away to the side of the operator and pointing to the direction of walk. The axle of the spinning disc was at an angle of 60°C to the ground level. By such positioning the drift hazard to the operator was minimized. The height of the spray head was 50 cm from the ground level and swath width was 1.2 m. Spraying of each plot was completed in one pass.

Observations: Visual observations of weed canopy coverage were taken on 0 to 100 scale where 0 was absolute absence of weeds and 100 complete coverage of weeds. The overall weed canopy coverage were scored on the above scale before treatment imposition (pre-treatment), at 30 days after spraying (DAS), at 60 DAS and at 90 DAS. The observation were statistically analysed without transformation.

RESULTS AND DISCUSSION

Narrow leaf weeds were predominant during the pre-treatment assessment, viz., *Paspalum scrobiculatum* (L), *Axonopus compressus* (SW), *P. beaux*, *Digitaria* sp., *Ottochloa nodosa*, *Ischaemum muticum* and *Panicum* sp. The broad leaf flora in the pre-treatment assessment were *Chromolaena odorata* (L) K & R., *Lantana camara* (L), *Piper* sp., *Borreria* sp., *Mimosa pudica* *Desmodium* sp and ferns. The pretreatment weed canopy coverage was not found to be significantly different.

Effect of the sprayers on the performance of herbicides Gramaxone: At 30 DAS, Gramaxone sprayed by LOK

Table IV. *Effect of herbicide – applicator interaction on % weed canopy coverage*

Treatments	Overall % of canopy coverage		
	30 days	60 days	90 days
	Mean SE:4.03 CD:11.8	Mean SE:2.38 CD:6.9	Mean SE:1.76 CD:5.1
T ₁ :S ₁ H ₁ .LOK + Gramaxone	25.0	100.0	100.0
T ₂ :S ₁ H ₂ .LOK + Gramaxone + Fernoxone	10.0	100.0	100.0
T ₃ :S ₁ H ₃ .LOK + Dalapon	23.3	90.0	93.3
T ₄ :S ₁ H ₄ .LOK + Glycel	20.0	86.7	93.3
T ₅ :S ₂ H ₁ .BO CDA + Gramaxone	40.0	100.0	100.0
T ₆ :S ₂ H ₂ .BO CDA + Gramaxone + Fernoxone	33.3	100.0	100.0
T ₇ :S ₂ H ₃ .BO CDA + Dalapon	28.3	91.7	96.7
T ₈ :S ₂ H ₄ .BO CDA + Glycel	25.0	90.0	91.7
T ₉ :S ₃ H ₁ .LO CDA + Gramaxone	30.0	100.0	100.0
T ₁₀ :S ₃ H ₂ .LO CDA + Gramaxone + Fernoxone	25.0	100.0	100.0
T ₁₁ :S ₃ H ₃ .LO CDA + Dalapon	31.7	83.3	90.0
T ₁₂ :S ₃ H ₄ .LO CDA + Glycel	13.3	81.7	85.0
General Mean	25.4	93.6	95.8

Table V. *Effect of herbicide – applicator interaction on % weed canopy coverage*

Treatments	% of Broadleaf canopy coverage			
	Pre-treatment	30 days	60 days	90 days
	Mean SE:5.46 CD:..	Mean SE:4.68 CD:13.7	Mean SE:3.26 CD:9.5	Mean SE:3.36 CD:9.8
T ₁ :S ₁ H ₁ .LOK + Gramaxone	31.7	5.0	71.7	73.3
T ₂ :S ₁ H ₂ .LOK + Gramaxone + Fernoxone	26.7	3.3	66.7	68.3
T ₃ :S ₁ H ₃ .LOK + Dalapon	18.3	23.3	90.0	88.3
T ₄ :S ₁ H ₄ .LOK + Glycel	21.7	20.0	86.7	93.3
T ₅ :S ₂ H ₁ .BO CDA + Gramaxone	26.7	16.7	68.3	70.0
T ₆ :S ₂ H ₂ .BO CDA + Gramaxone + Fernoxone	18.3	5.0	66.7	66.7
T ₇ :S ₂ H ₃ .BO CDA + Dalapon	23.3	28.3	90.0	86.7
T ₈ :S ₂ H ₄ .BO CDA + Glycel	28.3	25.0	90.0	83.3
T ₉ :S ₃ H ₁ .LO CDA + Gramaxone	23.3	5.0	70.0	70.0
T ₁₀ :S ₃ H ₂ .LO CDA + Gramaxone + Fernoxone	23.3	5.0	60.0	63.3
T ₁₁ :S ₃ H ₃ .LO CDA + Dalapon	26.7	31.7	83.3	88.3
T ₁₂ :S ₃ H ₄ .LO CDA + Glycel	15.0	13.3	81.7	85.0
General Mean	23.6	15.1	77.1	78.1

and LOCDA gave similar overall weed control, while Gramaxone sprayed by BOCDA gave significantly the lowest overall weed control (Tables IV, V, VI). Effective overall weed control was observed only up to 30 DAS with all the sprayers.

The effect of Gramaxone on broad leaves was similar with all the sprayers at 30, 60 and 90 DAS. At 30 DAS, Gramaxone with the 3 sprayers showed significant difference in control of narrow leaf weeds. LOK gave the best results followed by LOCDA and BOCDA respectively. At 60 and 90 DAS, all the three sprayers were at par. Considering the overall weed control, it can be seen that LOK sprayers can be replaced by LOCDA for spraying Gramaxone (Fig. 2).

Gramaxone + Fernoxone: At 30 DAS, Gramaxone + Fernoxone when sprayed with LOK gave a significantly better overall weed control as compared to LOCDA and BOCDA which were at par. At 60 and 90 DAS there was no significant difference in overall weed control with the 3 sprayers (Tables IV, V, VI). Broad leaf control with the 3 sprayers gave similar results at 30, 60 and 90 DAS.

At 30 DAS, Gramaxone + Fernoxone with the 3 sprayers gave significantly different narrow leaf control; LOK gave the best narrow leaf control followed by LOCDA and BOCDA respectively. At 60 DAS, LOK and BOCDA were at par and both significantly better narrow leaf control as compared to LOCDA. While at

Table VI. *Effect of herbicide - applicator interaction on % weed canopy coverage*

Treatments	% of Narrow leaf canopy coverage			
	Pre-treatment	30 days	60 days	90 days
	Mean SE:5.45 CD:..	Mean SE:1.18 CD:3.5	Mean SE:2.06 CD:6.0	Mean SE:2.19 CD:6.4
T ₁ :S ₁ H ₁ .LOK + Gramaxone	68.3	20.0	28.3	26.7
T ₂ :S ₁ H ₂ .LOK + Gramaxone + Fernoxone	73.3	6.7	33.3	31.7
T ₃ :S ₁ H ₃ .LOK + Dalapon	81.7	0	0	5.0
T ₄ :S ₁ H ₄ .LOK + Glycel	78.3	0	0	0
T ₅ :S ₂ H ₁ .BO CDA + Gramaxone	73.3	33.3	31.7	30.0
T ₆ :S ₂ H ₂ .BO CDA + Gramaxone + Fernoxone	81.7	28.3	33.3	33.3
T ₇ :S ₂ H ₃ .BO CDA + Dalapon	76.7	0	0	10.0
T ₈ :S ₂ H ₄ .BO CDA + Glycel	83.3	0	0	0
T ₉ :S ₃ H ₁ .LO CDA + Gramaxone	76.7	25.0	33.3	30.0
T ₁₀ :S ₃ H ₂ .LO CDA + Gramaxone + Fernoxone	76.7	20.0	40.0	36.7
T ₁₁ :S ₃ H ₃ .LO CDA + Dalapon	73.3	0	0	1.7
T ₁₂ :S ₃ H ₄ .LO CDA + Glycel	85.0	0	0	0
General Mean	77.4	11.1	16.7	17.1

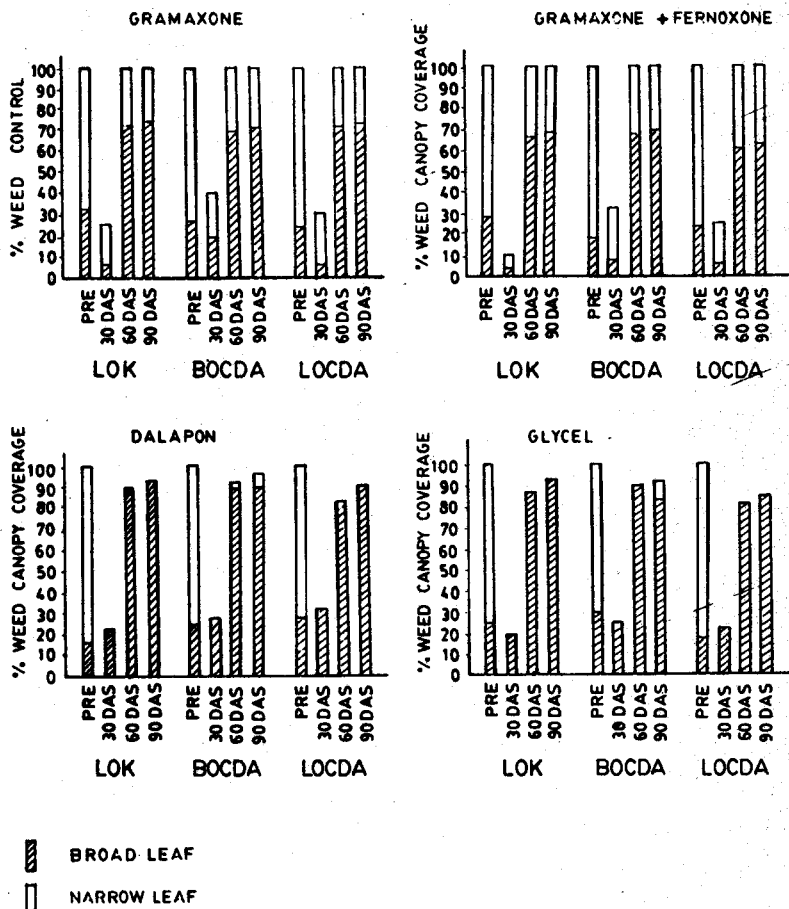


Fig. 1. Weed Flora shift at 30 DAS, 60 DAS, 90 DAS, as a function of herbicide applicator interaction.

90 DAS, BOCDA and LOCDA were at par but LOK gave significantly better narrow leaf control as compared to LOCDA.

Gramaxone + Fernoxone when sprayed by LOK sprayers were observed to give better overall and narrow leaf control when compared to BOCDA and LOCDA sprayers. The inefficient overall and narrow leaf control of Gramaxone +

Fernoxone when sprayed with CDA's may be due to the negative interaction of high concentration of Gramaxone and Fernoxone. From the results it also appears that in areas with predominance of broad leaf weeds, Gramaxone + Fernoxone could be effectively sprayed with CDAs (Fig. 2).

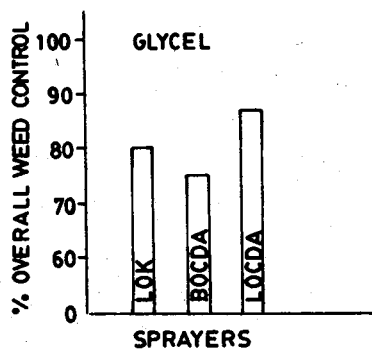
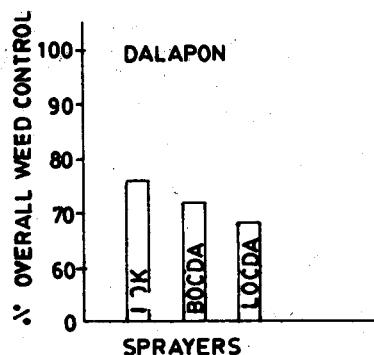
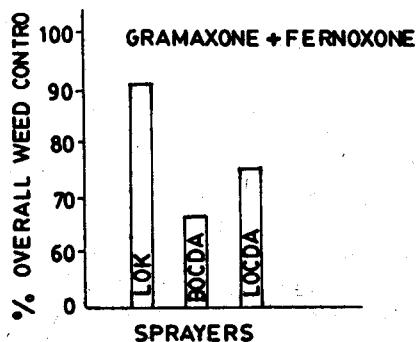
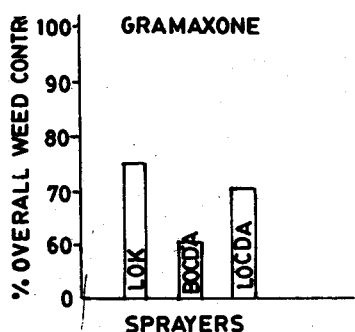
Dalapon: At 30 DAS Dalapon sprayed with LOK gave significantly

better overall weed control as compared to BOCDA and LOCDA which were at par. At 60 and 90 DAS LOK and LOCDA gave overall weed control and LOCDA was significantly better than BOCDA (Tables IV, V, VI).

At 30, 60 and 90 DAS there was no

significant difference in broad leaf control between the 3 sprayers with Dalapon.

At 30 and 60 DAS no significant difference in narrow leaf control was observed between sprayers, however at 90 DAS LOK and LOCDA with Dalapon gave similar narrow leaf control and



LOK - LEVER OPERATED KNAPSACK SPRAYER

BOCDA - BATTERY OPERATED CONTROLLED DROPLET APPLICATOR

LOCDA - LEVER OPERATED CONTROLLED DROPLET APPLICATOR

DAS - DAYS AFTER SPRAYING

Fig. 2. Effect of Herbicide - applicator interaction on weed control at 30 DAS

LOCDA gave significantly better control when compared to BOCDA.

It has been observed that Dalapon sprayed with LOK sprayers gave good weed control initially but for prolonged weed control LOCDA's performed better. Therefore it can be concluded that Dalapon sprayed by LOCDA gives better and prolonged weed control (Fig. 2).

Glycel: At 30 DAS, all the 3 sprayers gave similar overall weed control with Glycel. But at 60 DAS Glycel with LOK and LOCDA gave similar overall control, while with BOCDA at 90 DAS, Glycel with LOCDA gave significantly better overall weed control as compared to LOK and BOCDA (Tables IV, V, VI). At 30 and 60 DAS all the three sprayers gave similar broad leaf control with Glycel. But at 90 DAS, LOCDA with BOCDA gave similar broad leaf control, and with BOCDA the control was significantly better than when Glycel was sprayed with LOK. Glycel with all the 3 sprayers gave similar narrow leaf control at 30, 60 and 90 DAS.

Glycel sprayed by LOCDA gave a prolonged weed control which was observed to be significantly better than the control obtained by spraying Glycel with LOK and BOCDA at 90 DAS. Therefore for effective weed control for a longer period Glycel should be sprayed by a LOCDA (Fig. 2).

The weed flora shifted towards broad leaf spectra with *Crassocephalum* sp. taking over by 60 DAS in all the treatments. Glycel and Dalapon wiped out the grasses up to 90 DAS (Fig. 1).

Herbicide spraying with CDAs could

save up to 97% of the spray volume and utilized only $\frac{1}{4}$ th to $\frac{1}{6}$ th the mandays required to spray 1 ha with LOK (Table III). These factors assume greater importance in steep rubber growing tracts where water is scarce and water transport difficult. Since only low volume of water is required with CDA spraying, cleaner water can be used for spraying. A comparative study of the different applicators is summarised in Table III. Among the CDAs, LOCDA is better suited for small holders as it uses manual power for atomizing. The battery of BOCDA is not efficient. It requires recharging every 2 hours or so. LOCDA is more robustly constructed, easier to maintain and operate than BOCDA. It is very much less tiring to pump LOCDA than LOK. As the rotary atomizer in LOCDA is about a meter behind the operator drift hazard to the operator is minimal. However spray protectives are a must for operators as relatively concentrated herbicide solutions are used with the CDAs.

The following suggestions are made on the basis of observations.

1. Shields should be used with CDAs and LOK to reduce drift hazard when spraying is done in young rubber
2. Dyes should be used with CDAs as markers to distinguish sprayed swaths as droplet are invisible.
3. Multiple spray heads should be tried with CDAs to enhance swath width.
4. Oil based formulations should be tested for increasing the efficiency of herbicides with CDAs.

5. Testing of CDAs with lower dosages of herbicides.

6. Testing of CDAs with herbicides adjuvants and herbicide combinations to enhance herbicidal activity.

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LABORATORY EVALUATION OF TWO ANTICOAGULANTS AGAINST *RATTUS RATTUS WROUGHTONI* HINTON*

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ABSTRACT

Warfarin and fumarin are the two anticoagulant rodenticides available in India for rodent control operations. The toxicity and relative acceptability of these poisons to the black rat, *Rattus rattus wroughtoni* Hinton, an important rodent pest of coconut and cocoa in South India were evaluated in the laboratory. There was no significant difference in the toxicity between these poisons (LFP₅₀ around 4 days for both the poisons) to *R.r. wroughtoni*, but there was much difference in their acceptance. After consuming the poison baits, the animals started dying from the third day onwards. The peak mortality was on the fifth day for warfarin and the seventh day for fumarin. Cent per cent mortality was achieved within 12 to 14 days feeding. However the baits mixed with fumarin were preferred significantly to those mixed with warfarin and hence recommended to use such poison bait continuously for two weeks in the field.

INTRODUCTION

Warfarin (a phenyl compound) and fumarin (a furyl compound) are the two multiple dose anticoagulant rodenticides available in India for rodent control operations. These poisons being chronic in their actions have several advantages over single dose ones such as zinc phosphide (Dubock, 1978). Considering the effectiveness against rodent pests and safeness on non-target animals, these anticoagulants gained much importance in recent years in both indoor and outdoor rodent control operations.

The black rat, *Rattus rattus wroughtoni* Hinton, is a predominant rodent pest in coconut and cocoa plantations in South India (Bhat, 1978; Abraham and Remamony 1979; Bhat *et al.*, 1981; Advani, 1984). Studies were conducted on the efficacy (Girish *et al.*,

1976; Chaturvedi *et al.*, 1977, Agarwal *et al.*, 1979) and acceptance (Rai *et al.*, 1982) of different anticoagulants against the house rat, *R. rattus* that inhabits residential premises and godowns. But very little work has been done on the toxicity of multiple dose anticoagulants against *R. r. wroughtoni*. Hence attempts were made at CPCRI, Kasaragod to find out the toxicity and relative acceptability of warfarin and fumarin against *R. r. wroughtoni* infesting coconut and cocoa.

MATERIALS AND METHODS

The toxicity and relative acceptability of anticoagulants were studied during 1986 on live rats freshly captured from coconut and cocoa fields around Kasaragod (12°30'N; 75°E). The animals were housed individually in animal cages (45 × 30 × 20 cm) and allowed to acclimatize to laboratory conditions for

*Contribution No. 545, CPCRI, Kasaragod

one week before the commencement of the experiment. Those individuals found apparently healthy after the conditioning period, were used in the test. The toxicity was studied by feeding animals with powdered rice containing 0.025% warfarin or fumarin for restricted periods of 3,4,6,8,10,12 and 14 days. Water was provided *ad libitum*. Each experiment was conducted on 15 fresh individuals of known body weight. The quantity of the bait consumed was recorded daily. Mortality of the individuals was also noted daily and the symptoms of poisoning ascertained. After the bait feeding period, the survived animals were maintained on cereal feeds and observed

for 30 days starting from the first day of poisoning. Delayed mortality, if any, was recorded after ascertaining the cause of death. At the end of each experiment, the consumption of poison (active ingredient) per kg of five body weight of the animal was determined. The lethal feeding period (LEP₅₀ value was calculated by probit analysis.

Relative acceptability was studied by exposing two different baits simultaneously in separate containers. The quantity of each bait consumed was recorded daily and for comparison the absolute value of daily intake was computed to per kg body weight of live animals.

Table I. Toxicity of warfarin and fumarin each at 0.025% concentration to *R. r. wroughtoni*

Particulars		Number of days feeding						
		3	4	6	8	10	12	14
% mortality	W	20.0	46.7	73.3	86.7	93.3	100.0	—
	F	20.0	53.3	73.3	80.0	93.3	93.3	100.0
Days till death	W	4.7± 0.33	7.6± 1.91	5.7± 0.38	5.3± 0.29	6.2± 0.39	6.9± 0.75	—
	F	4.3± 0.67	6.1± 0.40	5.2± 0.35	6.9± 0.36	8.5± 1.30	9.0± 0.92	8.7± 1.05
Lethal dose*	W	6.7± 1.47	7.7± 0.91	11.1± 0.90	6.7± 0.65	8.1± 0.67	8.5± 1.08	—
	F	5.5± 0.73	8.7± 0.67	9.7± 1.18	8.4± 0.92	11.3± 1.63	11.5± 1.47	11.6± 1.70
Survival dose	W	6.6± 0.59	6.3± 0.40	13.0± 1.68	14.1± 1.40	17.9± ‡	—	—
	F	5.3± 0.23	7.9± 0.95	9.6± 1.50	16.3± 1.63	6.7 ‡	21.8 ‡	—

*mg/kg body weight of the animal

‡Only one animal survived.

After consuming the poison baits the animals started dying on the third day, but the rate of mortality was the highest on the fifth day for warfarin and seventh day for fumarin. However, it was extended upto 16 and 21 days with warfarin and fumarin, respectively (Fig-1). The mean survival day was slightly less with warfarin (6.14 days) as against 7.16 days with fumarin.

Relative acceptability

The consumption of both warfarin and fumarin was found to be significantly less than plain baits (Table II). However, when compared to plain bait, the consumption of fumarin was slightly more than that of warfarin. When both poison baits were exposed simultaneously the rats consumed significantly more of fumarin than warfarin mixed baits.

RESULTS AND DISCUSSION

Toxicity

The results of the study on the toxicity of warfarin and fumarin on *R. r. wrougtoni* are summarised in Table I. Three days feeding on the poison baits resulted in only 20% mortality. The LFP₅₀ value for both the poisons was 4.07 days. However, cent per cent mortality was achieved after feeding for 12 days on warfarin-mixed and 14 days on fumarin-mixed baits.

There was considerable variation in the susceptibility of individuals to these poisons. Some individuals died after consuming 2.25 mg (ai) of warfarin and 2.60 mg (ai) of fumarin per kg body weight, but some others even survived a dose of 17.93 mg of warfarin and 21.80 mg of fumarin.

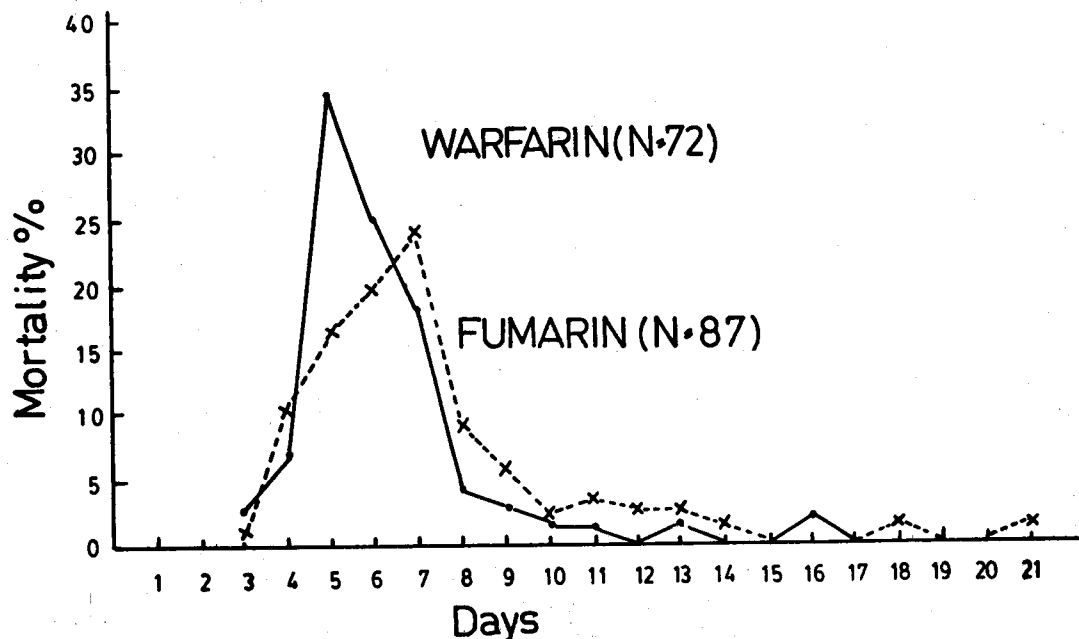


Fig. 1. Percentage of mortality of *R. r. wrougtoni* in different days of the test with anticoagulant - mixed baits.

Table II. *Relative acceptability of poison baits by R. r. wroughtoni*

Treatments	Consumption (g/kg) of baits			t value at P < 0.01
	warfarin	fumarin	plain	
Warfarin vs. fumarin	12.68 ± 2.34 (12.3%)	90.34 ± 5.43 (87.7%)	—	12.55
Warfarin vs. plain	30.83 ± 6.65 (30.0%)	—	71.96 ± 6.45 (70.0%)	4.91
Fumarin vs. plain	—	28.91 ± 3.22 (38.0%)	47.13 ± 3.92 (62.0%)	3.29

The present study thus revealed that both warfarin and fumarin were equally toxic to *R. r. wroughtoni*. Girish *et al.* (1976) also found that warfarin and fumarin were equally toxic, the mean days to death being 6.5(3-10) and 6.9(3-11), respectively. Chaturvedi *et al.* (1977) reported that the average days to death were slightly less with warfarin (5.0 days) than fumarin (5.9 days), but the former took longer periods (13 days) than the latter (11 days) to achieve 100% kill. Agarwal *et al.* (1979) however, obtained 100% mortality when rats were exposed to fumarin-mixed bait for 10 days, but only 75% mortality was noticed when exposed to warfarin-mixed baits even upto 16 days. All these studies revealed that there was high degree of variation in the susceptibility of *Rattus rattus* towards warfarin and fumarin. However the results obtained in the present study on *R. r. wroughtoni* are also in conformity with most of them.

It was further observed that the species *R. r. wroughtoni* significantly preferred fumarin mixed bait to warfarin mixed ones. This is in conformity with the observations of Rai *et al.* (1982) on the

house rat, *R. Rattus*. Other rodents viz. *Funambulus pennanti*, *Tatera indica* and *Meriones hurrianae* also showed an aversion towards warfarin mixed baits, (Mathur and Prakash, 1980; 1982). However, they have further observed that there was no significant reduction in the consumption of fumarin-mixed baits when compared to plain ones. In general, fumarin was found to be more effective than warfarin against field rodents, and hence it is preferred to use such poison bait continuously for about two weeks in the field, to achieve an appreciable reduction in the pest population.

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SESSION IV : DISCUSSIONS

Mr. T.S. Govindarajan: Dr. Jayaraj has given very interesting results on the field trial on the green scale. I would like to know whether trials have been taken on a multilocal basis, like in Palni area, Yercaud, Nilgiris, Coorg or Chickmagalur. This is important since there are distinct periodicity of the occurrence of some of these pests and some occur in South-West monsoon regions while others in North-East monsoon areas. Regarding *Verticillium*, how often and how many species you have come across, naturally occurring in the fields? One observation, made at the Coffee Research Institute was the severe phytotoxicity by using monocrotophos in certain times. What are the observations of Dr. Jayaraj in his experiments? Our observations reveal that young plants responded well than the older plants. What are the age of the plants that Dr. Jayaraj studied? One observation which impressed me is the implantation method. What may be the proportion of plants to be left without treatment so that natural enemies could be preserved because of the presence of the pest as inoculum for subsequent spread?

Dr. S. Jayaraj: We conducted multi-location trials on different parts of lower Palni hills at different elevations with varying rainfall conditions: Two trials in Yercaud and one trial in Kotagiri. In all the trials we had encouraging results during the cooler months. In the trials conducted in summer months the efficacy was less when we had to increase or add the

humectants or allow more shade. By regulating lopping, if we can allow more shade the ineffectivity was higher. Then we also integrated the use of insecticide like Fenthion and Phosphomidon at 1/8th the recommended dose, with 1/4th dose of fungus. Then there was synergism. With reference to the species of *Verticillium lecanii*, the pathogen was collected from Lower Palneys, Shevroys and Nilgiris and they were found to be the same. The variations were there on intensity in different places based on ecology. Effect of monocrotophos on the fungus *V. lecanii* was not studied, but my colleagues in the Horticultural Research Station, Thadiyankudissi made some studies on the implantation techniques with monocrotophos for controlling the coffee borer. Incidentally they made observations on coffee green bug. The treatments were very effective against both the pests and also the brown bug, mealy bugs. There was no case of phytotoxicity. Perhaps the method of application or dosages may be a factor. We tried different ages of bushes. Always such chemicals will be absorbed better in young bushes. Regarding preservation of natural enemies, I mentioned the case of *Opisina arenosella* control through natural enemies. But that should apply here also. Implantation techniques or even spraying with insecticides should not be resorted to on all coffee bushes. Some bushes may be left out so that there will be natural enemies on these bushes which will develop further and spread to other bushes. In the case of coconut, 5% trees were left untreated with chemicals.

That is enough for augmenting the natural enemies.

Mr. T.S. Govindarajan: This process will allow the pest to multiply.

Dr. S. Jayaraj: Biological control will be successful only if the pest population also is there. In plantation crops because of the perennial nature, biological control will be successful because of the successive generation of the pests. Without the pest, biological control agents will not be able to thrive.

A delegate: Is large scale application of *V. lecanii* possible?

Dr. S. Jayaraj: It is possible. In fact we trained some of the planters at lower Planes. After sterilising sorghum broken grains in a big pot – boiling it and then cooling – it was inoculated by the culture supplied by us. Within a matter of 3 weeks the fungus developed. We also developed another technology. Wild Jack tree ("Kattu Pala" in Tamil) is a shade tree. The fruits are not edible and full of seeds. These seeds can be broken into bits and they are found to give more number of spores, even compared to sorghum broken grains. So this can be adopted. *V. lecanii* is a wilt pathogen in number of plants but this isolate is safe to plants and it continues to infect the insects.

Mr. I.D. Singh: For the integrated management of coconut black headed caterpillar, trunk injection method has been tried. How effective is the method and how long it remains effective? Can this be of commercial practice in some tree plant? I am referring especially to the

tea where we grow shade trees that are very tall. Use of any of these high tree sprayers is not practicable. Can this be a recommended practice?

Dr. S. Jayaraj: Trunk injection has to be resorted to as a one time measure when biological control of *Opisina arenosella* fails. I said that in situations like interior Tamil Nadu, where summer temperature conditions are very high and the natural enemies are not thriving. In such places only during summer months we have to do it. If you do it repeatedly then it will affect the vitality of the trees. Then the residue hazards are very great. So it should be under supervised or organised plant protection programme, by the department of agriculture. It should not be resorted to by individual farmers. There are number of quacks now who started injecting coconut trees with number of chemicals. So there will be problems later on. So it should be organised by the department on a campaign basis only when the natural enemies are not effective. Even then some trees should be left for the further augmentation of natural enemies. Then tender coconuts should not be harvested from those palms. The mature nuts also should be stored at least for a month before they are sold. All these precautions have to be taken.

Dr. P. Rethinam: Dr. Jayaraj has very emphatically said that the stem injection should be done as a one time measure. I fully agree with him, but, I am informing this house that the stem injection is indiscriminately used, particularly in parts of Tamil Nadu. In Andhra Pradesh now they are giving these chemicals through root feeding. When stem

injection is adopted, it causes more stem tissue damage which is harmful to the coconut tree itself. So as in Andhra Pradesh why not we also resort to root feeding? Regarding biological control, we have been talking for a number of years and still we are yet to make a headway to say that this is good. We have established a network of biological units throughout the country; but still, we are not able to tackle this pest. May be the proper time of release, the quantum of release, and the stage at which we have to release are not being properly followed. I think that this should receive adequate attention, and the personnel involved may be given good training so that the systems work effectively.

Dr. S. Jayaraj: I fully agree with Dr. Rethinam that indiscriminate trunk injection is being resorted to in parts of Tamil Nadu, which has been discouraged now and the extension workers have been educated about the adverse effects of this method if adopted indiscriminately. Now there is better awareness in the case of trunk injection. This should not be adopted straightaway in number of other crops without generating data. Now the parasite breeding centres in Tamil Nadu have been given better methods of mass production of natural enemies, better methods of transport and better methods of release. We have been organising number of training programmes in the Tamil Nadu Agricultural University for the benefit of the workers in the parasite breeding centres. There are about 42 centres now in Tamil Nadu, the maximum in any one particular state. In our on-the-farm trials in both Madurai and North Arcot districts, we conducted such studies in large areas involving

several thousands of palms and compared with other untreated areas; we could show the usefulness of parasites, provided they were cultured properly.

Dr. N. Muraleedharan: Regarding the use of pesticides in the plantation crops, especially on tea, I have got one point to make. The chemicals which are extensively used in tea are only Dicofol, Tetradifon (acaricides), endosulfan, phosalone and ethion which are comparatively safe to parasites and predators. These are all cleared by the Environmental Protection Agency of the U.S.A. for residue tolerance levels on black tea.

Dr. S. Jayaraj: I fully agree with Dr. Muraleedharan that safety of pesticides to parasites, predators and pollinators should be given greater importance. In the case of plantation crops, the pesticide use is on the increase. If we resort to application of relatively safer chemicals there is a possibility of encouraging naturally occurring bio-control agents. For instance in cotton, Phosalane, Endosulfan and few other chemicals were found to be safer to natural enemies. Hence the scientists working on plantation crops should identify chemicals, work out method of application and dosage which are relatively safe to natural enemies. Perhaps more studies are needed in this. Then, studies on pesticide residues are very limited. The trunk injection or implantation technique or over spraying with chemicals should be considered in connection with the residue aspects.

Mr. Kuruvilla Jacob: I have one question to Dr. Varadarajan. In the

Placrosym-VI, we had a very interesting paper which described the mid cycle application with DDVP and Thiodan for shot-hole borer. It is an integrated approach and mid cycle application of DDVP + Thiodan with increased potash application was very good. But this treatment was not included in the present study. Only Fanvelerate is compared with some other chemicals. If the earlier finding was very good, you could have included that also in the study.

Dr. N. Muraleedharan: I shall answer this question on behalf of Dr. Varadarajan. These particular treatments were earlier included in some of the preliminary trials which we had undertaken but not projected here. In certain cases we were also getting inconsistent results with Endosulfan + Nuvan combination. The results which we got with the new chemicals were much more encouraging. That is why we have eliminated Endosulfan + Nuvan after the preliminary trials we found three chemicals which were much better than Endosulfan + Nuvan treatment and they were further tried.

Dr. Mohan Kumar: What is the possibility of using bio-technology for pest management? What is the success of the study with pheromones, if at all, in tea or coffee?

Dr. N. Muraleedharan: The use of bio-technology in pest management is mostly with reference to the production of better varieties or better adapted bio-control agents. For example, males of certain parasitoids are not useful for biological control and by some biotechnologic methods like genetic engineering, we can improve the

efficiency of the bio-control agents by increasing the production of female parasitoids. Regarding the pheromone traps, already there are some works done in Japan on the control of Japanese tea totrix and other allied caterpillars, like tea leaf rollers. Pheromone traps are being developed for the coconut caterpillar *Opisina arenosella*, and I understand that some attempts have already been made for developing pheromone traps for the white stem borer coffee as well.

Dr. S. Jayaraj: We can develop varieties through tissue culture resistant to number of pests and diseases. In fact, against banana bunchy top, one variety 'lady finger' developed through tissue culture is showing promise. You can develop mild strains of several viruses by genetic engineering which can be used for crop protection. In the case of insect pest management through microbial control agents like baculovirus, one can increase the virulence of these organisms through genetic engineering, and also break the maturation immunity of lepidopteran pest against the pathogen. In an International Conference held last month in Wageningen one scientist showed that gene of *Bacillus thuringensis* was modified by genetic engineering with one gene less; they were able to make the replication of the endotoxin crystal in every cell of the plant. Instead of applying on the surface of the plant you can make the plant to produce the crystal without affecting the plant itself.

Dr. Jayarathnam: We had a very interesting discussion on various aspects. Regarding the control of rodents, studies on single dose anticoagulants will be more interesting in future than multi-dose anticoagulants.

CHAPTER V

DISEASE MANAGEMENT

Chairman : Dr. P. K. KOSHY .
Rapporteurs : Mr. B. CHANDRA MOULI
: Dr. Y. R. SARMA

INTEGRATED DISEASE MANAGEMENT IN PLANTATION CROPS IN INDIA

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India is one of the leading producers of plantation crops namely, coconut, arecanut, tea, coffee, rubber, cardamom, pepper and cocoa. All these crops except arecanut are commodities of international trade. They play an important role in development of Agro-industries, economy, social set up and above all in the ecology. Approximately two per cent of the total cropped area in India is under plantation crops, and a foreign exchange of about 8900 million rupees is earned annually which amounts to about three-fourth of the total export earnings of all our agricultural commodities. Generally, cultivation of plantation crops requires large capital investments to meet the needs of intensive as well as extensive cultivation operations. These crops being labour intensive, provide employment opportunities to millions of men, women and children. Crops such as tea, coffee, cardamom and pepper are cultivated in remote areas where these provide jobs to tribals also.

The stiff international market is posing a constant threat on the many export-oriented plantation crops. In order to meet the challenge at international level there is a constant need to increase per unit production both quantitatively and qualitatively. It is pertinent to mention that the rise in cost of inputs is also influencing production targets substantially. New innovations in fertilizer application, agronomic

operations, soil management and use of high yielding varieties are bound to increase productivity. Plant protection will occupy a pivotal place in ensuring maximum harvests from other inputs. The very concept of higher production through elite varieties and better nutritional management co-exists with optimised plant protection measures. The perennial nature of plantation crops, their monoculture over many years and the atmospheric conditions under which they are grown are congenial for the many recurring epiphytotic diseases.

Major diseases of plantation crops

Based on their extent of damage and recurrence many diseases have been identified as major ones and are listed in Table I.

Magnitude of losses

Many diseases of plantation crops continue to be potential constraints for crop production. The century old root (wilt) of coconut has been steadily spreading to south and north directions, the mean percent of disease being 32.3%. The latest survey has shown that the loss due to root (wilt) disease in Kerala is 968 million nuts (Anonymous, 1985). The total estimated monetary loss on the basis of 1984 price of coconut is Rs. 3,000 million. The survey undertaken during 1976 in yellow leaf disease (YLD) affected areas revealed that 35.8 per cent of the

Table I. *Major diseases of plantation crops*

Crop	Common name	Organisms implicated
Coffee	Leaf rust	<i>Hemileia vastatrix</i> Berk and Br.
	Black rot	<i>Koleroga noxia</i> Donk
Tea	Blister blight	<i>Exobasidium vexans</i> Massee
	Red rust	<i>Cephaleuros parasiticus</i> Karst, <i>C. mycoidea</i> Karst
Rubber	Abnormal leaf fall and stem rot	<i>Phytophthora palmivora</i> Butler
Cocoa	Black pod disease	<i>Phytophthora palmivora</i> Butler
	Charcoal pod rot	<i>Botryodiplodia theobromae</i> Pat.
Coconut	Root (wilt) disease	MLO
	Bud rot	<i>Phytophthora palmivora</i> Butler
	Tanjavur wilt disease	<i>Ganoderma lucidum</i> (Leyss) Karst
Arecanut	Yellow Leaf Disease	MLO
	Koleroga	<i>Phytophthora arecae</i> (Coleman) Pethybridge
	Anabé roga	<i>Ganoderma lucidum</i> (Leyss) Karst
Cardamom	'Katte' or mosaic disease	Virus (Poty virus)
	'Azhukal' or panicle rot	<i>Phytophthora nicotianae</i> var. <i>nicotianae</i> <i>P. palmivora</i> Butler, <i>Pythium vexans</i> de Bary <i>P. aphididermatum</i> (Eds.) Fitz.

area out of 92,680 ha covered is affected with YLD (Rawther *et al.*, 1982). Similarly in Chickmagalur District of Karnataka 28 per cent of the area is affected with YLD. It is needless to mention that YLD is debilitating in nature and the yield loss is over 50 per cent within a period of 3 years immediately following the infection. The qualitative loss due to YLD is also higher since the nuts from the affected palms are of inferior quality. In the year 1978, the Koleroga of arecanut was rampant and crop loss ranged from 50-90 per cent in certain gardens (Reddy and Anandaraj, 1980). The wide spread occurrence of 'Katte' disease of small cardamom results in extensive losses in yield ranging from 10 to 98 per cent in different years of productivity (Varm, 1962; Venugopal and Naidu, 1984). 'Azhukal' disease of cardamom brings about 30% of crop loss during years of severe disease incidence. In Asia, coffee, rubber and tea suffer a loss of 15 per cent, 15 per cent and 16 per

cent respectively due to many diseases (Cramer, 1967).

Approaches to the management of the diseases.

Cultural practices

Roguing: The spread of 'Katte' virus disease of small cardamom and coconut root (wilt) can be contained by following regular roguing operation. Based on the intensity, distribution and the nearness of plantations to virus source, a precise management strategy has been suggested by Naidu and Venugopal (1982). Economic management of this disease has been reported through large scale testing (Varma, 1962; Naidu and Venugopal, 1982). The spread of coconut (root) wilt could be reduced effectively by repeated roguing of affected trees (Radha *et al.*, 1985). The beneficial effect is pronounced where the disease is scattered and of low intensity.

Integration of cultural and prophylactic practices

Practices like better drainage, clean cultivation, avoidance of over-crowding and isolation of affected palms by digging trenches are useful to contain *Anabe roga* of arecanut. Control of brown root disease (*Fomes noxius*) and red root disease of tea (*Poria hypolaterita*) is possible by taking suitable phytosanitary measures or by soil fumigation with Vapam, Metham sodium, D.D. or Methyl bromide (Venkata Ram, 1972). Phytosanitary measures include burning of infected plants on the spot itself and taking 4' deep trenches around one circle of apparently healthy plants for the latter disease and two circles of apparently healthy plants for the former. Branch canker of tea (*Poria hypobrunnea*), stem bleeding of coconut (*Thielaviopsis paradoxa*) and stem rot of rubber are better managed by scraping the infected tissues followed by sealing with hot coal-tar or Bordeaux Mixture. The spread and intensity of 'Azhukal' disease of cardamom can be reduced to great extent by sanitation and proper shade regulation coupled with timely application of one per cent Bordeaux Mixture (Joseph Thomas and Suseela Bai - unpublished). A package of better nutritional and phytosanitary measures are reported to check the spread of disease intensity in the Thanjavur wilt and root (wilt) affected coconut gardens (Bhaskaran and Ramanathan, 1983). Better management and intercropping coconut gardens with cassava, yam, elephant yam, cacao and fodder crops decreased the intensity of the root (wilt) disease (Sadanandan *et al.*, 1979).

Chemical control

Protection: Among all the

protectants, Bordeaux Mixture continues to enjoy the monopoly in the control of major fungal disease of plantation crops. It is extensively used for the the control of bud rot of coconut (*Phytophthora palmivora*), leaf blight of coconut (*Pestalotia palmarum*), leaf rot of coconut (*Helminthosporium halodes*), Koleroga of arecanut (*Phytophthora arecae*), capsule rot of cardamom (*Phytophthora nicotianae* var. *nicotianae*), black rot of coffee (*Corticium koleroga*) and of tea (*Corticium invasum*), coffee leaf rust (*Hemileia vastatrix*), secondary leaf fall of rubber (*Phytophthora palmivora*) and charcoal pod rot of cocoa (*Botryodiplodia theobromae*). Oil based copper fungicides are sprayed aerially on rubber and proprietary copper oxychloride formulations are used extensively for the control of blister blight of tea.

Integration of therapeutants and protectants

Most significant achievement in disease management techniques is the integration of fungicides possessing different modes of action against specific pathogens. Now, for the control of blister blight of tea, three sprays with systemic fungicide (Calixin - an antisporeulant) to reduce the inoculum load, followed by usual copper fungicide (protectant) plus nickel chloride (an eradicant) sprays on regular rounds of 7-10 days until the middle of September after which again 4 sprays with systemic fungicide to give additional protection is being recommended (Venkata Ram and Chandra Mouli, 1976; Chandra Mouli, 1983). Usefulness of similar approach in coffee rust control is also proved by Muthappa (1979) and Rajendran and Nataraj (1983).

Application of either oxycarboxin or Bayleton in the pre-monsoon period greatly reduces the spore load and also eradicates the lesions that had developed prior to treatment. Further, spraying with Bordeaux Mixture as protectant imparts much superior results. Keeping pathogen cycle, vulnerable stage of crop and specific action of fungicides, a very precise integrated schedule has been developed in the management of above two major diseases of coffee and tea. Such comprehensive approach to tackle other diseases needs investigations.

Evolving disease resistant types

Though this field needs top priority, it has been given due consideration against only a few diseases. Appreciable work has been done in isolating resistant lines against rust in coffee through interspecific crosses between the Arabica and Robusta. Efforts to isolate field resistant plants to overcome YLD of arecanut, 'Katte' virus disease of cardamom (Anonymous, 1985) and blister blight of tea appear to be promising. In rubber crown budding with resistant source such as BD-10, FX-516, F-4542 and RR II 33 successfully combated the *Phytophthora* leaf fall (Ramakrishna Sarma, 1985). This approach is very promising in reducing the recurring expenditure on the cost of aerial spraying. Similar efforts to isolate inherent resistant/tolerant selections against major diseases of other crops are worthwhile to attempt.

Future strategy for disease control

1. Realistic estimate of losses due to different diseases, their indexing systems and screening procedures still need to be refined.
2. Surveillance programmes in all the potential growing areas are to be carried out to monitor the changing status of diseases. The newly reported diseases such as Nilgiris Necrosis of cardamom (NNC), and yellowing disease of coconut are to be watched vigilantly and the exchange of planting material from affected areas should be strictly prohibited.
3. A thorough knowledge of the ecological factors that govern the seasonal abundance of pathogens in different areas and the factors responsible for sporadic outbreaks of certain diseases in some localised tracts are essential pre-requisites for evolving suitable integrated control schedules against them.
4. For root (wilt) disease of coconut, yellow leaf of arecanut, Anabe roga of coconut and arecanut, Thanjavur wilt of coconut, it is advantageous to evolve and adopt proper management practices to get additional income by raising subsidiary crops in affected plantations.
5. The experimental transmissions of YLD of arecanut, root (wilt) of coconut, Thanjavur wilt of coconut, Anabe roga of coconut and arecanut are still elusive. Concrete results on these aspects are needed to answer the long standing questions pertaining to etiology and possible means of spread.
6. Potentiality of Biotechnology in evolving disease resistant types and multiplication of resistant/tolerant

selections has not been harnessed to its full advantage. Immediate concentration is required in this direction to explore the vast scope present in this field.

7. Low-cost technology to reduce the cost of production by proper integration of genetical, cultural and chemical control measures needs utmost attention.

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RATIONALIZING INPUTS-USE IN PLANTATIONS, WITH SPECIAL REFERENCE TO LEAF RUST MANAGEMENT IN COFFEE

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ABSTRACT

Fertilizers and pesticides are the two major material inputs in coffee plantations. As the response to pesticide application markedly differs from that to fertilizer, ways to optimise or rationalize the use of this input plantations also differ. A rational pest management system would help the planters to maximise their profits, besides checking the adverse effects of pesticides in the ecosystem. Taking leaf rust (*Hemileia vastatrix* B. & Br.) control in coffee as a case, the necessity for the judicious use of fungicides based on a rust management system is discussed. A conceptual model to evaluate economic threshold is presented taking into consideration biological, climatological and economic factors which would influence the rust management strategy.

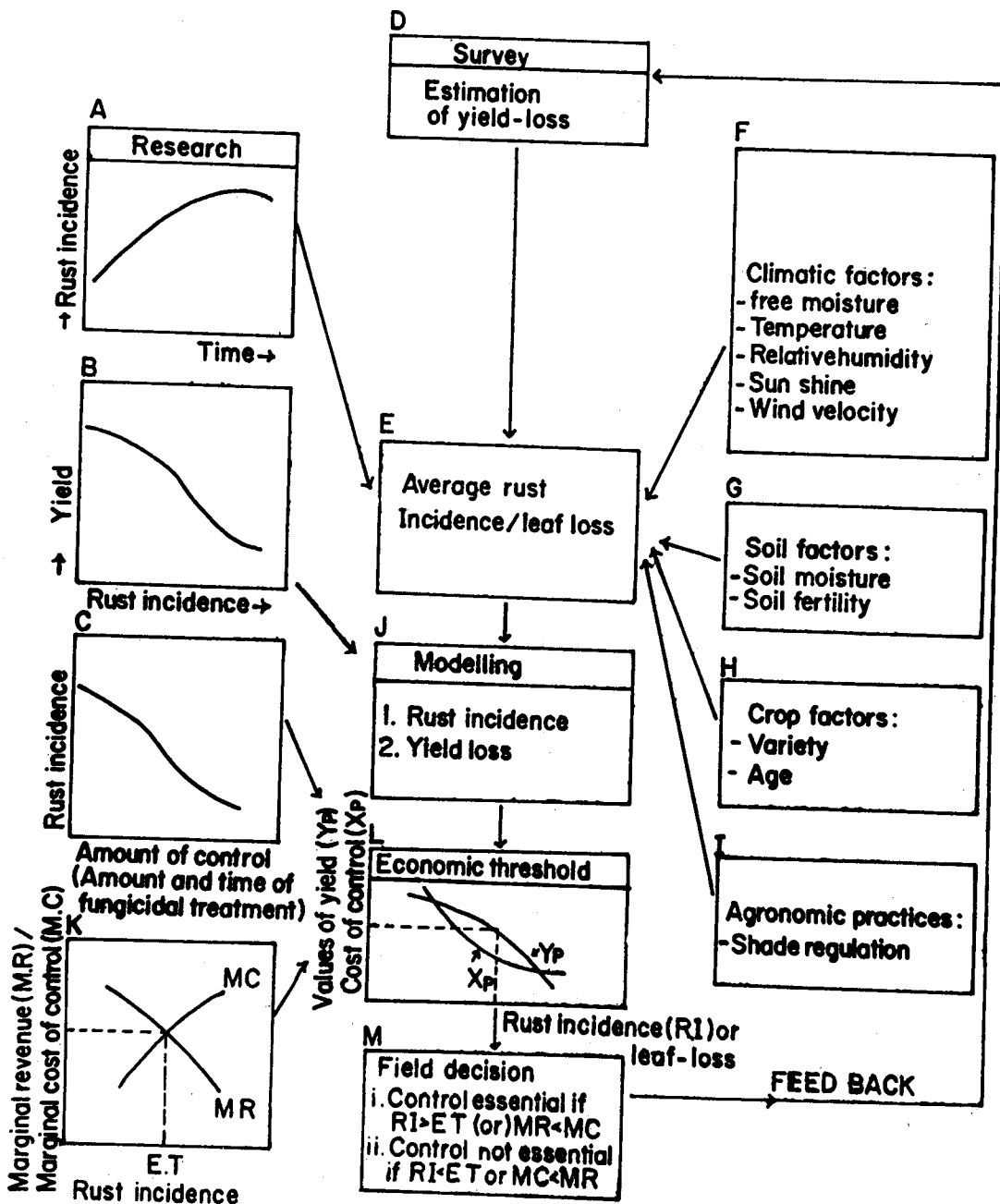
INTRODUCTION

An economic problem exists in agriculture when producers who are seeking to maximise some goal, have limited resources and must choose or decide between alternative courses of action. In a rational action producers make decisions to achieve specific objectives. One objective may be the maximisation of profits. This can be achieved by evaluating a particular technology for its economic efficiency. An improved technology, in a variety, fertilizer or pesticides, is well received by the producers and can be said to be efficient when its economic advantage is adequately demonstrated.

Fertilizers and pesticides are the major material inputs in coffee plantations. Their application involves considerable labour input. Economically optimal or

rational solutions are the best and are usually derived from input-output response curves. Radhakrishnan *et al.* (1985) stressed the need for judicious use of fertilizers. The response of output to pest control inputs, however differs markedly from that of fertilizer. While response in outputs to pest control is by allowing normal growth and development of plants, the response to fertilizer is by stimulated biological process (Anonymous, 1969). Therefore rationalization studies in pesticides call for a different approach, viz., rationalization through disease management strategies. It is in this context, development of a rust management strategy assumes importance. The general objective of this paper is to develop a rust management strategy, which besides maximizing producer's profit, will lay foundation to systems approach in plant disease management in coffee plantations.

Fig. 1. The Conceptual rust management system.



Different phases of rust management strategy

The various components of the conceptual rust management model have been illustrated in Fig. 1. Though they are grouped into different phases, they are interrelated and are complementary to each other. This strategy lays emphasis on management of rust rather than its control. Apple (1977) preferred the term "Pest management" to "Pest control" and opined that 'control' evokes the notion of complete elimination of a particular pest (which is highly impossible) while 'management' conveys the concept of continuous process rather than an event accomplished with the application of extrinsic factors.

The three different phases of the conceptualized strategy are: (i) Research or experimental phase, (ii) survey phase, and (iii) modelling phase.

Before going into the details of different phases, a brief review of the various factors that influence rust incidence is in order.

Factors that affect rust incidence

Disease epidemics is largely a function of different variables such as weather, soil, crop and other cultivation practices. Any meaningful disease management programme would have a precise assessment of the disease triangle viz., pathogen, environment and the host.

Precise definitions of environmental variables for development of rust epidemics under South Indian conditions are scanty. Waller (1982) quotes exhaustively the work done in different

countries on the factors that influence epidemiology of coffee rust. Climatic factors like rainfall, temperature, wind velocity, relative humidity and sunshine were found to influence rust incidence. (Mayne, 1937; Rayner, 1960; Waller, 1979; Rajaseb and Rajendran; 1983; Kushalappa and Chaves, 1980; Van de Walle, 1961; Muthappa, 1980).

Soil, crop and agronomic practices are also known to influence the epidemics of coffee leaf rust. Van de Walle (1961) reported that magnesium deficiency led to rust incidence.

Studying the effect of drought period on rust disease Mayne (1937) found that shorter the drought period, higher was the rust incidence.

Susceptibility of different varieties of coffee to different physiologic races of *Hemileia* was studied by Chinnappa and Sreenivasan (1969). Though S.795, an improved arabica variety, is mainly susceptible to race VIII of *Hemileia*, seed propagated plants were known to segregate for resistance to race I and hence succumb to both the races I and VIII (Ramachandran and Visveshwara, 1975). Thus there is a need to exploit varietal resistance through clonal propagation, which has been standardized by Purushotham (1982).

Young trees are rarely affected by rust while older trees are frequently affected (Van de Walle, 1961). The possible effects of shade on the development and epidemics of rust had been brought out by the observations of Mayne (1937).

Research phase

As a first step in the research phase, experiments to study the relationship between rust incidence and time (Fig.1.A) are the prerequisites. Mayne (1930) studying the seasonal periodicity of leaf rust disease in arabica coffee found that rust started to build up after the blossom showers and increased steadily afterwards till it reached its maximum in November. He gave a general idea of the disease development and control under South Indian conditions.

Evaluation of rust incidence in different periods of time will help construct disease progress curves (Fig.1.A). A standardized measurement of rust severity is inevitable to construct a progress curve. Muthappa (1974) and Kushalappa (1981) had advocated a suitable methodology to measure rust incidence in the field through standard area diagram. Van der Plank's (1963) logit transformation for disease progress curve, was found to be situation-specific and therefore a multiple regression model that will directly relate yield loss to the epidemic had to be developed.

Studies on the relationship between the percentage of rust incidence and yield of coffee (var. S.795) in different locations (Anonymous, 1972) did not give any conclusive results. Any yield increase due to Bordeaux spraying could be due to the "tonic" effect of copper (Waller, 1982).

Evaluation of the amount of fungicides and the time of control (Fig. 1.C) is another factor that would affect the cost of fungicidal treatment. Mayne (1930) recommended that, for older varieties of

coffee, the period between blossom showers and beginning of South-West monsoon was the critical period of Bordeaux treatment. Though single spray was found to be sufficient, he advocated an additional one as post-monsoon application in order to avoid risks and uncertainties involved in the disease development. Locating the critical period(s) of spraying based upon the expected rust severity taking the time and climatic variables into account may prove valuable in optimising the cost of spraying. Thus the research phase calls for extensive experimentations on rust severity and yield loss taking into consideration all the relevant variables that have been discussed elsewhere.

Survey phase

Field surveys aim at estimation of yield loss more rapidly due to rust severity and hence complement experiments. Suitable sampling and survey techniques are of vital importance to a successful survey. Khosla (1980) stressed the need of choosing the correct sampling procedure. Sample surveys can be carried out periodically depending on the data base required. Such a sample survey will provide informations on rust incidence with reference to time, status of control and yield data. A model survey format is presented in Appendix-I.

Modelling for leaf rust management

A model can simply be "a set of mathematical statement" (Gujarati, 1979) and assessment models are "at best simplified statements about the real world" (Main, 1977). The basic model for coffee would predict rust severity and leaf loss, thereby paving way to an yield loss

model. James (1980) broadly grouped the yield loss models into three categories as critical point models, area under curve models and multiple point models. James (1980) advocated the use of multiple point models to situations where there is high variability in epidemic infection rate or shape of the disease progress curve. Multiple point models employ multiple regression analyses or its modifications in which usually the disease development or the yield loss (Y) is regressed against the epidemiologically important explanatory variables ($X_1, \dots, X_n$). Such a model had been used to predict development of leaf rust in coffee (Kushalappa, 1981) and development of disease/yield loss in other crops (Burleigh *et al.*, 1972 a & b; James *et al.*, 1972).

Owing to the flexibility and sophistications, multiple point models can best be exploited for leaf rust management. Any model that would attempt to rationalize fungicidal use in coffee would always aim at predicting the rust epidemics at least 30 days or more in advance so that adequate planning for spray schedule is possible. Development of a model that would predict leaf rust severity in the field is a pre-requisite for estimation of yield loss. The probable rust incidence model would have rust incidence (at a later period) as the dependent variable (RI) and some of the important biological and meteorological factors as independent variables (equation 1).

$$RI = f(FIDP, NPL, PSAI, TMAX, TMIN, RH, RAIN, RDAY, WIND, SOIL) \dots (1)$$

Where

RI = Rust incidence

(Proportion of leaves rusted/ m^2): leaf rust incidence 30 or 45 days after DP. (DP = Date of Prediction)

RIDP = Rust Incidence on DP

NPL = Number of pustules per leaf on DP

PSAI = Proportion of Spore Area Index on DP

TMAX = Maximum

Temperature

TMIN = Minimum

Temperature

} As average of 7 or 14 days prior to DP

RH = Relative Humidity

RAIN = Rainfall in mm

RDAY = Rainy Day:

No. of rainy

days (=2.5 mm)

} Total of 7 or 14 days prior to DP

WIND = Windy day: No. of windy days (with wind velocity = 1m/s.)

SOIL = Soil Fertility score

The dependent variable RI can be estimated in terms of proportion or percentage of leaf area rusted. As discussed elsewhere, techniques to quantify RI in leaf rust of coffee are available. The variable SOIL, based on N, P_2O_5 and K_2O status may be assigned scores as follows:

All (N, P_2O_5 , K_2O), Low = 1; combination of low and medium = 2; all medium = 3; combination of medium and high = 4; all high = 5.

This model assumes the varietal and age factors to be constant and as such these are not included. If the experiment or survey has to be carried out in different varieties of different age groups, these factors can be quantified using dummies or scores. For example, the

variable 'variety' if included, can be a dummy: 0 if improved variety and 1, if susceptible variety. 'Age' may be assigned scores according to age groups as follows: - 5 years = 1; 6-10 years = 2; 11-15 years = 3; 16-20 years = 4 and > 21 years = 5.

The proposed model (eqn. 1) can be improved by various ways so that the model developed would simulate the real as closely as possible. Burleigh *et al.* (1972) and Kushalappa (1981) improved the predictability of their models on wheat rust and coffee rust respectively by stepwise multiple regression analysis. In this analysis, a variable Y is regressed exploratorily on other variables as $X_1, X_2, \dots, X_n$ taking various combinations to obtain a minimum of unexplained variation with fewest independent variables. Any independent variable that does not remove a significant portion of the variation in Y is dropped from the analysis.

Though multiple linear models are flexible they are not without problems. When many variables which perform similar functions are included, the problem of multicollinearity, which will distort the model, arises. This problem can however be overcome by redesigning the model with variables that are not related. Kushalappa *et al.* (1983, 1984) avoided this problem by transforming the meteorological variables to monocyclic process equivalents for environment and by calculating survival ratio for the monocyclic process of the pathogen (*Hemileia*) based on paths of biological action.

Once the association between rust incidence in the field and biological and meteorological factors is understood and established, leaf loss in coffee due to rust (which is a function of rust incidence) can be predicted. The general yield-loss function would be:

$Y = f(X_1, X_2)$, where Y = Per cent yield loss,
 X_1 = Per cent leaf loss, and X_2 = Stage of crop growth or time of disease onset.

Waller (1982) opined that leaf loss in a particular year in coffee will not only affect current year's yield but also will affect subsequent year's yield. Hence, yield-loss in coffee due to leaf loss is cumulative, at least for two years. This again calls for studies to understand yield loss through path coefficient analysis, in which, based on a prior or experimental evidence a direction or path in the causal system is assigned. Hampton (1975) used path coefficient analysis to bring out the subtle effects of mosaic viruses on yield of field bean.

Economics of rust management

As present rust control measures are frequently used as an insurance against a probable damaging infection. Since input-output relationships in rust control has direct bearing on costs and returns in plantations, development of an Economic Threshold (ET) ensures rationalization of the input costs. When economic returns are estimated for varying levels of control measures, ranging from no control to the use of complete system of control, a producer will be in a position to evaluate the risk and uncertainty associated with

different levels of rust control and will base his decision and actions on a rational way. To determine ET for rust, a thorough knowledge of the relation between the rust incidence, the extent of injury and the yield are necessary.

The concept of both economic threshold (ET) and economic injury level (EIL) referred to the relation between the population density of the pest and the profitability of control (Sylvén, 1968; Stern, 1973). The ET indicates a certain level of infection at that time when it is necessary to determine whether control is to be resorted to or not. If control is not taken up in such cases, the successive pressure of disease build up on the crop finally will attain EIL.

Headly (1972) defined ET as the pest population at which the incremental damage equals the cost of preventing it. Stern (1973) stated ET as the pest density at which control measures should be determined to prevent an increasing pest population from reaching injury level. This latter term was defined as the "lowest population density that will cause economic damage".

Hall and Norgaard (1973) improved Headly's definition by taking time and quantity of pesticides as variables, but using only a single treatment, while Talpaz and Borosh (1974) included several treatments. A dynamic model for cotton was developed by Talpaz and Frisbe (1975) which related net benefit to ET, taking into account variety, crop age, value of yield and cost of control.

The concept of economic threshold can be shown graphically (Fig. 2). As rust

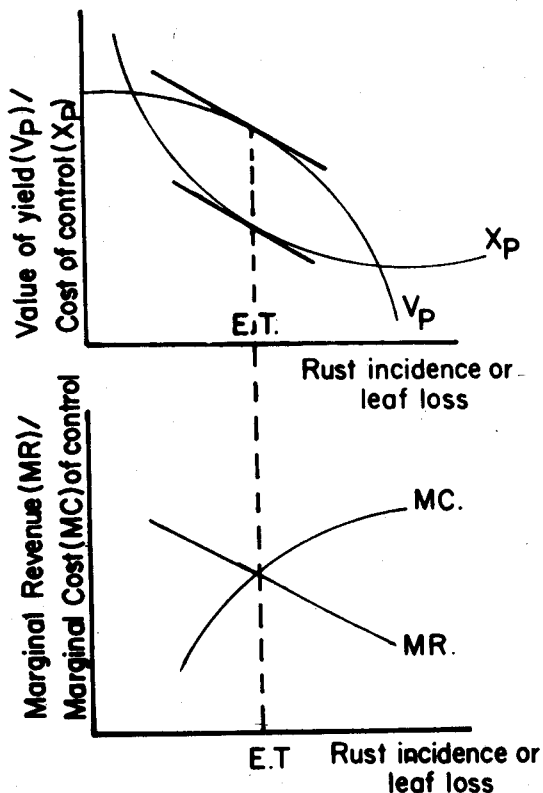


Fig. 2. Economics of rust control.

incidence or leaf loss increases above some crop tolerance level, the total yield and thereby the revenue (V_p) obtained diminishes at an increasing rate. On the contrary costs (X_p) are expected to decrease at decreasing rates at higher rust incidence as fewer resources are needed and total costs fall. Mathematically, the ET is defined as that rust incidence at which the slopes of the two curves (V_p and X_p) are equal or the rust severity at which the increased yield loss equals increased cost of control. In other words ET is the point of intersection of MC and MR curves. Below ET some crop income is always sacrificed. Above ET,

marginal cost is greater than marginal returns. If the controls are initiated successfully at the tolerance or damage threshold, which lies before ET, zero damage would occur, but the cost of control would not be justified. Stone and Pedigo (1972) derived specific formula to arrive at EIL and ET in the case of green clover worms in soybean and Walker (1980) suggested a generalized formula to estimate ET.

Estimation of ET for a disease is still at its beginning stage. With the advancements in modelling and computing with the aid of computers, it may not be impossible to introduce an ET based leaf rust management strategy in coffee in the near future.

CONCLUSION

Given the economic situations in which present day coffee plantations are operating, economically efficient technologies would always be well received by producers. Development of a leaf rust management system, following a similar methodology presented here may help the producers to plan their spray schedule based on ET. Evaluation of ET requires extensive data base that are to be fed by experimentations and sample surveys. An ET based rust management strategy not only can optimise fungicidal use in coffee plantations but also can cut down the social costs of environmental protection.

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*Original not seen

APPENDIX-I

1. Basic particulars:
 - i) Date of survey:
 - ii) Location of the estate/field/plot:
 - iii) Altitude:
2. Agroclimatic factors (Averages of 7 days preceeding the date of survey):
 - a.
 - i) Rainfall
 - ii) Maximum temperature:
 - iii) Minimum temperature:
 - iv) Relative humidity:
 - v) Wind velocity:
 - vi) Sun shine:
 - b. Total number of rainy days (2.5 mm) in the preceeding 7 days:
3. Crop:
 - i) Variety:
 - ii) Adjustment varieties:
 - iii) Age of the bush:
4. Soil:
 - i) Moisture status:
 - ii) Fertility status:
 - iii) Soil pH
5. Agronomic practices:
 - a. Status of fertilizer application:
 - i) Quantity applied:
 - ii) Time of application:
 - iii) Number of splits:
 - b. Status of rust control:
 - i) Name and quantity of fungicides:
 - ii) Strength of spray solution:
 - iii) Number of rounds and time of spray:
6. Light intensity in the estate:
7. Spore area index:
8. Rust severity:
 - i) Rust incidence (on Muthappa's scale):
Mild/Medium/Severe/Very severe/Damaging
 - ii) Per cent leaf area affected:
 - iii) Per cent leaf loss:
 - iv) Approximate per cent of plants infected:
9. Yield particulars:
Estimated yield on:
 - i) Blossom:
 - ii) Early berry:
 - iii) Green berry:

EFFECT OF FUNGICIDES ON CONTROL OF COFFEE BLIGHT

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INTRODUCTION

Coffee blight (*Phoma costaricensis* Echandi) first appeared in Costa Rica (Echandi, 1957). It was reported in India by Rajendran *et al.* (1983) in Honnametti estate at 6000'. Dark brown to black necrotic round spots on the leaves are the symptoms, the lesion diameter ranging from 1 to 30 mm. In severe cases, two or more spots would coalesce and affect a portion or entire leaf, including midrib and petiole. In very still advanced stages, spots are formed in concentric rings. Wet weather, high humidity and low temperature, particularly during monsoon, at higher elevations (above 1500 m) are found to be congenial for infection and disease build-up. The disease causes heavy defoliation. Nirmala Kannan *et al.* (1985) reported that Foltaf was superior to other fungicides. A trial was laid out at Honnametti Estate to find out optimum concentration of fungicide to effectively control the disease. The results obtained in this experiment are presented here and possible ways to check the further spread of disease are discussed.

MATERIALS AND METHODS

Foltaf was tested at 0.5, 0.4, 0.3, 0.2 and 0.1 per cent and Bavistin at 0.05 and 0.04 per cent on S.795 coffee plants at Honnametti Estate, Block III, during 1985. The field trial was laid out in randomised complete block design and replicated thrice with 15 plants per

replication. Pre and mid-monsoon sprays were given in May and July. Observations on infected leaves and healthy leaves on marked branches were recorded monthly from May to September. The percentage infection was calculated and analysed statistically, adopting the procedure suggested by Sundararaju *et al.* (1972).

RESULTS AND DISCUSSION

The results obtained are presented in Table I. In July, except in case of Foltaf 0.4 and 0.5%, all other treatments were on par in respect of infection. During September, the effect of fungicides varied among the treatments and the least infection (5.36) was in Foltaf 0.5%, whereas in check it was 14.88. Thus the results indicated that Foltaf sprays at 0.4% and 0.5% can control the disease. Bavistin was not effective at both concentrations tested.

The trial was laid out during May to September when the disease occurs generally. Wellman (1961) reported that blight can cause panic on the cooler coffee growing regions, and the best conditions for blight are long periods of intermittent light rains interspersed with foggy weather. In the present study at Honnametti, while the infection on untreated plants were to the extent of 15%, Foltaf treated ones had 5.5% infection. To achieve this two sprays in

Table I. *Field trial on the control of coffee blight*Location: *Honnametti Estate, 6000' MSL Material: S.795*

Treatments	Percentage of infected leaves (in transformed figures)						
	May	June	July	Mean	August	September	Mean
1. Foltaf 0.5%	0.00	5.05	6.24	5.64	5.64	5.36	5.50
2. Foltaf 0.4%	0.00	1.68	7.41	4.54	6.08	6.93	6.50
3. Foltaf 0.3%	0.00	3.36	9.51	6.43	9.93	8.88	9.40
4. Foltaf 0.2%	0.00	5.79	9.40	7.59	13.66	11.50	12.58
5. Foltaf 0.1%	0.00	7.16	10.18	8.67	11.45	12.09	11.77
6. Bavistin 0.05%	0.00	7.51	10.97	9.24	13.70	11.61	12.65
7. Bavistin 0.04%	0.00	9.33	10.44	9.88	12.76	12.17	12.46
8. Check (Water sprayed)	0.00	7.77	10.82	9.29	15.45	14.88	15.16
Significance	—	*	*	*	**	*	—
C.D at 5%	—	3.82	1.29	—	3.77	2.76	—
C.D. at 1%	—	—	—	—	5.24	3.83	—

*Significant at 5%

**Significant at 5% and 1%

Treatments	: 8
Number of replications	: 3
Number of sprays	: 2 (May and July)
Design	: RCBD

May & July were given. Nirmala Kannan *et al.* (1985) reported the efficacy of Foltaf on coffee blight. Wellman (1961) reported that none of the copper containing fungicides and organics like Zineb and Ferbam could control this disease in Costa Rica. Further Costa Rican workers assumed that grasshoppers are the predisposing factor of the disease. Hence a thorough observation was made in the present experiment to find out whether any insect played any role in disease incidence. But there was no indication of insect damage which could enhance the entry of this pathogen. Hence, addition of insecticide is not necessary for the control of this disease. Here it may be mentioned that in Guatemala, Difoltan at 906 g/225 litre of water when sprayed three times controlled this disease (Sanchez de Leon, 1975). Thus our findings confirm their results. However, only two sprays are needed in India. Shade management was

proposed by Wellman (1961) to check the disease. In Silver Oak (*Grevillea robusta*), severe defoliation was noticed in July and August. On careful examination the leaves were found to show lesions. The fungus *Phoma* was isolated from these diseased spots. It is proposed to study further in detail on the possible factors and collateral hosts responsible for the spread of this disease. Foltaf spray (0.4% or 0.5%) can be used to tackle coffee blight. From the economic point of view, Foltaf 0.4% can be recommended in controlling this disease.

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CONTROL OF TEA BLISTER BLIGHT (*EXOBASIDIUM VEXANS MASSEE*) WITH ORGANIC FUNGICIDES

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ABSTRACT

Blister blight disease of tea is incited by the basidiomycete *Exobasidium vexans* Massee. This fungus completes its life cycle in a short period of 11-28 days, thus warranting fungicide sprays at 5-7 day intervals for adequate control. Inorganic fungicides, namely, copper oxychloride and nickel chloride are generally used on an extensive scale to combat the disease. In the last 13 years 46 organic fungicides and their formulations were tested against this disease and of them, those based on chlorothalonil (Daconil 2787) 560 g, dithianon (Delan) 750 g, pyracarbolid (Sicarol) 500 ml, and tridemorph (Calixin) 180 ml per hectare offered good disease control. Pyracarbolid and tridemorph possessed long residual action and treatment interval with them could be extended upto 15 days. Chlorothalonil and dithianon on the other hand had to be sprayed at 7-10 day intervals for effective control. At present, only tridemorph (Calixin) is being used by the tea industry, and the other fungicides are yet to be available on commercial scale.

INTRODUCTION

Blister blight disease of tea caused by the basidiomycete *Exobasidium vexans* Massee appeared for the first time in tea tracts of southern India in 1946. This fungus under favourable climate of the South-West monsoon spread very rapidly and caused significant crop losses in the first few years, before effective control measures could be developed and implemented (Venkata Ram, 1964). *E. vexans*, an obligate parasite, with no other alternate host, completes its life-cycle in a short span of 11-28 days, thus, warranting intensive fungicide protection at short intervals. Since the fungus infects only the tender harvestable tea leaf, adequate protection of the susceptible material is essential to prevent direct crop loss.

Well laid out field trials were undertaken soon after the outbreak of the disease, in which a fixed copper fungicide and formulation, namely, Perenox was evaluated (Anonymous, 1949). Several estates were then using Bordeaux mixture and Burgundy mixture, but soon it became apparent that these held no great superiority over the easily dispersible fixed copper formulations. Between 1951 and 1960 several inorganic fungicides based on copper, sulphur and mercury were screened for efficacy. Copper fungicides containing 50 per cent metallic copper gave good disease control. One formulation of sulphur offered disease control on par with the standard copper fungicides; but as sulphur taints tea this product could not be further encouraged (de Jong, 1954).

Mercurials, being phytotoxic did not find a place in the protection of blister blight (de Jong, 1954). In 1960, a breakthrough was achieved with the introduction of nickel chloride which proved to be a powerful eradicator fungicide (Venkata Ram, 1961). Disease control was better when the protectant copper and the eradicator nickel were combined and sprayed, than either of them when treated singly. Over the last few years however, disease control obtained with copper and nickel has appeared to be slightly weakened, which perhaps could be due to the tolerance developed by the parasite (Chandra Mouli, 1979). It was, thus, essential to test and search for other effective fungicides.

Various organic fungicides were tried in earlier years but the success was limited. One of the very first to be evaluated was cycloheximide, which did not offer good protection (Venkata Ram and Jayaraman, 1960). Difolatan, containing captafol, provided adequate disease control at high dosage; But as it contained sulphur at higher dosages, the teas got tainted. An array of organic fungicides widely differing in their chemical nature and possessing both eradicator and systemic properties were evaluated in the last 13 years and based on their performance they were classified as good and poor (Table I). The results obtained with chlorothalonil (Daconil 2787) and dithianon (Delan) in two different field experiments are discussed in this paper.

MATERIALS AND METHODS

Experiment 1: A large field trial was undertaken in the North-East monsoon season to compare Daconil 2787 with the

Table I. *Organic fungicides tested against Blister Blight disease of tea*

GOOD :	BAS 421 OOF, CALIXIN 80EC, DACONIL 2787, DELAN 75WP, HOE 6052, PP 296 JF 7168, PP 347 JF 8590, S 619F IOWP*, SICAROL 50WP, SICAROL 15% DISP., SYSTHANE 10 WP*, SYSTHANE 12EC*, TILT.
POOR :	AGROZIM, BAS-317 OF, BAS-319 2F, BAS-327 IF, BAVISTIN, BAYLETON, BENLATE, CUMAN L, DITHANE 34F, FOLTAF 80W, KARATHANE, KITAZIN, MBC 50 WP, MILGO, NIMROD, PANORAM, PANOCTINE, PANOLIL, PLANTVAX, PP 296 JF 6570, JF 6620, JF 7166, PH-50 98, PROCHLORAZ, RH 2161, SAPROL, SYLLIT, THIOPHANATE, TOPSIN M, VITAVAX, ZIRAM.

*PRESENTLY UNDER INVESTIGATION. DATA BASED ON PRELIMINARY FINDINGS.

standard copper oxychloride - nickel chloride combination. The experiment was run in a 24-year-old seedling tea field which was in its third year from pruning. The size of each treatment was one hectare, with tea bushes planted on 120 × 120 cm spacing. Fungicide sprays were given with an airblast spraying machine at a spray volume of 45 litres per hectare, using nozzle no. 2, having a discharge rate of 60 litres of spray fluid per hour. While spraying, the mist was blown to cover 5 tea rows with and 2 against the wind direction. Sprays were imposed at 7-day intervals in both the treatments. Following the third spray application, the disease assessment was done at regular weekly intervals. From the pooled harvest of each plot, 1000 shoots were chosen at random and was examined individually for infection. The experiment

was initiated in September and concluded in December.

Experiment 2: In this experiment the treatments, replicated and randomised, were laid in small blocks comprising two rows each of 14 tea bushes. The investigation was carried out in a seedling tea block having 25 year-old tea bushes, planted 120×120 cm apart and were in the second year since last pruning. Fungicides were sprayed with a pressure retaining (2.8 kg/cm^2) knapsack sprayer, fitted with a conejet spray nozzle delivering 175 litres of spray fluid per hectare. A single row of tea bushes were sprayed on either side. The experiment was commenced in July in the South-West monsoon and continued in the North-East monsoon as well, till December.

Table II. *Evaluation of Daconil 2787*

Treatments	Rate/ha	% Blister incidence recorded on		
		October	November	December
Daconil 2787	560 g	16.6	11.4	9.7
COC+NICL	210 g each	29.4	35.0	18.3

COC = Copper oxychloride

NICL = Nickel chloride

Table III. *Evaluation of Daconil 2787 and Delan 75WP*

Treatments	Rate/ha	% Blister incidence recorded on				
		August	September	October	November	December
Daconil	560 g	44.1	33.0	12.4	18.4	14.2
Delan 75WP	750 g	42.4	46.9	20.2	29.6	20.5
COC+NICL	210 g each	29.4	22.6	17.9	15.2	14.9
Control	Untreated	58.5	54.1	43.1	48.9	49.6
CD at P = 0.05		7.0	7.4	7.6	10.2	7.5

COC = Copper oxychloride; NICL = Nickel chloride

*Transformed ARCSIN values

Fungicide treatments were put out at regular 7-day intervals. Disease assessment was commenced 3 weeks after the first spray and continued thereafter at weekly intervals. From the plucked crop of each plot 100 shoots were picked at random and examined individually for disease incidence. The percentage of infection, monthwise, based on the average of weekly assessments were analysed statistically for variance.

RESULTS AND DISCUSSION

In all the assessments blister blight incidence was less in Daconil-treated plots, than the standard copper-nickel combination (Table II). In the second experiment (Table III) blister blight infection was less in Daconil treatment in October and December, while it

exceeded marginally in November. Infection levels were higher in Daconil and Delan sprayed plots in August and September under severe wet weather condition.

At present there are only two inorganic fungicides, namely, copper oxychloride and nickel chloride which are widely used by the tea industry to control tea blister blight disease. Out of the many organic fungicides which had systemic action, only two, viz., tridemorph (Calixin 80 EC) and pyracarbolid (Sicarol) controlled the disease very effectively. They were powerful antisporulants and the blister lesions treated with them aborted with a very low basidiospore production (Venkata Ram and Chandra Mouli, 1976). They also possessed long residual action and permitted treatment on extended rounds (Venkata Ram, 1974, 1975; Chandra Mouli, 1979; Shanmughanathan and Saravanapavan, 1978; Satyanarayana *et al.*, 1975). However, application of the organic fungicides with systemic action, on extended rounds, during the severe wet weather of South-West monsoon, met with limited success (Venkata Ram and Chandra Mouli, 1976). This might have occurred due to poor retention of the fungicide in heavy rain, and subsequent exposure of the susceptible foliage to highly abundant inoculum in the atmosphere. In the present experiments also both Daconil and Delan failed to control blister blight satisfactorily when sprayed during the severe South-West monsoon period (Table III). Organic fungicides, if used, during less severe weather conditions provide excellent disease control (Table II and III). It will be advantageous to use organic fungicides in the beginning of the monsoon to reduce

the inoculum production and towards the end to prevent the build-up of mite pests, as these fungicides were also found to suppress the ubiquitous mite pests in the ensuing dry weather (Chandra Mouli, 1979).

By introducing organic fungicides in the spraying programme the disease could not only be controlled efficiently but also economically. As these fungicides permitted their application on extended rounds, their spraying in the beginning and end of the disease season reduced the number of spraying rounds and thus saved spraying cost and labour. In tea areas influenced by both S.W. and N.E. monsoons, blister blight could assume epiphytotic proportions right from the beginning of June to end of November. In such situations, 27 rounds of treatment, in all, are needed, when organic fungicides with systemic action are included in the spraying schedule (Fig. 1). In the case of inorganic fungicides a total of 34 spray applications at short intervals are

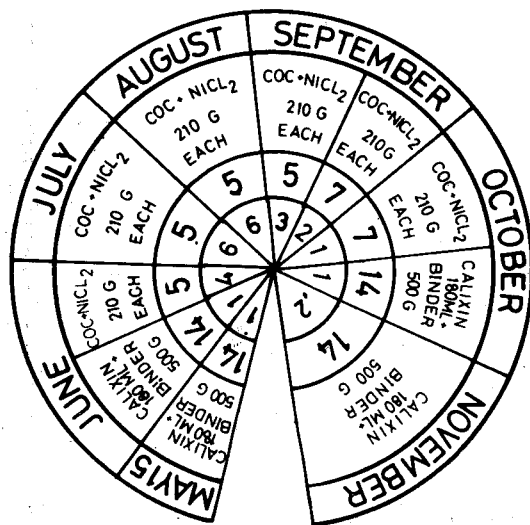


Fig. 1. Spraying schedule

Table IV. *Economics of spraying*

Fungicides	Inorganic inorganic (Conventional)	Organic + (Integrated)
1. No. of sprays	34	27
2. Fungicides	Rs.471.24	Rs.527.00
3. Labour	Rs.191.08	Rs.151.74
4. Fuel	Rs.149.09	Rs.118.39
5. Supervision	Rs. 59.84	Rs. 47.52
6. Depreciation	Rs. 9.52	Rs. 7.56
Total	Rs.880.77	Rs.852.21

Net savings per hectare per season (Rs. 880.77 - 852.21) = Rs. 28.56

required. Thus there is a reduction in fuel, labour and other spraying costs for 7 rounds, amounting to about Rs. 28/- per hectare per season (Table IV). In various investigations (Chandra Mouli, 1979) spraying of organic fungicides towards the end of the disease season also gave an average of about 10 per cent yield increase over the conventional inorganic fungicide application. This point further emphasizes the value of organic fungicides.

Although Daconil 2787 offered excellent disease control of blister blight, its application to the tea growers is not so far recommended because its residue levels and cost of spraying and other economics in tea are still to be worked out. Once these studies are completed and if the treatment is economical, tea industry will be adding one more useful fungicide to its limited list.

Thus, organic fungicides will be playing a vital role in combating tea blister blight in the coming years. Being quite

expensive, they have to be used judiciously in the spraying programme to achieve the desired results economically.

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SUSCEPTIBILITY OF COCOA PODS TO *COLLETOTRICHUM GLOEOSPORIOIDES* INFECTION

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ABSTRACT

Cocoa pods of different sizes and ages were inoculated by spraying a conidial suspension of *Colletotrichum gloeosporioides* Penz. with and without injury. Although all types of inoculations caused infection of cherelles and young pods, severity of infection depended upon the method of inoculation and age of pods. The cork borer method of inoculation was preferred on account of the highest percentage of infection and uniformity in the development of lesions, which facilitated the measurement of lesions and proper assessment of the disease. For the measurement of lesion size seventh day of inoculation of cherelles is ideal. When pods were inoculated without wounds, infection was initiated mostly from the stalk end indicating that the stalk end was more vulnerable for infection than other parts.

The susceptibility of pods decreased with increase in age of pods, the cherelles being more susceptible. Nearly mature pods did not take up infection. There was a significant variation in the lesion size between different age groups.

INTRODUCTION

Among the many important diseases of cocoa (*Theobroma cacao* L.) only a few have been reported from India. Of these, the diseases caused by *Phytophthora palmivora* (Butl.) Butl. (Ramakrishnan and Thankappan, 1965; Chandra Mohanan, 1978), *Colletotrichum gloeosporioides* Penz. (Sarma and Nambiar, 1976; Reddy and Chandra Mohanan, 1976), and *Botryodiplodia theobromae* Pat. (Nambiar and Nair, 1972) were recorded as the major diseases. Various species of *Colletotrichum* infecting cocoa pods have been reported from other countries. They are: *C. theobromae*, *C. luxificum* and *C. cradwickii* from West

Indies, *C. incarnatum* from Cameroons and Sri Lanka (Briton Jones 1934), *C. fructi-theobromae* from Brazil and *C. theobromicolum* from Congo (Thorold, 1975).

It has been reported that isolation of the pathogen from various cocoa gardens occurring in Kerala, Tamil Nadu and Karnataka States of South India invariably yielded *C. gloeosporioides*. It causes pod rot and three types of foliar infection viz., blight, shot hole and irregular spot (Chandra Mohanan and Kaveriappa, 1983a). The studies on the occurrence and distribution of *Colletotrichum* diseases of cocoa have revealed that the pod rot is wide spread in the

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southern states of India (Chandra Mohanan and Kaveriappa, 1983b). In recent years, the incidence of this disease is being increasingly noticed in all the cocoa growing areas of the country. Information on many important aspects of this disease such as susceptibility of pods of different ages is lacking and hence to fill up the gap, the present study was undertaken.

MATERIALS AND METHODS

C. gloeosporioides was isolated from infected cocoa pods of 'Forestero' variety from Vittal (Karnataka State). Inoculum was prepared from 5-day old cultures of the fungus on oat-meal agar medium for all the studies. The pods obtained from a single cultivar were used for the inoculation studies.

Pods of different sizes corresponding to various stages of development and free from bruises, cracks and mechanical injuries were inoculated in the laboratory with and without making wounds. The pods were inoculated by multiple pin prick and injuring by using cork borer. Prior to inoculation, the surface of the pod was sterilized with 0.1 per cent mercuric chloride solution and rinsed in several changes of sterile distilled water (SDW). Cut ends of the stalks were sealed with sterilized paraffin wax. Suitable number of controls were also maintained for each experiment.

(i) *Inoculation by multiple pin prick:* The multiple pin was made by using a cork through which ten randomly placed entomological pins protruded to an extent of 1 mm. Prior to inoculation the pins were sterilized and pressed gently on to

the surface of the pods. Conidial suspension was prepared in sterile tap water and about 0.06 ml of the suspension was aseptically transferred to the surface of each pod with the help of sterile one-ml-pipette.

(ii) *Inoculation by cork borer:* In this method a small cavity of three mm diameter and two mm depth was made on the surface of the pod in the middle region with the help of a three mm dia cork borer. Mycelial disc of similar size cut from the edge of an actively growing colony by using a similar cork borer was placed in the cavity.

(iii) *Inoculation without injury:* To study the mode of infection, entire surface of healthy pods of different ages without wounds was inoculated with conidial suspension in tap water.

(iv) *Disease development of pods:* To study the rate of spread of lesion, pods of different age groups were inoculated with sporulating mycelial disc at the middle part of the pod, using cork borer method.

In all the above experiments, immediately after inoculation the inoculated area was covered with a thin cotton wad dipped in SDW. The inoculated pods were kept in desiccators containing SDW to provide high humidity (90-100%). The desiccators were incubated at room temperature ($28 \pm 2^\circ\text{C}$).

Observations were made on the time taken for the appearance of initial symptoms and size of the lesions. The diameter of the lesion was measured in two directions at right angles and the average was taken.

Table I. *C. gloeosporioides* infection on pods inoculated with injury

Method of inoculation	Age group of pods	Pods inoculated	Pods infected after (days)							
			3	4	5	6	7	8	9	10
Pinprick method	Cherelles	10	2	10	10	10	10	10	10	10
	Young pods	10	0	1	3	5	5	6	10	10
	Nearly mature pods	10	0	0	0	0	0	0	0	0
Cork borer method	Cherelles	10	10	10	10	10	10	10	10	10
	Young pods	10	0	3	6	6	8	9	10	10
	Nearly mature pods	10	0	0	0	0	0	0	0	0
Control	Cherelles	10	0	0	0	0	0	0	0	0
	Young pods	10	0	0	0	0	0	0	0	0
	Nearly mature pods	10	0	0	0	0	0	0	0	0

(v) *Susceptibility of pods of different sizes*: Pods of different stages of development were selected for this study. Pods up to 100mm length, 100 to 160mm length and above 160mm length were considered as cherelles, young pods and nearly mature pods respectively.

Intact pods of different sizes from very small cherelles to nearly mature pods were inoculated in the field. The size of each pod was determined. Pods were inoculated by the cork borer method. After inoculation, each pod was covered with a sterile polythene cover containing sterile cotton was dipped in SDW. The humidity inside the covers ranged from 85-90% as determined with a hygrometer. The lesion diameter was measured seven days after inoculation as explained earlier. Each treatment was replicated three times with five pods per replication.

RESULTS AND DISCUSSION

Although all types of inoculations caused infection of cherelles and young pods, severity of infection and period of incubation for infection depended upon

the method of inoculation. Nearly mature and mature pods could not be infected by any of the methods.

Among the wound inoculation methods, cork borer method resulted in the highest percentage of infection (Table I). Maximum percentage of infected pods was observed after seven days of inoculation by the cork borer method. In addition the lesions caused by cork borer inoculation method were more uniform and regular than by the pin prick method.

The results of infection of pods inoculated without injury are summarised in Table II. In all the cases, cherelles were found to be more susceptible. Maximum infection occurred at the stalk end.

Although the percentage of infection on pods by cork borer and pinprick methods was more or less the same, the cork borer method was preferred for pod inoculation studies on account of the uniformity in the development of lesions which facilitated the measurement of the lesions and proper assessment of the disease. When pods were inoculated without wounds,

Table II. *C. gloeosporioides* infection on pods inoculated without injury

Region of inoculation	Age group of pods	Pods inoculated	Pods infected after (days)							
			3	4	5	6	7	8	9	10
1. Stalk region	Cherelles	10	0	6	8	10	10	10	10	10
	Young pods	10	0	0	0	1	2	3	4	5
	Nearly mature pods	10	0	0	0	0	0	0	0	0
2. Tip of the pods	Cherelles	10	0	0	3	5	8	8	10	10
	Young pods	10	0	0	0	1	2	2	2	3
	Nearly mature pods	10	0	0	0	0	0	0	0	0
3. Whole of pod surface	Cherelles	10	a. 0	5	7	8	10	10	10	10
			b.(0)	(0)	(3)	(3)	(5)	(7)	(8)	(10)
			c. 0	0	0	0	0	0	2	3
	Young pods	10	a.(0)	(0)	(0)	2	2	2	4	4
			b.(0)	(0)	(0)	(0)	(0)	(1)	(2)	(2)
			c. 0	0	0	0	0	0	0	0
	Nearly mature pods	10	a. 0	0	0	0	0	0	0	0
			b.(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
			c. 0	0	0	0	0	0	0	0

a = Infection from stalk end of the pod

b = Infection from tip of the pod

c = Infection from other regions

Values in parenthesis denote pods infected from both stalk end and tip

Table III. Disease development on cocoa pods inoculated with *C. gloeosporioides*

Age group of pods	Appearance of initial symptom (day)	Lesion diameter (in mm)* Days after inoculation				Mean
		4	5	7	9	
<i>Cherelles:</i>						
60-80 mm length	3	14.70	18.90	26.30	45.90	26.45
85-95 mm length	3	11.90	14.90	18.50	26.90	18.05
<i>Young pods:</i>						
95-115 mm length	4	10.70	14.72	18.70	23.70	16.96
120-135 mm length	5	0	6.70	10.30	12.40	7.35
140-160mm length	9	0	0	0	8.80	2.20
<i>Nearly mature pods:</i>						
180-200 mm length	No infection				No infection	
210-245 mm length	No infection				No infection	
Mean		7.46	11.04	14.76	23.54	-

CD (p = 0.05) for comparing days = 1.58

CD (p = 0.05) for comparing age group of pods days = 1.77

CD (p = 0.05) for comparing days × age group of pods = 3.54

*Mean of 3 replications.

infection occurred from the stalk end in maximum number of pods particularly at the point of attachment of stalk to the pod. This indicated that the stalk end was more vulnerable for infection than other parts. The finding is in agreement with the field observations where maximum number of pods were found infected at the stalk end (Chandra Mohanan and Kaveriappa 1983a). The collection of water and moisture at the point of attachment of stalk to the pod might have favoured the settlement of conidia, their germination and subsequent penetration and infection.

The time taken for initial appearance of

Table IV. *Susceptibility of cocoa pods of different sizes to C. gloeosporioides infection on*

Size of the pods (in mm)		Lesion diameter on 7th day (in mm)*
L	B	
<i>Cherelles:</i>		
60	× 20.7	30.50
66	× 24.2	25.33
67	× 23.9	22.83
76	× 24.2	23.33
80	× 27.1	23.33
85	× 28.7	17.50
95	× 34.4	16.83
95	× 33.4	15.33
98	× 36.6	15.00
<i>Young pods:</i>		
100	× 38.2	11.33
100	× 38.8	11.17
130	× 43.0	9.83
150	× 40.7	0
150	× 43.0	0
155	× 43.3	0
<i>Nearly mature pods</i>		
190	× 63.7	0
200	× 68.4	0
225	× 73.2	0
230	× 74.8	0

CD (P=0.05)

3.14

*Mean of 3 replications

the symptoms and the lesion size at different intervals after inoculation are presented in Table III. The rate of spread of infection was faster on cherelles than young pods. Lesions on cherelles developed uniformly up to seven days and thereafter spread irregularly. The period of incubation for infection depended upon the size of the pods.

The lesion diameter on pods of various sizes measured seven days after inoculation, is given in Table IV. The variation in the lesion size between different age groups was found to be highly significant. The pods of 60-80 × 20-27 mm were found to be highly susceptible. The maximum size of lesion was observed on pods of 60 × 20 mm size. Pods of 150-230 × 43-73 mm (nearly mature) could not be infected. This corroborates the observation of Reddy and Chandra Mohanan (1976) that natural incidence of *C. gloeosporioides* pod rot occurred only on cherelles and immature pods with the intensity being more on cherelles.

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EFFECT OF INSECTICIDES ON TRANSMISSION AND ACQUISITION OF 'KATTE' VIRUS OF SMALL CARDAMOM AND THEIR USE IN RELATION TO DISEASE SPREAD AND VECTOR CONTROL

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ABSTRACT

Thirty four insecticides were evaluated against nonpersistent aphid borne 'Katte' virus to determine their effect on transmission and acquisition under laboratory conditions. Transmission results showed that none of the insecticides tested was effective on acquisition and transmission of virus even on the day of spraying. Investigations were also carried to find out the feasibility of using systemic and contact insecticides for control of vector and disease. Regular application of insecticides such as Phosphamidon, Carbofuran and Phorate resulted in significantly more disease spread than control. But in the Methyl parathion, Dimethoate and Quinalphos treated plots the disease incidence was on par with control. However, suppression of aphid pupulation build up was significantly less in all insecticide treated plots.

INTRODUCTION

The 'Katte' or Mosaic disease is causing extensive losses in yield on small cardamom *Elettaria cardamomum* Maton. (Varma, 1962; Venugopal and Naidu, 1984). The first evidence of 'Katte' virus transmission by the banana aphid *Pentalonia nigronervosa* Coq. was reported by Uppal *et al.* (1945). Though extensive studies have been conducted on the virus-vector relationship (Varma and Capoor, 1958; Naidu *et al.*, 1982) and virus transmission by non-host vectors (Rao and Naidu, 1974) no approach was made to control the disease spread by

controlling the vector. Therefore the following studies were undertaken to examine the efficacy of insecticides on aphid vector in various stages of virus acquisition, transmission and disease spread in the field.

MATERIALS AND METHODS

In a green house study, eighteen different contact and systemic insecticides were tested as foliar spray and soil treatment to find out their effectiveness on the process of virus acquisition by the aphid. The aqueous solutions of the test insecticides were sprayed on virus

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infected plants at 0.05% concentration. The granular insecticides tested viz. Carbofuran and Phorate were applied at 1 g a.i./earthen pot of 30 × 32 cm size. Insecticides treated plants were tested as source of virus inoculum starting from day of application to 30 days. Pre-starved apterate aphids were made viruliferous by allowing an acquisition access of 30 min. and released in groups of 10/plant. After 4 hours of transmission feeding aphids were killed mechanically. In each treatment 25-30 seedlings of Malabar type CV-CI-37 at 5-6 leaf stage were maintained. Unsprayed virus infected plants served as control. Efficacy of insecticides was assessed on the basis of transmission percentage in test seedlings.

In a separate study thirty four insecticides were screened to study their effect on transmission under green house conditions. Healthy test seedlings of 5-6 leaf stage were sprayed with test chemicals at 0.05% (ai) concentration. The viruliferous apterate adult aphids were released in groups of 10/test seedling separately at different intervals starting from immediately to 30 days after insecticidal treatment. In case of granular insecticides, inoculation was done on 7th, 15th and 30th day after application. In each treatment 25-30 seedlings of Malabar type CV-CI-37 were maintained. The percentage of disease transmission was considered as the criteria to judge the effectiveness of insecticides.

To explore the possibility of disease control by suppressing vector population, a field trial with Malabar type was conducted for three years (1981-83). Two systemic, two contact and two granular insecticides along with one cultural

practice (removal of old and partly dried pseudostems and leaf sheaths) were tested to control aphid population. In all, eight treatments were replicated thrice. The replicates were arranged in RBD. Each replicate per treatment consisted of 49 plants with one 'Katte' infected plant in the centre. The differential treatments were given at monthly intervals except during monsoon (June to September). The data on the aphid population were recorded after 15 and 30 days of spraying and disease incidence at quarterly interval.

RESULTS AND DISCUSSION

None of the insecticides tested was able to prevent the vector by acquiring the virus from infected plants (Table I). This study clearly suggests that it is impracticable to check the spread of 'Katte' disease by insecticidal treatment of the infected plants only.

It is evident from Table-II that all the thirty four insecticides were not effective in killing the vector before transmission of the virus. Insecticides rarely kill rapidly enough to prevent the probing behaviour of vector. Being non-persistent virus (Rao, 1977; Naidu *et al.*, 1982) 'Katte' virus can be acquired with short probes and can be transmitted within short periods. This may be the reason for the ineffectiveness of insecticides. These results indicate that prophylactic treatment with insecticides may not help in preventing infection from the viruliferous aphids migrating from nearby plantations.

The vector population build up was significantly lower in all the sprayed plots

Table I. *Effect of different insecticides on 'Katte' virus acquisition by the aphids under laboratory condition.*

Sl. No.	Insecticides screened	% of transmission obtained					Mean
		acquisition after spraying					
		1 day	2 days	7 days	15 days	30 days	

Contact insecticides:							
1.	Primophos Methyl 0.05% (a.i.)	20	28	64	76	80	53.6
2.	Nicotine sulphate	24	36	52	76	88	55.2
3.	Permethrin	28	32	56	76	84	55.2
4.	Quinalphos	12	20	16	16	28	18.4
5.	Methyl parathion	25	25	20	24	28	24.4
6.	Chlorophyriphos	24	28	48	56	80	47.2
7.	Fenlorate	12	20	32	36	48	28.6
8.	Fenthion	16	12	12	28	40	21.6
9.	Dichlorovos	20	28	28	36	48	39.4
10.	Malathion	32	20	28	36	56	34.4
11.	B.H.C.	16	20	16	28	36	23.2
12.	Pyrethrum	28	20	24	40	48	32
Systemic insecticides:							
13.	Dimethoate	4	4	20	24	24	15.2
14.	Phosphamidon	4	4	20	24	28	16
15.	Monocrotophos	12	16	20	24	32	20.8
16.	Ethiofencarb	40	40	80	76	76	62.4
17.	Formothion	8	28	40	36	44	31.2
Granular insecticides:							
18.	Carbofuran (5g ai/plant)	—	—	20	28	36	28
19.	Phorate (1.0g ai/plant)	—	—	16	24	40	26.7
20.	Control	78	78	82	86	92	83.2

than unsprayed plots (Table III). Contrary to the expectations, the disease incidence was significantly higher in the treatment plots where phorate, phosphamidon and carbofuran were applied than unsprayed control. There was no significant difference among quinalphos, methyl parathion, dimethoate and unsprayed control. In the case of non-persistent viruses, for example, Potato virus 'Y' insecticides could neither protect the entry nor stop its spread (Burt *et al.*, 1964, Patkar *et al.*, 1969; Nirula and

Kumar, 1967). The cardamom aphid *P. nigronervosa* f. *caladii* is photophobic and it is found in colonies of 30-50 comprising nymphs, alate and apterate adults. These colonies are formed in between the pseudostems and loose leaf sheaths especially of old, partly dried or damaged parts. Occasionally, the colonies are found on the leaf spindles, young suckers and panicles. Because of their concealed placement in the older parts, the possibilities of direct access to contact insecticides and indirect contact

Table II. *Effect of different insecticides on transmission of 'Katte' agent under laboratory condition*

Sl. No.	Insecticide tested	Transmission in different treatments (%) spraying after					Mean
		1 hr.	24 hrs	48 hrs	7 days	15 days	
1	2	3	4	5	6	7	8
1.	Quinalphos	12.0	52.0	48.3	34.5	65.5	42.6
2.	Methyl parathion	30	27.6	46.1	50	53.3	41.4
3.	Phosalone	33.3	50	76.6	93.3	93.3	69.3
4.	Methamidophos	50	86.6	86.6	93.3	93.3	82
5.	Phosphamidon	16.6	23.3	30.0	46.6	56.6	35.3
6.	Dimethoate	16.6	23.3	33.3	46.6	56.6	35.3
7.	Monocrotophos	16.6	13.3	26.6	60	63.3	36
8.	Leybacid	30	36.6	56.6	63.3	63.3	49.9
9.	Fenitrothion	80	66.6	66.6	80	73.3	73.3
10.	Formothion	46.6	66.6	60	80	66.6	69
11.	Endosulfan	26.6	40.	50	63.3	66.6	49.3
12.	Permethrin	26.6	36.6	46.6	63.3	66.6	48.4
13.	Malathion	40	52	76	80	84	66.4
14.	Dichlorovos	34.6	55.1	72	66.6	66.6	59
15.	Ekatox	16.6	40	56.6	53.3	66.6	46.6
16.	Carbaryl (Sevimol)	23.3	36.6	63.3	66.6	70	52
17.	Ekatin	30	36.6	63.3	66.6	70	53
18.	Coroban	23.3	36.6	53.3	56.6	63.3	46.6
19.	Dipterex	33.3	40	50	53.3	56.6	46.6
20.	Birlane	23.3	36.6	56.6	66.6	70	50.6
21.	Phenthoate	16.6	30	33.3	46.6	43.3	34.9
22.	Metasystox	43.3	86.6	80	76	60	69.2
23.	Fenlorate	23.3	40	43.3	66.6	73.3	49.3
24.	Phosvel	66.6	63.3	50	64	52	59.2
25.	B.H.C.	60	64	72	72	72	68
26.	Carbaryl (Sevin)	26.6	50	53.3	83.3	86.6	60
27.	Disopropyl Benzyl thiosulphate (Kitazin)	82.5	75.9	82.2	85.8	92.4	83
28.	Primophos methyl	56	64	72	80	72	68.8
29.	Pyrethrum	33	50.4	80	68	92.4	66.6
30.	Ethiofencarb	64	52	64	68	92	68
31.	Nicotine sulphate	36	60	68	84	92.4	68.1
32.	Phorate (10gm/pot)	—	—	68	24	24	38.7
33.	Carbofuran (30g/pot)	—	—	24	52	20	32
34.	Dasanit (15g/pot)	—	—	40	36	36	37.3
35.	Control	75	76	81	82	88	80.1

with systemic insecticides are less. As a result of insecticides treatment, the colony might have been disturbed and their hyperactivity, probing and inter-

mittent migration in search of suitable host may be responsible for increased spread in some treatments. The increased spread of virus disease due to

Table III. *Effect of insecticide on 'Katte' disease and its vector (Mean of 3 replications)*

Sl.No.	Treatments	Progressive disease incidence (%)			Mean No. of aphids/clump		
		1981	1982	1983	1981	1982	1983
1.	Methyl parathion (0.05%)	2.78	8.33	9.72	0.90	0.19	1.16
2.	Quinalphos (0.05%)	3.47	8.33	9.72	1.09	0.15	1.55
3.	Dimethoate (0.05%)	4.86	9.02	10.41	0.65	0.42	2.61
4.	Phosphamidon (0.05%)	5.57	20.82	22.22	1.16	0.73	2.83
5.	Carbofuran (1.5 kg a.i./ha)	2.08	20.17	22.22	2.63	1.46	11.27
6.	Phorate (15 kg a.i./ha)	6.94	18.06	22.28	1.88	0.55	1.34
7.	Cultural operation Removal of breeding sites	8.78	7.64	9.02	4.47	1.68	9.88
8.	Control	1.72	10.42	10.42	9.54	5.09	37.33
	C.D. at 5%	N.S.	N.S.	3.83	1.31	3.83	4.08
	C.D. at 1%	N.S.	N.S.	5.30	1.82	4.30	5.65

insecticidal application has been reported in other crops also. Broadbent *et al.* (1963) observed that more Narcissus plants became infected with yellow stripe virus in plots sprayed with DDT or a systemic organophosphorous insecticide than control.

Thus the insecticides are ineffective in preventing the entry of infection from other sources and secondary spread of virus within the crop. Deshpande *et al.* (1972) recommended application of dimethoate (0.05%) as one of the pre-treatments in roguing operation of 'Katte' virus infected plants. Since no added advantage was observed, this treatment may be avoided to reduce the cost of crop production.

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EPIDEMIOLOGY OF 'KATTE' VIRUS DISEASE OF SMALL CARDAMOM-II: FOCI OF PRIMARY DISEASE ENTRY, PATTERNS AND GRADIENTS OF DISEASE ENTRY AND SPREAD

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ABSTRACT

Monitoring of forty nurseries raised through seed and voluntary seedlings and twenty two plantations situated at 6-9 Km from the source of inoculum revealed that voluntary seedlings collected from infected plantations and the nurseries located in the vicinity of diseased crop from the primary foci of disease spread. Entry of disease also occurs in contiguous and nearby plantations up to 1,000 m from the external inoculum source. Further centrifugal influx was recorded around primary foci due to secondary spread by the vector. Spatial pattern of spread is concentrated within 40 m radius with occasional introduction of disease up to 90 m distance. Sharp difference in the pattern of spread was observed between the plots with and without roguing. The gradient of the disease decreases steeply near the source of inoculum and less steeply at great distances.

INTRODUCTION

Wide spread prevalence of 'Katte' disease (Mayne, 1951; Venugopal and Naidu, 1981) has been responsible for lower yields in South India. The disease spread in nature occurs by the banana aphid, *Pentalonia nigronervosa* Coq. (Uppal *et al.*, 1945) in a non-persistent manner (Rao, 1977; Naidu and Venugopal, 1982). Within the plantations 'Katte' disease spreads internally (Deshpande *et al.*, 1972) and it tends to be concentrated in patches with occasional new infections. In an attempt to determine whether the foci of infection are from inside or outside the crop and whether any influx is followed by

secondary spread the present studies were undertaken.

MATERIALS AND METHODS

The studies were conducted in forest based pure cardamom plantations with Malabar type, in Kodagu District, Karnataka State.

To assess the role of nurseries in the epidemiology of 'Katte' disease forty primary and secondary nurseries raised through seeds and voluntary seedlings were surveyed. All the seedlings were examined and number of 'Katte' infected plants were recorded. The possibilities of inoculum introduction from external and

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internal sources was studied in twenty two plantations of various age groups located at different distances from virus source over a period of two years (1981-82). The plantations were surveyed at quarterly intervals and the number of independent outbreaks and secondary infections around primary source were recorded. By critical evaluation of pattern of symptom expression and stage of symptoms as suggested by Naidu and Venugopal (1984), the source and age of infection was determined.

The pattern of spread within the plantation was studied by selecting three blocks of 0.5 ha within the radius of 2 Km. In all the 3 blocks the primary infection sources were located and in two blocks the primary and secondary infections were rogued out at monthly interval to study the impact of plant sanitation on the pattern of secondary spread. In all the three blocks new infections were plotted at monthly intervals for a period of three years from 1981-83.

To study the gradient of infection within the plot, five blocks were selected in different locations. After identifying

primary source of infection the disease at different distances were plotted to know the gradient of infection from the primary inoculum source.

The gradient of infection due to multiple infection was studied in an isolated infected block of 6 ha. The infection at different distances from initial inoculum source was plotted upto the other terminus of the plantation.

RESULTS AND DISCUSSION

Role of nurseries in epidemiology of 'Katte' disease

It is seen from Table I that nurseries raised adjacent to infected plantations invariably were infected with 'Katte' disease. As high as 90% infection was recorded in such nurseries. In South India, it is very common that most of the small growers depend on the voluntary seedlings for their planting requirement. Although the 'Katte' disease is not seed transmitted, after germination the seedlings were exposed for infection for a period of 3-4 months in the infected plantation. Out of 14 nurseries raised through voluntary seedlings, six were infected with 'Katte' disease. Such

Table I. *'Katte' infection in nursery*

Seedling source	No. of nurseries examined	Distance from inoculum source(m)	Age of Seedlings (months)	No of seedlings	No of infected nurseries	Infection range (%)
Voluntary	5	100 - 200	6-10	38,000	4	0.04 to 0.2
- do -	9	More than 200	6-18	32,000	2	0.01 to 0.2
Seeds	7	10 - 100	6-18	32,000	6	0.05 to 90.0
- do -	2	101 - 200	6-18	14,500	1	0.00 to 32.0
	17	More than 200	6-18	10,24,000	1	0.00 to 0.2
Total	40	-	-	11,40,500	14	-

Table II. *Primary entry and secondary spread of 'Katte' disease in different plantations*

Sl. No.	Area (Ha.)	Age of the plantation (Yr)	Distance from virus source (m)	No. of primary infections	No. of secondary infections at various distances (m)					Total No. of infected plants	Source of virus entry
					5	10	20	40	100		
1	2	3	4	5	6	7	8	9	10	11	12
1.	10.00	4	500	2	5	4	2	1	-	12	Planting material
2.	12.00	4	800	2	5	-	-	-	-	5	Planting material
3.	2.00	3	1000	1	1	-	-	-	-	1	External
4.	1.00	2	2000	0	0	0	-	-	-	0	Healthy
5.	4.00	4	2000	1	8	5	-	-	-	13	Planting material
6.	3.00	3	300	1	10	1	2	-	-	13	External
7.	4.00	4	500	2	3	-	-	-	1	4	External
8.	1.50	3	1000	0	-	-	-	-	-	0	Healthy
9.	6.00	18	500	0	-	-	-	-	-	0	Healthy
10.	0.80	4	200	0	-	-	-	-	-	0	Healthy
11.	10.00	4	500	0	-	-	-	-	-	0	Healthy
12.	1.50	1	50	1	-	2	2	1	1	6	External
13.	90.00	15	8000	0	-	-	-	-	-	0	Healthy
14.	10.00	13	9000	0	-	-	-	-	-	0	Healthy
15.	4.00	13	5000	0	-	-	-	-	-	0	Healthy
16.	10.00	4	100	8	18	7	2	4	4	35	External
17.	3.00	5	500	0	0	0	0	0	0	1*	External
18.	5.00		1000	0	0	0	0	0	0	2*	External
19.	6.00	3	6	0	0	0	0	0	0	5*	External
20.	62.00	4-10	120	0	0	0	0	0	0	8*	External
21.	3.00	4	120	0	0	0	0	0	0	3*	External
22.	8.00	3	68	0	0	0	0	0	0	5*	External

*No of independent infections in to years.

infected seedlings form the initial source of disease in disease-free plantations.

Entry and spread of 'Katte' disease in plantations

The results presented in Table II clearly show that in many cases, in isolated plantations the disease entry occurs through infected planting material. The initial spread in the contiguous and nearby plantations occurs through the alate viruliferous aphids. The fresh entry in disease free plantations located at 6 to 9 Km from virus sources suggests that the source of infection is external and alate

aphids are playing a role in the external spread. Though 'Katte' is non-persistent and persistence with aphids is only for 2-3 hours, the alate aphids either actively or passively can travel quite distance within this interval and can play important role in external spread. The new infections around primary foci were found within 5 m radius and number of infections decreased as the distance increased. However, out of 22 plantations observed eight isolated plantations located at 200 to 9,000 m from virus source were found to be free from infection, though they were exposed for

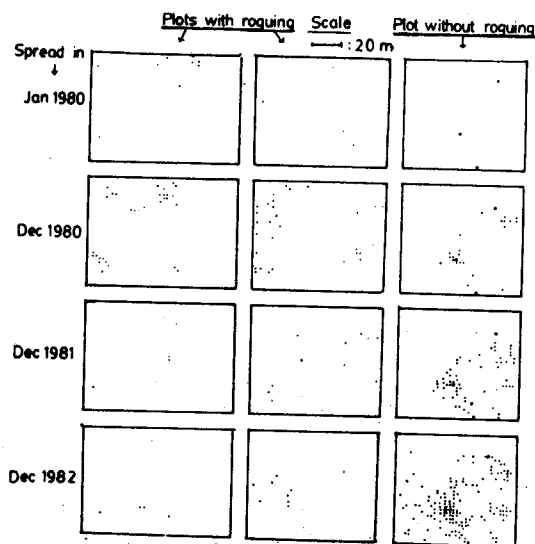


Fig. 1. The pattern of 'katte' disease spread in field experiments with and without roguing of infected plants.

natural infection for a period of 2-18 years.

The pattern of 'Katte' spread in the plots with and without roguing.

The regular tracing of infections around primary foci over a period of 3 years indicated that the disease spread is mainly centrifugal and it is concentrated around 20-30 m from inoculum source

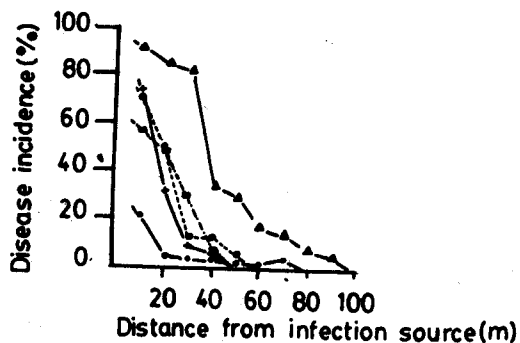


Fig. 2. The gradients of 'katte' virus spread within the plots at five locations.

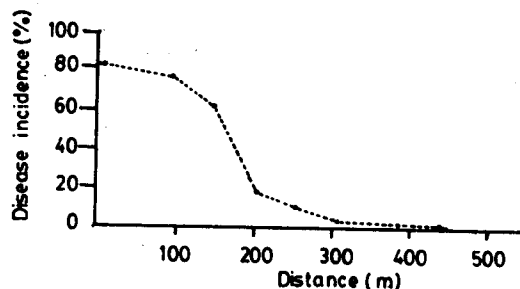


Fig. 3. The gradient of 'katte' disease spread in cardamom with four years infection on one side of the plantation.

(Fig-1). The spread of 'Katte' is more in the plot where no roguing was followed. Progressive decreased infections in the plot with roguing suggests that continuous elimination of inoculum source is having profound impact on the management of the disease. Naidu and Venugopal (1982) reported the benefits of roguing in minimising the 'Katte' disease spread. This study further confirms that pattern and number of new outbreaks are directly influenced by the amount of internal inoculum source.

Gradient of 'Katte' disease spread

It is seen from Fig-2 that the gradient of infection is steep within 40 m from virus source and it flattens thereafter. The influence of multiple infections on the gradient of disease spread is shown in Fig-3.

Though the test plantation was exposed to infection for over 4 years, the intensity of the disease was more in one end which was infected earlier. Thereafter, the disease gradient decreased steeply and it flattened as the distance increased. In spite of access to virus for over 4 years, no infection was noticed beyond 450 m from the initial inoculum source. On the basis of the above results,

the following recommendations are made for avoiding entry and secondary spread of 'Katte' Virus: (i) Raising nursery in isolated places away from infected plantations, (ii) Total avoidance of voluntary plants from infected plantations for propagation, (iii) Inspection of all plants in disease free plantations once a year to eliminate primary infections which spread from external sources, and (iv) Regular roguing to reduce internal inoculum and secondary spread.

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SPRAY FLUID REQUIREMENTS IN HIGH VOLUME SPRAYING OF RUBBER

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ABSTRACT

An experiment to determine the minimum spray volume required for adequate protection of mature rubber trees against abnormal leaf fall by spraying one per cent Bordeaux mixture revealed that satisfactory leaf retention could be ensured by using 3000 litres per hectare. The reduction in spray volume to 3000 litres from the current recommendation of 5000 litres helped in a saving of Rs. 560/- per hectare.

INTRODUCTION

The abnormal leaf fall disease of rubber (*Hevea brasiliensis*) caused by *Phytophthora* spp. is the most economically important disease in Kerala as it can cause an yield loss upto 30-50% (Ramakrishnan, 1960). Therefore, much importance has been given by planters for prophylactic spraying of fungicides to check the disease. Of the two types of spraying viz., low volume and high volume, the small holders usually prefer high volume spraying with 1% Bordeaux mixture to low volume due to many practical difficulties like the fragmented distribution of holdings, paucity of machines and high capital investments on low volume sprayers. The present study was undertaken to find out an optimum quantity of spray fluid (Bordeaux mixture) for a hectare of mature rubber to get good leaf retention.

MATERIALS AND METHODS

The experiment comprised 6 treatments having 4 replicates each, in which 1% Bordeaux mixture was used at five

different volumes viz., 1000, 2000, 3000, 4000 and 5000 litres per hectare, with an unsprayed plot serving as control. This was laid out in randomised block design at Central Experiment Station of RRII, Chethackal, and continued for 3 years. The plot size was 0.1 ha. having mature GG clonal trees of 1969 planting. The spraying was carried out in May prior to the onset of south-west monsoon using rocker sprayers. The delivery hose of the sprayer was attached to a 2.5 metres long bamboo lance fitted with multi-directional duromist nozzle.

To assess the percentage leaf retention of leaves on trees, four trees in the middle of each plot were selected and the leaves from two twigs each from the middle region of the crown of these trees were counted just after spraying and again after the disease season.

RESULTS AND DISCUSSION

Data presented in Table I reveal that T_1 (5000 l/ha) recorded the highest leaf retention in all the three years of trial,

Table I. *Mean percentage leaf retention for 3 years*

Year	Treatments						
	T ₀ Unsprayed	T ₁ 5000 l/ha	T ₂ 4000 l/ha	T ₃ 3000 l/ha	T ₄ 2000 l/ha	T ₅ 1000 l/ha	
1st year	36.43	59.58	53.71	51.72	46.08	41.28	SE + 3.87
	*(35.63)	(74.05)	(64.55)	(61.53)	(51.83)	(43.68)	CD at 5% 11.66
2nd year	42.41	74.52	71.28	66.20	55.88	51.70	SE 1.74
	(45.53)	(92.65)	(89.00)	(83.45)	(68.50)	(61.43)	CD at 5% 5.24
3rd year	50.72	67.64	66.79	63.59	56.39	57.99	SE 2.17
	(59.88)	(84.35)	(84.23)	(80.13)	(69.08)	(71.63)	CD at 5% 6.54

*Figures within brackets indicate percentage leaf retention + SE and CD for angles

followed by T₂ (4000 l/ha) and T₃ (3000 l/ha). T₁ differed significantly to all other treatments in the first year, whereas T₂ and T₃ were at par. However, T₂ and T₃ did not differ significantly within T₁ in the subsequent years. The unsprayed plots consistently showed the lowest leaf retention.

These results indicate that the treatments where low quantity of spray volume (1000 or 2000 l/ha) was used were

quite inadequate for sufficient coverage of leaves, whereas T₁, T₂ and T₃ recorded good leaf retention as the quantity of spray fluid could cover the entire canopy.

Earlier field experiments showed that a leaf fall upto 25% did not affect the crop yield whereas 50% leaf fall or more did cause considerable yield drop (Radhakrishna Pillai *et al.*, 1974). Peries (1966) recording similar observations from Sri Lanka opined that when a plant was de-

Table II. *Split up of the cost of spraying for one hectare mature rubber with 5000 and 3000 litres of 1% Bordeaux Mixture*

Items	5000 litres			3000 litres		
	Quantity	Rate Rs. Ps.	Cost Rs. Ps.	Quantity	Rate Rs. Ps.	Cost Rs. Ps.
Copper sulphate	50 kg	16.00	800.00	30 kg	16.00	480.00
Lime	50 kg	1.50	75.00	30 kg	1.50	45.00
Capital investment, repair etc.	—	—	25.00	—	—	25.00
Labour	30 Nos	21.00	630.00	20 Nos.	21.00	420.00
			1530.00			970.00

foliated by a disease or by mechanical means, the efficiency of the remaining leaves enhanced so as to compensate for the loss. When conditions are very much favourable for the disease, the leaf fall can exceed more than 25% even in the plots sprayed with 5000 litres of fungicide/ha, as observed in the first year. But in case of moderate to high infection, more than 80% leaf retention can be ensured with 3000 litres or more per hectare. Considering the economics of spraying and the fact that 25% leaf fall would not affect the crop, T_3 (3000 l/ha) can be preferred to T_2 (4000 l/ha) and T_1 (5000 l/ha). This reduction in spray volume can reduce the spraying cost considerably (Table II).

The scarcity of water in the plantations during the spraying season is one of the major constraints in the high volume spraying in small holdings. As the quantity of water is reduced considerably, the labour requirement can also be reduced proportionately. Data in Table II show that the cost of spraying with 1% Bordeaux mixture with the current recommendation of 5000 litres is Rs. 1530, whereas with 3000 litres the cost can be reduced to Rs. 970/-. Therefore, by the

reduction in volume from 5000 to 3000 litres a saving of Rs. 560 per hectare could be effected.

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CROWN BUDDING – A METHOD TO REDUCE COST OF PRODUCTION OF NATURAL RUBBER IN INDIA

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ABSTRACT

Since the abnormal leaf fall disease of rubber caused by *Phytophthora* spp. is very severe and debilitating, crown budding of high yielding susceptible clones, viz., GT 1, RRIM 600 and RRIM 628 with disease resistant/tolerant clones viz., F 4542, FX 516 and RRII 33 was tried to combat the disease.

Leaf retention against abnormal leaf fall disease of unsprayed crown budded plants was very good when compared to sprayed control plants. The yield of RRIM 600 and RRIM 628 crown budded plants was higher than control plants whereas yield of GT 1 crown budded plants was found to be lower in the cases of all three crown clones. Though, the crown budding appears to be a promising method in the control of abnormal leaf fall disease, further experimental data for all available high yielding clones are necessary for making general recommendation of this technique.

INTRODUCTION

Crown budding of high yielding susceptible panel clones with disease resistant clones was introduced in India in the rubber culture with a view to reducing the cost of production of natural rubber. Most of the high yielding clones and clonal seedling rubber cultivars used in India are susceptible to abnormal leaf fall disease caused by *Phytophthora* spp. In high yielding clones, annual loss due to this disease is estimated to be about 30 to 50 per cent (Ramakrishnan, 1960). Abnormal leaf fall disease recurring annually during south west monsoon period requires costly prophylactic spraying of copper fungicides (Radhakrishna Pillai, 1977) resulting in high cost of production of rubber. The control of abnormal leaf fall disease by fungicide application is also a short term remedy

only. The clones found to be resistant/tolerant to this disease are low yielders. Hence, the crown budding on high yielding clones with resistant/tolerant clones was tried and such technique will be more economic and permanent solution for reducing the cost of production of natural rubber.

MATERIALS AND METHODS

Two-year-old high yielding clones viz., RRIM 600, RRIM 628 and GT 1 were crown budded (Yoon, 1957, 1971, 1972, 1973) at a height of 2.5 to 3 m from the primary bud union with F 4542, FX 516 and RRII 33 which were found to be resistant/tolerant to abnormal leaf fall disease and also to other diseases. The crown budded plants were left unsprayed from the very beginning and leaf retention assessment against abnormal leaf fall

Table I. *Leaf retention against abnormal leaf fall disease (in %)*

Clone	Location I (Panel clone GT 1)						Location II (Panel clone RRIM 628)						Location III (Panel clone RRIM 600)					
	1979	1980	1981	1982	1983	1984	1979	1980	1981	1982	1983	1984	1979	1980	1981	1982	1983	1984
F4542	91	92	84	85	72	80	94	93	93	69	80	71	88	95	90	56	73	76
FX 516	93	91	89	90	64	80	91	93	92	72	82	79	92	96	92	57	78	80
RRII 33	88	87	88	84	73	80	90	94	94	70	90	84	87	97	91	84	81	82
Control	31	73	44	51	68	65	56	27	41	14	8	63	22	66	26	68	22	61

disease was carried out. Girth measurement was recorded at the height of 125 cm from the primry bud union during 5th, 9th and 13th year of crown budding. Yield of randomly selected plants was recorded by cup coagulation method from the second year of tapping.

RESULTS AND DISCUSSION

Leaf retention against abnormal leaf fall disease in crown budded areas was higher than that of copper fungicides sprayed areas (Table I). The powdery mildew disease incidence was very severe during 1984 and caused repeated leaf fall and die-back even in the three round sulphur-dusted areas due to unusual rains during the refoiliating period, but crown budded plants escaped from this disease by their early wintering habit.

During the immaturity period, girth of

control plants was more than that of crown-budded plants. Crown budded plants attained tappable girth by the seventh year while the control plants by the sixth year. But during the tapping period, girth of the RRIM 628 and RRIM 600 crown budded plants increased making them on par with control or in certain combinations even surpassing it. Whereas the girth of GT 1 crown budded plants was found to be less than that of the control plants (Table II).

The yield data indicate that yield of RRIM 600 and RRIM 628 crown budded plants was more than that of control plants. However, in the case of GT 1 the yield of crown-budded plants was found to be less than the control plants (Table III). Out of the three clones used RRIM 600 and RRIM 628 were most compatible to attain maximum girth and yield.

Table II. *Girth (in cm) at 125 cm height*

Clone	Location I (Panel clone GT 1)			Location II (Panel clone RRIM 628)			Location III (Panel clone RRIM 600)		
	5th year	9th year	13th year	5th year	9th year	13th year	5th year	9th year	13th year
F 4542	40	59	71	42	62	71	29	60	70
FX 516	40	68	81	35	66	69	34	57	72
RRII 33	36	61	75	35	59	74	31	58	75
Cqntrol	51	79	85	46	58	71	38	56	66

Table III. *Yield (dry rubber/tree/tap in g)*

Clone	Location I (Panel clone GT 1)						Location II (Panel clone RRIM 628)						Location III (Panel clone RRIM 600)					
	1979	1980	1981	1982	1983	1984	1979	1980	1981	1982	1983	1984	1979	1980	1981	1982	1983	1984
F 4542	20	26	30	32	40	42	41	74	62	67	61	62	38	40	41	50	42	48
FX 516	23	31	35	37	42	35	62	70	57	57	53	66	32	48	38	49	36	47
RRII 33	21	29	30	34	44	34	48	65	55	75	56	73	38	37	40	51	50	57
Control	36	47	47	49	62	46	33	41	41	46	50	52	36	36	35	30	31	41

By adopting crown budding it is observed that the immaturity period may be extended by about one year. This loss due to delay in attaining maturity will be more than compensated by the possible annual saving in spraying expenses and by increase in yield.

Though the crown budding appears to be a promising method in control of abnormal leaf fall disease, further experimental data for all available high yielding clones are necessary for making general recommendation of this technique.

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SPEAR ROT OF OIL PALM (*ELAEIS GUINEENSIS* Jacq.) IN INDIA

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ABSTRACT

Spear rot is characterised by yellowing of inner whorl of leaves and spear rot, and causes drastic reduction in vigour and productivity. The extent of the disease is up to 1 per cent in oil palm plantations of Kerala. The disease has not been reported from Andaman Islands. Preliminary observations on the pattern of spread indicate that while fresh occurrences are sporadic, palms adjacent to the disease affected ones are more vulnerable to the disease. Occurrence is severe in low lying marshy places and slopes. *Fusarium moniliforme* and *F. semitectum* were isolated from spear rot affected leaves. As a precautionary measure, eradication of diseased palms in mildly affected plantations is recommended.

INTRODUCTION

Oil palm grown in different parts of the world are reported to have been affected by many diseases, of which, a few such as Ganoderma basal stem rot, stem rot, Fusarium vascular wilt and spear rot are the serious ones. Since the introduction of oil palm for commercial cultivation in India in 1971, only bunch failure has been reported to cause any significant loss (Anonymous, 1984). In recent years a new disease called spear rot disease has been noticed in the oil palm plantations of Kerala to the extent of one per cent.

Symptoms

The initial symptom of the disease is yellowing of the youngest whorl of leaves. Yellowing starts from tip of the leaves progressing towards the base. Marginal yellowing of leaflets with a green portion along the mid-rib is also characteristic. On close examination of the spear, water soaked lesions are seen at the distal

portion extending downwards resulting in rotting and foul smell (Fig. 1). Examination of sixty disease affected palms of varying ages (3-15 years) revealed that rotting was confined to portions 50 cm above the meristem. The outer leaves remained green as in the case of healthy palms and the bunches produced were normal in the initial stages. The leaves emerging later on showed rotting and were reduced in size. With disease advancement (Fig. 2), the leaves became rudimentary with severe rotting. Though inflorescence initiation was noticed in axils of affected leaves, they became aborted before emergence, resulting in total loss of bunches. In older palms, tapering of trunk was noticed. The disease was nonlethal and debilitating in nature. Fish-bone leaf production was noticed on 5% the palms affected by this malady. Injuries due to Rhinoceros beetle infestation was noticed on 20% of the affected palms.

Occurrence of spear rot without

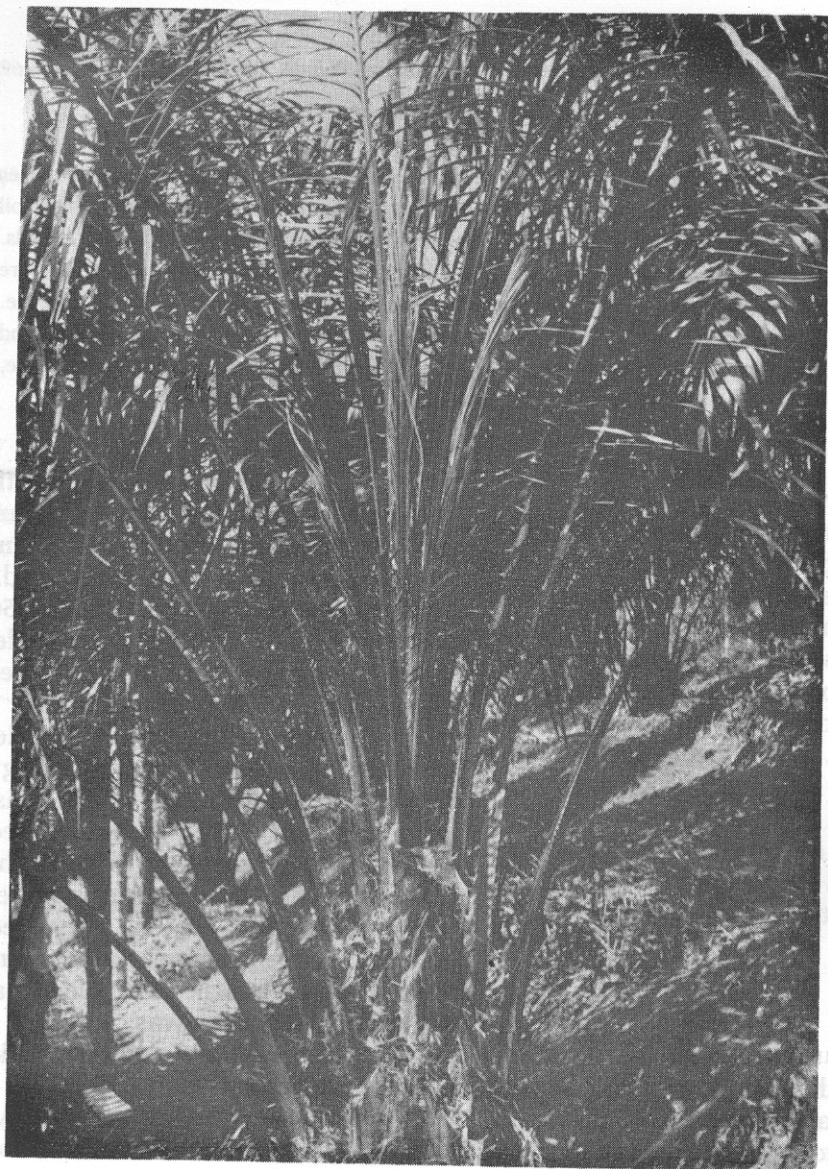


Fig. 1. Spear rot affected palm – early stage



Fig. 2. Spear rot affect palm – advanced stage

yellowing of the youngest whorl of leaves and vice versa was also noticed on a few palms. Such palms were not easily noticed since there is no yellowing of leaves.

Occurrence and Distribution

Initial occurrence of the disease was sporadic. The low lying marshy places and hill slopes were potential spots where disease incidence was more and the spread faster. However, there were low lying spots with no disease incidence either. Secondary spread was mostly on palms adjoining the diseased ones. Preliminary observations conducted at Palode, Chithara and Kulathupuzha

plantations in Kerala for one year from June, 1985 to May, 1986 indicated a higher disease incidence during the rainy season.

Disease incidence was more on palms in the age group of 3-5 years (Table I). All the introductions (from Nigeria, Malaysia, Republic of Zaire and Ivory Coast) were found affected by this malady. Disease incidence was very high (18%) in the Tenera $\times$ Tenera population in the Palode plantation. The locations within a plantation played an important role in disease incidence and spread indicating the role of predisposing factors in disease occurrence or individual host-

Table I. *Incidence of spear rot complex in oil palm plantations of Kerala*

Plantation	Area (ha)	Total no. of palms	No. of Disease affected palms	Year of Planting	Source
CPCRI Palode					
Tenera x Tenera plot Germplasm Collections	1.42	200	36	1983	Palode
Genetic Experiment	2.21	310	16	1981	Nigeria, Ivory Coast, Palode, Zaire
CPCRI, Kayangulam	13.45	1882	24	1976	-
Oil Palm India Ltd.	0.12	16	1	1969	-
Chithara	1018.25	145511	743	1981 to 1984	Nigeria, Zaire and Ivory Coast
Kulathupuzha	493.82	69135	22	1982	Zaire
	233.3	32662	101	1983	Ivory Coast
	271.65	38031	31	1984	-do-

pathogen relationship or involvement of pathogens of other crop diseases.

Another interesting observation was the total absence of the disease in 1600 ha of oil palm plantations in Little Andamans, where introductions from Malaysia, Nigeria, Zaire and Papua New Guinea were planted since 1976.

Etiology

Isolations carried out from spear rot affected tissues yielded *Fusarium moniliforme* and *F. semitectum*. Pathogenicity experiments with the fungal cultures are in progress. Involvement of other etiological agents such as mycoplasma like organisms, virus, bacteria, nutritional deficiency and heavy metal toxicity is being investigated.

DISCUSSION

Spear rot is a consistent symptom of about six prominent diseases of oil palm in various parts of the world. This disease is quite different from the other diseases like nursery spear rot, crown disease or juvenile disease or spear rot-bud rot-little leaf disease complex, wither tip, fatal yellow and patch yellow (Turner, 1981; Turner and Bull, 1967). Although yellowing of younger leaves in spear rot complex is similar to that of fatal yellowing, the other symptoms (especially the non-fatal nature of this malady) do not tally. Reddy *et al.* (1984) reported that the spear rot affected palms in Yeroor plantations showed foliar yellowing. Often spear rot and yellowing occur independently. This requires

detailed investigation to prove whether it is a manifestation of different symptoms due to the same etiological agent of spear rot complex or independent etiology.

A careful scrutiny of the characteristic symptom, nature and pattern of spear rot diseases abroad in comparison with spear rot complex is suggestive of its independent identity. Turner (1981) opined that the oil palm in new environment may be prone to new disease problems. Dollet (1978) reported that Cadang-cadang viroid of coconut could infect oil palm in Philippines. Infectious spread to adjacent palms is suggestive of the involvement of biotic agents in this malady. Absence of spear rot complex in plantations of Andaman Islands is indicative of the possible role of environmental factors or pathogens of other crop diseases in Kerala.

The symptomatology and etiology of spear rot of oil palm seem to be different from those of coconut root (wilt) and arecanut yellow leaf diseases. The characteristic symptoms viz., yellowing of outer whorl of leaves and flaccidity in arecanut yellow leaf disease and coconut root (wilt) disease respectively are not noticed in spear rot affected oil palms. In yellow leaf disease of arecanut symptoms are prominent only after rains (October-November), whereas there is no seasonal change of symptom expression in the case of oil palm. Mycoplasma like organisms which are observed in tissues affected by coconut root (wilt) and arecanut yellow leaf diseases are not observed in the oil palm samples examined (J.J. Solomon, Per. Comm.)

Association of *Fusarium moniliforme* (Colombia and Cameroun) and *F.*

semitectum (Colombia) with spear rot has been recorded (Anonymous, 1970). Preliminary observations indicate that eradication of diseased palms in mildly affected areas helps to contain the disease. Study on disease recurrence in replanted and adjacent palms is in progress.

There is considerable circumstantial evidence that attacks by *Oryctes rhinoceros* are the most important in promoting spear rot-bud rot-little leaf disease syndrome in the Far East, its incidence being greatest in young plantings when palms are most prone to beetle damage (Turner and Bull, 1967; Sharples, 1925). The possibility of injuries caused by Rhinoceros beetles serving as entry points for the pathogens spear rot complex will have to be studied.

The following precautionary measures are suggested: The severely affected palms are to be rogued and replanted. For palms in the early stage of disease, the affected portions should be removed and treated with a protective fungicide against *Fusarium* spp. A prophylactic spray to the spear leaves of palms during pre-monsoon period may help in tiding over fresh disease occurrence/spread. Strict plant quarantine measures to prevent the movement of oil palm planting materials from disease affected area in mainland to Andamans should be adopted.

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MANAGEMENT OF WILT AFFECTED BLACK PEPPER (*PIPER NIGRUM* L.) GARDENS

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ABSTRACT

The agro-technology for the management of wilt affected pepper gardens was studied for four years. Phytosanitation, rejuvenation of the garden by replacing the wilt-affected vines with high yielding types, replanting after the removal of all pepper vines in the garden, use of amendments, soil nutrient-moisture manipulation, cultural practices and use of pesticides were followed. Economics of management was worked out. Results show that management of the wilt affected pepper gardens is economically feasible.

INTRODUCTION

Among the pepper diseases, quick-wilt or foot rot (caused by *Phytophthora palmivora*) and slow wilt or yellow disease (caused by nematodes) take the heaviest toll of the crop. In a recent survey, Balakrishnan *et al.* (1986) estimated that 1.68 lakh vines perished during 1981-84 due to quick wilt alone in Calicut district amounting to an yield loss of 114 metric tonnes of pepper, and that the disease had spread to about 23% of the cultivated area within three years. de Waard (1979) estimated an annual global loss of 4.5-7.5 million dollars due to foot rot disease in the major pepper growing countries of the world. Information on disease management of pepper is meagre. A study was, therefore, undertaken in 1982-86 in which resort was made to various agro-techniques for the management of wilt diseases.

MATERIALS AND METHODS

The study comprised a field experiment in split plot design with four replications.

The experiment was started in 1976 in 1.80 ha land planted with two varieties of pepper (Panniyur-I and Karimunda) trailed on two living standards (*Erythrina indica* and *Garuga pinnata*) and three non-living standards (R.C.C. post, granite post and teak post) with two spacings (3 × 3 m and 3 × 2 m). The pepper vines in this experiment were devastated due to quick wilt disease during July-September 1982. The teak posts were replaced by the live standard *Glyricida maculata* in 1983, as the former got decayed due to white ant attack. The soil is latosol (pH 5.5, C = 1.66%, Bray-P 27 ppm, K 59 ppm, exchangeable Ca 6 m.e. per 100g and exchangeable Mg 2 m.e./100g, Fe 58 ppm, Mn 4 ppm, Zn 0.6 ppm and Cu 2.0 ppm). All the wilt affected vines were uprooted and pits burnt and drenched with 0.2% copper oxychloride @ 5 l/pit and gap filled with Panniyur-I or Karimunda in June 1983 after application of farm yard manure (FYM) at 9 kg/vine. Before planting, one kg neem cake and 0.5 kg bone meal were also added to each pit and mixed with

dolomite @ 1 kg/vine. Rooted pepper cuttings were planted a fortnight thereafter. At the time of planting pepper, phorate was applied at 10g/vine. The vine basins were mulched with green leaves @ 5 kg/vine during November-December every year.

Another field experiment, comprising pepper germplasm planted in 1976, using *E. indica* as standard was devastated due to wilt-diseases in 1982. This plot was used for studying the effect of complete replanting of wilt-affected garden. The soil is latasol (pH 5.3, C 1.44%, Bray-P 13 ppm, K 78 ppm, exchangeable Ca 8 m.e./100g and exchangeable Mg 3 m.e./100g, Fe 14 ppm, Mn 2 ppm, Zn 0.81 ppm and Cu 1.88 ppm). All the vines in the plot were uprooted and replanted with Panniyur-I or Karimunda at 1:1 ratio, after adopting the agrotechniques followed in the case of rejuvenation by gap filling described.

Inorganic nutrients @ 100g N (as urea), 40g P₂O₅ (as Mussoorie phos) and 140 g K₂O (as muriate of potash) were applied to each adult vine. The first half of the nutrients was applied in May-June and second half in August-September. Full dose of nutrients was applied to the plants during the third year only, while in the second year 2/3 of the dose and in the first year only 1/3rd was given.

Vines were sprayed with Bordeaux mixture 1% during May-June and August-September provided there was disease incidence. Bordeaux paste 10% was applied at the collar region of the vine each year in May-June. Disease affected runner shoots alone were clipped off, while other runner-shoots were tied to

the standards. Drainage channel was provided at the lower portion of the plots to drain off water from the diseased garden and to increase aeration. Pits of 30 cm³ were taken between two pepper plants and banana (cv. Mysore poovan) was planted in both the plots for imparting shade to young pepper vines. Phorate was applied at 10 g/pits to control nematodes. Banana was manured with NPK @ 100:200:400 kg/ha. Congo signal (*Brachiaria brizantha*) grass seed was broadcast at 4 kg/ha, and manured with 50 kg each NPK/ha., to reduce summer soil temperature and for keeping the soil firm against soil erosion. The economics of the disease management was worked out.

RESULTS AND DISCUSSION

Rejuvenation of the diseased gardens

Rejuvenation of the disease affected gardens was accomplished by (1) removal of the diseased vines and gap filling and (2) replanting after the removal of all the vines in the garden.

Data (Table I) show that after the incidence of wilt disease, significantly higher survival (12.32%) was registered in Panniyur-I as compared to Karimunda (4.48%) showing that under field condition quick wilt infection in Panniyur-I was less than in Karimunda. Kueh Tiong Kheng (1979) reported that in Sarawak, variety Kuching was very susceptible to quick wilt. while Sarma *et al.* (1982) in India, reported that Narayakodi, Kuthiravally, Uthiran Kotta and Balankotta registered lower percentage infection due to quick wilt as compared to other varieties.

Table I. *Relative percentage of survival of black pepper varieties trailed on different standards**

Standards Varieties	<i>Erythrina indica</i>	<i>Garuga pinnata</i>	R.C.C. post	Granite post	Teak post	Mean
Panniyur-I	25.98	13.94	8.79	7.46	5.44	12.32
Karimunda	7.29	6.25	4.16	1.56	3.12	4.48
Mean	16.63	10.09	6.48	4.51	4.28	8.90

*After the incidence of wilt disease in 1982

C.D. for varieties 3.75. C.D. for standards 5.93

As regards survival of pepper vines trailed on to different standards, those trailed on *E. indica* registered a significantly higher percentage of survival (16.63) than those on other standards (Table I). This may be attributed to factors like shade, mulching effect due to shedding of leaves of live standards, increased organic matter status in the soil etc. due to decomposition of leaves shed from the standards like *E. indica* or *G. pinnata*.

Rejuvenation by gap filling

After rejuvenation of the diseased

garden by gap filling, the recurrence of the disease over the years was very low i.e. 4.52% (Table II). The differences among the varieties with regard to recurrence of the disease was not significant, and this obviously shows that rejuvenation with individual replanting of the diseased vines and adopting agro-technology is one of the efficient methods of disease management.

Rejuvenation by replanting

With regard to the replanting of the diseased garden after the removal of all the vines, the recurrence of the disease

Table II. *Incidence of quick wilt disease in black pepper varieties after rejuvenation by gap filling (Mean percentage)*

Varieties Standards	Year 1984			Year 1985			Overall mean
	Panniyur-I	Karimunda	Mean	Panniyur-I	Karimunda	Mean	
<i>Erythrina indica</i>	3.01	6.30	4.65	6.13	5.55	5.84	5.24
<i>Garuga pinnata</i>	4.33	6.07	5.20	5.73	4.62	5.17	5.18
<i>Glyricidia maculata</i>	9.43	7.69	8.56	4.11	7.13	5.62	7.09
R.C.C post	3.99	3.06	3.53	2.08	4.39	3.23	3.38
Granite post	0.98	2.02	1.50	0.98	2.95	1.96	1.73
Mean	4.35	5.03	4.69	3.81	4.93	4.37	-
Overall mean	-	-	-	4.08	4.98	-	4.52

Table III. Incidence of foliar yellowing in black pepper varieties after rejuvenation by gap filling (Mean percentage)

Varieties Standards	Year						Overall Mean
	1984			1985			
	Panniyur-I	Karimunda	Mean	Panniyur-I	Karimunda	Mean	
<i>Erythina indica</i>	3.00	1.31	2.16	4.45	3.12	3.79	2.97
<i>Garuga pinnata</i>	1.04	0.52	0.78	1.04	0.52	0.78	0.78
<i>Glyricidia maculata</i>	0.46	1.04	0.75	0.52	0.52	0.52	0.64
R.C.C post	1.04	0.98	1.01	0.52	1.04	0.78	0.89
Granite post	1.04	0.98	1.01	1.44	0.52	0.98	0.99
Mean	1.32	0.96	1.14	1.59	1.14	1.37	—
Overall mean	—	—	—	1.45	1.04	—	1.25

over the years was only very meagre (3.0%). Panniyur-I registered lower disease incidence (2.8%) as compared to Karimunda (4.8%).

Foliar yellowing

The incidence of foliar yellowing (Table III) was very low (1.25%) over the years, after gap filling the diseased garden. Among the varieties, Karimunda (1.04%) seems to be less susceptible than Panniyur I (1.45%) in getting foliar yellowing over the years.

After replanting of the diseased garden, recurrence of foliar yellowing over the years was very low (2.32%), Karimunda registered lower percentage (1.85%) as compared to Panniyur-I (2.8%).

Nutrient Management

The application of NPK, liming and the increased microbial activities induced by the addition of neemcake, FYM and bonemeal together with dolomite resulted in an overall beneficial nutrient balance which would have contributed towards

better establishment and yielding from rejuvenated gardens.

Grass cover helped conditioning the soil due to its root effect and improvement of soil structure besides checking soil splashing and reducing summer soil temperature. Another contributory factor for lessening the disease could well be the drainage channel which helped in increasing soil aeration.

Economics

Data in Table IV show that an overall benefit-cost ratio during the third year was 2.09 per ha for rejuvenation by gap filling and ratio of 1.73 per ha for rejuvenation by adopting replanting in the management of the diseased pepper gardens.

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Table IV. *Cost/Benefit analysis of one hectare wilt diseased pepper garden by gapfilling as well as by replanting methods*

Years	Investment in rupees		Return in rupees			
	Pepper by gap filling	Pepper by replanting	By gap filling Pepper alone	Pepper + banana	By replanting Pepper alone	Pepper + banana
1	9075	9500	3050	13675	—	10625
2	8850	8900	15050	25675	10000	20025
3	9060	9300	27375	38000	23750	34375
Overall cost-benefit ratio for 3 years		1:2.09	1:1.73			

Investment cost for banana for 1,2 and 3rd year is Rs. 3500/- Rs. 2695/- and Rs. 2505/-
Return from banana is Rs. 10,625/- ha/year

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Short Scientific Report

EFFECT OF ROOT KNOT NEMATODE, *MELOIDOGYNE INCOGNITA* ON THE GROWTH OF TURMERIC

The root knot nematode, *Meloidogyne incognita* is an important pest of turmeric and has a wide distribution in Kerala State (Nadakai and Thomas, 1964; Sundararaju *et al*, 1979; Venkitesan and Charles, 1980). Though turmeric has been reported as host of *Meloidogyne incognita* there is hardly any information on the effect of this nematode on turmeric growth and yield. To fill up this gap, the present study was undertaken.

Turmeric rhizomes of variety 11316 Gorakpur, weighing 8g each with one sound eye bud were sown in 60 clay pots (18 × 18 cm) containing methyl bromide fumigated (1 lb/100 cu.ft.) sandy loam soil. At three leaf stage, 30 plants of uniform growth were selected. The nematode inoculum was collected from nematode infested black pepper roots and the seedlings were inoculated with graded inoculum levels (10, 100, 1000, 10,000 and 100,000) in June 1981. The uninoculated plants were kept as control. Each treatment was replicated five times. The pots were arranged in a randomised manner in a greenhouse with a temperature range of 27-34°C and watered daily with boiled and cooled water. The plants were uprooted after six months and observations were recorded on plant growth, yield, root knot index and nematode population (Tables I and II).

The inoculated plants exhibited stunted growth, marginal necrosis, drying of leaf tip, and reduction in number of tillers

compared to control plants over a period of six months. Highly significant reduction in shoot, root and rhizome weights were observed at inoculum level of 1000 larvae (Table I). An initial inoculum level of 100,000 nematodes per plant was found to cause 33.6, 29.1, 34.5, 46.5, 77.3, 89.0, and 76.7 per cent reduction over control whereas with 10 larvae it was only 10.3, 14.3, 4.8, 13.9, 24.4, 52.4 and 42.0 per cent reduction with respect to shoot length, length of lamina, maximum width of lamina, number of leaves, shoot weight, root weight and rhizome weight. A reduction of 64.2% and 76.7% in rhizome weight was noticed in plants inoculated with 10,000 and 100,000 nematodes per plant respectively. At this stage the plants started exhibiting signs of death due to severe galling and rotting of rhizomes and roots.

The root systems of all inoculated plants showed heavy root galling. An increase in initial inoculum from 10 to 100,000 larvae resulted in corresponding increase in root galling index (Table II). The total nematode population build up was not statistically significant in the rhizome. However, highly significant population build up was noticed in root and soil. The highest rate of multiplication (546.6 times) was observed in treatments with the inoculum level of 10 larvae and the lowest rate of 2.8 times with the inoculum level of 100,000 larvae. These results were in agreement with

Table I. *Effect of different inoculum levels of M. incognita on the growth of turmeric seedlings under greenhouse conditions (mean of 5 replications)*

Inoculum levels	Shoot length (cm)	Length of lamina (cm)	Maximum width of lamina (cm)	No. of leaves	Shoot weight (g)	Root weight (g)	Rhizome weight (g)
0	66.30	36.80	7.14	8.60	23.80	16.40	35.20
10	59.50 (10.3)	5.52 (14.3)	6.80 (4.8)	7.40 (13.9)	18.00 (24.4)	7.80 (52.4)	20.40 (42.0)
100	65.50 (1.2)	31.68 (13.9)	7.16 (-0.2)	6.00 (30.2)	15.80 (33.6)	3.92 (76.1)	18.20 (48.3)
1000	53.90 (18.7)	27.60 (25.0)	5.86 (17.9)	6.20 (27.9)	9.60 (59.7)	2.60 (84.1)	18.20 (48.3)
10000	47.64 (28.1)	25.72 (30.1)	4.74 (33.6)	5.00 (41.9)	8.60 (63.9)	2.34 (85.7)	12.60 (64.2)
100000	44.00 (33.6)	26.10 (29.1)	4.68 (34.5)	4.60 (46.5)	5.40 (77.3)	1.80 (89.0)	8.20 (76.7)
General Mean	56.14	29.9*	6.06	6.31	13.53	5.81	18.80
C.V. %	17.14	12.00	12.06	0.98	31.60	64.79	29.86
C.D.	12.69*	4.73*	0.97**	0.74*	5.64**	4.97**	7.41**

Figures in parentheses are the percentage reduction over control

Table II. *Effect of different inoculum levels on host infestation and population build up M. incognita on turmeric seedlings under greenhouse conditions (Mean of 5 replications)*

Inoculum levels	Root knot index*	Total Nematode population			Multiplication factor
		Rhizome	Soil	Root	
0	0	0	0	0	0
10	1.2	1745	1463	2259	546.6
100	2.4	8862	2350	4553	155.6
1000	3.2	9487	5205	14290	28.9
10000	4.0	12547	6502	81740	10.1
100000	4.0	53567	11029	216042	2.8
Gen. Mean	2.96	17201	3309	63779	-
C.V. %	28.57	113	31.01	65.46	-
C.D.	1.13*	NS	2207.95**	55976.71**	-

*Gall index rating: 0 = no galling, 1 = mild, 2 = moderate, 3 = severe and 4 = very severe

that of Koshy *et al.* (1979) on black pepper and Sudha Sukumaran and Sundararaju (1985) on ginger.

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SESSION V : DISCUSSIONS

Mr. C. Kuruvilla Jacob: In the lead paper presented today one of the aspects which was stressed is the yield loss studies. It is a very difficult aspect in tree crops, especially we do not have methodology for yield loss studies. A proper methodology should be developed.

Dr. R. Naidu: It is true that the methodology for crop loss estimation in trees crops is meagre. However, very good attempts have been made in coconut for root(wilt) disease, in arecanut yellow leaf disease etc. Similar studies are needed in other crops too.

Dr. S. Radhakrishnan: Methodologies are already available, especially for coffee leaf rust. Kushalappa in Brazil has done good work with the help of computers. So we can adopt that methodology though our climatic conditions are a little bit different.

Mr. T.S. Govindarajan: General Chairman in his keynote address as well as Dr. Naidu in his lead paper in this afternoon stressed two important aspects of spraying and control. One is the lack of adequate knowledge on chemical applications, spray technology and coverage. Though we are recommending certain chemicals against some diseases and pests, many farmers complain that these chemicals do not afford complete protection against the pests or diseases. I admit that there are some limitations.

When we probe a little deeper into the

aspects one can see that we are ignoring certain facts like spraying technique, timing of the spray schedule, effective coverage etc. The other important aspect is the biological control. Dr. Jayaraj also mentioned about the need for developing biological control. We have some practical difficulty to have effective biological control of coffee mealy bugs, though we have identified a parasite and a predator against this pest. For the establishment of the parasite used in biological control, the prevalence of a minimum population of the pest is required. How are we to achieve this under field conditions. As far as coffee is concerned, the initial build up of mealy bug population starts by about October/November ie. after the monsoon rains. Is it the time to release the parasite? Thus detailed study is necessary to know how the technology proved effective in the lab works under field conditions.

A delegate: I would like to know whether different *Fusarium* spp. could be isolated from infected plant parts and their pathogenicity established. Was there any effort to isolate *Fusarium* spp. from the soil?

Mr. M. Kochu Babu: Samples were collected from different portions of affected palms in the early and middle stages of the disease. Six species of *Fusarium* could be isolated of which three species have been included in the pathogenicity experiments using seedling in nursery. We have also made isolations of *Fusarium* from the roots but we have not

tried isolation from the soil.

Dr. P.K. Koshy: Do you get the same *Fusarium* from the leaf as well as from the root?

Mr. M. Kochu Babu: Most of the species are consistently isolated from the spear. We got one or two species from the roots. Some more isolates are to be identified.

Dr. P.K. Das: Mr. Kochu Babu gave very alarming picture. I was under the impression that oilpalm being a new introduction to this country, will not have much of disease problems. But Mr. Kochu Babu has shown many slides of different symptoms. Is it because of lack of quarantine measures that the disease is seen now, or is it really a problem in the soil or environment. These aspects need in depth study.

Mr. M. Kochu Babu: I have shown only the different symptoms which are associated with early and advanced stages of the disease.

Dr. M.K. Nair: I have got two questions to Dr. Sundararaju. One is whether he used really turmeric seedlings. Then the other one is when you put 1000 or more *Meloidogyne* larvae in a potted condition, they damage the root. But under natural conditions, do they cause any damage?

Dr. P. Sundararaju: We have used only rhizomes and not turmeric seedlings. Under natural conditions even 100 nematodes for 300g soil was found as the threshold level and maximum damage was caused.

Dr. P.K. Koshy: We have not done any survey for infestation of root knot nematode in turmeric. Regarding Dr. Das's comment on plant quarantine measures to be adopted on oil palm, I do not think there is any recommendation for introduction of oil palm as such. Dipping of seeds for 4 minutes in thiram or treatment with methyl bromide (24 g/ cubic metre) has been suggested. If we have to import seednuts the treatments are to be given both at the ports of export and entry. But there has not been any valid study in this regard. There is no information on the effect of repeated treatments/seednuts with methyl bromide on oil palm seeds. Whether the seeds are to dehusked before treating or what should be the moisture percentage of the seeds are other questions to be answered. If the moisture is less than 15% methyl bromide penetration is not very effective. We have been carrying out introduction of seed-nuts without carrying out these studies. This should be given first priority of research before introducing germplasm collection from various countries.

Dr. E.V.V.B. Rao: I am to inform the audience that there is a Government of India notification that any plant material going into Andamans should go through the quarantine station. This notification has come in 1985.

Dr. P.K. Koshy: We have the notification, but it is not being practised. I know that large number of banana suckers have been taken to Andamans from CPCRI, Palode where this very spear rot disease occurs. He would have carried along with this several diseases of banana too. We as scientists should be

more careful about these.

Mr. N. Harigopal: In recent times, particularly in plantation crops, we are emphasising so much about management of pests and diseases. Really I am unable to understand this. I am managing a research station in Andhra Pradesh where the conditions are entirely different. We are able to grow coffee excellently at 45°C and 0°C. There the rust is controlled by strong physical factors, light and temperature. We are not spraying anything, because uredospores do not mature at high temperature. The inoculum present in the soil is extremely low and unable to sporulate. I think these factors may also be considered in our integrated approach.

Dr. P. Rethinam: The introduction of oil palm into the main land on a large scale is being talked about for many years, but only we could establish the plantations in two places: Andaman as well as in Bharathipuram. Now as Chairman has pointed out scientists are to take utmost care in sending the material to other places. We are taking care to remove each and every palm identified as spear rot in CPCRI, Palode and Thodupuzha where we have seed production programmes. Since *Fusarium* is likely to be seed borne, seed treatment also is being done. Because of the country's interest, we had to introduce oil palm into India, including Andamans. It is not that we intentionally bring the disease, but when a disease occurs we should be in a position to tackle it.

Dr. P.K. Koshy: I think that Mr. Kochu Babu has already carried out some

studies on methyl bromide fumigation and we should be in a position to bring out some recommendations within six months. That should at least help us in deciding the time of exposure, the dosage, number of treatments etc.

Mr. M. Kochu Babu: The experiments on fumigation will be over within three months.

Dr. P.K. Koshy: Regarding integrated control, Dr. Naidu in his lecture had very clearly brought out all the concepts and philosophy involved in integrated control. He has suggested that it is only an integration of various control measures. In this we are trying to use minimum amount of fungicides or insecticides along with biological and cultural control measures.

Dr. K.K. Krishnamurthy: We talk about nutrition on one hand and disease occurrence on the other hand. For example we know that nutrient like potassium has got some effect on water relations, pest and disease resistance. One of our studies has proved that a higher application of potassium may reduce the shot-hole borer incidence. This sort of application of nutrient for pest control is again towards integrated approach, because it involved both nutrient management and pest management. Clean culture can reduce number of pests and diseases. Likewise many factors, when put together have additive effect and will work out finally in a cost effectiveness and a cost benefit ratio.

CHAPTER VI

GERMPLASM

Chairman : Dr. M. K. NAIR

Rapporteurs : Dr. K. U. K. NAMPOOTHIRI
: Dr. M. S. SREENIVASAN

PLANTATION CROPS GENETIC RESOURCES RESEARCH IN INDIA

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INTRODUCTION

In India, crops like tea, coffee, and rubber which were grown as organized plantations under colonial rule, are traditionally referred to as plantation crops. However, crops like coconut, arecanut, cashew, spices etc., even though are essentially small holders crops, are also considered as plantation crops. In addition to these crops cacao and oil palm also fall under this category. The perennial nature, sustained income from plantation over a period of time, and tropical habitat of these crops lend support to this definition. Even though the cultivation of these crops is fairly ancient in India, they are primarily small holder crops occupying only about 2% of the total agricultural land. But in terms of national economy they contribute around 75 per cent of the export earning from agricultural commodities (Bavappa, 1977). Crops like arecanut, cashewnut, small cardamom, ginger, turmeric and tea rank first in world production while black pepper and coconut are in second and third position respectively in the total world production. In this context, it becomes very essential to give a high priority for genetic resources of these crops. Till recently, many of these crops did not receive much attention with the exception of tea and coffee which were bestowed with best attention. The plantations established in early years still exist in certain parts due to lack of

systematic replanting programmes. It is to be noted that most of these crops, except spices are introduced into India. But the situation of the plantations as indicated above led to the preservation of sizeable variability that was present in the original introductions, but with the growing awareness of the importance of these crops in the international trade, especially spices and cashew, and the advent of superior planting materials in these crops underline the urgent need to take stock of the situation and conserve available resources for posterity.

Status of germplasm holdings

The genetic resources programmes in plantation crops are being handled both in the ICAR Research Institutes (Central Plantation Crops Research Institute, National Research Centre for Spices, National Research Centre for Cashew) and Commodity Board's research institutes like Coffee Research Institute, Rubber Research Institute, Cardamom Research Institute and research units of private agencies like Toklai Research Institute and UPASI. In addition, under the three All India Coordinated Crop Improvement Projects on Palms, Spices and Cashew some of the University Centres also undertake collection and conservation programme in plantation crops. While in crops like tea, coffee, and rubber the research efforts are concentrated in a few centres, there is no duplication of effort between different research

units; but in case of crops like coconut and cashew, there is a scope to rationalize the efforts that are being made in collection and conservation to avoid duplication. For maintenance of collec-

tions, large areas are required and this land stands committed to those collections for a very long period as the life span in most of the cases range four to six decades. The centres which are main-

Table I. *Major plantation crops germplasm maintenance centres in India*

Crop	C.P.C.R.I		All India Co-ordinated Crop Improvement Project Centres and others
	Main Centre	Alternate Centre	
Coconut	Kasaragod	Andamans	Pilicode (Kerala); Veppankulam (Tamil Nadu); Coimbatore (Tamil Nadu); Arsikere (Karnataka); Ambajipet (Andhra Pradesh); Ratnagiri (Maharashtra); Mahuva (Gujarat); Kalyani (West Bengal) and Cuttack (Orissa).
Arecanut	Vittal	—	—
Cashew	Vittal	Shantigodu	Mannuthy (Kerala); Bapatla (Andhra Pradesh); Vridhachalam (Tamil Nadu); Vengurla (Maharashtra); Bhubaneswar (Orissa), Ullal (Karnataka).
Cacao	Vittal	Kidu	Mannuthy (Kerala).
Oil Palm	Palode	Andamans	—
Pepper	Calicut	Peechi	Panniyur (Kerala)
Ginger	Calicut	—	Solan (Himachal Pradesh); Pottangi (Orissa); NBPGR Centre, Peechi (Kerala).
Turmeric	Calicut	Palode	Solan (Himachal Pradesh); Pottangi (Orissa)
Nutmeg	Calicut	—	—
Clove	Calicut	Peechi	—
Cinnamon	Calicut	—	—
Cardamom	Appangala	—	Mudigere (Karnataka); Pampadumpara (Kerala); Cardamom Research Institute, Myladumpara.
Coffee	—	—	Central Coffee Research Institute, Balehonnur (Karnataka)
Tea	—	—	Toklai (Assam), UPASI (T. Nadu)
Rubber	—	—	Rubber Research Institute of India, Kottayam

taining the plantation crops (other than coffee, tea and rubber) germplasm in India are given in Table I.

While the collections in crops like coconut, arecanut, cardamom, pepper and cashew are largest in the world they cannot be considered as comprehensive and in quite a few instances the variability is minimum. In the absence of reliable information on the source population variability from which the collections are made, it becomes difficult to define these collections in strict terms as access-

ions. In general, in plantation crops the accessions constitute plant sample collected from a single location and are often identified by the place of origin/collection. However, the most systematic attempt in collecting germplasm in terms of species and definite characters were made in pepper (Rahiman *et al.*, 1979). This is one crop wherein clear differentiation of the germplasm into cultivated types and wild types has been made. In the case of all other spices (except ginger, turmeric and cardamom) the presence of wild types is not recorded. The germ-

Table II. *Germplasm holdings in Plantation Crops at CPCRI Centres*

Crop	Centre	No. of Accessions		
		Exotic	Indigenous	Wild
COCONUT (<i>Cocos nucifera</i> L.)	Kasaragod Andamans	62 24	35 —	— —
ARECANUT (<i>Areca catechu</i> L.)	Vittal	29	43	—
CASHEW (<i>Anacardium occidentale</i> L.)	Vittal Shantigodu	5 —	243 150	— —
CACAO (<i>Theobroma cacao</i> L.)	Vittal	48	—	—
OIL PALM (<i>Elaeis guineensis</i>)	Palode	6	1	—
NUTMEG (<i>Myristica fragrans</i> , <i>M. beddomei</i> , and <i>M. malabaricum</i>)	Calicut	—	301	—
BLACK PEPPER (<i>Piper nigrum</i> L.)	Calicut	—	184	76
GINGER (<i>Zingiber officinale</i>)	Calicut	—	124	3
TURMERIC (<i>Curcuma longa</i> , <i>C. aromatica</i>)	Calicut	6	166	8
CLOVE (<i>Eugenia caryophyllus</i>)	Calicut	2	150	—
CINNAMON (<i>Cinnamomum verum</i> , <i>C. malabaricum</i> <i>C. aromaticum</i>)				
CARDAMOM (<i>Elettaria cardamomum</i>)	Appangala	—	213	—

plasm holdings in different plantation crops at CPCRI are listed in Table II.

In the case of pepper and cardamom, systematic surveys were undertaken for documenting and collecting indigenous germplasm. Efforts are underway in coconut, cashew and tree spices like clove, nutmeg etc. The exotic germplasm was mainly obtained through exchange programmes. In these exchange programmes, material often was collected from a few individual plants, as is apparent from lack of easily identifiable and discernible variability and sent to India on request. In most of the cases the source population description is not available, thereby limiting the utilisation potential of these collections. For example, the collection site description, altitude and latitude will be of a great help in choosing the accessions that can be evaluated at a given site. Even though the collections, as mentioned earlier, are the largest in the world, the impact can only be realized if proper collection record descriptors are maintained. The long life span of these crops which is normally considered as a disadvantage in the evaluation programmes, is in fact a blessing for retracing a collection sources (site) as well as source population even at a later date. Hence the attempts now should be made to collect such of those informations which are at present not readily available at the maintaining centres. The first systematic exotic collection programmes in these crops undertaken was in coconut in six Pacific Ocean Islands with the financial assistance from IBPGR (Bhaskara Rao and Koshy, 1982).

Collection priorities

In the future programmes, to overcome this lacuna, crop-based descriptors should be used in all the survey collection programmes. Some of the proforma which are developed on these crops by the Central Plantation Crops Research Institute are already in use.

In India the National Bureau for Plant Genetic Resources is the nodal ICAR Institute with the mandate to coordinate genetic resources programmes for all the crops. They are also vested with the responsibility of both introduction of the material from abroad and for organizing crop specific collection programme within the country as well as in exotic locations. The crop priorities for some of the plantation crops are listed in Table III.

The priority areas should be viewed primarily from three different angles namely conservation, collection of variability and locating resistance to a specific pest/disease. The top priority naturally in germplasm programme is conservation. The germplasm collections are often defined as the material preserved for posterity and it is not always possible to visualise the needs of the future. This necessitates even conservation of material from endangered areas. For example, the Western Ghat region which is very rich in indigenous spices genetic resources is an area which is perpetually threatened with the new settlements and denuding of the existing forests. Similarly the population pressure in smaller islands in Pacific and Indian Oceans resulting in migration to hitherto uninhabited islands, might endanger the available resources which are

Table III. *Priority areas for collections in some of the Plantation Crops*

Crop	Exotic	Indigenous
Arecanut	South Pacific, Nigeria	NE Region, Attapadi (Kerala)
Coconut	Indian Ocean Is South America, Melanesia and Micronesia	Gujarat; Andaman and Nicobar; Karnataka, West Bengal, Andhra Pradesh, Orissa
Cashew	Brazil, Mozambique Tanzania and Madagascar	Goa, Orissa, Tamil Nadu Andhra Pradesh, West Bengal, NE Region and Maharashtra.
Cacao	Amazon, Ghana, NC America	Karnataka, Kerala (Idukki, Kottayam and Wynad Dist)
Oil Palm	South and Central America, Malaysia, Nigeria	Kerala, Andhra Pradesh, Maharashtra (Sattar District)
Nutmeg	Moluccas Is. (Indonesia) Papua New Guinea	NE Region, Andaman and Kerala
Black Pepper	Malaysia, Indonesia, Brazil and Sri Lanka	Kerala, Karnataka, Tamil Nadu, Assam, Andamans
Ginger	Australia, Jamaica, Chinga Brazil	All over India
Turmeric	Malaysia, Indonesia, Guatemala, Sri Lanka, Pakistan	Assam, Meghalaya, Andamans
Clove	Moluccas Is. (Indonesia) Zanzibar, Indonesia, Solomon Is.	Courtallam, Nagercoil (Tamilnadu)
Cinnamon	Sri Lanka, Indonesia, China	NE region and Andamans
Cardamom	Guatemala, Sri Lanka	Kerala, Karnataka, Tamil Nadu, Assam
Great Cardamom	—	NE Region, Kerala
Vanilla	Seychelles, Solomon Is.	Western Ghats (Kerala)

present. Hence, the collection strategy of any given crop should also include the programmes for collection from such areas. In this context, the clearing of tropical forests which has been estimated to be about 47 hectares per minute

(Mayers, 1979) warrants programmes for collection of these crops in all the tropical forests especially in South America, and Brazil for crops like coconut, oil palm, cacao and cashew. Africa which is also rich in plantation crops like coconut, oil

palm, and coffee should be included in collection programmes. Even though the centre of origin need not necessarily be the centre of diversity, it is imperative to include the collections from these areas for both conservation as well as for enriching the variability. Priority areas for collections made from the regions where those for variability should be well defined. The regions to be included for collection for resistance of pest/disease is not an easy task. Prevalence of pests or disease in any given area gives an indication on the resistance reaction of given genotype of that area, the collections made from the regions where the pest or disease is absent needs to be studied again. In plantation crops in the absence of reliable screening techniques, field testing is the only alternative for locating the resistance/tolerance. This not only consumes considerable time but also resources. Therefore, a judicious approach is needed while making collections for pest and disease resistance. The possibility of locating the resistance/tolerance in the hotspots appears to be bright. This is also based on the postulation that any given genotype can evolve/mutant only under the selection pressure. However, the genotype which is not exposed to a specific pest/disease may be also included in screening programme.

From the above, it is apparent that the collection programme can be defined only in terms of the need or the objective. This is also true while collecting the proven cultivars. In other words, the priorities have to be defined in terms of gene introductions (for resistance) and plant introductions (for variability) (Frankel, 1985).

Sampling procedures

In plantation crops especially coconut,

oil palm, cashew etc., which occupies large area for maintenance, the representative sample to be maintained in the germplasm collection need to be realistic. In the case of coconut large size of seed imposes severe limitation on transportation as well. It has been recommended that a sample size of 100 nuts is sufficient for making a representative sample from any given site. For cross pollinated tree crops a minimum of 25 and a maximum of 50 are recommended for germplasm maintenance. The study carried out by Rajanaidu and Hassan (1985) is probably the most comprehensive one in plantation crops on defining sample size. Based on a study of 919 accessions of oil palm collected from different countries in Africa and South America, they have concluded that an extreme population has diversified from rest while within a given population the variability between palms is limited. Bhaskara Rao and Koshy (1982) during their coconut collection in Pacific Islands also recorded that between sites (different islands) there was much variability while the variation within a given population was low. Therefore, the sampling of individual plants at a given site can be kept low while number of sampling sites which are far apart have to be more in collection programmes where sampling genetic variability is the objective.

In the indigenous collections the priority at present is being given for collection of desired plant types for immediate exploitation in crops like coconut, cashew, pepper as well as in cardamom. In coconut, cultivars which are well adopted in drought prone regions and those with high yield potential have been collected from Tiptur

area in Karnataka. High yielding selections of Karimunda and Kottanadan cultivars of pepper in Kerala were collected during survey collection. Similarly, in cashew the immediate objective is to be collect the plant types with compact canopy, bold nuts and short flowering period. In an exotic germplasm collection in oil palm which is programmed for this year the priority will be to collect plant type with high yield which also showed desirable characters with high heritability. In these programmes, the sampling obviously is to be biased and collections made from individual trees.

While in the above defined programmes the collections itself is of no difficulty but possibility of realising the same genotype is doubtful mainly due to the cross-breeding nature of these crops. Therefore, collection of vegetative material has been thought of in case of pepper, cardamom and cashew where it is feasible. In the case of coconut and oil palm the necessity for secondary evaluation cannot be avoided. While looking for resistance in the hotspot areas the situation will be different. Large number of plants which does not show the symptoms need to be collected for retesting.

Quarantine precautions

It is necessary to define the minimum quarantine precautions that have to be observed before embarking on collections. Hewilt and Chiarappa (1978) defined the quarantine precautions for some of the plantation crops. The quarantine has to be viewed from two angles: (1) quarantine at the site of

collection; (2) the quarantine precautions at the port of entry. In this context, it may be emphasized that most often collections made will be added to the existing germplasm of that centre and the chances of being planted together are high. Hence, quarantine precautions need not necessarily be meant only for the exotic collections but also should be followed for indigenous collections as well. This is especially true in coconut where large number of diseases of uncertain aetiology are prevalent in different parts of the country. In pepper slow wilt, in ginger the rhizome rot, in cardamom Nilagiri necrosis and Katte diseases are a few examples of maladies which warrant strict quarantine precautions even during indigenous collections.

It is advisable that a collection team comprising a Plant Protection person and a Plant Breeder should visit the collection site. This is necessary not only to ensure that the collection worthiness of the material but also to document the pest and disease that are present in collection site. As mentioned earlier this will enable the identification of accessions which are to be given priority for screening for resistance to a given pest/disease. Crop specific quarantine schedules at the collection site as well as at port of entry need to be worked out. At present the procedure that should be adopted at collection site and also at the port of entry for quarantine inspection is available only for few crops (Bhaskara Rao and Koshy, 1984). This will facilitate fast clearance of the valuable material. Preparation of crop specific pest and disease list will help both collection teams as well as quarantine inspection officials.

While it is the first priority to see that there is no inadvertant introduction of pest/disease through new collection it is also essential to see that the collected material is safeguarded against indigenous pests and diseases that are prevalent at the maintenance site. Considering this, Central Plantation Crops Research Institute has established an offshore genebank in the Andaman Islands for maintaining world coconut germplasm. The collections from South Pacific, which often recorded as original home of coconut, has been made with the primary objective of locating resistance to root wilt disease. In an earlier attempt to locate resistance to lethal yellowing in Jamaica Whitehead (1966) made the collections from the same region and planted in natural epiphytotics. Most of the collections proved to be susceptible to lethal yellowing and these collections are now currently not available for any future programmes. A given genotype, susceptibility to a specific pest/disease does not rule out the possibility of the same genotype being resistance/tolerance to some other pest/disease. Therefore, while maintaining the collections in a protected offshore gene bank the utility of these collections can be enhanced. By producing sub samples, these collections, can be tested against a number of diseases. Therefore, it is not out of place to conceive an offshore quarantine statistics along with a genebank separately for plantation crops. Considering the importance of these crops in the national economy establishment of such a station appears to be a priority.

Characterisation, evaluation and documentation

Genetic resources programme is one of

the first priorities which have been thought of in any crop improvement programmes. A number of collections were made in different crops especially in cereals, millets and legumes. More than 20,000 accessions of crop germplasm were collected by about 40 missions in the different countries of South East Asia during past decade; but less than 10 per cent of the accessions have been characterized (Chamchalow and Singh, 1985). While constraints like lack of manpower and other resources are understandable, considering the importance of characterization it has to be emphasised that preliminary characterization is a mandatory task. Unless the material collected is characterized the utility of the collection remains nil. Fulfilling this basic task also enables in avoiding redundancy in collection efforts. Very often a crop is collected from same site due to lack of information on the collections made earlier. This is more so in case of gene collections where sampling is done for specific characters. Yet another hazard in neglecting the characterization is, adding duplicate collections and making available resources more scarce for important functions like evaluation. In plantation crops where the collections are often maintained as active collection in field, there is a need to limit the collection size to optimise resource utilization. The preliminary characterization of data should be limited to collection record descriptors and data on characters which are easily distinguishable in different environments. Quantitative characters which are more often dependent on environmental factors could be misleading. As mentioned earlier the information on a given accession reaction to pest/disease at the source of collection

will be of immense value. Similarly reaction to drought, altitude at which collection is made will help in immediate utilization of the collections. The best example could be the San Ramon coffee which has become popular at low elevations.

The characterisation gives a preliminary insight into collection, but does not supplement evaluation. The performance at a given location needs to be tested separately. Even though characterization data are lacking in most of the plantation crops the evaluation data are fairly exhaustive. Almost in all the plantation crops, we have selections from germplasm which have certainly added to the high production and productivity of these crops in the country. However, it is to be mentioned that only a fraction of the material collected in different crops has been evaluated, especially for reaction to biotic and abiotic factors. The evaluations in different crops have been directed more towards higher yields, only with lone exceptions being coffee and to some extent pepper in which screening for disease resistance has received fairly good emphasis.

In plantation crops where data on an accession are collected over a period of few decades starting from source population characterization, nursery evaluation, juvenile stage evaluation, stabilized yield evaluation, the need for systematic information management cannot be over emphasized. Central Plantation Crops Research Institute has established a good documentation system with separate data registers for each of the crops. However, retrieval of information still is a tough task. With the advent of computerized

genetic resources management systems, this task has become relatively easier but is yet to be fully adopted in Plantation crops. Efforts in this direction are underway in coconut and cashew.

The immediate priority should be to consolidate the available information and bring out crop specific catalogue. This will not only enable effective use of collections already made but will also help in identifying gaps in collection, so that more systematic genotype resources programmes can be drawn up for this important group of crops.

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COFFEE GERMLASM IN INDIA

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ABSTRACT

The utilization of breeding materials from various parts of the world is essential to improve coffee material for commercial cultivation. Maintenance of genotype is of utmost important for both arabica and robusta in India since both the species are commercially cultivated in the coffee tracts side by side.

To accomplish the task of coffee improvement to suit the domestic needs, a gene bank was established at Central Coffee Research Institute during 1954 with mutual co-operation with other coffee institutes/agencies, besides the collections made during the coffee expeditions organised by FAO. To date the gene-bank comprises of 416 genotypes of arabica, 18 types of robusta and 18 diploid species of coffee inclusive of 4 indigenous species. Confined studies on these genotypes with particular reference to resistance to leaf rust, production, quality and adaptability to different agroclimatic conditions and utilization of the desirable characters has resulted in release of 12 genotypes of arabica and 3 in robusta. At present more than 80% of coffee area in India is occupied by the varieties bred at the Central Coffee Research Institute.

The genetic divergence in the germplasm is discussed.

INTRODUCTION

The genus *Coffea* belongs to Rubiaceae. Except for a few species majority of them are indigenous to Africa. The taxonomic classification by Chevalier, (1947) (Table I and II) which is being adopted to date includes four selections (i) *Eucoffea*, (ii) *Mascarocoffea*, (iii) *Paracoffea* and (iv) *Argo coffea*. All the cultivated species comes under *Eucoffea* which have five sub-sections viz., (a) *Erythrocoffea*, (b) *Pachycoffea*, (c) *Nanocoffea*, (d) *Melanocoffea* and (e) *Mazombicoffea*. Incidentally *Erythrocoffea* comprises of widely cultivated species viz., *C. arabica*, *C. canephora* and *C. congensis*.

(Sybenga, 1960). Charrier and Berthaud (1985) have proposed to review the classification system of Chevalier (1947) in view of the enormous data accumulated on the genus *Coffea* in respect of cytotaxonomy and cytogenetics, ecology and plant geography, as well as biochemical and serological affinities. All the species are diploid ($2n = 22$) except arabica which is a tetraploid ($2n = 44$) and differs in breeding behaviour. *C. arabica* is autogamous and all other are allogamous except a species resembling *C. brevipes* which was reported to be autogamous. (Charrier and Berthaud, 1985). Arabica takes its origin from Ethiopia. It has made its entry into India as an ornamental plant during 1960.

Table I. Chevalier's botanical classification of the Genus *Coffea* L.

Genus : <i>Coffea</i> L.	
Section I.	PARACOFFEA
Species:-	1. <i>C. bengalensis</i> 2. <i>C. wightiana</i> 3. <i>C. travencorensis</i> *4. <i>C. khasiana</i> 5. <i>C. horsfieldiana</i> 6. <i>C. fragrans</i> 7. <i>C. merguensis</i> 8. <i>C. dongnaiensis</i> 9. <i>C. cochinchinensis</i> 10. <i>C. malayana</i> 11. <i>C. floreifolia</i> 12. <i>C. grevei</i> 13. <i>C. floresiana</i> * Included in <i>Lachnastoma</i>
Section II.	ARGOCOFFEA
Species:-	1. <i>C. subcordata</i> 2. <i>C. jasminoides</i> 3. <i>C. pulchella</i> 4. <i>C. scandens</i> 5. <i>C. afzelli</i> 6. <i>C. nigeriana</i> 7. <i>C. rupestris</i> 8. <i>C. nudiflora</i> 9. <i>C. melanocarpa</i>
Section III.	MASCAROCOFFEA
Species:-	1. <i>C. lancifolia</i> 2. <i>C. humblotiana</i> 3. <i>C. mauritiana</i> 4. <i>C. nossikumbaensis</i> 5. <i>C. gallienii</i> 6. <i>C. resinosa</i> 7. <i>C. alleizetti</i> 8. <i>C. bertrandi</i> 9. <i>C. commersoniana</i> 10. <i>C. boiviniana</i> 11. <i>C. buxifolia</i> 12. <i>C. pervilleana</i> 13. <i>C. augagneuri</i> 14. <i>C. bonnierii</i> 15. <i>C. macrocarpa</i> 16. <i>C. mogenetii</i> 17. <i>C. dubardi</i> 18. <i>C. tetragona</i>
Section IV.	EUCOFFEA
Sub-Section 1.	ERYTHROCOFFEA
Species:-	1. <i>C. arabica</i> 2. <i>C. canephora</i>

Sub-Section 2.	NANOCOFFEA
Species:-	1. <i>C. humilis</i> 2. <i>C. brevipes</i> 3. <i>C. mayombensis</i> 4. <i>C. montana</i> 5. <i>C. togoensis</i>
Sub-Section 3.	PACHYCOFFEA
Species:-	1. <i>C. liberica</i> 2. <i>C. klainii</i> 3. <i>C. oyemensis</i> 4. <i>C. obeokutae</i> 5. <i>C. dewevrei</i> 6. <i>C. excelsa</i> *7. <i>C. arnoldiana</i> *Included in <i>C. liberica</i>
Sub-Section 4.	MELANOCOFFEA
Species:-	1. <i>C. stenophylla</i> 2. <i>C. affinis</i> 3. <i>C. carrisoi</i>
Sub-section 5.	MOZAMBICOFFEA
Species:-	1. <i>C. zanguebariae</i> 2. <i>C. racemosa</i> 3. <i>C. eugenioides</i> 4. <i>C. salvatrix</i> 5. <i>C. ligustroides</i> 6. <i>C. schumanniana</i> *7. <i>C. kapakata</i> Included in <i>Psilanthopsis</i>

Table II. Species of *Coffea* in India

Section/Sub-section	Species
PARACOFFEA	1. <i>C. bengalensis</i> 2. <i>C. wightiana</i> 3. <i>C. travencorensis</i> ← 4. <i>C. khasiana</i> →
PACHYCOFFEA	5. <i>C. liberica</i> 6. <i>C. abeokutae</i> 7. <i>C. dewevrei</i> 8. <i>C. excelsa</i> ← 9. <i>C. arnoldiana</i> →
MELANOCOFFEA	← 10. <i>C. stenophylla</i> →
MOZAMBICOFFEA	11. <i>C. zanguebariae</i> 12. <i>C. racemosa</i> 13. <i>C. eugenioides</i> 14. <i>C. salvatrix</i> ← 15. <i>C. kapakata</i> →
ERYTHROCOFFEA	16. <i>C. arabica</i> 17. <i>C. canephora</i> 18. <i>C. congensis</i>

Among the species introduced to India of *C. canephora* has come to the level of commercial cultivation, because of its adaptability to different agro-climatic conditions.

The wild coffee plant (*Coffea arabica*) was discovered in about 850 A.D. and was cultivated in the arabian colony of Harar. It then spread to Mecca, from where it was taken to home by pilgrims to other parts of Islamic world. The raw beans were not allowed out of the country of origin without ensuring the loss of viability. Strangers were not allowed to visit the plantations. But it was Bababudan a pilgrim from India who smuggled seven coffee seeds from Mecca to Mysore around 1690. But the present Mysore coffee is more likely to have been derived from the introduction by the British. Brazil entered the field of coffee cultivation through a Brazilian officer who while on a visit to French Guiana in 1727, received a plant hidden in a bouquet of flowers as a token of affection from Governor's wife. This was the start of the coffee empire of Brazil which now holds supremacy in world of coffee production (Smith, 1985).

MATERIALS AND METHODS

The pioneering studies of Mr. W.W. Mayne on the biology of coffee leaf rust fungus (*H. vastatrix*) indicate that it occurs in physiological races. These rust races were specific in host-pathogen relationship. This necessitated screening of genetically diverse coffee materials for rust resistance as a primary step in coffee improvement in India.

To accomplish the target of producing

rust resistant, high yielding coffee strains, initial germplasm of diverse coffee materials available in India was collected during 1925-40 for which Dr. M.K. Venkat Rao was mostly responsible.

About 251 genotypes of arabica and 37 of robusta were established and evaluated for their superior characteristics. Interspecific crossing was undertaken to evolve synthetic types for obtaining desirable characters of both the species. As the natural interspecific hybrids having superior characters were identified, further exploitation by systematic breeding was planned. Hybrid combinations of diploid $\times$ diploid, diploid $\times$ tetraploid were established.

During the period between 1940-1960 the Central Coffee Research Institute, had taken up collaborative studies with Coffee Rust Research Centre (Portugal) and other Coffee Research Institutes of the world. As a result several exotic wild and cultivated arabicas and robustas and other species were introduced to build up a massive germplasm bank. Even though there is a gene bank comprising of more than 416 collections of arabica, most of them come under "E" type (susceptible to more than 20 physiological races of rust). Hence, a few types were isolated based on their rust resistance and other desirable characters. They are Caturra, San Ramon, S 12 Kaffa, Tafari-kela, Geisha, Villasarchi, Mundonovo, Pachy, Bourban, Typica, Kents, Cioccie and Agaro.

Gene bank also represents repetition of some genotypes. Among arabica collections Cioccie, Agaro, S 12 Kaffa, Geisha,

Caturra, San Ramon, Tafarikela are the important ones finding place in the evolution of newer station selections. Among the spontaneous hybrids introduced, Hybrido-de-timor having immunity to all known races of rust, occupies a prominent place in the breeding programme.

Progenies of back crossed/sibmated hybrids of inter-specific combinations were established and studied for economic characters. During 1964 FAO sponsored a team of scientists from different countries to explore the available wild forms of coffee in Ethiopia for collecting and establishing different genotypes in different countries. The team comprised a representative from India also. With this exploration about 80 wild arabica collections were added to the gene bank. These varieties are representative samples of wild arabica from different provinces. These includes Shoa, Illubabor, Gojam, Kaffa, Erytra, Sidamo and Harer. As a few of these collections were found to have good quality parameters, these were being utilised in plant breeding programme.

During the expedition seed materials from different provinces have been established in the following institutions (Anon. 1968).

- i) Jimma Agricultural Technical School, Ethiopia
- ii) Central Coffee Research Institute, India*
- iii) Coffee Research Station, Lyamungu, Tanzania

- iv) Estacao Agronomica Nacional, Oeiras, Portugal
- v) Instituto Interamericana de Ciencias Agricolas de la Oea, Zona Andina, Lima, Peru
- vi) Instituto Interamericana de Cienoiias Agricolas de la Oea, Turrialba, Costa Rica

In addition to above institutions the following centres are also maintaining arebica germplasm (Anon. 1980).

- a) Institut des Sciences Agronomiques du Rwands (ISAR), Rubona, Butare, Rwanda
- b) Institut Francais du Cafe et du Cacao (IFCC) Bingerville, Ivory Coast
- c) Institute for Industrial Crops, Bogor, Indonesia

From 1970's onwards complex crosses including important high yielding rust resistant genotype of arabica have been added to the CCRI gene bank. Among the crosses, importance is given to plant type particularly dwarfs which renders more population per unit area, coupled with resistance to rust. Most of these dwarfs are introduction from CRRC, Portugal. From Philippines two new types of arabica have been received and established in the gene bank. Further, improvement work was emphasised on the crosses involving Caturra, Mundanova, Villasarchi for economic characters and HDT for leaf rust resistance. These materials are being further improved at CCRI by pedigree slection, back crossing and sibmating. At present the gene bank of the Institute

*According to International Board for Plant Genetic Resources, Rome, 1980, Central Coffee Research Institute has been recognised as one of the Chief Genebanks of C. arabica

Table III. *Details of Coffee Germplasm collections at CCRI*

Sl.No.	Country	Arabica	Robusta	Species	Hybrids	Clones
1.	Africa	—	—	2(1962)	—	—
2.	Australia	4(1964)	—	—	—	—
3.	Belgium Congo (Zaire)	2(1956)	—	—	—	—
4.	Congo (K)	6(1953), 8(1954)	—	—	—	—
5.	Costarica	28(1964), 18(1969)	4(1969)	1(1969)	1(1969)	—
6.	East Africa	1(1956)	1(1956)	—	—	—
7.	Ethiopia	3(1953), 24(1955), 25(1963), 80(1964-65)	—	2(1956)	—	—
8.	Guatemala	15(1953), 4(1956)	—	—	—	—
9.	Guinea	10(1954)	—	—	—	—
10.	Indonesia	—	—	1(1953), 1(1954)	1(1953), 2(1954), 1(1971)	—
11.	Kenya	14(1954)	—	—	—	—
12.	Malaysia	—	1(1953)	3(1953)	1(1953)	—
13.	France	10(1954)	—	—	—	—
14.	Portugal	3(1954), 7(1955), 7(1959), 3(1961), 23(1964), 21(1965), 7(1975), 10(1979), 6(1981), 9(1986)	1(1953)	4(1954), 1(1955) (4 types)— 1(1958) (15 types)	—	11(1965) Indicator plants
15.	Puertorica	8(1956)	1(1956)	—	—	—
16.	Rome (FAO)	3(1954)	—	—	—	—
17.	Saigon	—	1(1956)	—	—	—
18.	Srilanka	—	1(1955)	—	—	—
19.	Surinam	1(1955)	1(1955)	3(1955)	—	—
20.	Tanzania	7(1953), 8(1955)	—	3(1955)	—	—
21.	Uganda	4(1957)	3(1957)	1(1957)	6(1957)	—
22.	U.S.A. (USDA)	11(1957)	—	1(1957)	—	—
Total		415	15	26	12	11

comprises 415 genotypes of arabica, 15 of robusta, 26 collections of 18 species, 12 hybrids and 11 clones in addition to original local gene pool (Table III).

RESULTS AND DISCUSSION

With preliminary collections from different estates during 1925-40 about 251 arabica and 37 robusta collections were

established and evaluated for their superior characteristics. Out of these a promising genotype S.26 topped the list with its vigorous nature and round shaped beans with rust tolerance. This has the resistant to races I and II of leaf rust which was most common in occurrence. A self bred generation of S.26, the S.288 was released as the first station selection. But this had a few undesirable

characters in the quality of produce. Further, this was crossed with the 'Kents' material known for its quality and good bean characters which resulted in the production of S.795. At present this cultivar occupies an area of 85% arabica cultivation in India. Meanwhile other promising mother plants of arabica such as S.31, S.44, S.48 etc., were spotted and cross bred to introduce good bean characters and rust resistance. Here again S.333 another important selection is worth mentioning.

On the robusta front clonal progenies of mother plants showing bold fruits and constant high yield were established. Hybridization between arabica and robusta and between different coffee species were undertaken and progenies were established.

The period between 1940-60, saw the fast recovery of Indian Coffee Industry. Cultivation of improved varieties like S.795 and S.1934 took arabica coffee industry on the road to economic prosperity. These cultivars are the hybrids of plants selected out of established gene bank during 1925-40. Further, the arabica collections made during the period 1940-60 were used for crossing with these popular cultivars to incorporate desirable characters.

In robusta, S.274 gained popularity on account of its bold fruit and high yield. Nevertheless, S.268 and S.270 ranked next to S.274 in economic characters. By applying back crossing technique, advanced generations of robusta × arabica hybrids and *congensis* × robusta hybrids were evolved. Interspecific hybridization between *C. liberica*, *C. excelsa*

and *C. eugenioides* were undertaken and the progenies established. *Congensis* was used as one of the parents in for improvement robusta in terms of quality and reduction in bush size.

During the period between 1960-85, lot of work on breeding was done and a good number of hybrids with different desirable traits were released for cultivation in coffee growing areas. As a result of intensive breeding programme undertaken utilising not only the indigenous collections but also collections of the gene bank, eight new arabica selections (Sln. 4, 5, 6, 7, 8, 9, 10 and 11) and two more robusta lines namely Sln. 2R (Balehonnur robusta series) and Sln. 3R (*C. congensis* × *C. canephora*) were released for commercial cultivation. Tafarikela, an Ethiopian arabica was assessed and found to be drought hardy. So this was utilised and hybrid, Sln. 9 was released as it has resistance to rust and drought conditions. Similarly San Ramon was made use of in developing Sln. 7 hybrids which are dwarf in nature. Sln. 5 and Sln. 6 have horizontal resistance and was suitable for border areas. Agaro/Cioccie were utilised for producing hybrids with popular cultivar, S. 795 for improving the bean quality, rust resistance and to some extent suitability for continued wet condition of the soil.

Among the selections, Sln.8 is unique in its character for rust resistance. It has resistance to all known races, so far, identified. So it was used in many of the cross combinations involving other arabica types. Recently a hybrid of Caturra × HDT which is named as 'Cauvery' has been released. This material has vertical resistance. It is a

semidwarf, early bearer and also good yielder under ideal conditions.

So far, in the genus *Coffea* about 40 genes have been identified and some more are under analysis (Monaco and Carvalho, 1975). The important genes such as Typica, Caturra, San Raman, Mundanova, Kona, Cera, Nana are of economic importance in the breeding programme. CCRI genebank is composed of all the genes so far recorded, and being exploited through improved techniques of plant breeding and genetics.

BREEDING STRATEGY

In order to gear up to the needs of the coffee cultivation for the immediate future, emphasis for breeding is envisaged to be on the following points.

1. Breeding for rust resistance, adaptability, production and quality are to be pursued.
2. In case of Robusta, the gene pool at CCRI is inadequate. Exploration and expansion of gene pool is essential.
3. Development of an idio-type identification index for both arabica and robusta with special reference to dwarfs.
4. Selection of plant types for adaptability to the extremes of climatic conditions.
5. Interspecific hybridization aimed at evolving synthetic types.

6. Tissue culture: technique for rapid multiplication of elite types already established and to be utilized in the breeding programme.

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STUDIES ON MORPHOLOGY AND QUALITY OF ETHIOPIAN ARABICA COFFEE

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ABSTRACT

Coffea arabica L. of Ethiopian origin possesses good quality, acidity, body and flavour and is considered to be the superior type. In order to find out the best cultivar, fifty, four accessions from Kaffa Province were evaluated for cup quality characteristics. Cup grade of accessions like S.2611, S.2618, S.2621, S.2624, S.2632, S.2636, S.2638, S.2639, S.2642 and S.2677 were ranked from fine to good. These accessions have fruit with long pedicel, early ripening and tolerance to 'Wet' conditions of the soil. However, out-turn, grade percentages, yield, the extent of berry drop and tolerance to leaf rust disease varied among the accessions.

The possibility of exploiting these qualitative characters of exotic arabicas into the indigenous hybrids is being explored.

INTRODUCTION

Coffea arabica L. is reported to occur naturally in Ethiopia (Sybenga, 1961). The Kaffa Province in Ethiopia is reckoned to be the genetic centre for *C. arabica*, wherefrom arabica varieties of excellent quality were spread to all parts of the world (Sylvain, 1955).

Coffee collections of Ethiopian origin have been added to the gene bank at the Central Coffee Research Institute from 1953-54 onwards, with the aim to exploit elite genotypes for their utilization in plant improvement. From the F.A.O. sponsored expedition in 1964 eighty collections of arabica from various provinces of Ethiopia were introduced into India (Narasimha Swamy 1965). They consist of one from Eriteria, two from Gojjam, three from Harar, six from

Sidamo, six from Shoa, eight from Illubabor and fifty four from Kaffa.

Observations on seedling characters, colour of the young unfolding leaves and the nature of primaries of these collections have been reported (Ramamurthy and Visveswara, 1965).

Evaluation of elite genotypes of Kaffa accessions based on several morphological and cup quality characters was made and the results are presented in this paper.

MATERIALS AND METHODS

Fifty four accessions of Kaffa were planted in 1965 at Central Coffee Research Institute under mixed shade tree canopy maintained under standard

cultural practices. All the accessions acclimatized to South Indian agro-climatic conditions remained free from pests and diseases.

In view of the importance of quality and tolerance to 'Wet' condition of the soil, five vigorous plants from individual accessions of S.2621, S.12622, S.2623 and S.2624 were selected at random to study morphological characters like girth of the stem at 6" above ground level, length of primary branch, length of internodes, leaf size, number of inflorescence per node, number of flowers per inflorescence and pedicel length of the fruit. From the data mean of fifty observations per character were calculated to compare with hybrid Cv. S.795 taken as standard.

To measure the clean coffee ratio, from individual accession six kilograms of ripe cherry were collected to prepare clean coffee samples by 'Wet' method. The samples were initially analysed for out-turn, grade percentages, size, shape and colour and later on sent to cup tasting unit, Coffee Board at Bangalore. The variety S.12 Kaffa was taken as standard to compare the quality characters.

RESULTS

a) *Morphological characters:*

It was found that the exotic plants were compact bushes, the stem girth varying from 21.0 to 22.5 cm. in all varieties including the standard cultivar S.795. Length of primary branches varied from 76.9 to 94.3 cm. and in S.795 it was 98.9 cm. Kaffa plants have relatively longer inter-nodes ranging from 6.1 to 7.5 cm. whereas in S.795 the inter-node was 6.1 cm. Leaves in Kaffa were of medium

length ranging from 13.5 to 15.9 cm. breadth 5.4 to 6.5 cm., where as in S.795 leaves were bigger having length of 16.5 cm. and breadth of 7.8 cm.

The pale green tip of unfolding leaves is the characteristic feature of these varieties. Further the plants could be easily distinguished by their erect to semi-erect branching habit. The secondary and tertiary branches were relatively less than in S.795. The number of inflorescence per node varied from 4 to 5 and number of flowers per inflorescence from 3 to 5 in comparison with 4 to 5 flowers per inflorescence in S.795.

Fruits were borne on longer pedicel (5.7 to 5.9 mm.) in comparison with S.795 (4.9 mm.). Fruits were oblong to round and on ripening the pericarp is maroon red. Beans are longish to round varying in length 8.8 to 10.0 mm., breadth from 6 to 7 mm. and thickness from 3.6 to 4.8 mm. with bluish-grey to bluish-green colour. In S.795 beans were 9.9 mm. long, 7.3 mm. wide and 4.0 mm. thick with blue to greyish colour.

b) *Out-turn, grade percentages and quality:*

The accessions S.2611, S.2618, S.2632 and S.2677 gave better out-turn which varied from 995 to 1075 g, where as S.2621, S.2624, S.2636, S.2638, S.2639 and S.2642 gave considerably low out-turn ranging from 850 to 897.50 g. as compared to 1085 g. in S.795.

'A' grade percentage of these accessions varied from 18.7 to 41.5, 'B' grade from 25.2 to 44.3, 'C' grade from 5.1 to 19.6, triage from 5.1 to 11.3 and pea berry from 8.4 to 24.4.

Further quality assessment was made based on colour, size and weight of the bean. Accessions S.2611, S.2618 and S.2621 were having blue to greyish colour and liquor had fair body with good acidity. Similarly S.2624, S.2632, S.2636, S.2638, S.2639, S.2642 and S.2677 were bluish to green and liquor had fair body with good acidity and the cup quality was good to fine. The cup rating varied from 6 to 7 (higher the grade better the quality).

In general, the cup quality is considered to be good if length of 100 'A' grade beans exceeds 9 mm., breadth 6 mm., thickness 3.5 mm. and weight 15 g.

c) Fruit set, tolerance to leaf rust and yield:

Studies on flower to fruit set under open pollinated condition revealed that S.2632 recorded maximum set (67.6%) and minimum in S.2636 (50.3%) while S.795 recorded 61.0% set. When these accessions were screened for leaf rust race I, the percentage of resistance varied from 0 to 50.

Average yield over eleven years at Central Coffee Research Institute indicated that S.2621 was the highest yielder with 944.2 kg/ha and S.2636 was the lowest yielder with 427.7 kg/ha as compared to 2,000 kg/ha in S.795.

DISCUSSIONS

Present study was undertaken on morphology, quality and visual observation on adaptability over two seasons at Central Coffee Research Institute. The visual observation on different accessions indicated that S.2621, S.2622, S.2623 and S.2624 were tolerant to 'Wet' conditions

of soil as they were originated from rain forest of Kaffa Province in Ethiopia (Feredrick, 1963).

In morphological characters the Kaffa accessions resembles S.795, but differs in possessing long internodes and long pedicel of fruit. The long pedicel helps in proper growth and enables easy harvest. Fruit set was found to be better than S.795 and the yield was lower than S.795 in these accessions. This may be attributed to the lower out-turn of Kaffa accessions when compared to S.795.

Assessment of out-turn, grade percentage and quality showed that 'A' grade beans are considerably low, 'B' grade was high 'C' grade and triage was better in almost all accessions. The increase of pea berry can be reduced by breeding. Accessions S.2611, S.2618, S.2632, S.2636, S.2638 and S.2639 were fine to good in their cup grades, colour of the raw bean was blue to greyish as in S.12 Kaffa taken as standard. Work done in Kenya also indicated that S.12 Kaffa possess good quality, acidity body and flavour of the liquor. (Sylvain, 1955).

According to Wormer (1964) coffee picked in late in the year is superior to the early crop. Further the quality of coffee from young trees (6 to 10 years) was superior to that produced by older ones (16 to 20 years) (Fernie 1965).

The present investigations on quality showed that, coffee picked in early from the older trees (21 years) of Kaffa accessions gave superior quality. Further, early relieving crop from the plant is essential for the development of flower buds (Visveswara, 1979).

From the foregoing, it is seen that cup qualities along with long pedicel of fruit, early ripening and tolerance to 'Wet' characters can be incorporated into station varietal hybrids like S.3161 (Kents X HDT), S.2790 (HDT X Tafarikela), S.2794 (HDT X Geisha), S.2717 (333 XHDT), S.2464 (Liberica X Eugenoides) and S.3708 (San Ramon) which have good production potential and are resistant to leaf rust; Work in this direction is in progress.

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CONSERVATION AND UTILIZATION OF TEA GENETIC RESOURCES IN NORTH EAST INDIA

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ABSTRACT

The methodology adopted for the conservation of tea genetic resources in N.E. India and achievements made so far are reported in the paper. Since the inception of Clonal Selection Scheme in 1971-72, over 6110 ha of old seed grown sections of tea representing about 2% of N.E. India tea acreage, surveyed, 6654 elite tea geno-types identified and 293 genotype after evaluation, have been maintained in field. Out of 1205 genotypes collected since 1900, a total of 101 have been released from 493 genotypes evaluated since 1971-72 compared to only 26 varieties released out of 712 collections prior to 1971. Besides their use as commercial varieties, 104 such genetic variability have been used in various breeding programmes either to develop bicalonal seed stocks or to study taxonomic relationships among *Camellia* spp.

In Darjeeling 204 elite genotypes have been collected and evaluated over last 15-20 years. Out of which 20 clonal varieties have been released exclusively for Darjeeling.

A ratio of 1:180,000 tea plants for finding an outstanding genotype from old seed grown populations of tea in West Bengal have been estimated.

The need of further strengthening the efforts to conserve tea germplasm in N.E. India and future strategies for the same are discussed.

INTRODUCTION

Genetic diversity is the basis to the continued improvement of crop plants, whether through natural selection or directed plant breeding. Among the various sources of diversity, the most important are gene pools that evolve by spontaneous mutations, recombinations and natural selections. Gene pools are preserved in seeds, vegetative parts and living plants.

Historically the collection and utilization of tea germplasm in N.E. India started with the discovery of Assam tea in 1923 by Robert Bruce. However, organized efforts could be made only after the establishment of Tocklai Experimental Station at Jorhat in 1900. The state of tea germplasm in N.E. India has been reviewed by several workers (Bezbaruah and Dutta, 1977; Bezbaruah and Singh, 1978; Singh and Bezbaruah,

1978; Singh, 1979, 1980a, 1980b, and 1984).

In spite of considerable efforts made in the past in N.E. India to collect tea germplasm, it is far from adequate to represent the tea gene pool. The old seed grown tea populations representing over 65% acreage of the N.E. Indian tea plantations are highly heterogeneous and thus are the gold mines of genes. The need for collecting tea germplasm in N.E. India has gained further importance due to massive uprooting of old seed grown sections to be replaced with few popular clones, having narrow genetic bases which were developed in last three decades or so (Bezbaruah and Singh, 1978). If genetic variability from such areas are not collected and preserved now, they will be lost for ever. Such alarming situation of our tea germplasm in N.E. India lead us to intensify our efforts of collecting the genetic variability in 1971-72.

The methodology adopted to collect, evaluate, utilize and preserve the tea germplasm and achievements made since then are presented in the paper.

MATERIALS AND METHODS

The experiments were conducted at the Tocklai Experimental Station and Nagra-kata Sub-Station of the Tea Research Association during 1971-72 to 1985-86. The experimental materials consisted of the old seed grown sections of tea plantations, abundant and wild patches of tea, progenies of small and obscure seed baris found growing in N.E. India, seed from old seed baris, tea sections grown with improved seed varieties and any

vigorously growing sections of tea. While deciding the conservation strategy, the degree of risk of losing existing genetic variability, the size and quality of existing collections, the recognised requirements of the users and economic and social importance were taken into consideration. Seeds as well as vegetative parts of genotypes were collected.

The collection of tea germplasm was taken under a District Selection Scheme which was carried in two phases. Firstly estate selected genotypes were evaluated for their agronomical and breeding suitability through field and factory trials. Promising genotypes were multiplied and planted in the field collections. Those genotypes found suitable for commercial cultivation were released as new clones to the tea industry.

In the second approach to collect, preserve and utilize the germplasm, interesting sections of tea estates having wide genetic variability were surveyed to locate desirable genotypes following the procedures described by Barua (1965) and recently modified by Bezbaruah (1984). In this method, selection of motherbushes in the field was based primarily on eye judgement and selection by trials. Among the selection criteria by eye judgement density of pruning sticks in the table, thickness of pruning sticks, size of the bush frame, number of buds per stick, evenness of flush, lateral growth, size of leaf, degree of pubescence and density of plucking points were observed. Crop yield, rooting efficiency and cup characters were judged through field and factory trials.

Initially a large number of bushes were

selected after careful field examinations before making the final selections because the chance of finally selecting superior genotypes have been reported to vary between 0.2 to 0.0025% (Wellensick 1938; Wight, 1958).

After field selection by eye judgement, genotypes were evaluated in randomized block design for their rooting efficiency and yield. After evaluation outstanding genotypes were released as clonal varieties and genotypes with distinctive characteristics and included in the field collections as valuable germplasm for future use.

The evaluation of germplasm in the field collections was done in augmented randomized complete block design (ARCBd) which allowed evaluation of large number of genotypes in one experiment. The experimental materials so planted in ARCBd were kept as living museum of tea germplasm.

RESULTS AND DISCUSSION

The results of our organized efforts to collect, preserve and utilize tea germplasm in N.E. India since 1971-72 to 1985-86 are presented in Tables I and II. A total of 6110.63 ha area of tea plantations from 174 tea estates were surveyed which represent about 2.14% of N.E. Indian tea acreage (Table I). Considering about 65% of the acreage under seedling plantings which need to be surveyed to collect tea genetic variability, still a large area (over 97%) of tea plantations need to be surveyed. It has to be done fast before such seed grown sections are uprooted and replaced by few popular clonal and seed varieties as

Table I. *Collection of tea germplasm in North East India since 1971-86.*

Region	Survey of tea Estate		No. of Collections
	No.	Area, ha	
Assam and*			
Tripura			
South Bank	70	2402.26	2851
North Bank	41	1971.26	1714
Cachar	9	479.66	280
Tripura	3	118.44	90
West Bengal			
Dooars	27	974.20	1123
Terai	16	209.81	433
Darjeeling	8	155.00	163
Total	174	6110.63**	6654

*Ann. Sci. Rep. Tocklai Expt. Sta. 1984-85, p. 75.

**N.E. India tea acreage = approx. 285,000 ha. represented by over 1000 tea estates.

uprooting is being recommended @ 2.50% annually. Initially 6654 superior genotypes were collected from old seed grown populations whose original sources of seeds no longer exist. Since tea is grown primarily for its vegetative parts i.e. leaf, unless genotypes are evaluated for leaf yield and cup quality, potentiality of an individual is difficult to know by eye judgement.

After initial selection of genotypes, based on further eye judgement and nursery evaluations, only 664 genotypes out of 6654 could be put to field evaluation. Out of these only 293 superior genotypes were finally identified and preserved as valuable germplasm of tea during a decade of clonal selection work in tea estates.

Out of a total of 1205 germplasm of tea collected and preserved by Tocklai

Experimental Station from 1900 to 1986, 101 were released as clonal varieties to the tea industry of North East India. It is interesting to note that in 70 years (1900-1970) only 712 genotypes were collected whereas 493 diverse genotypes have been collected in only last 15 years from 1971 to 1986, as a result of our concerted efforts for the same.

Furthermore, out of early collections, only 26 varieties could be released whereas from clonal selection scheme, 75 clonal varieties have been released. By doing so the narrowing of genetic base of N.E. Indian tea populations is being arrested besides conservation of tea genes before they are lost.

The collected genotypic variabilities were not only used to release clonal varieties but were also used extensively in the breeding programme. So far 104 such genotypes were used in the breeding of tea either in intraspecific crossing or interspecific hybridization as potential combiners. Many collections were used to establish the taxonomic relationships among *Camellia* species. The identification of *Camellia* spp. like *C. irrawadiensis* and *C. assamica* was possible only with the use of diverse germplasm collected at Tocklai (Wood and Barua, 1958).

The Chinery type tea plants found growing largely in Darjeeling, are different from those in the plains primarily due to their low productivity. Due to the economic importance of Darjeeling tea in tea map of the world coupled with distinct agroclimatic conditions of the region and distinct need of planting materials by the region, had lead

us to collect, preserve, evaluate and utilize the tea germplasm from Darjeeling separately. Since 1967, 204 promising genotypes collected either by the industry or Tea Research Association, were evaluated for their suitability as commercial clonal variety in Darjeeling at clonal proving station, Ging. Out of these 10% could be released as clonal varieties. Among the released clones, 12 are being used in biclonal breeding programme in Darjeeling. The progress in the collection of tea germplasm in Darjeeling is very slow and laborious due to geographical constraints and adverse climatic conditions. There is a vast genetic variability in the tea plantations of Darjeeling as still over 95% of the area is seed grown and old. It needs to be preserved. The results of an estimate to select superior genotypes from the old seed grown sections of tea whose seed sources no longer exist, are presented in Table II. It was estimated that one genotype out of almost 180,000 tea bushes or 0.0005% could be a desirable one. Similar estimates have been made by Wellensick (1938) and Wight (1958). The above estimates indicate that a large area of tea plantations has to be surveyed to locate superior genotypes.

The foregoing discussions emphasize the need for collection and preservation of tea germplasm in India. The achievements comparing the need are meagre. The clonal selection scheme is giving high dividends. However, it needs to be strengthened to cover up a vast area of tea genetic diversity yet untouched but is endangered due to fast uprooting of old and less productive sections of tea to be replaced with few popular clonal or seed varieties.

Table II. *Estimated probability of selecting outstanding tea bush from old seed grown tea populations in West Bengal*

Region	Area (ha)	Estimated* bush population	No. of initial selections by eye judgement	No. of selec- tions by trial **	Proportion	
					Selected bush: Total No. Bush	% of total bush population
Dooars	937.20	5044010	1042	26	1:193628	.0005
Terai	209.10	1124892	418	10	1:107645	.0009
Darjeeling (11960 plants/ha)	72.00	843898	105	3	1:324576	.0003
Total:	1218.21	70,12,800	1565	39	1:179263	.0005

*6727 plants/ha considering 20% vacancy

**Estimated at 2.5% original selection

Based on (i) the degree of risk of loss of existing genetic variability, (ii) the size and quality of existing collections, and (iii) the recognized requirements of the users, the exploration, collection and preservation of tea germplasm should be taken.

The diverse agroclimatic regions of tea growing in the country require the establishment of germplasm centres of tea at more than one place to maintain and proper evaluation. To execute such strategy for the collection, evaluation and preservation of tea germplasm in India, collaboration among two tea research organisations namely; Tea Research Association (TRA) and the United Planters Association of South India (UPASI) is highly essential.

Among the potential methods of conservation only *ex situ* living conservation i.e., field gene banks have been employed in tea. Other methods like longterm seed storage (genebank), *in situ* conservation (in botanic garden, arboreta, plantation reserves etc.,) cryo-preservation (vegeta-

tive parts) and *in vitro* conservation of tea genes may also be tried. In order to complement *ex situ* conservation of tea, *in vitro* conservation should be developed and adopted.

N.E. India is fortunate to have a vast genetic reservoir of tea. The tea industry, with the help of all possible assistance from national and international organization, will have to conserve and judiciously utilize the genetic resources of tea.

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EVALUATION OF GERMPLASM IN CARDAMOM

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ABSTRACT

Preliminary evaluation of 34 accessions of small cardamom (*Elettaria cardamomum* Maton) was carried out. Comparison was made with respect to eight important plant characters, both within and between different panicle type accessions. Number of panicles/plant, number of panicles/tiller, number of racemes/panicle and number capsules/raceme were found to be important factors contributing to yield in cardamom.

INTRODUCTION

At Indian Cardamom Research Institute, Regional Station, Saklespur, Karnataka, preliminary evaluation of 34 of the 61 small cardamom (*Elettaria cardamomum* Maton) accessions were carried out with a view to isolating superior clones for further evaluation.

MATERIALS AND METHODS

Germplasm accessions were collected from different parts of Western Ghats of South India as well as from Ceylon and Guatemala. The collected material was grown under similar agroclimatic condition with 2M × 2M spacing in observation lines. Uniform suckers were planted during August 1982 and the observations were recorded during 1984-85 crop season. Morphological and yield characters were recorded during the crop season. The accessions were made into three groups based on their panicle characters. Among the 34 accessions studied, 19 were with prostrate panicles (cv. Malabar), 9 accessions were erect panicle type (cv. Mysore) and 6

accessions were semi-erect panicle type (cv. Vazhukka).

For the comparison between the different panicle types, six accessions in each case performing better within the groups were averaged and compared.

RESULTS

The accessions were compared with respect to eight important characters. Comparisons were made within individual panicle types as well as between different panicle types.

Between the types, significant differences were found in all the characters studied, except in number of tillers per plant where there was no significant difference (Table I). The value for number of panicles per plant, length of panicles, percentage of fruit set and mean yield per plant were significantly high in prostrate panicle types. Number of racemes per panicle was higher in prostrate and semi-erect panicle types. The number of capsules per raceme was more in semi erect type.

Table I. *Comparison of mean values of yield characters between types*

Treatments	No. of tillers/ plant	No. of panicles/ plant	No. of panicles/ tillers	Length of panicle (in cm)	No. of raceme/ panicle	No. of capsules/ %	Fruitset plant	Mean yield/ plant
T ₁ Erect type	34.06	19.72	1.61	30.51	13.25	3.21	40.01	325.50
T ₂ Semi-erect type	31.44	19.22	1.49	40.51	18.96	5.43	37.29	429.28
T ₃ Prostrate type	32.56	32.94	1.58	43.53	1796	3.69	51.03	797.00
CD	NS	S 5.33	S* 0.09	S 1.23	S 1.58	S 0.40	S 1.51	S 233.40

NS = Not significant, S = Significant at 1% & 5% level

S* = Significant at 5% level only.

Table II. *Mean values of important yield characters in prostrate panicle type*

Treatments	No. of tillers/ plant	No. of panicles/ plant	No. of panicles/ tiller	Length of panicle in Cm.	No. of raceme/ panicle	No. of capsules/ raceme	Fruit set %	Mean yield/ plant
T ₁ Malabar	28.33	20.67	2.06	49.50	17.00	4.20	46.75	416.67
T ₂ Kanni Elam	32.67	21.67	1.75	37.83	20.33	4.20	55.44	583.00
T ₃ Malabar LC	38.33	27.33	1.77	46.87	18.67	3.22	45.82	777.00
T ₄ Hema	26.33	25.33	1.63	37.63	15.00	3.99	48.61	363.33
T ₅ Malabar 57	30.67	21.00	2.04	47.98	14.25	4.10	50.25	446.00
T ₆ Cinchona selection	19.00	15.33	1.32	82.00	10.10	3.50	57.12	548.00
T ₇ Walayar Selection	25.67	15.00	1.53	34.00	20.00	6.15	54.96	428.67
T ₈ PV1	47.00	13.90	1.25	21.53	18.17	2.70	48.08	399.33
T ₉ PV2	22.33	17.67	1.22	37.50	19.50	3.20	49.92	612.67
T ₁₀ PV3	13.33	12.67	1.39	20.93	15.17	3.15	41.47	122.67
T ₁₁ PV4	22.33	16.00	1.49	34.08	16.10	4.40	27.01	158.33
T ₁₂ PV6	17.00	9.67	1.15	25.72	16.00	3.78	34.23	64.33
T ₁₃ PV7	28.00	19.00	1.47	33.33	19.33	3.81	48.82	227.67
T ₁₄ Malabar SI	35.33	24.33	1.44	33.25	17.97	3.83	52.20	532.33
T ₁₅ APG 5	26.33	31.67	1.70	39.50	17.00	4.00	49.52	599.67
T ₁₆ Malabar LBC	37.00	57.67	1.73	68.42	17.73	4.33	46.05	1537.33
T ₁₇ " HY	23.00	22.00	1.54	34.42	15.00	4.23	53.17	297.00
T ₁₈ " MBP	25.67	16.33	1.47	29.25	13.22	3.75	55.60	244.67
T ₁₉ " TP	38.67	41.67	1.28	31.07	14.50	3.20	59.45	672.33
CD	S 14.99	S 14.42	S 0.18	S 4.34	S 2.55	S 0.63	S* 14.66	S 526.61

S = Significant at 1% and 5% level.

S* = Significant at 5% level only.

Table III. *Mean values of important yield characters in erect panicle type*

Treatments		No. of tillers/ plant	No. of panicles/ plant	No. of panicles/ tiller	Length of panicles (Cm.)	No. of raceme/ panicles	No. of capsules/ raceme	Fruit set %	Mean yield plant
1		2	3	4	5	6	7	8	9
T ₁	Mysore	34.67	13.67	1.79	21.08	12.03	4.33	41.02	181.00
T ₂	Narrow leaf	39.67	14.33	1.72	10.87	10.75	2.73	46.14	151.33
T ₃	Alfred clone	52.33	26.67	2.05	38.77	15.57	2.62	40.76	350.67
T ₄	Ty. 15 LP	24.00	12.67	1.64	19.92	11.25	2.97	29.24	213.67
T ₅	Ty. 15 LBC	31.00	16.00	1.41	37.43	9.35	3.48	34.70	158.33
T ₆	Ty. 7	17.67	11.33	1.17	27.34	4.07	2.50	44.94	144.00
T ₇	Ty. 15	30.00	18.33	1.38	27.50	12.83	2.97	36.23	176.67
T ₈	Ceylone	30.00	14.67	1.44	32.63	17.37	3.05	37.14	86.33
T ₉	Guatemala	32.33	31.00	1.45	38.37	17.47	2.90	58.08	866.67
CD		S*	S*	S	S	S*	S	S	S*
		16.58	9.55	0.15	2.35	4.35	0.25	3.10	423.03

Within the prostrate panicle type, the mean yield in eight of the accessions exceeded 500 g per plant. T-16 Mal. LBC gave significantly higher yield than all the other accessions (Table II).

When accessions within erect panicle type were compared, it was observed that T₉ - Guatemala accession was superior to all the others in majority of

the characters studied. The mean clump yield was significantly high in T₉ (Table III).

Among accessions of semi-erect type accessions T₄ - CP2 and T₅ - CP3 had significantly higher yield (Table IV).

DISCUSSION

In general the prostrate panicle types

Table IV. *Mean values of important yield characters in semi-erect panicle type*

1		2	3	4	5	6	7	8	9
T ₁	Vazhukka	44.67	24.33	1.58	34.47	19.13	6.12	53.10	449.67
T ₂	Pink tiller	36.67	19.00	1.71	32.13	19.40	3.15	44.90	248.67
T ₃	CP - 1	16.33	7.67	1.12	48.46	21.27	7.17	28.93	214.00
T ₄	CP - 2	26.00	18.00	1.75	45.51	19.80	7.13	25.50	500.00
T ₅	CP - 3	42.33	31.00	1.47	51.37	19.50	4.90	31.03	737.67
T ₆	Ty - 6	22.67	15.33	1.31	31.12	14.67	3.85	40.27	426.67
CD		S	S	S	S	S*	S*	S	S
		11.39	7.97	0.10	2.18	0.85	1.12	4.28	245.42

S = Significant at 1% and 5% level.

S* = Significant at 5% level only.

performed better than the semi-erect and erect panicle types with respect to majority of the characters studied, indicating better suitability of prostrate panicle varieties to Karnataka region. This has earlier been suggested by Mayne (1951).

Among the prostrate panicle accessions 8 accessions yielded more than 500 gm of green capsules per plant on an average. Among these, T16 – Malabar LBC was yielding significantly higher than all the other accessions. Even though among these 8 good yielders the yield was comparable, they differed with respect to 4 important characters, i.e., the number of panicles per plant, number of panicles/tiller, number of racemes per panicle and number of capsules per raceme. Thus, it is found that these 4 characters are the important factors contributing to yield in cardamom. During selection, preference should be given to the plants with high values in one or more of these characters. In the present study, T 16 – Malabar LBC was found to have high values in all the important characters except in the number of racemes per panicle. This

accession is a promising one as a high yielder.

Among the erect panicle type, T9-Guatemala selection had significantly higher yield and was superior in other characters also. Hence, among the erect panicle type T9 was found to be a promising clone.

Among semi-erect panicle type, T1-Vazhukka, T4-compound panicle-2 and T5 compound panicle-3 were the promising lines. Further evaluation is under progress.

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NURSERY EVALUATION OF SOME EXOTIC GENOTYPES OF *HEVEA BRASILIENSIS* MUELL. ARG

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ABSTRACT

With a view to broadening the genetic base of *Hevea brasiliensis* Muell. Arg, the International Rubber Research and Development Board launched an expedition in 1981 to the Amazon rain forests of Brazil, the centre of origin of *Hevea*.

Nucleus materials of hundred genotypes belonging to the clones established from the seeds collected from two provenances during the expedition, were introduced to India. These were vegetatively multiplied and established in the nursery. Scion height and basal diameter were recorded nine months after nursery planting. Total number of leaves and number of flushes were also recorded. Juvenile yield was recorded by the pricking method 14 months after planting. The genotypes exhibited variability with regard to the characters observed. Morphological variability was also observed. The significance of introduction of new germplasm for improvement of this crop is discussed.

INTRODUCTION

The history of tree improvement in *Hevea brasiliensis* reveals that all improved planting materials have been evolved from a few trees raised from the limited number of seeds collected at the end of the last century. *Hevea* breeders from different rubber producing countries have expressed serious concern over the limitation of the narrow genetic base available for crop improvement programmes.

A slow down of genetic advance in more recent breeding phases (Tan, 1981) could be accounted for the limited genetic stocks available. Screening tests of clones for resistance to South American Leaf Blight (SALB), have shown that none of

the oriental clones has any form of resistance to this devastating disease (Wycherley, 1977). There are also indications of eroded resistance to *Oidium* and *Gloeosporium* in the original Wickham material (Anon, 1981). Hence Simultaneous steps are necessary for the introgression of SALB resistance into high yielding cultivars as well as to conserve the gene pool. Rubber cultivation in India, being extended to non-traditional tracts, emphasis will have to be given to breeding for resistance to diseases, drought, cold, wind etc. Therefore the availability of a wide array of diverse genotypes for use in breeding programmes assumes much significance.

Wild genotypes of *Hevea* are available

only in the Amazon forests of Brazil, the centre of diversity of the genus. There are reports of constant threat to the survival of the genus in this region (Allen, 1984, Wycherley, 1977). The International Rubber Research and Development Board (IRRDB), considering the gravity of the situation, launched an expedition to the Amazon forests of Brazil in 1981. The team collected over 60,000 seeds, budwood from 162 trees and a few seedlings (Allen, 1984). All these materials were sent to the National Rubber and Oil Palm Research Centre (CNPSP - Centro Nacional de Pesquisas de Seringueira and Dende), at Manaus in Brazil. The entire budwood and 50% of the seeds were retained at CNPSP. The two IRRDB germplasm centres at Malaysia and Ivory Coast received 37.5% and 12.5% of seeds respectively after intermediate quarantine at U.K. By mid 1981, ca 15000 new genotypes were established at the Malaysian Centre and 3300 in Ivory Coast. In the RRIM the seedlings were moved to a 22 ha gene pool garden late in 1982. In addition, insurance budding was done to establish a source bush nursery and the Malaysian centre started despatch of materials by 1984. In September 1984, India received the first set of 100 genotypes. A second set of 100 genotypes were received early in 1985 and another 600 genotypes just recently. These introductions have to be conserved as well as exploited. In the present paper an attempt is made to evaluate the first set of 100 genotypes with respect to certain growth parameters and other characters at the nursery stage.

MATERIALS AND METHODS

Hundred genotypes of *Hevea brasiliensis*

from the wild germplasm collection, introduced to India in 1984, were used in the present study. These genotypes belonged to three different sources viz., Ro/J/05 (36 genotypes), Ro/JP/3 (17 genotypes) and MT/IT/14 (47 genotypes) the former two from the Territory of Rondonia and the latter from the state of Matto Grosso. The nucleus materials, received as budwood were grafted on to seedling stocks and the clones were successfully established in a budwood nursery at the Central Experiment Station of the Rubber Research Institute of India. Sixteen plants each were planted at a spacing of 90 × 90 cm along with RRIM-105 as control. At the age of nine months, scion height, diameter of the scion at the base, length of the third flush, number of flushes, total number of leaves and number of leaves in the third flush were recorded. The stem portion at a height of nine cm was pricked using a fork and the latex oozing out was collected using pre-weighed blotting paper strips and quantified after drying.

RESULTS

The genotypes exhibited wide variability with respect to all the characters studied. Among the different genotypes, scion height ranged from 83 (Ro/JP/3 22/15) to 180 cm (Ro/J/05 33/51) in comparison to 71 to 105 cm for the control. Similarly the basal diameter of the scion showed a range of 8 (MT/IT/14 30/105) to 23 (Ro/J/05 33/85) mm (9 to 12 mm in control), number of flushes 3 to 5 (3 to 4 in control), total number of leaves 12 (MT/IT/14 30/86) to 67 (MT/IT/14 30/82) (21 to 33 in control), number of leaves in third flush 7 (Ro/JP/3 22/15) to 16 (Ro/J/05 33/68) (3 to 13 in control) and the length of the third flush 6 (Ro/J/05 33/85) to 25

cm (Ro/J/05 33/68) (8 to 15 cm in the control). The dry weight of rubber ranged from 0.002 (Ro/J/05 33/69) to 0.046 g. (MT/TT/14 30/121) compared to 0.02 to 0.77 g. in the control. The mean of the different characters in the germplasm genotypes viz., plant height 125.71 cm (89.88 cm in the control), diameter at the base 12.95 mm (10.2 mm in control), number of flushes 3.92 (3.6 in control) total number of leaves 34.35 (25.4 in control) number of leaves in the third flush 10.94 (10.2 in control) and the length of the third flush 11.42 cm (10.4 cm in the control) also varied considerably compared to the respective mean values of the control (Table I). The average dry weight of rubber in the latex, collected after pricking, was 0.017 g in comparison to 0.038 g in the control.

The genotypes in general appeared more vigorous than the control. Among the materials from three different sources, Ro/J/05 exhibited the highest vigour and Ro/JP/3 the least.

Apart from the variability noticed in the different characters mentioned, certain clones exhibited morphological

variations also. High vigour was observed in Ro/J/05 33/53 (Fig. 1), Spindle growth in MT/TT/14 30/38 (Fig. 2) and low branching in MT/TT/14 30/15 (Fig. 3). Variability in leaf size and shape like long and narrow, short, broad and cuspidate, boat shaped, wavy leaf margins etc. (Fig. 4) were observed. Similarly close flushes with large number of leaves (Ro/J/05 33/89 Fig. 5), distant flushes (Ro/J/05 33/66 Fig. 6), dome shaped flushes (MT/TT/14 30/85 Fig. 7), prominent leaf scar (Ro/J/05 33/93 Fig. 8) plants with large number of small narrow leaves (MT/TT/14 30/127 Fig. 9), pale green leaves distributed throughout the stem (MT/TT/14 30/22), leaning stem (Ro/J/05 33/68), very close internodes with prominent pulvinus (Ro/JP/05 33/70 Fig. 10), etc. were also recorded. The occurrence of morphological variability was the highest in the group Ro/J/05. Visual observation for certain common diseases indicated that the clone MT/TT/14 30/108 showed susceptibility to shoot rot caused by *Phytophthora* spp and MT/TT/14/30/1, 30/6, 30/12 etc. were susceptible to secondary leaf fall caused by *Gloeosporium* spp. The materials, however, have to be screened thoroughly at periodic intervals

Table I. Growth parameters (mean) and dry weight of rubber of the 100 genotypes from Brazil

Source	Scion height (cm) $\pm$ SD	Scion diameter at base (mm) $\pm$ SD	Number of flushes $\pm$ SD	Total No. of leaves $\pm$ SD	No. of leaves in third flush $\pm$ SD	Length of third flush $\pm$ SD	Weight of latex (g) $\pm$ SD
Ro/J/05	134.11 $\pm$ 22.3	13.72 $\pm$ 2.7	3.80 $\pm$ 0.62	34.27 $\pm$ 6.40	11.69 $\pm$ 1.82	11.50 $\pm$ 3.78	0.021 $\pm$ 0.027
Ro/JP/3	118.88 $\pm$ 23.62	12.18 $\pm$ 1.51	3.53 $\pm$ 0.51	27.70 $\pm$ 5.18	9.65 $\pm$ 1.77	10.29 $\pm$ 1.99	0.011 $\pm$ 0.008
MT/TT/14	121.74 $\pm$ 23.05	12.64 $\pm$ 2.35	4.14 $\pm$ 0.59	36.81 $\pm$ 8.7	10.81 $\pm$ 1.36	11.74 $\pm$ 2.44	0.022 $\pm$ 0.014
General mean	125.71 $\pm$ 23.54	12.95 $\pm$ 2.63	3.92 $\pm$ 0.68	34.35 $\pm$ 8.07	10.94 $\pm$ 1.75	11.42 $\pm$ 2.96	0.017 $\pm$ 0.009
Control	89.88 $\pm$ 16.92	10.20 $\pm$ 1.30	3.60 $\pm$ 0.55	25.4 $\pm$ 5.37	10.20 $\pm$ 1.92	10.40 $\pm$ 2.79	0.038 $\pm$ 0.022

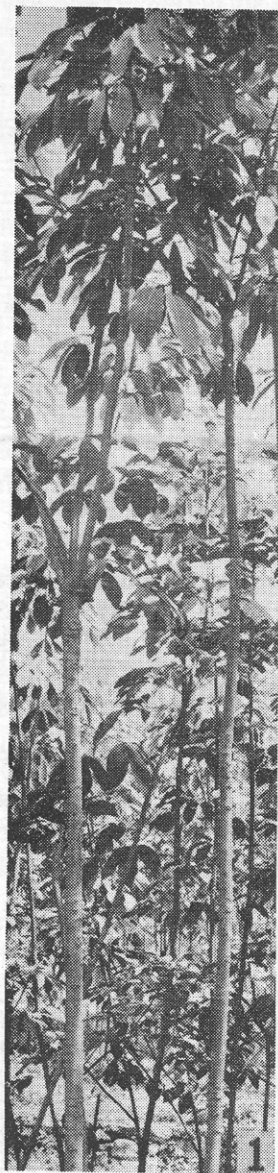


Fig. 1. Highly vigorous clone

Fig. 2. Spindle growth

Fig. 3. Low branching

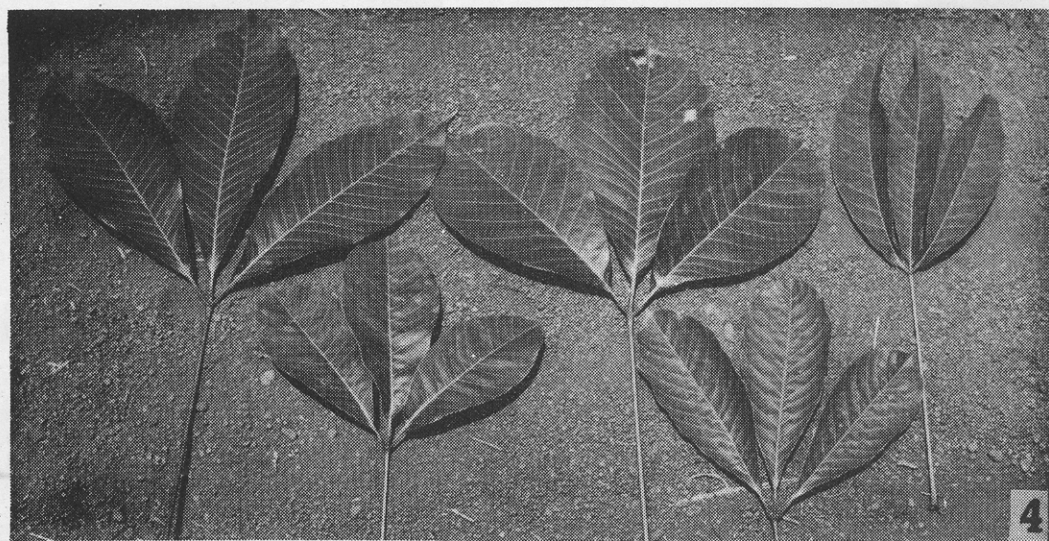


Fig. 4. Leaves of different sizes and shapes Fig. 5. Close flushes Fig. 6. Distant flushes (right) and control (left) Fig. 7. Dome shaped flushes



Fig. 8. Prominent leaf scars Fig. 9. Large number of small narrow leaves
 Fig. 10. Very close internodes with prominent pulvinus

to study the occurrence of common diseases.

DISCUSSION

The population of *Hevea brasiliensis* in

the South East Asia can be traced back to a narrow genetic base comprising 20-22 seedlings (Subramaniam, 1980, Simmonds, 1985). Added to the constraint of limited genetic stock, the wider adaptation of clonal propagation has narrowed down the genetic base in the breeding pool. In the early years of crop improvement, main emphasis was given to high yield which resulted in a sort of directional selection for yield (Markose and Panikkar, 1984). The cyclical breeding pattern in *Hevea*, which may be called generation wise assortative mating, where the best genotypes are crossed with the best in each cycle (Simmonds, 1985) has also resulted in narrowing down the genetic base while increasing genetic uniformity.

The genotypes belonging to the recent collection of Brazilian germplasm exhibited wide variation in growth measured in terms of morphological parameters. This is in accordance with the general expectation that wild species and primitive forms from the centre of origin exhibit much diversity.

Similarly the increased vegetative vigour of genotypes over the control as evident in Table I could also be attributed to the diverse nature of the wild materials. The control clone RR11 105, being a selection for high yield has reduced vigour in comparison to the primitive genotypes. Indications of increased yield potential of RR11 105 over the germplasm genotypes are shown in the nursery stage itself. However a few genotypes show yield figures comparable to that of the control.

Among the 100 genotypes from three

different sources, the material Ro/J/05 exhibited the highest vigour. This may be due to hybrid vigour since reports on the probable hybrids of *Hevea brasiliensis* and *Hevea guianensis* in Costa Marques of Rondonia provenance (Anon, 1982) are available. However the 17 genotypes belonging to Ro/JP/3 did not show the same extent of vigour.

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SESSION VI : DISCUSSIONS

Dr. M.K. Nair: This is the first time we are having a session on germplasm at PLACROSYM. This shows that we are realising the need for conserving the plant genetic resources in view of rapid deforestation and depletion of resources.

Mr. S. Krishnan: For a layman like me Dr. Bhaskara Rao's paper was most enlightening and then I heard Dr. I.D. Singh on growing of tea. When we look at germplasm collection in coffee and even recently in rubber, we have the largest area of any plantation crop under tea and you take the value of export earnings in tea, when you look at the future breeding programme in tea the germplasm collection looks to be pathetically low. Now we have the General Chairman, the Director of Research in UPASI Tea Research Institute. I think you must take it to the Executive Committee and Tea Technical Committee and TPSC of UPASI as to how we compare with other plantation crops. I certainly feel that even in S. India, I know tea plants, like in Anamallais which are as old as 120 years, still yielding 3000 kgs made tea per hectare. So the most important thing I feel is that we should certainly have on every reputed estate a plant reserve and I certainly feel that no time should be lost in the interest of tea industry to achieve this. Dr. I.D. Singh's paper was an eye opener. One more point before I leave, I am very grateful for the point made by Dr. Bhaskara Rao on internal quarantine. If we had only known about internal quarantine we would not have had blister blight in South India. Now, how lucky these African

Rs.1000/ha in South India to control countries are. Here we spend over blister blight. I heard from my friends, who recently had been to Malawi, that they have very high yielding selections yielding in the region of 6 to 7000 kg of made tea/ha and after all it was Indian seed. So certainly I feel that there must be jewels in our collection. Tea industry should lose no time in looking into the germplasm collection. I remember Dr. Swaminathan about 15 years ago made a reference on having a good germplasm collection in tea.

Dr. K.K. Krishnamoorthy: I react to Mr. Krishnan's very good suggestion about germplasm in tea. I would like to mention to him and to the audience that we would like to have the world germplasm collection of tea by the UPASI T.R.I. Already we have the land for that. Very soon we will be embarking on this project of collecting the world germplasm collections.

Mr. M.R. Sudharshan: While projecting the slides on different institutions maintaining germplasm Dr. Rao has omitted Indian Cardamom Research Institute which is having more than 300 accessions which is perhaps highest in the world.

Dr. E.V.V.B. Rao: I have put it under Cardamom Board but I will correct it.

Dr. P.K. Koshy: Dr. Rao has briefly touched upon the internal quarantine. We are always worried about exotic collection, and plant quarantine in that.

On internal quarantine we have not paid much attention. To take a specific case, as an example some years back we made a collection of ginger. We have collected ginger from all ginger growing tract in India and they were all distributed to three places in India. I do not think any treatment was given to rhizomes collected. If we have some important diseases or pest in Assam, we would have brought them to Trichur and other places. In such collections, we should make it a point that if it is rhizome of ginger we should wash the rhizomes and dip in a fungicide-insecticide mixture at the point of collection, so that we are not carrying any insects or diseases to other parts of the country. We have not been doing it. We do not give any importance while collecting to internal plant quarantine in India. I think we should be paying some more attention to this.

Dr. M.K. Nair: I think there is a need for taking this into consideration and a decision on what Dr. Koshy has raised now.

Dr. P.K. Koshy: As far as cardamom is concerned we have got nurseries run by Cardamom Board and various agricultural departments for black pepper or for coconut. In most of these materials we have not been careful in using methyl bromide fumigated soil and hardly there is any fungicide or insecticide treatment to these plants when they are distributed all over India through coordinated projects. I know cardamom plants go from Anamallais to Idukki. But I do not think we have been careful in protecting these plants or giving sprays before they are sent out of nurseries.

Dr. R. Naidu: We had a very bitter

experience on large scale fumigation on nurseries of Karnataka. Though in initial stage we could minimise the population of nematodes, at later stage the seedling rot has taken upper hand and we lost many seedlings and when we go for the total sterilization, we will kill a lot of beneficial insects and pathogens will take an upperhand.

Dr. P.K. Koshy: The problem which Dr. Naidu raised is that because they used EDB. They have not used methyl bromide. If we use EDB you only control the nematodes but when you use Methyl bromide it results in total sterilization and you will not have any fungus to take a heavy toll.

Dr. M.S. Srinivasan: As far as coffee is concerned, Director of Research is the only person who has been authorised to import living parts of coffee and fortunately for coffee we do not have any seed borne diseases. Leaf rust cannot enter through seeds. Any seed material which we are getting through other research institutes will be fully kept under quarantine. Only thing which we have to be careful about is berry borer which has been prevalent even in Sri Lanka. Berry borer is so far absent in India. If at all Indian Coffee is having very good quality, especially robusta, it is because of the absence of berry borer which is present in Indonesia and ivory cost.

Mr. E.V.V. Bhaskara Rao: The point which I forgot to mention in my lecture was brought out by Mr. I.D. Singh. For each germplasm collections in plantation crops it is very essential to have an alternate centre because we are maintaining it in the field. We are exposing our collections to the danger of eradication by any natural calamities. So CPCRI has already

made an attempt and we are maintaining our precious collections in two centres. The General Chairman has made a comment that he is going to have world tea germplasm centre. I think the point mentioned by I.D. Singh has to be very seriously considered and we have to establish the link between both these tea institutes. At least some of the more important collections have to be duplicated in both the centres.

Dr. Y.R. Sarma: Referring to the large scale damage of cardamom nursery by *Pythium* it is mostly because, irrespective of EDB or methyl bromide fumigation, once you fumigate the soil all organisms naturally occurring in the soil are being killed. Normally the possibility of aggravation of this sort of disease occurs, when there is a contamination of natural soil with the fumigated soil. So, special precautions should be taken to prevent the contact of fumigated soil with natural (unfumigated) soil. Regarding pepper, during 1979, Dr. Swaminathan actually mentioned in one of his recommendations that any sort of material that is sent from Kerala should have the phytosanitary certificate and internal quarantine regulations with respect to nematodes and phytophthora. Recently in a publication from a North-Eastern complex, where pepper is of very recent origin, they have reported Phytophthora. So we should definitely take a decision regarding internal quarantine taking into consideration all crops specifically for vegetative propagated crops so that we do not spread the disease in the name of plant propagation, and plant introduction.

Dr. M.K. Nair: Before concluding I would like to make two or three observations to supplement what Dr.

Bhaskara Rao has said. One is that most of the plantation crop Research Institutes have got very valuable germplasm collection, but the documentation is very poor. The documentation in the manner in which it is generally accepted and approved can be thought of and either the document can be brought out individually or in a combined form. Another important point is that normally breeders are doing the collection and we do not do seed preservation or plant preservation. This I am mentioning because we ourselves have run into problems now. In the case of ginger germplasm collection even though we have collected about 220 germplasm at present we are having only 120. so there is a need to initiate studies on preservation of seed as well as clonal material. Even in cases where normal propagation is by clones, if seed is there seed preservation will help us in preserving the gene pool so that later on we can go back to the seed. Probably NP, PGR will be able to help in this case by either providing a central preservation module or the individual institutes where funds are available. For example Cardamom Research Institute can think of the preservation module. It is to be considered whether joint exploration is possible specially in the case of pepper, cardamom, arecanut and tea in N.E. India. Now the individual institutes are already doing survey and lot of resources are being spent. Last item which I would like to mention is on tissue culture and embryo preservation because that is being followed in most of the developed countries for germplasm preservation. Most of the institutes working on plantation crops have tissue culture laboratories but we have to go for germplasm preservation also.

CHAPTER VII

CROP VARIETAL IMPROVEMENT

Chairman : Dr. K.V. AHAMED BAVAPPA

Rapporteurs : Dr. A. O. N. PANIKKAR

: Dr. K. J. MADHUSOODANAN

VARIETAL IMPROVEMENT IN PLANTATION CROPS

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Researches on varietal improvement in plantation crops are beset with a variety of problems such as narrow genetic base, long juvenile phase, self incompatibility barriers, exclusively seed propagated nature of some of the species and highly heterogenous nature of the phenotypes involved. Unlike most others, the polymorphic origin and consequent wide genetic diversity and amenability to vegetative propagation makes crop improvement in tea through clonal selection easy. This method of improvement has resulted in a number of clones with high yield potential and quality and about 40% increase in productivity has been achieved in the last quarter of a century. In coffee rust resistance breeding had precedence over all other requirements. Of late double cross and inter-specific hybridisation followed by back crossing have resulted in improved rust resistant hybrids with yield potential of about 1200 kg/ha/year. Starting with a yield level of 150 kg dry rubber/ha/year through selection and hybridization in a complementary manner an average yield of over 850 kg/ha/year has been achieved in India. A yield potential of about 10,000 kg/ha/year has been predicted by Malaysia.

In coconut and arecanut selection procedures adopted have yielded varieties like Lakshadweep Ordinary, Mangala, VTL-11 and 17 having higher yields upto

70%. Coconut hybrids involving different dwarfs and tall have yielded about 130% more compared to the best parent. In addition, single trees yielding over 400 nuts/palm/year are already available in the natural population. A quantum jump in the yield of coconut from its present national average of 30 nuts to even 200 can be achieved if an efficient method of tissue culturing of such palms can be standardised. The monotypic nature of coconut will, however, continue to be a limiting factor in breeding coconut varieties suitable for cultivation in diverse ecological situations.

In cashew 16 varieties and hybrids have been evolved having yield potential of about 15 kg/tree/year when the plants are about 10 years of age. This success if could be exploited extensively through vegetative propagation methods will have decisive impact on cashew production in the country. Though intra-varietal variation in this crop is fairly wide broadening of the germplasm base through introductions from Brazil and African countries will have to be undertaken.

The Panniyur-I pepper released has a yield potential of 10-15 kg of green berries/vine/year. The available genetic diversity in this crop is extremely good and yield evaluation trials in progress in Karimunda and Kottanadan holds out

considerable promise for evolving not only varieties having high yield potential but also capable of performing well under diverse ecological situation. Intensive search for resistance to quick wilt of pepper has yielded useful results and a number of wilt resistant lines are under evaluation. In cardamom, through selection, clones capable of yielding upto 1000 kg/ha/year have been isolated against the national average of 65 kg/ha/year. Katte resistant lines evolved through mutation breeding are in the final stages of yield evaluation.

Though the success achieved in the varietal improvement is creditable there is an evident need to further intensify exploitation of the available variability through wide crossing and selection. In doing so it is essential that parents having specific qualitative traits such as disease resistance, quality superiority, stress tolerance etc. are identified and used in crossing programmes. Sustained efforts to develop homozygous lines for exploiting hybrid vigour are also called for. Since *in vitro* screening for disease resistance and stress is possible large number of parents can be subjected to such micro techniques and the gene sources identified in the parents. Performance prediction of seedling progenies and clones using biochemical and physio-

logical markers should be prefected for making the seedling selection in the nursery more purposeful. The dwarfing genes available in coffee, arecanut and coconut have to be used for developing types suited for mixed cropping systems. Efforts to develop varieties to meet special needs such as mechanised tapping in rubber and plucking in tea, uniform ripening in cashew and coffee have to be planned.

In the prediction of the progeny performance both statistical tools like D^2 statistic for selecting parents and molecular techniques such as mitochondrial complementation will have to be thought of to cut short the time lag involved in such programmes. While the self-sterility and self-incompatibility mechanisms are handicaps in pure line selections, commercial production of hybrids using biclonal parents become easy in such cases. While choosing parents for hybrid seed production due consideration may be given for this. The possibility of attaining yield plateau in many of the crops is imminent and to have further break-throughs in yield increase, breeders will have to work hand-in-hand with bio-chemists, biotechnologists and physiologists. These aspects are discussed in the light of the achievements so far obtained.

GENETIC VARIABILITY OF GROWTH AND YIELD CHARACTERS IN SOME SELECTIONS OF COFFEE

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ABSTRACT

Variability in certain growth and yield characters was studied in eight different coffee selections growing under the eco-climatic and edaphic conditions of the Regional Coffee Research Station situated in the Eastern Ghats of Visakhapatnam District, Andhra Pradesh. The data collected for four years were subjected to statistical analysis to find out the estimates of variability, phenotypic and genotypic coefficients of variation, heritability and genetic advance. Highly significant differences (at 1%) existed between selections in respect of all growth and yield characters. The higher yields in Sln.4A (Agaro), Sln.11 [S. 2464 (*Coffea liberica* × *Coffea eugenioides*)] and Sln.7 (San Ramon Bulk) were due to higher length of primaries and more number of fruiting nodes and berries per primary in the initial years. Phenotypic and genotypic coefficients indicated substantial variability in most of the growth and yield characters. Maximum phenotypic and genotypic coefficients of variability was observed in number of fruiting nodes per primary and secondary, number of berries per primary and in yield per plant. Heritability was high for majority of the growth and yield characters studied. Relatively higher genetic advance was found in the order of: yield per plant, number of berries on primary, primary length and number of fruiting nodes on secondaries, as compared to other characters.

INTRODUCTION

Arabica coffee (*Coffea arabica* L.) is considered as a polymorphic species due to its wide variability in growth, yield and other morphological characters (Srinivasan and Vishveshwara 1981; Anon., 1985). Variability for many characters although reported by some workers (Vishveshwara and Jamsheed Ahmad, 1975., Jamsheed Ahmad *et al.*, 1977., Srinivasan *et al.*, 1979., Thimma Reddy and Srinivasan, 1979; Srinivasan and Vishveshwara 1981; Srinivasan, 1982), the exact nature and extent of variation present in the growth and yield

characters of certain selections of arabica coffee introduced for large scale cultivation under the eco-climatic and edaphic conditions of Andhra Pradesh have not been studied. Carvalho *et al.*, 1969 and Srinivasan *et al.*, 1979, stressed the need of testing coffee in the different eco-climatic conditions for selecting progenies suitable for particular regions as well as for wide adaptability. The biometrical studies indicated that selection of a particular arabica type with higher yields could be done efficiently by taking into account of various growth parameters and yield characters (Singh, 1968;

Srinivasan and Vishveshwara, 1973, 1981; Walyaro and Van der Vossen, 1979; Srinivasan, 1980; Van der Vossen, 1985).

The present study was taken up to find out the precise variability existing in the five growth characters viz., stem girth, number of primaries per plant, length of primaries, number of secondaries per primary, number of tertiaries per primary and four yield characters like the number

of fruiting nodes per primary, number of berries on primary, number of fruiting nodes on secondaries and yield per plant in eight selections of *Coffea arabica* including Sln.11 [S.2464 (*Coffea liberica* × *Coffea eugenioides*)], which were growing in the Eastern Ghats of Andhra Pradesh.

MATERIALS AND METHODS

The materials for the study comprised of eight coffee selections (Table I)

Table I. Mean growth and yield characters in different selections of coffee

Sl. No.	Coffee selections	Growth characters					Yield characters			
		Stem girth (cm)	No. of primries per plant	Length of primaries (cm)	No. of secondaries per primary	No. of tertiaries per primary	No. of fruiting nodes primary	No. of berries on primary	No. of fruiting nodes on secondary	Fruit yield per Plant (g)
1.	Sln. 3 (S. 795)	15.3	10.7	65.0	5.1	7.0	2.2	6.4	22.3	75.0
2.	Sln. 3 (S.1934)	15.0	9.9	54.4	5.6	8.9	1.1	3.8	5.6	64.8
3.	Sln. 4T (Tafarikela)	14.6	9.0	60.8	5.9	9.3	3.4	9.2	13.7	136.3
4.	Sln. 4A (Agaro)	16.1	9.3	93.7	6.2	8.6	4.8	22.9	28.6	280.2
5.	Sln. 3.4 [S.2494 (S.1934 × Agaro)]	16.1	9.0	84.9	8.0	12.1	4.0	11.3	14.8	38.9
6.	Sln.6 [S.2089 (Robusta S.274 × Arabica 'Kents')]	16.5	9.8	70.9	6.1	7.7	3.1	18.3	20.2	104.0
7.	Sln.7 (San Ramon Bulk)	12.8	17.6	46.0	3.8	2.3	5.8	77.7	7.2	144.1
8.	Sln.11 [S.2464 (<i>Coffea liberica</i> × <i>Coffea eugenioides</i>)]	14.7	15.4	80.0	6.8	7.6	4.5	19.3	14.5	146.3
	C.D. at 5%	1.6	1.9	11.1	0.8	2.1	1.1	27.3	5.3	100.9
	C.D. at 1%	2.1	2.5	14.7	1.0	2.8	1.5	36.0	7.0	132.8

established at the Regional Coffee Research Station situated in the Eastern Ghats of Visakhapatnam District, Andhra Pradesh. These were evolved at the Central Coffee Research Institute (located in Western ghats), Coffee Research Station - 577 117, Chikmagalur District, Karnataka, and introduced in Andhra Pradesh. Among these selections, Sln.7 (San Ramon Bulk) is a dwarf plant and others are tall arabica type. These selections were raised in a Randomized Block Design with four replications planted during 1976 under natural shade trees. All the cultural operations in vogue were carried out regularly for all the selections.

The growth observations and yield characters were recorded for four years (1981-82 to 1984-85) prior to harvest of berries from ten randomly selected plants in each replication. Thus, the total number of plants for each selection was forty. Stem girth was measured by taking the circumference of the main stem at ground level by means of measuring tape in cm. Length of primaries was arrived by

taking the mean length of top five primaries in each plant. Yield was recorded as fruit (berry) weight (in g) per plant. Means were calculated for each of the growth and yield characters.

The data were subjected to statistical analysis following suitable methods. Analysis of variance was carried out according to Panse and Sukhatme (1978), variability as suggested by Burton (1952), heritability in broad sense according to Lush (1940) and genetic advance at 5 per cent intensity of selection as followed by Johnson *et al.*, 1955.

RESULTS

The means of five growth and four yield characters for eight coffee selections are presented in Table I. The analysis of variance indicated that highly significant differences existed between selections in respect of all the characters studied. The magnitude of variation for these characters are given in Table II. The number of berries on primary and yield per plant showed high coefficient of variation (C.V)

Table II. Mean, range and coefficient of variation for growth and yield characters in coffee

Sl.No.	Characters	Mean	S.F.	Range	C.V. %
GROWTH					
1.	Stem girth (cm)	15.12	0.83	12.0 - 18.0	7.77
2.	No. of primaries per plant	11.34	0.98	8.2 - 18.9	12.25
3.	Length of primaries (cm)	69.42	5.70	41.6 - 98.4	11.62
4.	No. of secondaries per primary	5.94	0.42	3.3 - 9.5	10.10
5.	No. of tertiaries per primary	7.93	1.09	1.6 - 12.6	19.49
YIELD					
6.	No. of fruiting nodes per primary	3.61	0.59	0.7 - 6.5	23.01
7.	No. of berries on primary	21.09	13.96	2.5 - 150.2	93.63
8.	No. of fruiting nodes on secondaries	16.09	2.74	3.3 - 32.8	24.08
9.	Yield per plant (g)	123.70	51.50	26.5 - 421.5	58.88

Table III. *Estimates of variance, phenotypic and genotypic coefficients of variability, heritability and genetic advance in growth and yield characters of coffee*

Sl.No. Characters	Phenotypic variance	Genotypic variance	Coefficients of variability		Heritability (%)	Genetic advance
			Phenotypic	Genotypic		
<i>GROWTH</i>						
1. Stem girth (cm)	2.41	1.03	10.27	6.71	42.7	1.37
2. No. of primaries per plant	12.12	10.19	30.69	28.14	84.1	6.02
3. Length of primaries	307.72	242.66	25.67	22.44	78.9	28.50
4. No. of secondaries per primary	1.75	1.39	22.24	19.81	79.4	2.16
5. No. of tertiaries per primary	9.45	7.06	38.76	33.50	74.7	4.73
<i>YIELD</i>						
6. No. of fruiting nodes per primary	12.76	2.07	46.05	39.88	75.0	2.57
7. No. of berries on primary	840.24	450.35	137.44	100.62	53.6	32.01
8. No. of fruiting nodes on secondaries	69.82	54.81	51.93	46.01	78.5	13.51
9. Yield per plant (g)	9,552.36	4,247.97	79.01	52.69	44.4	89.54

with a very wide range. Moderately higher range and C.V. were also observed for other yield and growth characters. High values of phenotypic and genotypic variance (Table III) were obtained for certain characters such as yield per plant, number of berries on primary and primary length. Genotypic coefficient of variability was high for all the yield characters. Both phenotypic and genotypic coefficients of variation had a very wide range (10.27 to 137.44 and 6.71 to 100.62, respectively). The heritability estimates in the present study were high for majority of the characters. Moderate heritability estimates were obtained for yield per plant and stem girth. Highest genetic advance was obtained for the yield per plant, and relatively higher genetic advance was noticed in the number of berries on primary, length of

primaries and number of fruiting nodes on secondary.

DISCUSSION

The means of growth and yield characters indicated that the higher fruit yields in Sln.4A, Sln.11 and Sln.7 were due to higher primary length and more number of fruiting nodes and berries on primaries. Highly significant differences between selections for the characters studied revealed that substantial variability existed in the plant materials. Wide range was observed for all the yield characters and also some growth characters in the present study. This large extent of variation appears to be mainly due to the presence of a dwarf cultivars S.7 (San Ramon bulk) which is seen to perform better under the eco-climatic and edaphic conditions of Andhra Pradesh.

The genotypic coefficient of variation generally helps to measure the extent of genetic variability in a character, thus helping in selection and genetic improvement of a character under consideration (Gupta, 1972). In the present study, high amount of genetic variability has been observed in yield characters like number of fruiting nodes per primary, number of berries on primary, number of fruiting nodes on secondary and yield per plant. The sizable portion of observed phenotypic variation was due to genetic causes. Therefore, this result prompts for a possibility for improvement of yield by exploiting these existing variability in the yield characters by selection, particularly in the initial years, since the number of bearing nodes occurs mainly on tertiaries, quarternaries and higher order branches in later years.

Estimates of heritability in the present study were high for a majority of the growth and yield characters. In most of the crop plants, heritability of yield is generally reported to be low. In these studies, moderate heritability for yield per plant was observed. In earlier investigations, Srinivasan *et al.* (1979) reported low to moderate heritability for yield character in arabica coffee. Walyaro and Van der Vossen (1979) reported high heritability of yield in coffee grown under the environmental conditions of Kenya. Srinivasan *et al.* (1979) ascribed this type of variation in heritability and genetic variance to environmental influence on the genotypes. According to Panse (1957), if the heritability is due to additive genetic effects, the genetic gain would be low. In the present studies, the highest genetic advance for yield per plant with moderate heritability may be

attributed to additive gene action for the character. Moderate to high heritability in yield per plant, number of berries on primary, number of fruiting nodes on secondary and length of primary with higher to relatively higher genetic advance indicated that there is a possibility to obtain good response to selection in these coffee materials due to the above inherited characters of growth and yield. The above studies would help to screen a number of coffee selections and select the more promising ones in terms of their growth and yield for large scale cultivation under the prevailing eco-climatic and edaphic conditions in the Eastern Ghats of Andhra Pradesh.

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MECHANISMS OF MALE-STERILITY IN SOME SPECIES OF *COFFEA*

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ABSTRACT

Cytochemical and developmental mechanisms involved in the expression of male-sterility in four species of the genus Coffea viz. C. congensis, C. liberica, C. kapakata and C. khasiana were studied and compared with the normal development. It was found that the supply of basic nutrients such as proteins and lipids to the generative tissue was hampered at early developmental stages (sporogenous cell and pollen mother cell stages) in the male-sterile materials of C. congensis and sterile anthers of C. liberica. Suppression of androecium was resulting in male-sterility in C. kapakata and C. liberica. In some plants of C. liberica, adifferentiation of generative tissue was the cause of male-sterility. Tapetal hypertrophy leading to the breakdown of sporogenous tissue and resulting in male-sterility was found in C. congensis and C. liberica. In the anthers of C. khasiana the tapetal differentiation would not take place leading to the degeneration of sporogenous tissue and manifestation of male-sterility. The possibilities of utilizing male-sterility in coffee breeding were outlined.

INTRODUCTION

Male-sterility was effectively used in the production of hybrid seed of various crop plants (Jones and Clarke, 1943; Duvick, 1959; Gabelman, 1956; Horn, 1974). This also provides a strong out-breeding mechanism leading to the release of genetic variability locked up in the relatively inbred plant populations (Ho and Ross, 1973; Ross and Shaw, 1971). This important phenomenon was recorded in some species of the genus *Coffea* (Ram and Ramachandran, 1981; Vishveshwara, 1967; Vishveshwara and Ahmed, 1975). Present paper outlines the various cytochemical and developmental phenomena that result in male-sterility in some species of *Coffea*.

MATERIALS AND METHODS

Floral initiation in the various species of *Coffea* L. takes place in the months of September/ October and the flower buds reach a dormant stage by January/ February. For the present study, the floral buds were collected at 15-day intervals from early December upto the end of February and after rain (in March) at 24 hr. intervals to follow the changes consequential to rain. The normal and male-sterile materials of *C. congensis* Pierre, *C. Liberica* Bull. ex Hiern. and male-sterile materials of *C. kapakata* Hirsch. and *C. khasiana* Hook. were fixed in a mixture of Ethanol-Acetic acid-Chloroform-Lactic acid (16:1:2:1). Dehydration, paraffin infiltration and em-

bedding were done in accordance with Johansen (1940) and Jensen (1962). Serial sections were cut on a Spencer rotary microtome at 8-10 μ m thickness. Cytochemical tests were carried out as follows:

- (i) Pectin: Methylene blue method (Johansen, 1940).
- (ii) Callose: Stockwell's variation of Flemming's triple stain routine (Johansen, 1940; Warmke and Overman, 1972).
- (iii) Starch: IKI reaction (Johansen, 1940).
- (i) Insoluble polysaccharides: PAS reaction (Hotchkiss, 1948; McManus, 1948)
- (v) Proteins: Ninhydrin-Schiff reaction and control by deamination in a mixture of 20 ml of 60% Na NO₂ and 60 ml of 1% Ho Ac at room temperature for 24 hrs. (Yasuma and Ichikawa, 1953).

- (vi) RNA, DNA: Differential extraction by perchloric acid method (Erickson et al., 1949) and localization by methyl green - pyronin method (Brachet, 1953).
- (vii) Lipids/Free fatty acids: Nile blue procedure (Cain, 1947).

RESULTS

Cytochemistry:

Tests to characterize the cell wall constituents indicated the positive presence of pectins and callose in the walls of the tapetal, sporogenous and pollen mother cells. Pollen grains also gave a positive reaction to these tests (Table I). Starch test gave a negative result in the sporogenous and pollen mother cells (Table I). Starch made its first appearance in the connective at late sporogenous stage and continued to increase until meiosis is over. In the connective of the sterile anthers of *C.*

Table I. *Cytochemistry of pollen development in normal and male-sterile materials of some* species of coffea*

Constituent	Stages					
	Sporogenous cell	Pollen mother cell	Meiotic	Microspore tetrad	Uninucleate microspore	O gametophyte
Normal materials						
Pectins	+++	+++	+++	+++	+++	+++
Callose	+++	+++	+++	+++	+++	+++
Starch	—	—	—	+	++	+++
Insoluble polysaccharide	++	++	++	++	++	++
Protein	++(+**)	++(+)	++(+)	++	+++	+++
RNA	+(++)	+(++)	(+)	+++	+++	+++
DNA	+	+	+	+	+	+
Lipid/Free fatty acid	+(++)	+(++)	+(++)	+++	+++	+++

**Coffea kapakapa*, *C. liberica*, *C. congensis* and *C. khasiana*

(Results of normal *C. kapakapa* adopted from Ram et al, 1985; *C. khasiana* normal material not available)

**Reaction in normal material includes that shown in parenthesis

congensis and *C. liberica* starch continued to increase after the collapse of the sporogenous tissue. Starch is also localized in the uninucleate microspores and it registered an increase towards the mature male gametophyte stage (Table I). The tapetum produced a negative reaction for starch during the entire process of pollen development. However, in *C. liberica* and *C. congensis* normal anthers recorded starch traces during pre-meiotic stage. A uniformly intense (++) reaction for insoluble polysaccharides was obtained during the entire course of pollen development in the tapetum, sporogenous tissue and pollen grains (Table I).

Uniformly positive (+++) reaction for protein is obtained during the early developmental stages in all the normal materials studied (Tables I and II). During the sporogenous and pollen mother cell stages there is greater concentration of proteins in the generative tissue than in the tapetum. In the male-sterile material of *C. congensis* and *C. liberica*, this situation is reversed (Table II). A similar result is encountered in the RNA test also (Fig. 1A). Deamination also resulted in positive colour development in the anther locule. A strong positive reaction for DNA is

obtained in the nuclei of all the materials. However, a weak positive DNA reaction is observed in the cytoplasm of sporogenous and pollen mother cells also.

Testing for lipids/free fatty acids indicated that there is no accumulation of reserve fats in the sporogenous cells at any stage during the pollen development. In the tapetal cells, orbicules giving a positive reaction in PAS, protein and lipid tests were noted from late sporogenous upto the mature male gametophyte stage. In the locule reserve, fats appeared in the walls of the uninucleate microspores and mature male gametophyte. Abundant presence of free fatty acids (++++) was recorded throughout the developmental process (Table I). In the sterile anthers of *C. congensis* and *C. liberica*, a situation similar to that noted for proteins and RNA was noted (Table II).

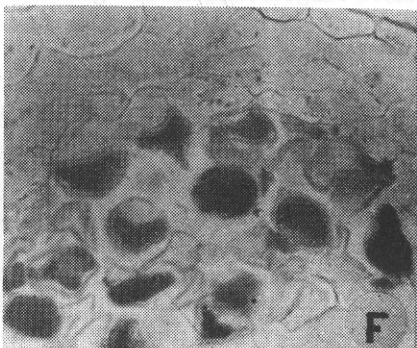
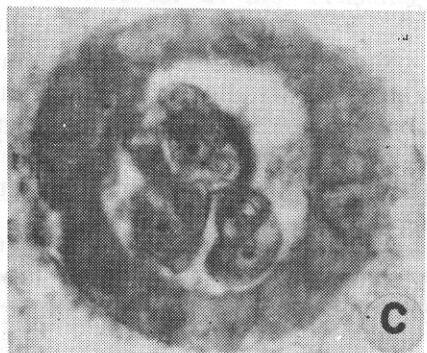
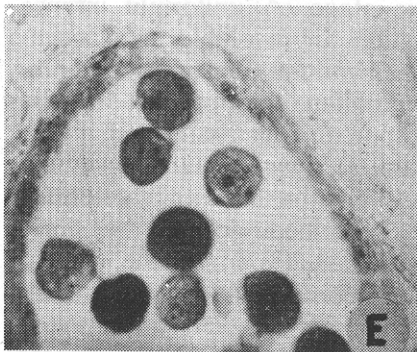
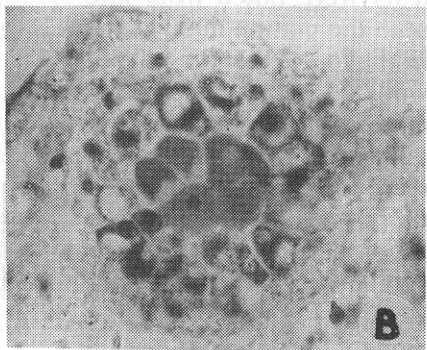
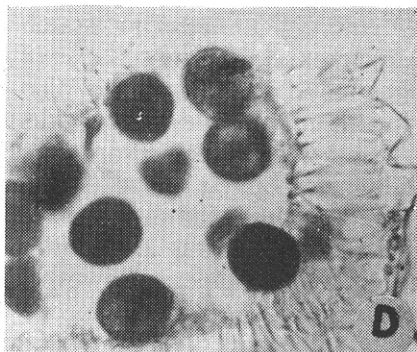
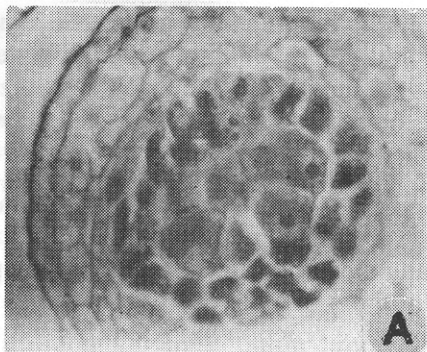
Development:

Suppression of androecium was found to be leading to male-sterility in *C. kapakata* and *C. liberica*. Adifferentiation of generative tissue in the anther (petallody) also leads to male-sterility in *C. liberica*.

In the materials studied, the tapetum is

Table II. *Cytochemical differences between tapetum and sporogenous cells in normal and male-sterile materials*

Constituent	Normal material		Male-sterile materials	
	Tapetum	Sporogenous tissue	Tapetum	Sporogenous tissue
Protein	++	+++	+++	+(+)
RNA	++	+++	+++	+(+)
Lipid/Free fatty acid	++	+++	+++	+(+)



- A. Sterile anther of *C. congensis* in transection showing greater RNA content in the tapetal cells than the sporogenous cells ($\times 1800$). B. Transection of the sterile anther of *C. liberica* showing vacuolation of tapetal cells ($\times 1800$). C. Transection of a sterile anther of *C. kapakata* showing hypertrophy of the tapetum (note: degenerating sporogenous cells) ($\times 1800$). D. Transection of a sterile anther of *C. congensis* showing the absence of tapetum at the uninucleate microspore stage ($\times 1800$). E. Transection of a normal anther of *C. congensis* (Note: the presence of active tapetum at the 2-celled pollen grain stage) ($\times 1800$). F. Transection of a sterile anther of *C. khasiana* showing the a differentiation of tapetum (note: degenerating sporogenous cells) ($\times 1800$).

uniseriate on the parietal side and irregularly multiseriate on the connective side of the anther locule. Cells of the active tapetum are evacuolate with alveolar cytoplasm; they are uni- or binucleate. Degeneration of tapetum commences after the uninucleate microspore stage. First sign of degeneration is vacuolation of the tapetal cells. It is followed by a shrivelling of the protoplast and gradual depletion of all cell contents after the 2-celled pollen grain stage. In the sterile anthers of *C. congensis*, *C. liberica* and *C. kapakata* the tapetum shows vacuolation of its cells at early sporogenous (Fig. 1B), pollen mother cell or pollen tetrad stages and their eventual degeneration leads to the degeneration of the sporogenous tissue or pollen. In some anthers of *C. congensis* there is a rapid degeneration of tapetum at the uninucleate microspore stage which leads to the degeneration of maturing pollen (Fig. 1D), while in the normal anthers the tapetum remains active until 2-celled pollen grain stage (Fig. 1E). In the sterile anthers of *C. liberica* and *C. congensis* the tapetum shows hypertrophy and overproliferation resulting in the degeneration of the sporogenous tissue (Fig. 1C). Partial breakdown of the tapetal cell walls resulting in the formation of a tapetal syncytium was found in *C. liberica* and *C. kapakata*. A differentiation of tapetum leads to the manifestation of male-sterility in *C. khasiana* (Fig. 1F).

DISCUSSION

Cytochemical features in the various materials studied revealed a great deal of homogeneity in the genus *Coffea* and are in conformity with the earlier study (Ram et al., 1985).

Presence of callose in the walls of sporogenous cells and pollen grains of Angiosperms is well known and is possibly important in the nutrition of sporogenous cells and pollen germination (Currier, 1957; Laser and Lersten, 1972; Heslop-Harrison, 1976; Pacini and Franchi, 1983).

Appearance of starch in the anther connective and its increase/decrease pattern is similar to that observed in other species of *Coffea* (Ram et al., 1985). Lipid/free fatty acid cycle is also similar to that in Mozambicoffea (Ram et al., 1985).

Increase of starch and PAS positive granules in the connective of sterile anthers after the collapse of sporogenous cells, noted in the present study is in agreement with the observations of Hosokawa et al., (1963). Protein and RNA test results corroborate each other. However, in the sterile anthers, the tapetum manifests a higher density of these constituents as well as free fatty acids and this is in rapport with the situation in various other crops (Hosokawa et al., 1963; Knox and Heslop-Harrison, 1966; Heslop-Harrison, 1972).

Positive colour development for protein in the deaminated tissue as observed in the present study indicates the presence of glycoproteins (Heslop-Harrison, 1975). DNA positive staining in the cytoplasm of sporogenous cells could be due to the presence of DNA-carrying particles. Reserve fats/oils in the pollen wall are the constituents of pollenkit and tryphine (Echlin, 1971; Dickinson, 1973).

Sex suppression is known to promote out-breeding in Angiosperms and is effectively used for hybrid seed production of certain crops (Frankel and Galun, 1977). Suppression of androecium noted in the present study could be due to the inadequacy of endogenous growth regulators which are known to suppress or reverse sex expression (Galun, 1959) or the presence of sex-suppressor genes as in maize (Singleton, 1962).

Tapetal abnormalities recorded in the sterile anthers are known in several other crop plants also. Premature vacuolation of tapetal cells is an universal feature indicating male-sterility (Heslop-Harrison, 1972). This eventually leads to an early degeneration of tapetum and deprives the developing sporogenous cells/microspores of nutrients resulting in their degeneration as noted in *C. congensis* (see Murthi and Weaver, 1974). Tapetal hypertrophy leading to the degeneration of sporogenous tissue found in *C. liberica* is known in certain other crops also (Alam and Sandal, 1967; Kaul and Singh, 1966; Horner and Rogers, 1974). Tapetal syncytium formation observed in *C. liberica* and *C. kapakata* is known in *Sorghum* (Overman and Warmke, 1972), carrot (Zenktele, 1962) and flax (Dubey and Singh, 1965). From the foregoing discussion it can be concluded that the tapetum is a very crucial organ in pollen development (Mephram and Lane, 1969; Echlin, 1971; Mascarenhas, 1975).

Further work on the identification of sources of pollen restorer genes and sex suppression by exogenous application of growth regulators is underway to evolve a standard procedure for pollination control in coffee hybrid seed production.

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INDUCED POLYPLOIDS IN CARDAMOM

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ABSTRACT

Polyploidy was induced using colchicine, in germinating seeds of small cardamom (*Elettaria cardamomum* Maton). In gross morphology, induced polyploids resembled their progenitors. Polyploids had significantly thicker leaf blades, fewer but larger stomata than the diploids. Induced polyploids were found to be fertile.

INTRODUCTION

In cardamom, which is a cross pollinated crop, a chromosome number of $2n = 48$ has been reported by Raghavan and Venkata Subban (1943) and Ramachandran (1969). No attempt has been made so far to induce polyploidy in cardamom. Hence the present work was undertaken to induce polyploids and to exploit the phenotypic variations arising as a result of polyploidy, through breeding programme.

MATERIALS AND METHODS

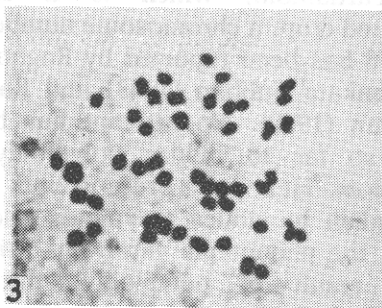
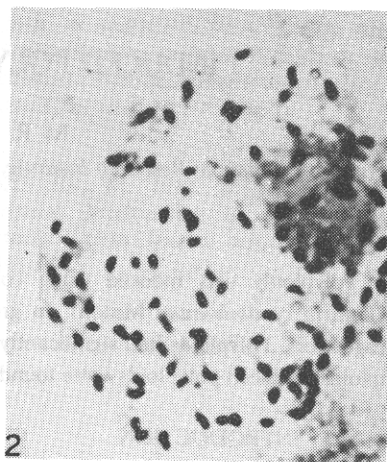
Open pollinated cardamom seeds were collected from high yielding mother clumps and germinated in petri dishes. Germinating cardamom seeds were immersed in 0.25% and 0.5% aqueous colchicine solution for 60-90 minutes. The control seeds were immersed in distilled water for similar duration. After treatment, seeds were washed with distilled water and sown in polybags. Ten months old seedlings were planted in the field in a completely randomized block design, with $2M \times 2M$ spacing. For mitotic studies actively growing root tips

were pre-treated with 0.002 M aqueous solution of 8-hydroxy quinoline for 2 hours and washed. The pre-treated root-tips were fixed in Carnoys-II fluid for 24 hours. A modified Haematoxylin squash method was used to study mitosis (Sudharshan, 1982). For meiotic studies, the flower buds were fixed in Carnoys-I fluid for 24 hours followed by usual carmine smear technique. Pollen germination studies were conducted using 5% aqueous sucrose solution.

Morphological comparisons were made between tetraploids and corresponding diploid lines grown under similar agro-climatic conditions. Leaf peals were prepared as suggested by Metcalfe, (1960). Microtome sections of leaves were taken using paraffin method and double stained with safranin and fast green as suggested by Johansen (1940).

RESULTS

Polyploidy was induced in 52% of the germinating seeds treated with 0.5% aqueous colchicine solution for duration of 90 minutes. When germinating seeds



1. Habit of tetraploid (4x) and diploid (2x) cardamom plants.

2. & 3. Somatic metaphase Cells (x 1000)

2. $2n = 4x = 96$ Chromosomes. 3. $2n = 2x = 48$ Chromosomes.

were treated for the same duration with 0.25% aqueous colchicine solution, polyploidy was induced in only 4% of the seeds. At shorter duration of time no induction of polyploidy was observed either in 0.25% or 0.5% colchicine solutions. Cytological studies revealed $2n = 48$ chromosomes in the root tips of control diploid plants and $2n = 96$ chromosome in polyploidy induced plants (Fig. 2 & 3).

Morphologically much variation could not be observed with respect to the

number of tillers produced in 12 months and also in five of the morphological characters studied (Fig. 1). Mean values of these morphological characters of 10 tetraploid plants and 10 diploid progenitors are given in Table I.

Considerable variation could be observed between tetraploids and diploids in their leaf anatomical characters. Tetraploids had thicker leaves with thick wax coating on the abaxial surface. The leaf peel studies of the abaxial surface revealed larger

Table I. *Mean morphological characters of tetraploids and their progenitors.*

Ploidy	Number of tillers planted	Number of tillers after 12 months	Percentage increase	Ht. in cm.	Mesh of leaves	Length of leaf cm	Breadth of leaf in cm.
Diploid	8.9	34.73	76.02	191.50	16.60	57.60	8.90
Tetraploid	4.9	22.82	77.24	180.10	15.27	55.40	9.57

stomata in tetraploids (Fig. 5&6). When stomatal index was calculated it was observed that the number of stomata in tetraploid leaves were lesser than that in diploid leaves. The mean values of leaf anatomical studies and pollen grains are presented in Table II. It was interesting to note that the adaxial epidermis of the leaf was single layered in the inter-costal region except near the major veins in diploid plants, whereas, it was double layered throughout in tetraploids (Fig. 7&8).

The meiotic studies showed regular meiotic division in diploids with 24 bivalents at metaphase plates. The segregation was normal at anaphase - I with 24-24 distribution of chromosomes and the pollen fertility was found to be 46.65% as judged by their germination percentage.

Meiotic studies of the tetraploids revealed normal and stabilized chro-

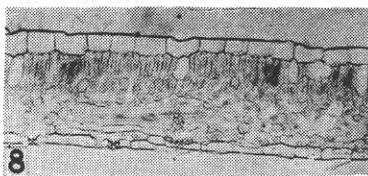
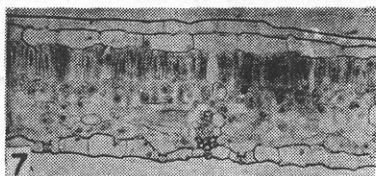
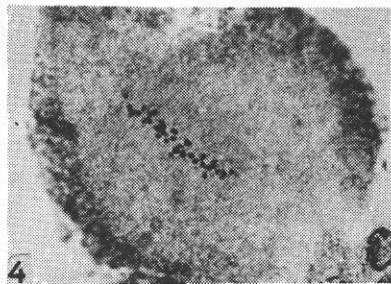
mosome behaviour with the least disturbance. During metaphase I 24 tetra-valents formed regularly with very low percentage of trivalents and univalents. The segregation at anaphase was regular with 48-48 chromosome distribution. At anaphase-I only in 2.4% of cells, lagging of 2-4 chromosomes was observed. Second meiotic division was also normal (Fig.4) with normal tetrad formation. In both diploids and tetraploids the tetrads were of linear, tetrahedral and isobilateral type. Pollen fertility as judged by the germination percentage was 33.06%. Th pollen grains in tetraploids were bigger in size than the pollen grains of diploids (Table II). Good capsule setting has been observed in tetraploids both in selfed and cross pollinated cases.

DISCUSSION

Induced polyploids of cardamom are found to be robust with thicker leaves,

Table II. *Leaf anatomical and pollen characters of tetraploids and their progenitors. (mean values)*

Ploidy	Thickness of leaf (μm)	Number of stomata per Cm ² of lamina	Diameter of pollen grain (μm)	Pollen germination percentage
Diploid	185.19	1363.89	114.02	43.65
Tetraploid	221.25	787.86	120.27	33.06



II Meiotic metaphase cell with $n = 48$ chromosomes ($\times 283.5$)

5. & 6. Leaf peel of abaxial surface showing stomata ($\times 283.5$)

5. Tetraploid. 6. Diploid

7 & 8. T.S. of Lamina ($\times 63$)

7. Tetraploid 8. Diploid

larger stomata and larger pollen grains. It has been observed that auto-polyploids are stockier and more vigorous than the diploids from which they are derived and tend to have larger leaves, larger flower and seed and larger cells and nuclei (Poehlman and Borthakur, 1969).

In induced polyploids of cardamom, the occurrence of thick wax coating on the abaxial surface of the leaf and fewer stomata per unit area of the leaf surface are some of the characters which could effectively check the rate of transpiration and thereby withstand drought better than their diploid progenitors. The wax coating on the abaxial surface of the leaf

may act as a deterrent to sucking insects feeding on the leaves of cardamom.

Cytological investigations of cardamom has previously been done by several workers and a basic number of 12 chromosomes has been suggested for the genus (Ramachandran, 1969). In the present study of diploids and tetraploids remarkable chromosomal stability has been observed. Ramachandran (1969) has also reported that during meiosis regularly 24 bivalents are formed and the segregation is normal. Present findings concur with this, hence it may be taken for granted that for all practical purposes, the cardamom plants occurring

in nature are diploids with $2n = 48$ chromosomes.

In tetraploids the stabilized chromosome behaviour during meiosis and good capsule set indicate the normal division during megasporogenesis even under higher ploidy level. Such stabilized chromosomal behaviour has also been observed in autotetraploids of *Matricaria chamomilla* be Madhusoodanan and Arora (1979).

Doubling the chromosome number of a large number of clones and then starting at tetraploid level a new breeding programme with conventional methods of selection seems to have a tremendous potential in cardamom to evolve high yielding, disease resistant and drought tolerant types.

ACKNOWLEDGEMENTS

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STUDIES ON CAPSULE MORPHOLOGY OF LARGE CARDAMOM CULTIVARS (*AMOMUM SUBULATUM* ROXB.)

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ABSTRACT

Morphological studies on the capsules of 9 cultivars of large cardamom (*Amomum subulatum* Roxb.) have revealed significant differences in number of capsules/panicle, size, colour, shape and number of seeds. Dwarf Bush had the maximum number (389) capsules/clump. Although, capsules of White Golsey were the heaviest in weight but lost maximum weight during drying. Golsey Dwarf capsules had maximum number of seeds (54.50) as compared to minimum in White Ramna (25.25) only. The capsule skin weight and thickness also differed significantly. The fresh skin lost about 79-83 per cent in weight and 75-80 per cent in thickness after drying. The exact shape and colour of the fresh capsules have been standardized for different varieties of large cardamom.

INTRODUCTION

Large cardamom (*Amomum subulatum* Roxb.) is indigenous to the eastern sub-Himalayan tracts of Sikkim, Darjeeling district of West Bengal, Arunachal Pradesh, Nepal and Bhutan at altitudes ranging from 500 to 1500 m above MSL. Hooker (1892) reported 6 species of Genus *Amomum* from this area. Out of these only *A. subulatum* Roxb. is of commercial importance as spice and condiment. Great variation is noticed in the shape, size and other morphological characters in the plant and capsules of various cultivars. This variation also results in their climatic adoption, yield, volatile oil content and market value.

MATERIALS AND METHODS

The investigations were carried at Sikkim Centre of ICAR Research Complex for NEH Region, Gangtok, on five year old plants of nine cultivars with prevalent

local names including Dwarf-Bush (the name given by the author for a high yielding selection. The experiment was actually laid during 1977 with RBD having 8 plants in each plot in 4 replications. Detailed plant and capsule (fresh and dry) characters were recorded in 1981 and 1982. The data for both the years were pooled and analysed as per method suggested by Barlett (1957). Only capsule characters are discussed here.

RESULTS AND DISCUSSION

All the characters studied differed significantly amongst the cultivars in the present investigations. The large cardamom plant (clump) had several leafy shoots (pseudostems) and the flowering panicles are born on these pseudostems near the ground. The capsules are enclosed in these panicles.

The quantitative characters of capsules (Table I) have shown that the

Table I. *Weight and population of capsules of large cardamom (Means of 1981 & 1982)*

Varieties	Number of capsule/panicle	Number of capsules/clump	Wt. of single fresh capsule(g)	Wt. of fresh capsules/panicle (g)	Wt. of fresh capsules/clump (g)	Wt. of single dry capsule (g)	Loss of moisture (%)
Golsey Dwarf	4.25 c	25.25	3.95 a	16.80 c	93.85 c	0.91 a	77.15
Golsey Tall	5.22 c	39.00 b	3.72 a	10.71 c	143.37 c	1.00 a	73.00
White Golsey	8.90 b	70.50 b	4.16 a	36.19 a	249.44 c	0.80 b	80.76
Dwarf Bush	14.97 a	389.00 a	3.21 b	47.20 a	1195.23 a	0.76 c	76.32
Sawney Tall	8.80 b	148.75 b	3.09 b	27.21 b	447.59 b	0.86 b	72.16
Red Sawney	12.10 a	321.00 a	2.98 b	36.40 a	964.41 a	0.75 c	74.83
Ramsey	10.95 b	162.50 b	2.87 b	31.52 b	468.32 b	0.67 c	76.66
Sawney Small	12.57 a	130.50 b	2.58 c	32.89 b	340.57 c	0.56 d	78.29
White Ramna	10.62 b	287.75 a	2.57 c	27.95 b	757.35 b	0.52 d	79.76
SEm $\pm$	1.15	45.13	0.21	3.94	136.14	0.028	
CD at 5%	3.37	131.73	0.60	11.49	397.39	0.083	N.S
CD at 1%	4.56	178.51	0.82	15.57	538.52	0.112	N.S

Note: Figures carrying same superscripts do not differ significantly.

number of capsules in a panicle varied amongst different cultivars. It varied from 14.97 in Dwarf Bush to 4.25 in Golsey-Dwarf. Other cultivars has in-between 12 to 8 capsules in a panicle. Accordingly the number of capsule/clump also varied. These figures were arrived at by multiplying the number of capsules/panicle into number of panicles/clump. Dwarf Bush recorded a very high value of 389.0 capsules/clump which was closely followed by 321.0 in Red Sawney. Both these cultivars are highly productive as well as early maturing.

The single fresh capsule weight was the highest in White-Golsey having a of 4.16 g/capsule, while in two other cultivars of Golsey group viz. Golsey Dwarf and Golsey-Tall it was found to be 3.95 g and 3.72 g respectively (Table I). On drying the capsule weight was weight 16 g/capsule, while in two other

be 0.80, 0.91 and 1.00 g respectively for the above three cultivars. It appears that the loss of moisture in White-Golsey was maximum (80%) as compared to 77.15 and 73.00 per cent in other two cultivars. The weight of single fresh capsule of other cultivars was in between 3.21 g to 2.57 g the lowest being that of White Ramna. On drying these cultivars recorded a weight between 0.86 g to 0.52 g. Similar studies were made by Upadhyaya and Ghosh (1983) for wild species of *Amomum* and reported a dry capsule weight of 1.4, 2.65, 2.2 g for Babo, Tali, and Boklok types of cardamom of Arunachal Pradesh. Similar studies on the recovery of dry capsules have been conducted by Vijyan and Zachariah (1974) in small cardamom who reported a recovery of 20 to 30% after drying of fresh capsules.

Significant differences in the size of the

Table II. *Size of capsules and number of seeds in large cardamom (Means of 1981 & 1982)*

Varieties	Length of fresh capsules (mm)	Diam. of fresh capsules (mm)	Length of dry capsules (mm)	Diam. of dry capsules (mm)	No. of seeds/capsule
Golsey Dwarf	26.33 a	21.00 a	21.60 a	16.33 a	54.50 a
Golsey Tall	24.48 a	20.60 a	21.73 a	16.35 a	46.50 b
White Golsey	22.73 b	20.10 a	16.42 d	15.98 a	40.00 c
Dwarf Bush	22.70 b	17.98 b	19.96 b	12.54 c	29.50 e
Sawney Tall	22.13 b	19.45 a	20.78 a	13.49 b	36.50 d
Red Sawney	21.20 b	18.68 b	19.46 b	12.34 c	25.50 f
Ramsey	20.70 b	17.28 b	17.16 d	11.36 d	31.75 e
Sawney Small	19.55 c	17.40 b	18.40 c	12.34 c	26.25 f
White Ramna	17.25 c	17.60 b	13.57 e	13.70 b	25.25 f
SEm $\pm$	0.81	0.57	0.39	0.15	0.82
CD at 5%	2.36	1.67	1.13	0.44	2.40
CD at 1%	3.19	2.27	1.53	0.59	3.26

Note: Figures carrying same superscripts do not differ significantly.

fresh capsules of different cultivars were noticed (Table II). All the cultivars were having more length than diameter except White Ramna which was roundish. This variety with its roundish, small and yellowish colour has more acceptability in some Indian dishes as intact capsules.

On drying the length and diameter of capsules are reduced considerably. The reduction in length of the capsules varies from 6.0 per cent in Sawney Small to 14.0 per cent in Golsey-Dwarf. However, reduction in length of capsules in White Ramna and White Golsey were 21.33 and 27.76 per cent respectively. Similarly diameter of the capsules also showed reduction and varied from 20.45 per cent in White Golsey to 34.25 per cent in Ramsey. In general the capsules of Golsey Dwarf were bigger in size and those of White Ramna were smaller. Similar studies were reported by

Upadhyaya and Ghosh (1983) for capsules of some wild species of large cardamom of Arunachal-Pradesh belonging to *A. aromaticum*, *A. dealbatum* and *A. costatum* besides *A. subulatum*.

The number of seeds in a capsule is one of the most important characters in large cardamom. It is revealed from Table II that number of seeds in Golsey Dwarf (54.50) were more than double than in Ramsey, Sawney Small and White Ramna. Sawney Tall and Dwarf-Bush which had medium sized capsules contained 36.50 and 29.50 seeds/capsule. Moreover, the seeds of Golsey group were bold as compared to those of other cultivars.

The skin weight of fresh capsules differed significantly (Table III). It varied from 2.13 g in White Golsey to 1.26 g in White Ramna and Sawney Small. On dry-

Table III. *Weight and thickness of capsules skin of large cardamom (Means of 1981 and 1982)*

Varieties	Weight of fresh skin (g)	Weight of dry skin (g)	Thickness of fresh skin (mm)	Thickness of dry skin (mm)
Golsey Dwarf	2.04 b	0.33 b	3.62 a	0.73 b
Golsey Tall	1.87 c	0.36 a	2.95 b	0.66 c
White Golsey	2.13 a	0.40 a	2.42 c	0.57 d
Dwarf Bush	1.62 d	0.31 b	3.35 a	0.73 b
Sawney Tall	1.49 e	0.31 b	3.50 a	0.80 a
Red Sawney	1.44 e	0.30 b	2.42 c	0.56 d
Ramsey	1.42 e	0.26 c	2.35 c	0.59 d
Sawney Small	1.25 f	0.21 d	2.32 c	0.58 d
White Ramna	1.26 f	0.22 c	2.27 c	0.49 e
SEm $\pm$	0.021	0.013	0.113	0.009
CD at 5%	0.061	0.036	0.33	0.03
CD at 1%	0.082	0.049	0.45	0.04

Note: Figures carrying same superscripts do not differ significantly.

ing in electric oven the skin weight was significantly reduced in different cultivars. However, the total moisture loss in the skin was recorded to be between 79 to 83 per cent in all the cultivars. Significant differences were also noticed in the thickness of fresh as well as dry skin of the capsules of different cultivars. On drying the skin thickness is reduced to the extent of 74.89 per cent in Ramsey to 79.83 per cent in Golsey Dwarf. Thus thickness of capsule skin of large cardamom is reduced by 75 to 80 per cent in different cultivars after drying.

The morphological studies on the shape and colour of fresh capsule has revealed differences amongst cultivars. The shape varies from oblong to obovate and their intermediate types. The capsules of Golsey group are roundish ovate as against obovate of Dwarf Bush. The capsules of White Ramna were

roundish as against globular or oblong in case of Red Sawney and Ramsey. The capsules of most of the cultivars were of pink colour except White Golsey and White Ramna whose capsules were of very light yellow colour which on drying become almost dull pale. The capsules of all the cultivars were having ridges or wings in varying degree, Gyatso et al. (1980) reported yellow colour for Ramsey. There however, seem to be some confusion in this respect, since local names vary for the same variety in different localities.

The exact shape and colour of fresh capsules is given below.

1. Sawney Tall Roundish obovate, red, ridges prominent
2. Golsey Tall Roundish obovate, dull pink, top dark red, ridges prominent.

- | | |
|--------------------------------|--|
| 3. Dwarf Bush | Obovate, light pink, ridges medium prominent |
| 4. White Ramna | Roundish, dull light yellow, ridges less prominent |
| 5. Sawney Small (Syn-Madhusoy) | Roundish obovate, deep red, ridges prominent |
| 6. White Golsey (Syn-Sethuram) | Roundish obovate, very light yellow. ridges less prominent |
| 7. Ramsey | Oblong to obovate, light red, ridges prominent |
| 8. Golsey Dwarf | Roundish obovate, dull pink, ridges prominent |

- | | |
|----------------------------|--|
| 9. Red Sawney (Syn-Ramnag) | Oblong to obovate, dark red, ridges medium prominent |
|----------------------------|--|

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EARLY PERFORMANCE OF A FEW *HEVEA* CLONES IN LARGE SCALE TRIAL

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ABSTRACT

Eleven clones of *Hevea brasiliensis* Muell. Arg., three (RRII 5, RRII 104 and RRII 116) evolved by the Rubber Research Institute of India and eight (RRIM 513, RRIM 519, RRIM 600, RRIM 628, PB 5/76, PB 206, PB 213 and PB 217) of Malaysian origin were evaluated in a statistically laid out large scale trial in the South Central part of Kerala. Clone Tjir 1 was used as the control. Vigour during the immaturity period, girth increment on tapping, thickness of virgin bark, thickness of renewed bark, yield during first four years of tapping, yield depression during wintering, incidence of diseases like pink and brown blast and damage caused by wind were recorded. Clonal differences were observed with regard to the major characters and the results are discussed.

INTRODUCTION

The Rubber Research Institute of India is making regular attempts to develop new clones of *Hevea* by hybridization and ortet selection. In addition, improved clones are periodically introduced to India from other rubber growing countries. These clones are evaluated under experimental plantings and promising ones are released for commercial use. In this paper observations made on twelve clones in a large scale trial in Quilon region of Kerala State are presented.

MATERIALS AND METHODS

The clones RRII 5, RRII 104, RRII 116, RRIM 513, RRIM 519, RRIM 600, RRIM 628, PB 206, PB 213, PB 217, PB 5/76 were evaluated in a field trial. The clone Tjir 1 was used as the control. RRII 5 is a

primary clone (Joseph *et al*; 1980) and RRII 104, and RRII 116 are secondary clones, developed by the Rubber Research Institute of India (Bhaskaran Nair and George, 1968). The RRIM clones were evolved by the Rubber Research Institute of Malaysia and are of hybrid origin (Bhaskaran Nair and Joseph, 1975). The Prang Besar Research Station of Malaysia has produced the PB clones (Ang and Shepherd, 1979) of which PB 206 is a primary clone and PB 213, PB 217 and PB 5/76 secondary in origin (Paardekooper, 1965). These exotic clones were introduced to our country (Anonymous, 1962) for their evaluation under Indian conditions. Quilon region, where the study was conducted, is an important rubber growing region of the main rubber growing tract of India. The trial was laid out in a randomised block design with three replicates. The spacing

was 4.9 m × 4.9 m, with a plot size of 0.23 ha. The number of plants per plot was 30 gross and twelve net. The important characters recorded were girth during immaturity period, girth increment after commencement of tapping, thickness of virgin bark and renewed bark, annual yield of rubber, yield depression during summer, susceptibility to diseases and proneness to damages caused by wind. Girth during immaturity phase and girth increment after opening were recorded by measuring the girth of the trunk at a height of 150 cm above the bud union with a tailor's tape. Thickness of bark was noted with a Schleipers gauge (Bhaskaran Nair and Joseph, 1981). Yield was determined by coagulating the latex from individual trees in collecting cups itself. Incidence of pink disease and wind damage was ascertained by counting the

number of affected trees. Diseases of general nature like abnormal leaf fall and powdery mildew were assessed by visual observation. Yield depression during summer was computed by considering the yield during the period February to May as the percentage of the average yield during the year. Data on mean yield, yield during wintering, girth at opening, girth increment on tapping, thickness of virgin bark and thickness of renewed bark were statistically analysed. The values for RRIM 513 in one of the three replicates are estimated by Missing Plot Technique due to the low number of trees present.

RESULTS AND DISCUSSION

Data on yield and secondary characters are presented in Table I.

Table I. *Performance of clones in the trial*

Clone	Mean yield in Panel 'A' g/tree/tap	Yield during wintering as percentage of mean yield	Mean girth at opening (cm)	Mean annual girth increment after opening (cm)	Mean thickness of virgin bark (mm)	Mean thickness of 4 year renewed bark (mm)
RRII 5	57.46	71.0	63.80	4.38	9.84	8.58
RRII 104	46.75	65.0	54.90	5.29	10.94	9.61
RRII 116	52.14	73.0	62.30	5.22	9.66	8.15
RRIM 513	47.73	60.7	56.30	3.36	8.55	8.04
RRIM 519	46.02	54.7	56.79	5.32	10.10	9.41
RRIM 600	49.05	78.0	59.64	4.87	9.17	8.62
RRIM 628	58.33	74.3	54.21	3.63	8.85	7.90
PB 206	49.12	78.7	56.20	4.78	8.88	7.65
PB 213	42.28	55.0	52.89	4.16	9.44	8.42
PB 217	40.07	73.7	58.42	5.28	9.47	8.69
PB 5/76	38.90	69.3	59.02	4.66	9.43	8.16
Tjir 1	44.44	62.0	59.44	4.96	10.16	8.92
General						
Mean	47.69	67.9	57.83	4.66	9.54	8.51
S.E.	4.04	8.7	2.09	0.37	0.32	0.28
C.D.	11.85	—	6.12	1.09	0.94	0.83
C.D.*	13.41	—	6.92	1.23	1.09	0.94

*for comparing RRIM 513 with other clones

The 12 clones evaluated had very wide variation for yield. RRIM 628 recorded the highest yield (58.33 g) and PB 5/76 the lowest (38.90 g). Only two clones viz., RRIM 628 and RRII 5 were found to be significantly superior to the control. Earlier reports also indicate that these two clones are high yielding in the initial years (Anonymous, 1980; Joseph *et al.*; 1980).

There was variation among clones in their yield during wintering period also, PB 206 giving the maximum (78.7%) and RRIM 519 the minimum (54.7%). Malaysian reports indicate that RRIM 519 give high yield during wintering period (Anonymous, 1971). This difference in performance may be due to the difference in climatic conditions existing in India. No clone had significant superiority for girth at the time of opening for tapping, although RRII 5 was numerically better. PB 213 was found to be significantly inferior to Tjir 1. High vigour of RRII 5 and low girth of PB 213 have already been reported (Joseph *et al.*, 1980; Paardekooper, 1965). Rate of girth increment after commencement of tapping also differed among the various clones. PB 519 (5.32 cm) and RRII 104 (5.29 cm) showed more girth increment compared to RRIM 513 (3.36 cm) and RRIM 628 (3.63 cm). The two least vigorous clones mentioned above were found to be significantly inferior to Tjir 1. High girth increment of RRIM 519 has already been reported from Malaysia (Anonymous, 1971). Earlier reports also indicate that RRIM 513 and RRIM 628 show poor girth increment after tapping (Anonymous, 1976, 1980). Thickness of virgin bark at the time of commencement of tapping was maximum (10.94 mm) in

RRII 104 minimum (8.55 mm) in RRIM 513. Tjir 1 had a thickness of 10.16 mm and was second in the order of performance. Difference between Tjir 1 and RRII 104 was however not significant, whereas the four clones, RRIM 600 (9.17 mm), PB 206 (8.88 mm), RRIM 628 (8.85 mm) and RRIM 513 (8.55 mm) were found to be significantly inferior to the control in this aspect. Thin virgin bark has already been reported in RRIM 513 (Anonymous, 1965) and RRIM 600 (Anonymous, 1980).

Rate of bark renewal was another character in which the clones under evaluation varied. When renewed bark of RRII 104 attained a thickness of 9.61 mm, that of PB 206 had attained only 7.65 mm. Though none of the clones was found to be significantly superior, RRIM 628 (7.90 mm) and PB 206 (7.65 mm) were significantly inferior to the control. Poor bark renewal of RRIM 628 has been reported earlier (Anonymous, 1983).

All clones were found to be susceptible to abnormal leaf fall disease caused by *Phytophthora* spp. While four clones showed comparatively less incidence four others were found to be more severely affected by this disease. High susceptibility of clones like RRIM 600 to this malady observed in the trial has been reported earlier also (Anonymous, 1980). Powdery mildew caused by *Oidium* was also found infecting all clones at varying degrees of intensity. The severity of the incidence was moderate in RRIM 600, which confirm the reports from Malaysia (Anonymous, 1983).

Detailed observations on secondary characters are given in Table II. Incidence of pink disease was noticed

Table II. *Secondary characters of clones*

Clone	Wind damage percentage incidence	Pink disease percentage incidence	Brown, bast incidence %	Bark rot percentage incidence	Powdery mildew incidence	Abnormal leaf fall incidence
RRII 5	Nil	Nil	3.6	3.6	Severe	Severe
RRII 104	3.8	Nil	3.8	3.8	Severe	Severe
RRII 116	4.5	Nil	Nil	Nil	Very severe	Moderate
RRIM 513	Nil	Nil	Nil	Nil	Severe	Moderate
PRIM 519	3.8	Nil	Nil	Nil	Severe	Moderate
RRIM 600	7.1	10.7	10.7	Nil	Moderate	Severe
RRIM 628	9.9	13.3	13.3	10.0	Moderate	Moderate
PB 206	8.0	4.0	Nil	Nil	Very severe	Severe
PB 213	3.2	3.2	3.2	Nil	Moderate	Moderate
PB 217	3.2	3.2	Nil	Nil	Very severe	Severe
PB 5/76	Nil	7.7	3.8	Nil	Severe	Severe
Tjir 1	4.5	Nil	Nil	Nil	Very severe	Severe

only in the case of six clones three of which showed high susceptibility and the remaining low susceptibility. RRIM 600 and RRIM 628 which showed high susceptibility in the trial are reported to be highly susceptible to this disease in Malaysia also (Anonymous, 1980). Six clones showed proneness to Brownbust at varying degrees. While RRIM 628 (13.3%) was the most susceptible to this disease, PB 213 (3.2%) was the least susceptible. High susceptibility of RRIM 628 is indicated in Malaysian reports also. However, RRIM 600 which is reported to be more resistant (Anonymous, 1980), does not show the same trend in India. Only three clones, RRIM 628, RRII 104, and RRII 5 were affected by bark rot.

Out of the 12 clones under observation nine clones were affected by wind. Incidence of wind damage was the highest in RRIM 628 (9.9%). All the major three types of wind damage, namely, trunk snap, branch snap, and uprooting

were found affecting the trees. Trunk snap was the most common type of damage affecting a total of eight trees followed by branch snap and uprooting damaging four and one tree respectively in the trial. Incidence of trunk snap was maximum in the case of RRIM 600 (7.1%) and minimum in PB 213 (3.2%) out of the six clones affected. Four clones showed branch snap. Only PB 206 was damaged by uprooting, affecting four percent of the trees. Reports from Malaysia also show that RRIM 628 is highly susceptible to wind damage (Anonymous, 1980).

Results discussed above indicate that the general trend of performance of the imported clones in India is comparable to that in Malaysia the country of their origin. However, in certain specific characters some of the clones exhibited slight difference from their reported performance in Malaysia. In their early performance RRIM 628 and RRII 5 were found superior to other clones with regard to yield.

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AN ATTEMPT TO IMPROVE TEST TAPPING IN *HEVEA* SEEDLINGS

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ABSTRACT

Studies on a population of *Hevea* seedlings revealed a close correlation of test tapping yield with the yield of the first year regular tapping and a drop in correlation value with the subsequent yield. The mean yield of three rounds of test tapping was more reliable than that of one round alone. Analysis of the data on yield and girth with a view to looking in to the possibility of further improvements in the early evaluation methods, revealed a fair degree of highly significant positive correlation of the girth at test tapping with the mean yield of test tapping ($r=0.4630$, $p<0.010$). Its influence on the first year yield of regular tapping was low ($r=0.1869$, $p<0.05$) and the correlation with the mean yield over five years of tapping was not significant. Similar trend was noted in the relationship of the girth at opening with the first year yield of regular tapping ($r=0.2248$, $p<0.01$) and with the mean yield over five years of tapping ($r=0.1832$, $p<0.05$) although there was high correlations among the girth at different stages. On the contrary the girth increment on tapping was highly correlated with the yield increment on tapping ($r=0.7023$, $p<0.01$). This indicated that girth increment govern the yield more than the actual girth. Hence, for further improvement in early evaluation methods potential of the tree for high rate of girth increment on tapping should also be identified at the early growth phase.

INTRODUCTION

Hevea brasiliensis Muell Arg being a perennial tree, improvement through breeding and selection is very time consuming. The tree takes about seven years to attain tappable girth and long duration of observation is required further for reliable selection. The two important methods of early evaluation tried earlier were the incision method of grading nursery plants developed by Crafter (1968) and the test tapping method suggested by Hamaker (1914) and modified by Vollema (1934) and Dijkman (1939). Test tapping experiments based on the Hamaker method showed correlations between the test tapping yield with that of the first year of

normal tapping only. A drop in correlation was observed during later years (Dijkman, 1941; Morris and Mann, 1931-1938).

In the present study an attempt was made to improve the method of test tapping by taking into consideration girth and yield at different growth phases of the tree.

MATERIALS AND METHODS

A population comprising of 286 seedlings involving 22 crosses, resultant of 1970 breeding programme, were planted in a newly cleared forest area at the Central Experiment Station of the Rubber Research Institute of India at Chethackal

in 1972. The spacing was 5 m $\times$ 5 m and conventional cultural operations were carried out.

At the fourth year, the trees which had attained a girth of 15 centimetres or above, at a height of 125 cm, were test tapped for which Hamaker-Morris-Mann method was followed with slight modifications. The trees were opened for test tapping at a height of 50 cm from the ground level, on a half spiral cut with a slope of 25 to the horizontal plane. Daily tapping was carried out for ten days. The crop of the last five days of test tapping was collected by cup coagulation method and the cuplumps were dried and weighed. The first round of test tapping (Test tapping 1) was done in May 1976. The test tapping was repeated in October 1976 and January 1977 (Test tapping 2 and Test tapping 3 respectively). The mean yield of three test tapplings was calculated (referred to as the mean yield of test tapping).

The trees were opened for regular tapping in 1979 March, at the age of seven years and the S/2 d/2 system was followed. Yield recording was carried out by cup coagulation method. Annual mean yield/tree/tap(g) was assessed from monthly yield recordings. Annual recordings of girth at a height of 125 cm were made from the year of opening.

The yield increment over five years of tapping was calculated as percentage of the yield on first year tapping and the girth increment over five years of tapping was calculated as percentage of girth at opening.

The data were statistically analysed for

the correlations of the yield on test tapplings, their mean, the girth at test tapping and the girth at regular opening with the yield of first year regular tapping and the mean yield over five years of regular tapping. Correlations of the girth at test tapping with the mean yield of test tapping, girth at regular opening and the girth at the fifth year of tapping as well as the girth at opening with the girth at the fifth year of tapping were also studied. Along with this, the correlation between the percentage yield increase over five years of regular tapping with the percentage girth increment over five years after regular opening was examined.

RESULTS AND DISCUSSIONS

Correlations of the yield of each round of test tapping, mean yield of the test tapplings, girth at test tapping and the girth at regular opening with the yield of first year regular tapping and with the mean yield over five years of regular tapping are given in Table I. The test tapping yields and their mean showed highly significant positive correlations with the yield of first year regular tapping with fair degrees of correlation coefficients. There was considerable drop in the correlation coefficients when these characters were correlated with the mean yield over five years of regular tapping although the correlations were significant. This result was in agreement with earlier studies (Dijkman, 1941 and Morris and Mann, 1931-38).

The data in Table I indicated that the correlation of yield on test tapping 1 with mature yield was not so close as in the case of that on test tapplings 2, 3 and their mean. It may be mentioned that test

Table I. *Correlations among the girth and yield factors at immature and mature phases*

Character Yield	Yield				Girth		
	Test Tapping 1	Test Tapping 2	Test Tapping 3	Mean	at test tapping	at regular opening	Girth increment on tapping
First year	**	**	**	**	*	**	
regular tapping	0.4313	0.5287	0.5343	0.5456	0.1869	0.2248	
Mean over five years of regular tapping	*	**	**	**	0.0800	*	
	0.2037	0.2702	0.3309	0.2931		0.1832	
Mean of test tappings					** 0.4630		
Yield increment on tapping							** 0.7023

** = $P < 0.01$ * = $P < 0.05$

tapping 1 was done during May which is part of the summer season. The seasonal yield variation in *Hevea* and an yield drop during summer season is well known (George, *et al.*, 1980; Premakumari, Sherief and Sethuraj, 1980 and Young and Paramjyothy, 1982.). However this result signified that the mean yield of different test tappings, covering different seasons, is more reliable for screening young rubber trees than the yield of a single test tapping.

The girth at test tapping had significant correlations with the mean yield of test tapping. But the correlation coefficients showed considerable drop when it was correlated with the first year yield and the relationship was not significant when it was correlated with the mean yield over five years of tapping. Correlations among the girth at test tapping, at open-

ing and at the fifth year of tapping are given in Table II. The girth at test tapping showed high correlations with the girth at opening and the girth at the fifth year of tapping. The girth at opening was also highly correlated with the girth at fifth year of tapping.

The girth, at which regular tapping was commenced on the trees, was significantly correlated with the yield during the first year as well as the mean yield over five years of tapping. The correlation however was more pronounced with the first year yield ($r=0.2248$), but showed a decline with the mean yield over five years of tapping ($r=0.1832$). At the same time the percentage yield increase over five years of tapping was highly correlated with the percentage girth increase over five years after tapping ($r=0.7023$, $P<0.01$). The importance of girth

Table II. *Correlations among the girth characters*

Character	Girth at regular opening	Girth at 5th year of tapping
Girth at test tapping	** 0.7939	** 0.6097
Girth at regular opening		** 0.8683

** = $P < 0.01$

increment of tapping on the yield of *Hevea* clones had already been suggested (Sethuraj, 1981).

In this context, the high drop of correlation coefficients when the test tapping yields were correlated with the mean yield over five years of regular tapping is recalled. This drop in the degree of

relationship between the test tapping yield and mature yield after a few years of tapping can be attributed to the high influence of girth increment on tapping on the yield increase on tapping. This result also implicated that a more reliable early prediction for yield in *Hevea* is possible only if the girth increment on tapping can also be predicted during the immature phase of the genotypes for which further work is needed.

The familywise yield and girth at test tapping as well as at regular tapping are shown in Table III. Substantial differences in yield as well as girth among the families were evident from the table. It was also noticed that the families involving RR11 6 as one of the parents gave comparatively high yield in test tapping as well as at regular tapping.

Table III. *Familywise yield and girth of the progenies of 1970 hand pollinations*

Sl.	Families	Mean yield of test tapping	Yield on regular tapping g/tree/tap $\pm$ SE			Girth cms $\pm$ SE	
		(g/tree) $\pm$ SE	1st year	Mean over five years	At test tapping	At regular opening	
1.	RR11 6 $\times$ RR11 105	18.89 $\pm$ 8.5	52.07 $\pm$ 4.51	50.10 $\pm$ 7.31	21.67 $\pm$ 7.14	62.00 $\pm$ 6.21	
2.	RR11 6 $\times$ IAN 45.313	23.42 $\pm$ 5.02	23.01 $\pm$ 0.73	26.51 $\pm$ 2.31	23.00 $\pm$ 2.09	57.00 $\pm$ 3.03	
3.	RR11 6 $\times$ FX 516	30.44 $\pm$ 12.95	41.85 $\pm$ 6.75	35.20 $\pm$ 2.72	29.00 $\pm$ 2.55	66.33 $\pm$ 3.33	
4.	RR11 102 $\times$ RR11 6	41.33 $\pm$ 12.20	51.17 $\pm$ 20.07	38.88 $\pm$ 14.58	26.33 $\pm$ 1.75	58.00 $\pm$ 3.06	
5.	FX 516 $\times$ RR11 6	22.85 $\pm$ 4.35	24.50 $\pm$ 2.73	30.22 $\pm$ 2.75	26.23 $\pm$ 1.23	57.00 $\pm$ 1.74	
6.	FX 516 $\times$ PB 5/60	11.04 $\pm$ 2.58	14.75 $\pm$ 2.71	18.94 $\pm$ 1.70	20.63 $\pm$ 1.78	50.63 $\pm$ 1.55	
7.	FX 516 $\times$ AV 255	7.22 $\pm$ 1.69	25.44 $\pm$ 3.64	34.63 $\pm$ 7.76	19.83 $\pm$ 1.26	48.94 $\pm$ 2.35	
8.	FX 516 $\times$ GL 1	15.04 $\pm$ 1.83	25.82 $\pm$ 1.74	32.86 $\pm$ 1.96	21.54 $\pm$ 0.60	52.16 $\pm$ 0.92	
9.	RR11 102 $\times$ PB 86	23.82 $\pm$ 4.4	29.51 $\pm$ 4.38	32.14 $\pm$ 3.78	23.61 $\pm$ 1.34	53.11 $\pm$ 1.99	
10.	RR11 102 $\times$ RR11 19	15.67 $\pm$ 8.17	15.69 $\pm$ 2.02	31.49 $\pm$ 4.81	22.83 $\pm$ 1.09	57.57 $\pm$ 5.57	
11.	PB 86 $\times$ RR11 33	13.16 $\pm$ 2.30	17.14 $\pm$ 2.15	19.63 $\pm$ 1.67	26.27 $\pm$ 1.56	60.20 $\pm$ 1.86	
12.	PB 86 $\times$ FX 516	12.91 $\pm$ 1.99	17.21 $\pm$ 3.80	18.99 $\pm$ 3.62	24.43 $\pm$ 1.21	53.64 $\pm$ 2.84	
13.	PB 86 $\times$ F 4542	10.34 $\pm$ 4.67	13.81 $\pm$ 4.8	17.65 $\pm$ 3.68	26.75 $\pm$ 2.95	62.25 $\pm$ 4.75	
14.	RR11 1 $\times$ RR11 33	13.9 $\pm$ 3.46	23.31 $\pm$ 4.12	26.38 $\pm$ 4.90	24.00 $\pm$ 1.03	61.50 $\pm$ 1.17	
15.	RR11 106 $\times$ RR11 33	15.13 $\pm$ 3.17	17.80 $\pm$ 1.07	23.21 $\pm$ 2.24	27.20 $\pm$ 0.75	61.40 $\pm$ 0.91	
16.	RR11 526 $\times$ RR11 33	10.22 $\pm$ 0.95	17.69 $\pm$ 1.22	22.73 $\pm$ 6.95	25.00 $\pm$ 1.80	57.00 $\pm$ 2.65	
17.	RR11 12 $\times$ RR11 501	19.38 $\pm$ 1.88	29.67 $\pm$ 4.82	32.30 $\pm$ 3.72	24.86 $\pm$ 2.22	56.57 $\pm$ 2.80	

Test tapping in *Hevea* seedlings

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VIGOUR INDEX AS AN ADDITIONAL PARAMETER IN IDENTIFYING ELITE PALMS IN ARECANUT

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ABSTRACT

Multiple regression and path analysis was attempted to study the causal relationship of the yield and ten vigour variables for the local South Kanara variety of arecanut. Palm height, internodal distance at permanent mark and maximum length of leaf sheath showed high correlations and high direct effects, whereas the girth at permanent mark had a high negative direct effect, but its positive correlation with yield was largely due to highly positive indirect effect via palm height, thereby indicating the importance of these four vigour variables in identifying the actual potential elite areca palms. A vigour index is formulated by regressing these four selected variables on the yield and a selection criterion is proposed to select elite areca palms using yield and vigour index.

INTRODUCTION

Plant yield in general, a complex entity determined by the interplay of a number of attributes and it is more complex in a perennial crop such as arecanut. Adequate knowledge of inter-relation of factors influencing such a complex character is essential for application in selection of elite palms in a garden, yield forecast and so on.

When it comes to selection of elite palms for collecting the seed material, it is a common practice to search for the high yielding mother palms. The fact that the yield heritability for arecanut is low as reported by Bavappa and Ramachander (1967a) and Bhagavan et. al. (1981). it necessitates search for additional parameter which expresses the

genotypic structure of the palm phenotypically and which have direct or indirect bearing on yield of the palm. Bavappa and Ramachander (1967b) have established positive correlation for some of the seedling variables and yield of arecanut. Bhagavan (1982) has highlighted the influence of seed and seedling variables on the yield of arecanut. The vigour variables of the adult palm which remains more or less stable after the palm establishes itself, presumably play a significant role in influencing the yield. Keeping this in view, both multiple regression analysis and path co-efficient analysis are attempted to select variables which are of indicative importance. Based on these variables identified a vigour index has been arrived at and a procedure has been outlined for refinement in selection of elite palms.

MATERIALS AND METHODS

From an experiment involving 18 types of South Kanara variety of arecanut replicated three times, laid out in 1966 at Central Plantation Crops Research Institute, Regional Station, Vittal, the data on ten vigour variables in 1976-77 and yield data on weight of nuts (Y) averaged over four years (1973-74 to 1976-77) were collected. The vigour variables were: palm height (X_1), girth at permanent mark (X_2), girth at last exposed node (X_3), internodal distance at permanent mark (X_4), internodal distance below the crown (X_5), number of nodes (X_6), leaf sheath maximum length (X_7), leaf sheath maximum breadth (X_8), number of leaves (X_9) and length of largest leaf (X_{10}).

Since the experiment was laid out in RBD, with the model $y_{ij} = \mu + r_i + t_j + e_{ij}$; $i = 1, 2, 3$ and $j = 1, 2 \dots 18$ with the usual assumptions, where i classification refers to replications and j classification refers to types, all the data on yield and vigour variables were transformed to uniformity trial data with the model.

$y_{ij} + \mu + e_{ij}$; $i = 1, 2, 3$ and $j = 1, 2 \dots 18$ by eliminating the replication effect and effect due to types. Similar such transformation was done for estimating optimum size and shape of plot from fertilizer trial data (Ray et al., 1973).

Two models $Y = a + \sum b_i X_i$ (A)
 $Y = a \prod X_i^{b_i}$ (B)

of regression were fitted to the transformed data and after deleting the variable which had very low correlation with the yield, path co-efficient analysis developed by Wright (1921) was carried

out to study the direct and indirect effects of the vigour variables in relation to yield.

Four vigour variables were selected based on path co-efficient analysis and a vigour index has been arrived at by regressing these four variables on yield.

Given below is a procedure for selection of elite palms which ensures not only high yield but also high vigour.

Step 1 : Select a desired percentage of palms based on yield

Step 2 : Select same percentage of palms based on vigour index

Step 3 : Pick out those as elite palms which are common to these two groups of selected palms.

As an illustration, from the present population 12 palms were selected based on step 1 and 12 palms were selected based on step 2. The 6 palms which were common among these were identified as elite palms.

RESULTS AND DISCUSSION

The mean values, standard errors and correlations with yield for the various characters studied are presented in Table I. All vigour variables have shown positive correlation with yield, thereby indicating that a good vigoured plant results in a better yield mostly. It is observed that palm height internodal distance at permanent mark and maximum length of leaf sheath have shown significant positive correlations with the yield.

The multiple regression analysis for the models (A) and (B) indicated R^2 to be of

Table I. *Mean, Standard Errors and Correlations of various characters*

Characters	Mean	Standard Error	Correlation with wt. of nuts
Palm height (cm)	5.33	0.08	0.50**
Girth at PM (cm)	45.66	0.37	0.11
Girth at LEN (cm)	34.31	0.27	0.20
Internodal distance at PM (cm)	13.98	0.19	0.40**
Internodal distance BC (cm)	7.14	0.12	0.21
Number of nodes	51.06	0.44	0.25**
Leaf sheath Max. length (cm)	89.18	0.51	0.32*
Leaf sheath Max. width (cm)	37.86	0.46	0.21
No. of leaves	10.40	0.07	0.25
Length of largest leaf (m)	1.80	0.02	0.07
Wt. of nuts (kg)	3.24	0.18	1.00

PM – Permanent Mark, LEN – Last Exposed Node, BC – Below crown

*Significant at 5% level

**Significant at 1% level

order 44.3% and 43.4% respectively which means that the multiplicative model (B) is not of any special advantage over the linear model (A). It may however, be observed that the vigour variables which remains more or less stable over a period of time has a significant

contribution ($F = 3.42 > F_{10,43; 0.05}$) with 44.3% predictability.

Since the correlation co-efficient by itself does not give a true picture about the causal relationship, path co-efficient analysis was attempted for all the vigour

Table II. *Correlation matrix between nine vigour variables*

Characters	1	2	3	4	5	6	7	8	9
1. Palm height	1	0.52**	0.65**	0.430**	0.47**	0.49**	0.14	0.33	0.43**
2. Girth at PM		1	0.40**	0.33*	0.23	0.20	0.13	0.24	0.32*
3. Girth at LEN			1	0.10	0.35*	0.36**	0.08	0.38**	0.52**
4. Internodal distance at PM				1	0.05	0.40**	0.05	0.00	0.07
5. Internodal distance BC					1	-0.22	-0.19	0.08	0.17
6. No. of nodes						1	0.24	0.07	0.09
7. Leaf sheath Max. length							1	0.24	0.14
8. Leaf sheath max. width								1	0.21
9. No. of leaves									1

*Significant at 5% level

**Significant at 1% level

Table III. *Correlations and path co-efficients showing direct and indirect effects of nine attributes on wt. of nuts*

Characters	1	2	3	4	5	6	7	8	9	Correlation with wt. of nuts
1. Palm height	.48	-.15	-.10	.13	.05	-.03	.04	.02	.06	0.50
2. Girth at PM	.25	-.28	-.06	.10	.02	-.01	.04	.01	0.11	
3. Girth at LEN	.31	-.11	-.16	.03	.04	-.02	.02	.02	.07	0.20
4. Internodal distance at PM	.21	-.09	-.02	.30	.00	-.02	-.01	.00	.01	0.40
5. Internodal distance BC	.22	-.06	-.06	.02	.10	.01	-.05	.01	.02	0.21
6. No. of nodes	.23	-.06	-.06	.12	-.02	-.05	.07	.01	.01	0.25
7. Leaf sheath Max. length	.06	-.04	-.01	.01	-.02	-.01	.29	.02	.02	0.32
8. Leaf sheath Max. width	.16	-.07	-.06	.00	.01	.00	.07	.06	.03	0.20
9. No. of leaves	.20	-.09	-.08	.02	.02	.00	.04	.01	.13	0.25

Underlined figures denote direct effects.

variables excepting one i.e., length of largest leaf which has 0.07 correlation with yield. The correlation matrix for the nine vigour variables and the yield is presented in Table 2 and the path diagram of these nine attributes on yield is depicted in Fig.1. The estimates of direct and indirect effects are presented in Table 3. The path co-efficient analysis showed that the direct effects of palm height internodal distance at permanent mark and maximum length of leaf sheath were high and positive in accordance with their correlations with yield. Although the girth at permanent mark and high negative direct effect, its positive correlation with yield was obtained largely due to its high indirect effect via palm height. All the remaining characters too had high indirect effect via palm height, but their individual direct effects were not that marked. These results indicate the importance of palm height, internodal distance at permanent mark, maxi-

mum length of leaf sheath and girth at permanent mark for their contribution to yield.

The importance of height, girth and internodal distance even otherwise is justified in earlier studies of Bavappa and Ramachander (1967). But they had considered seedling vigour in relation to yield and had established strong relationship. Our study upholds this result for the adult palm vigour.

After having established the importance of palm height, girth at permanent mark, internodal distance at permanent mark and leaf sheath maximum length, with these four variables and yield, multiple regression analysis was again carried out and found that R^2 is 40.4% and is significant ($F = 8.30 > F_{4,49;0.05}$). This expresses nearly 91% contribution of all the 10 variables put together. The regression equation with these 4 variables.

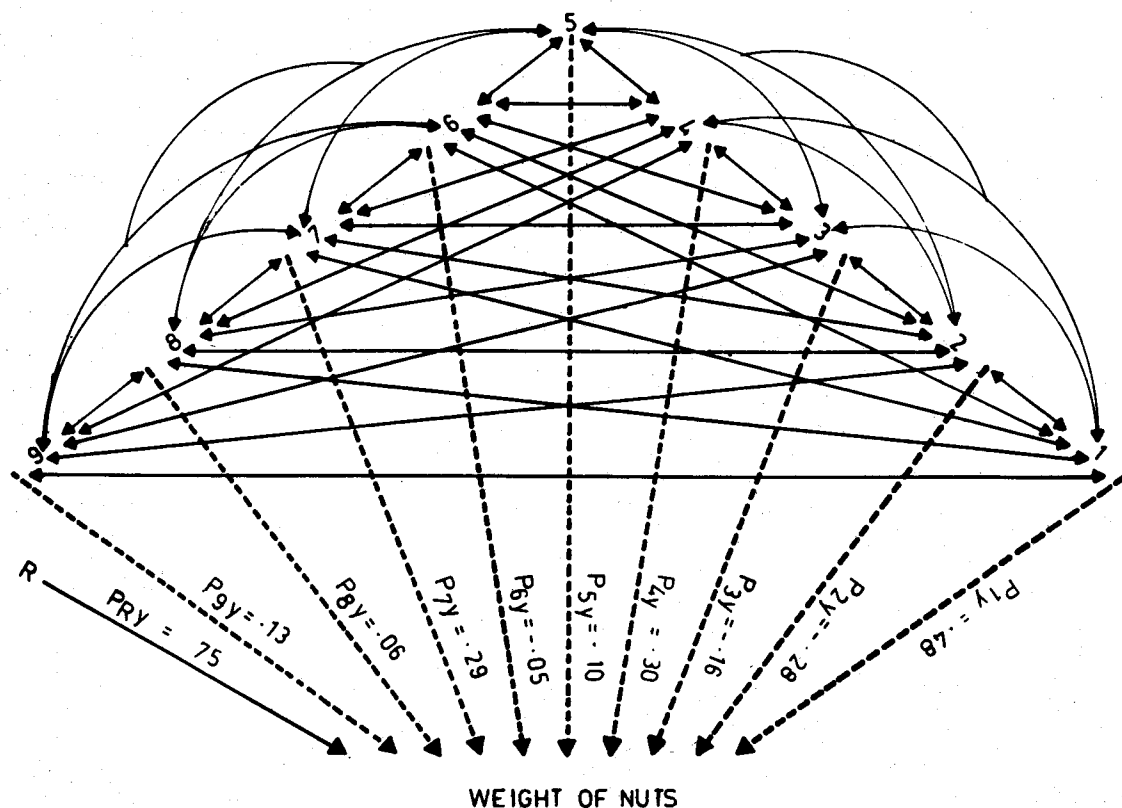


Fig. 1. Path diagram showing direct and indirect effects. Dotted lines with unidirectional arrows represent direct effects, bi-directional arrows represent correlation co-efficient between two arrow heads for (1) Palm height, (2) Girth at PM, (3) Girth at LEN, (4) Internodal distance at permanent mark, (5) Internodal distance below crown, (6) Number of nodes, (7) Leaf sheath maximum length, (8) Leaf sheath maximum breadth and (9) Number of leaves.

$$I = -8.23 + X_1 - 0.13 X_2 + 0.25 X_4 + 0.09 X_7$$

(.28) (.06) (.11) (.04)

may be considered as the vigour index, where the values within bracket denote standard errors for regression co-efficients.

Selection of elite palms as detailed above, ensures both high yield and high vigour of palms. This may be more precise than selecting elite palms on yield

alone which has low heritability. In the illustrative example, the six palms which meets selection norms based on both yield and vigour index are ranked 1,2,3,5, 10 and 11 with respect to yield alone. The palms ranking 4 and 6 in respect of yield were observed to have 14 and 18 as their vigour index ranks indicating that their high yield may be due to locational advantage and genotypically they may not have potential as indicated by its vigour parameters considered.

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SESSION VII : DISCUSSIONS

Dr. M.K. Nair: Dr. Santharam has presented an interesting paper on male sterility in coffee and from the studies he has concluded that male sterility is either due to the suppression of androecium or due to lack of food material to the generative tissues. I would like to know the actual mechanism involved. From the presentation I thought it is cytoplasmic. If so, for all the species does the same mechanism works has he got evidence in reciprocal crosses and how does he propose to transfer this male sterility to the cultivated species., i.e. *Coffea arabica* and *Coffea robusta*.

Dr. A. Santharam: In all the species of *Coffea* we know that there is a large degree of genetic homology and manifestation as observed in the slides we have prepared which are more or less same where the cytoplasm and nuclei are involved in the reaction. As for the transfer of the straight to commercial species also the same answer holds good. Due to a large degree of genetic homology there is free gene flow between species of *Coffea* and it has been reported in many of the earlier publications. We have got a viable hybrid a *congensis* × *robusta* hybrid surviving in the field, and we have identified the male sterility in the species *Congensis* also. We propose to use this and utilise it for hybrid seed production. The other matter is we have also got a source of restorer gene which has come to our notice very recently. We have raised a progeny from this male sterile plant and that shows restoration of male fertility in part of the progeny.

Dr. K.V. Ahmed Bavappa: Is it cytoplasmic or genic? What is the indication?

Dr. A. Santharam: From the mechanism as it appears from the manifestation in our studies it is cytoplasmic male sterility with reference to *Congensis* which we are actually proposing to utilise in breeding.

Dr. R. Naidu: Dr. Gupta has given a very clear picture about large cardamom in relation to variability and varieties and on where we stand today. I would like to know on the yield potentiality of some of the selections he has shown over the existing ones so that we can utilise these for future plans quickly.

Dr. P.N. Gupta: Only one selection has yielded about 1300 kgs of dry capsules whereas another variety has given about 1000 kgs of dry capsules per hectare. This is according to the planting distance, because planting distance varies from clone to clone and variety to variety depending on vigour, rhizome, spread, no. of suckers and the ultimate canopy which it forms. So regarding the yield the dwarf bush was found to be the highest yielder followed by red samne. Further four more clones have been selected and we are evaluating it on the yields and it will take not more than two years to give definite results on other selections.

Dr. K.V. Ahmed Bavappa: In plant breeding programme whether increase is due to plant population or due to variety, leads to problem. So a clearcut view

should be kept on this.

Dr. P.N. Gupta: The number of suckers produced per clone has also been calculated. So the spread depends on the canopy that is formed. Therefore we can adjust the distance. Some varieties are very tall and some are very dwarf so distance should be given importance in breeding programme. So the ultimate size of the plant produced by a clone should be taken for yield calculations.

Dr. K.V. Ahmed Bavappa: This is an important point which has to be noted, especially in the case of coffee. So especially for plants with different morphological frames and vigour, while evaluating one should be very careful that these variables which will affect the production are not brought in.

Dr. P.N. Gupta: One thing which I would like to make clear is that in the entire experiment in which 60 components were studied the planting distance were the same, i.e. 1.5 metres.

Dr. K.V. Ahmed Bavappa: We can run experiments with common spacing for comparison and different spacing according to the variety so that all the questions can be answered simultaneously. so experiments require broader planning, giving waitage to this sort of needs.

Dr. V. Raja Gopal: I would just like to make some comments about the points made by Director, C.P.C.R.I. about the screening for the drought resistance and this is an important area wherein the collaboration between the geneticist, and physiologist and Biochemist are very essential and that has been done in the

annual crops. And very rightly he has pointed out that it should be given importance in the case of plantation crops. We have already made a beginning. At least some of you are aware that we had a drought workshop where we tried to identify the problems and tried to look into it from different angles.

Dr. I.D. Singh: I have a comment on Dr. Bavappa's categorising tea in the strategy for breeding plantation crops. He outlined that tea has been put under vegetatively propagated group. To go back to the history of tea, it was a seed grown plant when we started planting. Even now the planters given a choice would like to grow tea as seedling grown plant rather than clonal plant. But in the breeding strategy which we started in 1930-35 at Tocklai the idea was that the clones or outstanding plants were selected out of the seedling populations. Now there are about 28 clones released from Tocklai and almost about the same number UPASI has released. A large number of area is currently grown under clonal planting. But hardly there are only 25 to 30% of the area under clonal tea. Today what we have seen by doing clonal planting we have narrowed the genetic base and if we continue to do that we will have still narrow genetic base of our plant population of tea. Are we in the right direction to have limited number of clones in the plantation crops and done away with seed plants. Our experience has been in N.E. India is that the area available for planting are a marginal nature and we are going for non-traditional areas where we have seen that seed grown plants are more adoptable. There the yield is more predictable whereas clones are very specific in their

growing requirements. They have very narrow adoptability. Should we in our breeding strategy in various plantation crops go for few clones to be grown in such a vast agro-climatic areas or carry on the dual policy of seed and clone. We in N.E. India never recommend to grow clone alone. The idea is that at any point of time half of the area should be under clonal planting and half under seed planting. Among the clones never grow one clone but grow at least 6 to 7 clones so that the genetic base is not narrowed. The second point which I would like to make is that these improved clones have been used in producing seed varieties. The seed varieties are F_1 hybrids. But not in the true sense F_1 varieties because getting pure lines is difficult because they are highly heterozygous materials. But they have shown superiority. So two clones when combined together and tested, their progenies were found to be better than the parents. This biclonal seed stock are recommended for growing. So developing seed varieties from these clones and again selecting the clones, use them for clonal planting and again this is repeated. So in plantation crops where we have good clones that has to be combined to produce seed varieties. But both should go parallel, not in isolation. The next aspect is that most of the plantation crops are of perennial nature and are cross-pollinated. Their nature of breeding system, especially compatibility should be studied. What we have seen at least in tea, we try to produce pure lines by inbreeding and hardly after second generation of inbreeding the depression is so high that hardly a plant survives. So any highly heterozygous material when we go for inbreeding the depression is very high. Anybody who is trying to

attempt this kind of approach should be cautious. In the case of tea it is cross-pollinated and self incompatible. So breeding system should be studied to develop the proper strategy for breeding. Thirdly we come across the problem of field plot technique. Hardly information is available on how to evaluate the materials you have for breeding. So development of proper field plot techniques should be taken up. Germplasm collection which has to be of the priority in starting an extensive breeding programme.

Dr. K.V. Ahmed Bavappa: Dr. I.D. Singh has widely covered a very vital area. As he pointed out rightly, a balanced approach of both v.p. and seedlings has to be there. But when we come to F_1 with very high potential we may not be able to go F_2 and F_3 levels because of variability. We do not want ourselves to be criticised tomorrow that we were responsible for a total breakdown in the system. We should know about the likely risks in the foreseeable future. After all with all our best of planning, if tomorrow something happens, like what happened for coffee in Sri Lanka, nothing can be done. But in our germplasm reserve we should have second line of reserve. But when we have high production material demonstrated we cannot also hold back. Regarding inbred lines, I think it should continue at least on a pure academic interest. Even, for germplasm reserve planting a statistical design should be adopted so that we can get faster results.

Mr. T.S. Govindarajan: I have three points for the information of the house. Certain lines of work we have taken up at Regional Research Station in Wynaad.

One is about identification of drought tolerant materials. By exploiting a situation after the unprecedented drought in 1982-83, we made a very rapid survey Wynaad and we could collect from the field about 18 materials. We have developed seed progenies and established a plot. My apprehension is, how to assess this material for further reliability on the drought tolerance under field conditions. If scientists here could enlighten us on this point, it will be very helpful. Secondly, how different materials of different morphological characters are to be grown under the same environmental condition to increase the productivity. Third point is about the high density population. In Kerala homesteads they maintain a very high density of varied crops in a small area. To identify the economic potential of this we have developed a homestead plot in one hectare and we have planted 18 different varieties of coffee. In course of time this will throw more light on this.

Dr. Ahmed Bavappa: Drought is an important problem in all our plantation crops. It is very interesting that they have done a 'hot spot' survey. This is what one should do. Once if you have a total drought and the crop has been wiped out, there will be few plants surviving. How are they surviving. They have collected the material. You have raised the seedlings, I only wish that we had some vegetative propagated plants of this coffee. Would Dr. Raja Gopal tell us on the evaluation of coffee on drought tolerance.

Dr. V. Raja Gopal: I think Dr. Venkataraman is doing lot of work on the different physiological parameters on drought resistance. Already he has got

some established physiological parameters.

Dr. D. Venkataramanan: We have developed a methodology, by planting the seeds in the secondary beds and inducing the drought conditions by withholding watering. We are able to find the differential behaviour. We are screening the cultivars by subjecting to similar conditions and I am sure that this will tally with field observation. This we are seeing in arabica but yet to see in Robusta.

Dr. N. Hari Gopal: Usually when we assess drought tolerance in any crop we will take the yield as the parameter. So all the 18 collection made by Mr. Govindarajan, let them grow and record the yield first. Under drought conditions if they are yielding they are really drought tolerant, because in plantation crops to really assess on other physiological parameters will be very difficult. But stress can be induced and studies on yield can be done.

Dr. P.N. Gupta: I have to suggest that stomatal count and size of the stomata is one of the best parameters to assess the drought resistance. This work has been done in temperate fruits particularly in apple.

Dr. V. Raja Gopal: Actually we have lot of data particularly on stomatal regulation and water potential components. Dr. Balasimha has collected data in cocoa on these and we have been able to identify 2 or 4 accessions to drought resistance. So also in the coconut we have been doing it. In some coconut hybrids, we also found that the higher

stomatal resistance and lower transpiration rate. But one important fact here is that the resistance noticed at seedling stage will not and need not necessarily be the same at the mature stage, particularly in plantation crops. So we should not give so much importance to seedling resistance. No doubt we have to do it for rapid survey for screening, but it should be carried out at the mature or yielding stage.

Mr. M.S. Srinivasan: I would like to react to Dr. I.D. Singh's idea. His apprehensions as far as coffee is concerned has been taken care of. In fact, the germ-plasm we have collected so far has been very well utilised. We are going in for much genotype complex instead of monogenotype. We have taken the lesson from Sri Lanka. They had only one genotype which succumbed to leaf rust ultimately they have to abandon coffee and go to other crops. Gradually we are replacing earlier coffee with superior ones. In fact, when there is a vacancy in established coffee, we prompt the planters to plant the newer genotypes. By doing this we are maintaining the variability for further exploitation.

Dr. N. Harigopal: Normally the results what we get in the laboratory based on parameters like stomatal index, transpiration rate, etc. will never hold good in the field. So a drought-tolerant variety which has been identified as drought tolerant at the laboratory has to be evaluated under field conditions not only for plantation crops but also for others.

Dr. M.R. Sethuraj: When we talk of drought tolerance one should be very specific about it whether it is drought

tolerance in growth or in yield. These two things need not necessarily be the same. So drought tolerance at initial stage taking growth parameters into consideration, necessarily need not reflect in the yield. So this basic aspect has to be accepted as a preliminary philosophy. Drought tolerance is an ability to maintain turgidity. So the parameters directly related to the ability to maintain turgidity should be studied. At what stage, at what time and what should be the comparison; these things have to be very well planned from a physiological point of view. If you compare three parameters, i.e. water potential, solute potential and osmotic potential and turgidity, at normal and drought situation, it could be two seasons, or two periods in a day, it could be pre-dawn or mid-day. So by carefully choosing the situations to compare these parameters one might get some indications. When osmotic potential falls, certain drought tolerant varieties have got the capacity by osmo regulation to maintain turgidity. This is an important mechanism in many of the drought tolerant plants. What is necessary is that people should have the basic equipment to measure these parameters in the field. As pointed out the old conventional measurements in the laboratory by floating leaf on different solutions of toxicity, that may not reflect in the field at all. It is true. But this situation was happening a decade ago. Now we have very useful, very accurate instruments available. Only thing is it should be made available to the scientists and also they should know how to use it and also all the aspects related to it. One has to have a comprehensive view in drought tolerance with accurate instruments. Coming to the yield for example coconut or rubber even

if it maintains the turgidity as far as growth is concerned, it need not necessarily mean that the physiology related to yield will be taken care of. Because drought could have very direct effect on yield physiology. Physiology is a basic science. One has to do basic work, generate basic understanding of the situation. Till such an approach is accepted by the plantation crop scientists very little would come from physiologists.

Dr. K.V.A. Bavappa: Thank you Dr. Sethuraj for giving a very nice position of the problem. I think when we were discussing the idea here was that laboratory evaluation is not substitute to field evaluation. But we want a number of tools to be applied so that our evaluation becomes more meaningful and more precise. In a team work every individual and every group has a role of its own and provided we put all of them together in a meaningful way and then you approach your goal with much more science get at your goal much faster. Whereas you go as a matter of fact the whole trouble with us was we were going on in our long pathway. Put the material in the field and see what happens. It takes years, whereas we want to go with the lesser number evaluate that at the laboratory with number of techniques. As rightly pointed out drought by itself is no solution for yield. There are many parameters you have to build in. That is why the whole gamut of biochemistry and physiology has to be now jointly exploited by breeders. That is why we want a very large inter-disciplinary approach. With all our multigenic or multi-species or whatever we have with us can break down at a very given point of time. The

one example which I can give is about the lethal yellowing in Jamaica. There was resistance and within 5 years it broke down. We must always have a second line of defence with us and in that all the disciplines should be involved and share the responsibility. We are far behind in this interdisciplinary approach and we can go a long way. One more point is that the statisticians should come out with statistical designs which could be advantageously used even in evaluation of germplasm collection. This will give more acceptable result within shorter time.

Dr. K.K. Krishnamoorthy: About Dr. Singh's suggestion about whether seedling or clonal material, with my experience in tea, I find there are some sentiments also attached to certain things like seedlings. Some planters feel that seedlings are always better and clonal material at any time cannot be proved better than seedlings. But keeping the larger interest in mind, we have to develop clonal material capable of very high yields, which should be suitable for various agro-climatic zones. Planters in Darjeeling enquire as to whether it is possible to combine the aroma of their tea with the high yield of South India. It is a challenge for the scientific community and we have to continue work on this line. Secondly, the uptake of nutrients need not necessarily reflect on the yield of the plants. So when you consider all these multifaceted parameters, we have to find out whether they are additive or synergistic or complementary or antagonistic etc. So various factors including statistics have to be considered to arrive at a optimum yield per hectare.

CHAPTER VIII

CROP HUSBANDRY

Chairman : Dr. K. K. KRISHNAMOORTHY
Rapporteurs : Mr. S. NATESAN
: Mr. C. KAILASAM

NUTRITIONAL MANAGEMENT OF PLANTATION CROPS

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ABSTRACT

Concepts involved in the determination of nutritional requirements of crops, influence of shade and its contribution to crops through nutrient transfer on responses to fertilizer application, limitations of soil testing, agronomic practices and their influence on fertiliser use efficacy, effect of various moisture regimes on nutrient absorption etc. are discussed. Importance of initiating nutrient balance studies in plantation crop agro-ecosystems, standardisation of new techniques such as EUF (Electron-Ultra filtration method) as a tool for refining fertiliser recommendations, recognition of micro-nutrient fluxes in soils of plantation crops are identified as future strategies.

INTRODUCTION

Plantation Crops in the country occupy around 2 per cent of the total cultivated area and the country earns foreign exchange to the tune of Rs.8900 million rupees annually and this amounts to three fourths of the export earnings of all agricultural commodities.

Fertiliser usage in plantation crops is half to one century old. The use of fertilisers in tea is half a century old (Venkata Ram, 1980). In coffee, it is nearly a century old (Rao *et al.* 1985). Soil fertility was maintained through the use of bulky organic manures such as compost, farm yard manure, oil cakes etc. Attempts were made later to shift to the usage of inorganics realising the slow releasing nature of organics and the bulk quantities required. During the first 40 years of this century, the use of fertiliser was reported to be mainly confined to plantation crops such as tea, coffee and rubber only (Anon. 1982). Series of simple manurial

trials initiated in cultivator's fields and research stations resulted in the generation of tentative recommendations. Refinements in fertilizer recommendations were made later to achieve higher production.

Tea

Nutrient removal

One thousand kg made tea removes 110.0, 16.5 and 37.0 kg of N, P and K respectively. Ranganathan (1973) reported that only 20 per cent of the total biomass produced was removed from the tea field. The proportion of nutrient removal as against total nutrients in the biomass of tea was 45.5., 40.6 and 35 per cent of NPK respectively.

Ranganathan (1973) reported that an NPK ratio of 4:3:3 was best suited for sound wood formation in tea. Recent studies in young tea indicated the superiority of an NK ratio of 2:3 for initial

two years and 1:1 over the next three years and until first prune (Ranganathan, 1979).

On the basis of nutrients removed by the leaf and wood, recommendation formulated for tea fields by Venkata Ram (1980) in the pruned year are given below:

Type of prune	N (kg/ha)	P ₂ O ₅ (kg/ha)	K ₂ O (kg/ha)
Light prune skiff	180	80	210
Med. prune	160	80	210
Hard/rejuvenation	120	100	210

Venkata Ram (1980) made the following fertiliser recommendation for tea in young clearings.

Age	N	P ₂ O ₅ kg/ha	K ₂ O kg/ha
1st year	180	80-100	270
2nd year	240	80-100	360
3rd year	300	80-100	300

The decomposition rate of organic matter and release of N in tea soils does not vary at elevations above 250 m even at relatively high organic matter status. Application of N even when organic matter is high was considered essential.

Ranganathan (1968) reported that 40 to 60 kg N/ha was released by every one per cent organic matter and that tea utilised only 30 kg out of the release. Maintenance of organic matter through additions was vital.

The average release of K due to weathering of soils was estimated to be

equivalent to 10 ppm per month and was not adequate to meet crop requirement.

Usefulness of EUF technique in tea production has been investigated by Natesan *et al.* (1985). The results showed the existence of a close relationship between EUF-N, EUF-P and EUF-K on the one hand and the conventional soil test, N, P and K values on the other. EUF-N and EUF-P extractable at 20°C was significantly associated with tea productivity. It was concluded that EUF analyses could offer great potential to increase tea production.

EUF technique seems to offer an opportunity to improve the predictability of soil N availability by supplying information on the quantity of labile organic soil N likely to be mineralised during growing season and also more information on Q/I relationships. Evaluation of this technique as a tool for refining fertiliser schedules needs to be undertaken in all plantation crops.

Agronomic practices and their effect on nutrient use efficiency.

Methods of application in relation to source, choice of source in relation to weather conditions, split applications and increasing 'Y' max by good crop husbandary practices have increased N fertiliser use efficiency greatly in tea (Ranganathan, 1981).

Placement of P fertilisers at 15 to 25 cm depth gave 7% increase in tea yield over shallow placement (Ranganathan and Natesan, 1978).

Use of soluble phosphates is discouraged in the soils as the soluble P

compounds could result in considerable breakdown of Kaolin by phosphatylis leading to lowering of CEC values (Ranganathan, 1982).

Application of K is recommended in tea in as many splits as possible (around 4 to 6) and this ensured 10 to 13 per cent increase over two splits (Ranganathan, 1981).

Coffee

Nutrient removal

Coffee (arabica) remove 40.0, 2.4 and 43.0 kg of N, P and K respectively per 1000 kg clean coffee, while robusta removes 43.0, 4.0 and 48.0 kg for same yield.

The proportion of nutrients removal through harvest as against total nutrients in the biomass of the coffee plant was 57, 64 and 60 per cent for N, P_2O_5 and K_2O respectively in arabica coffee (Rao and Ramaiah, 1985).

Short and long term manurial trials in coffee often produced varying and some times conflicting results. Application of 100 kg/ha N was beneficial to young and old coffee alike. Application of N alone at 90 kg/ha increased the yield by 250 kg/ha over control. Inclusion of P at 50 kg/ha increased yield further by 170 kg/ha. Linear and increased yields were perceptible upto a dosage of 160:120:160 kg of N, P, K.

The results of field experiments in coffee have not been consistent and statistically significant, but greatly helped in formulation of general recommendation. Crop removal data helped in ration-

alisation of the schedule for a crop level of 1000 kg arabica coffee as 175:80:170 kg N P K/ha (Rao and Ramaiah, 1985).

Basis for fertiliser recommendation

A review of the basis of the recommendation discussed above reveals that they are mostly based on the philosophies of balance sheet concept of meeting output requirements and the maintenance concept aiming at nutrient status of soil/fertiliser dosage aimed at higher yield levels.

Organic matter flux in soils cropped to those plantation crops, the rates of decomposition at different altitudes, the quantitative additions of shade tree litter and loppings, the rate of transfer of nutrients especially N through these are not considered in working out the recommendations.

Yield responses to applied nutrients in coffee grown under a canopy of mixed shade comprising leguminous and non-leguminous trees have been generally non linear, non significant and not consistent (Rao and Ramaiah, 1985, Iyengar and Awatramani, 1973, Mathew and Rao, 1980). Shade in plantation crops is generally considered as an interfering factor between response and applied nutrients. Organic matter flux under this context and transfer rates especially that of N become important.

Ten tonnes leaf litter per ha/annum is reported to be available to coffee fields in India under a mixed canopy of shade contributing 100 kg N, 35 kg P_2O_5 and 45 K_2O /ha.

Ingajiniculi species could fix about 40 kg N/year and thus a coffee plantation

received 100 kg/H/annum through mineralisation of organic matter and fixation.

Aranguren et al. (1982a) conducted detailed studies on the transfer of N through litter fall in a traditional coffee plantation that was densely shaded. The species of shade trees were *Musa*, *Ficus*, *Cedrela*, *Helicarpus*, *Erythrina* and *Inga* sp. The results revealed a litter fall of 11.2 t/annum. The leaf litter comprised shade leaves 43.3%, coffee leaves 14.8% twigs, 28.6% fruits and flowers 12.8% and not identifiable 0.4%. Total transfer of N through this pathway was 189 kg/ha/year. Coffee litter decomposed faster than shade tree litter.

Aranguren et al. (1982b) concluded that N output by harvest could be exceeded by shade tree leaves alone and stressed the importance of understanding N cycle better in coffee agroecosystems in the formulation of recommendations.

Thirtysix to 72 per cent of soils cropped to coffee were acidic requiring use of amendments. The available phosphorus status in general was low to medium while available potassium was medium to high. Adjustments on the basis of soil test values in fertilizer usage are recommended (Rao and Ramaiah, 1985, Mathew and Rao 1980).

Studies in coffee revealed that organic matter additions were adequate but information on release of nitrogen from organic matter in relation to soil physical and chemical properties are not available.

Nemeth (1979) has shown Electro-Ultra

filtration (EUF) method of analysis to have considerable advantages over conventional soil testing methods. EUF method offers a convenient way to describe Q/I relationships, permits simultaneous extraction of inorganic N and easily available, mineralisable organic N enabling prediction of the replenishment of N from reserves, gives information on the productivity potential of a site and closely correlated with nutrient uptake by a crop (Nemeth, 1985).

Application of N carriers in rotation, avoidance of chilean nitrate as a source of N for coffee, discontinuance of continuous use of ammonium sulphate, application of N in four splits during the year etc. are recommended by Rao and Ramaiah (1985) for increased fertiliser use efficiency of N carriers.

Application of P in trenches 30 cm away from the coffee plant enhanced the soil P status as against placement in pits encapsulated. Placement of NP compound fertiliser in trenches 30 cm away from the plant produced higher availability by 13 per cent. Application of N in the surface and dibbling in general resulted in better growth (Anon. 1980).

The use of total water soluble 'P' through high grade complexes (17:17:17) or 19:19:19) on acid soils of pH less than 6.0 is unwarranted due to large fixations (Sankaran, 1985) and is especially true to coffee (Mathew and Rao, 1980) and tea (Venkata Ram, 1980, Ranganathan, 1982).

The review above suggests a rethinking on use of phosphate (Raju and Ramaiah, 1986) in plantation crops, the method of

Table I. *Comparative root characters of arabica and robusta species of coffee*

	Tap root length	Tap root Circumference cm.	Lateral root No.	Root fresh wt.	% of dry	Feeder root dry (wt.) (g)
Arabica	37.8	5.6	7.5	118.9	27.25	8.20
Robusta	55.1	6.5	8.8	182.4	38.65	19.18

application etc. to increase fertiliser P use efficiency.

For Robusta (*C. canephora* P) the nutrient requirement for production of a crop of 1000 kg/ha is estimated to be lower and around 120:90:120 kg N:P₂O₅:K₂O/ha as against 160:120:160 N:P₂O₅:K₂O/ha for arabica cultivars (Rao and Ramaiah 1985).

Field trials conducted at CCRI with different combinations of NPK ratios indicated positive responses to a 4:3:4 NPL fertiliser ratio (Iyengar and Awatramani, 1975, Mathew and Rao 1980).

Comparative root characters of arabica and robusta species of coffee indicate better characteristics of robusta.

The dense active and shallow root characteristics of robusta coffee make the variety more efficient in utilising native soil available nutrients and applied nutrients than arabicas.

Inter varietal yield differences at lowest fertiliser dosage are significantly different and the variety S.7 produced highest yields than others.

Variety	Yield kg/ha
S.7	3777
S.5	3642
S.6	3256
S.1934	1716

Irrigation during dry months increased the nutrient content in both fertilised and unfertilised plots in robusta coffee. This signified higher rate of absorption. Leaf calcium content fell rapidly and substantially at low soil moisture (1.8% in Oct. and 1.35 in Feb.).

The absorption of major minerals at high medium and low moisture regimes in arabica coffee was as under.

Moisture regimes	Absorption (accumulation in leaf for depletion from soil)		
	N %	P ppm	K me%
Height			
95% FC	3.07	5.5	0.45
Medium			
55% FC	3.15	6.2	0.47
Low			
40% FC	3.98	7.3	0.25

Absorption of N and K was more at medium moisture status whereas P absorption increased with decreased moisture level.

Rubber

One thousand kg of dry rubber removes 7, 2 and 5 kg of N, P and K respectively. The nutrients immobilised by a stand of 400 plants of 24 year old rubber are 1080 kg N, 120 kg P_2O_5 and 1060 kg K_2O (Mathew 1986).

Mathew (1986) recommended 300 kg of 10:10:10 NPK mixture per annum per hectare at 1 kg/tree for rubber. Lack of responses to N were attributed to large responses of N from drying leguminous cover plants in rubber.

Cardamom

Cardamom removes 120.0, 6.1 and 166.0 kg N, P and K respectively per 1000 kg of capsules. Nutrients locked up by cardamom plants in an hectare including underground portion has been reported to be 25.97 kg N, 4.35 kg P_2O_5 and 52.11 kg K_2O (Kulkarni, 1971).

No conclusive information are available from field experiments in cardamom. Zachariah (1978) reported that there was little need for fertiliser for cardamom although rare instances of good responses were noted. Maintenance dose of 30 kg N, 60 kg P_2O_5 and 30 kg K_2O per ha/annum is currently recommended for cardamom.

Zachariah (1978) reported that 5 to 8 tonnes dry leaf litter is added over an hectare per annum and transfer around 50 to 80 kg N, 10 to 15 kg P and 75 to 120 kg K/ha.

Pattanshetti *et al.* (1982) reviewed the results of fertiliser trials conducted over the past decade in cardamom and con-

cluded that the inconsistent and non-significant results were mainly due to lack of uniformity in shade due to mixed tree species and to their evergreen or deciduous nature and heterogenicity created by the differential leaf fall from the mixed tree species. They observed that controlling these sources of inconsistency resulted in significant response with respect to sucker production.

Understanding nitrogen cycle better in plantation crop agro-ecosystems especially in formulation of N requirements is needed. Balance studies in this context are important.

Agronomic, cultural and nutritional factors are increasingly becoming limiting factors in maintaining productive trends. Identification of factors limiting well in advance is important. Rate of uptake, rate of replenishment of nutrients in the root zone should be balanced. Studies on thermodynamic and kinetic aspects of ion movement should be undertaken.

Soil testing has been a primary tool of monitoring fertiliser use in all the plantation crops.

Soil test results for the period from 1971 to 1977 have revealed that soils cropped to cardamom are rich in organic matter, available K and Mg. Available P status in most of the cases is in the low to medium range and application of fertilisers had no positive effect on cardamom (Zachariah, unpublished). Therefore other means of nutrient management for improving productivity of cardamom should be thought off, as responses to applied fertilisers were remote.

Coconut

One hectare coconut garden (70 palms) having yield of 40 nuts/palm/year removed 22.5 kg N, 5.2 kg P and 28.4 kg K/year. Fertiliser demonstration trials conducted at different locations revealed that application of 0.34 kf N, 0.34 kg P_2O_5 and 0.68 K_2O per palm/year increased nut yield in coconut by 35 per cent in West Coast.

Muliyar and Nelliatt (1971) observed that application of 0.40 to 0.65 kg N, 0.89 to 1.21 kg K for palms yielding less than 60 nuts was optimum. Nelliatt (1973) recommended 500g N, 320g P_2O_5 and 1200g K_2O per palm per year on the basis of nutrient removal for palms yielding less than 50 nuts/palm. Application of double the rate mentioned above for palms under neglected cultivation in the initial year yielded additional revenue (Nelliatt *et al.* 1982).

Soils cropped to coconut are medium to coarse textured with a poor buffering capacity and nutrient status. Hameed Khan *et al.* (1978) opined that ordinary norms of soil fertility employed for other crops may not hold good for understanding of minerological make up of the soil.

Hameed Khan *et al.* (1985) opined that soil P levels are to be relied in judging P needs of coconut more than leaf levels and evaluation of critical soil P, levels under constant use of N and K was important due to the lack of relationship of plant P levels on yield.

Hameed Khan *et al.* (1983) indicated skipping of P application (soil available P based on Bray II test of 24 ppm) was not detrimental but profitable.

D×T coconut is reported to have greater and higher ability to exploit the native fertility of the soil as well as to use the applied nutrients than west coast tall (Bavappa *et al.* 1986).

	WCT	Nuts Y/Palm D × T	T×D
M ₀	23	31	17
M ₁	61	75	60
M ₂	67	76 (Nut) g	61
Q of fert. to be applied to get 75% maximum yield	N 1025 P 1025 K 2050	140 140 280	170 170 345

Foliar diagnosis has been assessed as a diagnostic tool in coffee (Rao, 1978) Coconut (Gopi *et al.* 1982) and Pepper (Sushma *et al.* 1982) but in general, it did not permit prediction of fertiliser requirement for targeted yield.

The relationship between plant and soil nutrient status generally follows an asymptotic curve, indicating that tissue tests are reliable only in the lower range of soil nutrient status and that soil test values are highly reliable.

Research in this direction would be highly beneficial.

Cocoa

Havord (1959) reported that cacao plantations under shade did not respond to N fertilisation. Boyer (1973) reported a litter fall of 8500 kg/ha per annum in a moderately shaded cacao plantation corresponding to a flux of 50 kg.

Aranguran *et al.* (1982b) also studied N cycle in cacao plantation grown under shade.

Litter amounted to 20.9 t/ha and N transferred was 321 kg/ha. Cacao contained 302 kg N/ha in its phytomass. Mineral store of total N was 35 t N/ha and 40 per cent was at 20 cm depth. Nitrogen output through harvest (636 kg/dry cacao/ha/y) was 45 kg N/ha. Ten kg is returned to the soil through hulls. Thus they concluded N output by harvest could be exceeded by shade contribution alone.

Balance of gains and loss of N in cacao plantations needs to be studied carefully.

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SUITABLE EXTRACTANT TO DETERMINE THE AVAILABLE MANGANESE STATUS OF SOILS CROPPED TO COFFEE

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ABSTRACT

A pot culture experiment using seven soils representing different coffee growing zones, to standardise a suitable extractant for assessing available manganese content in soils cropped to coffee was carried out. Out of six extractants tried, Neutral normal ammonium acetate (NH_4OAc) and Neutral normal sodium acetate (NaOAc) were found suitable. There was a significant correlation between soil manganese extracted by these two reagents and total uptake of manganese by coffee plants at 5% level ($r = 0.4834$ and 0.5248 respectively). 0.2% Hydroquinone in normal neutral ammonium acetate extracted more of manganese and was highly correlated with that of total soil manganese. The correlation between pH and plant uptake manganese was negative and statistically significant.

INTRODUCTION

Micronutrients are of vital importance in crop growth and in recent years research on zinc, manganese and iron has received considerable attention. Instances of crop failures and plant diseases arising from the deficiency or excess of manganese have been reported in a number of crops, such as sugar cane, rice, tobacco, citrus, areca and mango in India (Kanwar and Randhawa, 1967). Solution culture experiments with coffee in India (Iyengar, 1968) have indicated that high concentration of manganese in the growing medium induced interveinal chlorosis of leaves by depressing the absorption and utilization of iron by coffee. Iyengar (1972) in a survey conducted observed that total as well as

active forms of manganese were generally high in soils cropped to coffee particularly in Giri and Kalasa areas and had the potential to cause toxicity.

Demarcating zones of toxicity and deficiency was a prerequisite. Consequently Dhruvakumar and Rao (1982) determined the extent of distribution of manganese in soils cropped to coffee. They observed that soils cropped to coffee in general had high manganese content.

Hoff and Mederski (1958) observed that 1 M. $\text{NH}_4\text{H}_2\text{PO}_4$ and 0.1 NH_3PO_4 gave the highest correlation with that of plant manganese. Hammes and Berger (1960) pointed out that EDTA extracted manganese gave the highest correlation

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co-efficient with the manganese contents of plants. Neutral normal ammonium acetate with the without 0.2% Hydroquinone, Neutral normal sodium acetate and Morgan's reagent (pH 4.8) are some of the other extractants used by several other workers.

Iyengar (1972) while determining the contents of various forms of manganese in soils cropped to coffee extracted available manganese using 1 M. $\text{NH}_4\text{H}_2\text{PO}_4$, 0.27 N NaOAc + 0.52 N HOAc at pH 4.8 (Morgan's reagent) and 0.1 N H_3PO_4 and found close agreement between the amounts of manganese extracted by ammonium dihydrogen phosphate and orthophosphoric acid. For routine adoption of one of the above two reagents, he suggested that the manganese extracted by these two extractants should be correlated with uptake of manganese by coffee.

Standardisation of an extractant for estimating the plant available manganese in coffee was felt necessary, therefore, a pot culture study was conducted to correlate the manganese uptake by plant with the manganese extracted by different reagents from soils. The results obtained are reported in this paper.

MATERIALS AND METHODS

Bulk surface soil samples (0-9") representing seven different coffee growing zones were collected. All the samples were airdried and screened through 2 mm sieve and 10 kg of soils were filled into plastic pots. Initial characteristics of these soils such as pH (1:2.5 soil water ratio), available P and available K and organic carbon were

determined. The texture of soils chosen ranged from clay loam to sandy loam with organic carbon content varying between 1.2 and 2.5 per cent. The pH of the soil ranged from 4.60 to 6.48.

Coffee seeds (S.795) germinated previously in sand medium were transplanted into these pots. Four seedlings were maintained in each pot. The experiment was replicated thrice. The seedlings were allowed to grow for one year, and plants were harvested. The plants were separated into roots, stem and leaf, fresh and dry weight were recorded. The plant samples were washed, dried and powdered as described by Aduayi (1975).

Total manganese in plants was determined by the wet digestion method as described by Piper (1950). The permanganate colour was developed from the acid extract with potassium per iodate in H_2SO_4 and HNO_3 medium as described by Willard and Greathouse (1917).

Soil samples were extracted for available manganese by using 6 extractants namely (i) 0.1 N Phosphoric acid, (ii) Neutral normal ammonium acetate, (iii) Neutral normal sodium acetate, (iv) 1.5 M ammonium di-hydrogen phosphate, (v) Morgan's reagent (pH 4.8), and (vi) Neutral normal ammonium acetate + 0.2% hydroquinone.

All the samples were shaken for 1 hour at a soil to solution ratio of 1:5. After shaking, the samples were filtered and suitable aliquot was taken for the determination of manganese. The manganese was determined as described by Black (1965) using the calorimetric method

Table I. *Manganese extracted by different reagents from soils as well as those taken up by coffee plants grown in these soils.*

Sl. No.	Place	Mn uptake by plants mg/g	0.1 N H ₃ PO ₄ (ppm)	Neutral 1N NaOAc (ppm)	Neutral 1N NH ₄ OAc (ppm)	Morgan's reagent (ppm)	1.5 M NH ₄ H ₂ PO ₄ (ppm)	Neutral 1N NH ₄ OAc + 0.2% hydroquinone (ppm)
1.	Balehonnur	0.67	43	5	6	22	62	314
2.	"	0.29	41	4	6	25	63	302
3.	"	0.59	36	3	5	18	44	334
4.	CCRI, Bison Valley	5.06	59	18	23	36	69	119
5.	"	4.04	58	14	18	32	63	103
6.	"	3.56	50	16	18	35	68	106
7.	CCRI, Robusta Block	4.92	54	16	22	40	65	314
8.	"	4.44	50	15	24	41	71	318
9.	"	5.07	58	14	24	51	74	291
10.	Coorg	6.95	94	41	58	100	101	365
11.	"	14.40	111	50	63	110	105	333
12.	"	16.97	104	42	58	100	98	433
13.	Kalasa	3.04	86	21	31	84	135	419
14.	"	4.83	87	23	38	82	139	406
15.	"	2.02	86	22	32	82	138	410
16.	Pulney	2.45	63	23	31	53	62	88
17.	"	7.65	76	26	31	63	94	162
18.	"	20.13	65	21	32	55	68	103
19.	Saklespur	2.83	93	28	42	83	105	239
20.	"	2.69	109	37	56	102	126	327
21.	"	3.10	103	37	57	91	123	355

developed by Willard and Greathouse (1917).

Similarly total soil manganese was also determined by digesting 1 gram of soil with sulphuric acid and hydrofluoric acid.

RESULTS

The data on plant uptake of manganese by coffee seedlings and the available manganese extracted by different extractants are given in Table I. Correlation co-efficients worked out between the manganese uptake by coffee and

Table II. *Correlation coefficients for various 'Mn' extraction methods.*

Sl. No.	Extractant used	Correlation 'r' co-efficient
1.	0.1 N H ₃ PO ₄	+ 0.3688
2.	Neutral normal NaOAc	+ 0.5248*
3.	Neutral Normal NH ₄ OAc	+ 0.4834*
4.	Morgan's reagent	+ 0.3858
5.	1.5 M NH ₄ H ₂ PO ₄	+ 0.0370
6.	Neutral Normal NH ₄ OAc + 0.2% hydroquinone	- 0.0755

*Significant at 5% level.

manganese extracted by different methods are given in Table II.

Manganese uptake ranged between 0.29 and 20.13 mg/g. The quantity of manganese extracted by different extractants were as follows:

0.1 NH_3PO_4 extracted 36 – 111 ppm, Normal neutral sodium acetate extracted 3 – 50 ppm, Normal neutral ammonium

acetate extracted 5 – 63 ppm, Morgan's reagent (pH 4.8) extracted 18 – 110 ppm, 1.5 M $\text{NH}_4\text{H}_2\text{PO}_4$ extracted 62 – 139 ppm while Normal neutral NH_4OAc with 0.2% hydroquinone extracted 88 – 433 ppm. The lowest concentration of 3 ppm was extracted by Neutral normal NaOAc and the highest of 433 ppm manganese was extracted by Neutral normal NH_4OAc with 0.2% hydroquinone.

Table III. Manganese extracted by different reagents and the total soil manganese and their correlations.

Sl. No.	Place	Total Mn in soils (ppm)	0.1 N H_3PO_4 (ppm)	Neutral 1N NaOAc (ppm)	Neutral 1N NH_4OAc (ppm)	Morgan's reagent (ppm)	1.5 M $\text{NH}_4\text{H}_2\text{PO}_4$ (ppm)	Neutral 1N NH_4OAc + 0.2% hydroquinone (ppm)
1.	Balehonnur	1350	43	5	6	22	62	314
2.	"	1250	41	4	6	25	63	302
3.	"	1250	36	3	5	18	44	334
4.	C.C.R.I. Bison Valley	500	59	18	23	36	69	119
5.	"	500	58	14	18	32	63	103
6.	"	500	50	16	18	35	68	106
7.	C.C.R.I. Robusta Block	1000	54	16	22	40	65	314
8.	"	1075	50	15	24	41	71	318
9.	"	1075	58	14	24	51	74	291
10.	Coorg	1075	94	41	58	100	101	365
11.	"	1500	111	50	63	110	105	333
12.	"	1402	104	42	58	100	98	433
13.	Kalasa	1500	86	21	31	84	135	419
14.	"	1500	87	23	38	82	139	406
15.	"	1500	86	22	32	82	138	410
16.	Pulney	950	63	23	31	53	62	88
17.	"	625	76	26	31	63	94	162
18.	"	950	65	21	32	55	68	103
19.	Saklespur	1020	93	28	42	83	105	239
20.	"	1402	109	37	56	102	126	327
21.	"	1402	103	37	57	91	123	355
Correlation co-efficient		r=	0.6192**	0.2864 NS	0.3663 NS	0.5164*	0.7839**	0.8660**

**Significant at 1% level

*Significant at 5% level

NS Not significant

Statistical examination of the data revealed that the manganese extracted by Neutral normal sodium acetate and Neutral normal ammonium acetate were positively correlated and were significant at 5% level ($r = 0.5248$ and 0.4834 respectively). Other extractants was not significantly correlated. Correlations worked out between plant Mn uptake and Mn extracted by other extractants were not significant. Total Mn in soils ranged between 500 and 1500 ppm.

The correlations worked out between total manganese in soils and manganese extracted by different reagents are given in Table III. The manganese extracted by 1 N Neutral NH_4OAc with 0.2% Hydroquinone was positively and significantly correlated with total Manganese ($r = 0.8660$) followed by 1.5 M $\text{NH}_4\text{H}_2\text{PO}_4$, and 0.1 N H_3PO_4 at 1% level the correlation co-efficients being 0.7839 and 0.6192 respectively. Total soil manganese and manganese extracted by Morgan's reagent was positively and significantly correlated at 5% level, the correlation coefficient being 0.5164.

The correlation co-efficient worked out between pH and plant uptake is given in Table IV. The data revealed that there was a negative correlation between pH and plant uptake of manganese and it was significant at 1% level ($r = 0.7382$).

DISCUSSION

Results of the present study indicated that Neutral 1 N ammonium acetate with 0.12% hydroquinone extracted the highest amounts of manganese while Neutral 1 N ammonium acetate and Neutral 1 N sodium acetate extracted the lowest

Table IV. *pH of the soil and plant uptake of the Manganese by Coffee plants and their correlation.*

Sl. No.	Place of manganese		Plant uptake
1.	Balehonnur	6.48	0.67
2.	"	6.48	0.29
3.	"	6.35	0.59
4.	C.C.R.I. Bison Valley	5.38	5.06
5.	"	5.93	4.04
6.	"	5.91	3.56
7.	C.C.R.I. Robusta Block	5.90	4.92
8.	"	5.90	4.44
9.	"	5.80	5.07
10.	Coorg	4.76	6.95
11.	"	4.60	14.40
12.	"	4.68	16.97
13.	Kalasa	6.45	3.04
14.	"	6.42	4.83
15.	"	6.40	2.02
16.	Pulney	5.05	2.45
17.	"	5.10	7.65
18.	"	5.00	20.13
19.	Saklespur	6.32	2.83
20.	"	6.05	2.69
21.	"	5.98	3.10
Correlation co-efficient		$r = -0.7382^{**}$	

****Significant at 1% level**

quantities of manganese. Acidic reagents like 1.5 M ammonium di-hydrogen phosphate, 0.1 N phosphoric acid and Morgan's reagent extracted fairly high quantities of manganese from the soil in the order of merit.

The treatment of soil with strong salt solution like Neutral 1 N ammonium acetate and Neutral 1 N sodium acetate extracted the exchangeable as well as the water soluble forms of divalent manganese. Acidic reagents like 1.5 M ammonium dihydrogen phosphate, 0.1 N phosphoric acid and Morgan's reagent,

extracted more manganese than the solution of neutral salts. Neutral 1 N ammonium acetate containing 0.2% hydroquinone extracted the easily reducible manganese and hence the extracted manganese was higher than that of other reagents. Mehta and Patel (1969) while standardising a suitable extractant for the estimation of available manganese with Jowar as a test crop also found acid extractants (H_3PO_4 , HCl and Morgan's reagent) extracted high quantities of manganese from the soils than neutral 1 N NaOAc and NH_4OAc .

The correlation between total soil manganese and the manganese extracted by Neutral 1 N ammonium acetate + 0.2% hydroquinone was positive and highly significant, while manganese extracted by Neutral 1 N sodium acetate and Neutral 1 N ammonium acetate though positively related to total soil manganese, was not significant.

The general methods like Neutral 1 N ammonium acetate + 0.2% hydroquinone, 1.5 M ammonium di-hydrogen phosphate, 0.1 N phosphoric acid and Morgan's reagent extracted more manganese and were positively correlated with that of total soil manganese. On the contrary, Neutral 1 N ammonium acetate and Neutral 1 N sodium acetate extracted less quantities of manganese and they were not significantly related to the total soil manganese. This may be due to the fact that these two methods extract only water soluble and exchangeable manganese. While Neutral 1 N ammonium acetate + 0.2% hydroquinone extracted insoluble oxides of trivalent (MnO_3) and tetravalent (MnO_4) fractions of manganese by reducing them into

divalent from (easily reducible manganese). This present findings are in conformity with the earlier studies of Iyengar (1972), who reported a positive and significant correlation between total manganese in soils and active manganese (watersol + Excha + E.R.). He found that exchangeable manganese was not significantly correlated though positive.

Correlation studies to find out the relationship between pH and plant manganese uptake revealed that pH was negatively correlated and was significant at 1% level. The non-availability of manganese due to the formation of insoluble higher oxides at higher pH values may be the reason for the negative correlation. Similar observations were made by Iyengar (1972) and Page (1962) who reported the increase in pH decreased the availability of manganese in soil. pH and manganese extracted by 1 N NH_4OAc was negatively and significantly correlated (Dhruvakumar, and Rao 1982).

Out of six methods tried, reagents Neutral 1 N ammonium acetate and Neutral 1 N sodium acetate though they extracted low quantities of manganese were found to be positively correlated with that of plant uptake of manganese. Though manganese extracted by other reagents like 0.1 N H_3PO_4 , Morgan's reagent and 1.5 M $\text{NH}_4\text{H}_2\text{PO}_4$ were positively correlated with plant Mn uptake they were not significant. Manganese extracted by Neutral 1 N NH_4OAc + 0.2% hydroquinone had the negative relationship with plant uptake but it was not significant. Similar relationships were reported by several investigators (Dikshit and Verma, 1978

and Mukhopadhyay *et al.* 1983). They also found that the Neutral 1 N ammonium acetate extracted manganese had the highest correlation with that of plant uptake of manganese, while Baser (1967) observed that the manganese extracted by sodium acetate had the highest correlation with that of plant uptake of manganese.

Considering the degree of correlation between methods and the plant uptake of manganese, it could be concluded that Neutral 1 N NaOAc and Neutral 1 N NH_4OAc are suitable for the estimation of available manganese in soils cropped to coffee.

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EFFECT OF CENTERING OF TEA PLANTS IN THE NURSERY ON GROWTH PERFORMANCE IN THE FIELD

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ABSTRACT

As the Tea industry in southern India embarked upon a large scale infilling programme from late 1970s and limited replanting in recent years, many estates started training young plants in the nursery to promote lateral branching and to produce a miniature tea bush ready for planting in the field. An experiment, conducted at Madupatty Estate, Munnar Kerala (1677 m M.S.L.) showed that centering of nursery plants at 10 or 15 cm in to green or red wood with the object of inducing lateral branches, affected the growth of root system adversely. Centering of plants in the nursery resulted in higher mortality and lower yield after planting when compared to those centered in the field.

INTRODUCTION

As in other plant species, in a young tea plant axillary buds do not sprout if the terminal bud continues to grow. If the apical dominance is arrested, one or more of the lateral buds immediately below the apical bud usually sprout. This is achieved in young tea plants by centering. The term centering is referred to removing the leader stem as low as possible leaving two or three lateral branches with the object of inducing the growth of more lateral branches. This is usually undertaken six to twelve months after planting. As Tea Industry in South India embarked upon large scale infilling programme from late 1970s and later, replanting to a very limited extent, many estates started training of young plants in the nursery itself to produce a miniature bush for planting. By adopting this practice it was expected to avoid

centering in the field and advancing the cropping.

MATERIALS AND METHODS

An experiment was laid out in Madupatty Estate, Munnar (at an altitude of 1677 m, M.S.L.) in 1980 to study the effect of centering the plants in the nursery on growth performance in field. Eight-month old plants of the clone UPASI-9 (B/6/61) were selected for the trial. The following treatments were imposed in the nursery, when the plants attained the required developmental stage:

1. Centering at 10 cm into green wood
 2. Centering at 10 cm into red wood
 3. Centering at 15 cm into green wood
 4. Centering at 15 cm into red wood
 5. Untreated standard
- (Each treatment comprised 104 plants)

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During September 1981 the plants treated in the nursery along with standard plants were planted in separate but contiguous plots.

RESULTS AND DISCUSSION

Visual observations during the first year (1982) indicated that plants which were not centered in the nursery had put forth better growth than the centered plants. The side branches of untouched plants were more vigorous than centered plants. The centered plants were brought into bearing by the end of twelve months from planting by light plucking to a mature leaf, commencing 50 cm from ground. The plants in the standard plot were centered in August 1982. All the plots were brought into bearing, thirteen months after planting. The yield data recorded during 2nd, 3rd, 4th and part of 5th year are presented in Table I.

During the drought, it was observed (1983) that the plants which were not centered in the nursery withstood drought much better than the plants that were cut

Table I. *Productivity in the field.*

Treatment	Yield - Made tea Kg/ha.			
	2nd year	3rd year	4th year	5th* year
1. Centering at 10 cm into green wood	238	1404	3719	2683
2. Centering at 10 cm into red wood	313	1941	3695	2581
3. Centering at 15 cm into green wood	417	2045	4957	3417
4. Centering at 15 cm into red wood	363	1513	3050	2348
5. Untreated standard	551	2818	5462	3934

*Till the time of formative prune in May 1986.

Table II. *Casualty percentage in the second year.*

Treatment	% Casualty
1. Centering at 10 cm into green wood	6
2. Centering at 10 cm into red wood	5
3. Centering at 15 cm into green wood	1
4. Centering at 15 cm into red wood	1
5. Untreated standard	0

in the nursery (Table II). After receiving rains in April 1983, one representative plant from each of the plots was carefully uprooted to determine the shoot and root growth. The data are given in Table III.

Weight of pruned material was recorded at the time of formative pruning during May 1986 (Table IV).

As expected, removal of the leader stem induced the sprouting of lateral buds and promoted the growth of lateral branches; this was advanced into the nursery by early centering of the plants in the nursery. Such handling of the plants (in the nursery) under the concerned treatments, promoted a vigorous shoot

Table III. *Shoot-root ratio.*

Treatment	Dry matter accumulation at the end of 24 months		
	Dry Weight (G)		Ratio
	Shoot	Root	Shoot/Root
1. Centering at 10 cm into green wood	96	39	2.46:1
2. Centering at 10 cm into red wood	203	84	2.41:1
3. Centering at 15 cm into green wood	175	120	1.45:1
4. Centering at 15 cm into red wood	131	49	2.67:1
5. Untreated standard	312	150	2.08:1

Table IV. *Effect of centering in nursery on wood development in the field.*

Treatment	Weight of Prunings* (kg)
1. Centering at 10 cm into the green wood	466
2. Centering at 10 cm into red wood	451
3. Centering at 15 cm into green wood	507
4. Centering at 15 cm into red wood	431
5. Untreated standard	617

*Pruned at 35 cm from ground

growth, at the expense of root growth; additionally, the root growth has been constrained by the size of the containers in the nursery. This in turn resulted in a high shoot/root ratio (Table III).

A high shoot/root ratio is generally a handicap in the establishment of the plants in the field, particularly through drought, as reflected by the vigour of the plants under untreated standard as also per cent casualty under various treatments (Table II).

Higher yield obtained from the plot under untreated standard indicates two points: (a) the plants centered in the nursery had suffered through successive drought resulting in lower yields through

the period up to the formative pruning. (b) centering in the nursery while promoting laterals at any early stage, is not adequate to promote the desired spread and filling in of the bush to form a large plucking surface area; as such, centering in the field once again appears to be inevitable.

Thus, it could be seen, that centering of young tea plants in the nursery is self-defeating while the desired results are not achieved.

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NUTRITIONAL STATUS OF THE SOIL AND PLANT IN RELATION TO THE INCIDENCE OF CHENTHAL DISEASE OF CARDAMOM

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ABSTRACT

An investigation was carried out to study the nutritional status of the soil and plant in relation to the incidence of chenthal disease in cardamom. The study has revealed that the content of total nutrients in the soil did not influence the development of the disease in any of the cultivars. The status of most of the nutrients in plants of the various disease categories also was not appreciably different, indicating their minor role in the development of the disease. However, the K and Mg content of the plants showed a decrease with increase in disease incidence. Eventhough there was no difference in the status of total or exchangeable K in soil, the exchangeable Mg content of the soil around the diseased plants was much lower. The observations suggest a possible association of K and Mg with the incidence of chenthal disease in cardamom.

The K/Mg and K/Ca+Mg ratios of both the soil and plant narrowed with the severity of the disease. Whether the development of the disease was a result of an imbalance in the monovalent to divalent cationic ratio in the plant or whether an imbalance in the ratio has resulted in the development of the disease, however, could not be brought out from the results of the study.

INTRODUCTION

Among the various diseases that affect the crop, "Chenthal" is a malady which is reported to bring about considerable damage to the plant and cause heavy reduction in yield. This disease is characterised by the development of reddish streaks on the leaf lamina accompanied by water soaked lesions that cover the entire leaf surface. A team of Scientists from the Kerala Agricultural University who conducted a survey on the incidence of this disease in Idukki district of Kerala have attributed the disease

condition to a combined effect of nutritional, physiological and environmental factors rather than to the attack by any specific pathogen (Anon, 1979). This paper embodies the findings of an investigation carried out at the College of Agriculture, Vellayani during 1981-83 to assess the nutritional status of the soil and plant in relation to the incidence of Chenthal disease in cardamom.

MATERIALS AND METHODS

Three common cultivars of cardamom

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viz. Malabar, Mysore and Vazhuka, at different intensities of the disease along with the soils around each of these plants collected from different plantations in Idukki district formed the materials for the study.

The plants from each variety were categorised into four disease intensity groups (healthy, low, medium and high) based on the intensity of infection of leaf lamina and the proportion of diseased leaves per clump. Twenty plants under each of the above categories were selected as observational plants for taking biometric observations and for assessing the nutritional status by chemical analysis. For chemical analysis, the second, fifth and eighth leaves from the top of the plants were sampled.

Surface soil sample (0-15 cm) at a distance of 50 cm away from the base of the 240 observational plants ($3 \times 4 \times 20$) were taken twice during the year 1982. First sampling was done before the onset of South West monsoon (pre-monsoon period) during the 1st week of March and second after the heavy rains (Post-monsoon period) during the last week of September. The plant and soil samples were chemically analysed for total and exchangeable nutrients by adopting standard analytical procedures.

RESULTS

Growth characters

There was no significant variation among the number of tillers, panicles and capsules or the weight of capsules produced per clump in the three cultivars of cardamom showing different intensities of disease infection. However, a decreas-

ing trend with respect to the number and weight of capsules with increasing severity of the disease was noticed among the three cultivars. The maximum reduction of 7 to 13% in the yield of cardamom was noted in the case of highly diseased plants of variety Mysore.

Soil and plant nutrient status

The total nitrogen content of the soils (0.17 to 0.21%) as well as the plants (2.1 to 2.2%) did not show any significant difference at different levels of disease intensity in any of the three cultivars during both the pre and post monsoon periods. Compared to the healthy plants, a gradual but not significant reduction in the content of P was noticed in the case of diseased plants. In the case of K also, the content did not significantly differ among the soils of healthy and diseased plants while it was significantly low in diseased plants (2.4 – 2.9% K for healthy plants and 1.7 to 2.3% K for diseased plants).

Unlike Ca, the Mg content of the soil and plant showed remarkable differences with respect to the levels of disease in all the cultivars, a low Mg status being associated with disease affected plants and their corresponding soils. There was no marked variation in the content of micronutrients such as Fe, Mn and Zn between the healthy and diseased plants.

DISCUSSION

Lack of appreciable reduction in the growth and yield characters of cardamom by the onset of Chenthal disease, although may point to a complacent

situation, can become a significant limitation while considering the long term economics of the crop. Considerable drying up of the flowers noticed on the panicles of severely infected plants might be a reason for the diminution in the number of capsules per clump and the decreased yield of cardamom.

A reduction in the yield of cardamom due to the incidence of Chenthal disease has been reported by George (1978). Another probable reason contributing to the reduction in the yield from disease affected plants could be a reduction in the quantity of photosynthates available for the filling up of the capsules, on account of the damage caused to the net photosynthetic area of the leaf lamina. In plants most severely affected by the disease more than 60% of the area was covered with water soaked lesions which could suppress both photosynthetic assimilation as well as the translocation of photosynthates to storage parts.

Soil and plant nutrient status

The fact that the total nitrogen content of the soil or plant did not influence the incidence of the disease possibly eliminates the deficiency of nitrogen acting as a pre-disposing factor for the development of the disease. A high nitrogen status of cardamom soils has been earlier reported by Dattu Rao (1971) and Zachariah (1975). Compared to the healthy plants, a gradual reduction in the content of phosphorus was noted in the leaves of plants affected by the disease. Although this reduction was not marked, it may indicate either a lower absorption rate or an impaired capacity of the plants with progressive increase in the severity

of the disease, to assimilate the phosphorus.

While there was no significant difference between the exchangeable K content of soils of healthy and diseased plants, its content was significantly low in the diseased plants. Since K is known to be associated with imparting disease resistance to crops (Agarwala and Sharma, 1976), it is likely that a low K status of the plants, presumably has acted as a pre-disposing factor in the expression of the disease syndrome. Alternatively, impaired physiological condition of the plant associated with the disease might have affected the uptake from the soil and translocation of K in the plant.

Unlike Ca, the Mg content of the soil and plant showed remarkable differences with respect to the levels of disease in all the cultivars, a low Mg status being associated with disease affected plants and their corresponding soils. Since the soil Mg content around the diseased plants is also low, it has to be ascertained whether the low content of plant Mg is due to a lack of proper uptake by the plant or due to a poor Mg status of the soil.

With regard to the content of micronutrients Fe, Mn and Zn in the soils and plants at different levels of disease intensity, there was no significant difference. Probably, these nutrient elements were not directly correlated with the development of the disease.

Cation ratios

The $K/(Ca+Mg)$ as well as K/Mg ratios of the soils at the three different locations

indicated a decreasing trend with the onset of the disease and with increase in severity of the disease recorded a gradual rise (Fig. 4). This shift in the ratio of the elements may be either due to an increased utilisation of one element over the other or due to a shift in the concentration of one of the elements from the exchangeable to unavailable pool. A similar trend was shown by the different cultivars for these ratios in the plants also. Thus, it could be presumed that a shift in the cationic ratio might have favoured the onset of the disease or the development of the disease itself might have altered the cationic balance in the plants resulting in a shift in the ratio. In either case, the disease was found to be associated with an imbalance in the ratio of monovalent (K) to divalent (Ca+Mg) cation in the soil as well as plant.

Correlation between yield and nutrient factors

The highest correlation with yield was obtained for phosphorus both in the soil (0.666, 0.743 and 0.627 respectively for Vazhukka, Malabar and Mysore) and in the plant (0.988, 0.840 and 0.869 for Vazhukka, Malabar and Mysore respectively). This indicates that inspite of the comparatively low requirement of phosphorus, cardamom yield was highly influenced by the content of this element both in the soil as well as in the plant. Even though there was a direct correlation between yield and content of other nutrients, the relationship was only random and weak.

The results from the present study did not clearly identify any of the nutrient factors as a pre-disposing factor for the incidence of the disease. However, the disease was found to be associated with an imbalance in the ratio of potassium to calcium and magnesium in the soil as well as plant. This has to be ascertained by carefully laid out field experiments.

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EFFECT OF FERTILISER LEVELS ON VESICULAR ARBUSCULAR MYCORRHIZA COLONISATION IN CARDAMOM

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ABSTRACT

Roots of cardamom plants growing in experimental plots with three fertiliser levels were examined twice once before and once after the South-west monsoon. Samples revealed the presence of the following three spp. of VAM fungi: *Glomus macrocarpa*, *G. fasciculatum* and *Gigaspora coralloidea*. Percent colonisation in roots varied from 40-100 per cent in pre-monsoon samples and 63-94 per cent in post-monsoon samples. Infection grading varied from 4.5 to 76.0 in pre-monsoon and 30.0 to 77.0 in post monsoon samples. Results showed that increasing doses of fertiliser tended to decrease the intensity and incidence of the VAM population in soil and roots.

INTRODUCTION

The beneficial effects of vesicular arbuscular mycorrhizae (VAM) on crop growth is now well established (Ross and Harper, 1970; Kleinschmidt and Gerdemann, 1972 and Crush, 1974). Evidence is now accumulating that under certain conditions, mycorrhizal plants grow better than non-mycorrhizal plants. Apart from benefits like better survival in poorly fertilised soils, resistance to plant disease and tolerance to water stress, mycorrhizae act as auxilliary absorption systems for nutrients like phosphorus. Earlier reports indicate that variations in phosphorus levels and many other trace elements in media have shown variation in mycorrhizal infection and intensity (Mosse and Philips, 1971).

Maton), an important export earning plantation crop is cultivated mainly in the high altitude areas of Western Ghats. Mycorrhizal association in cardamom roots was reported for the first time by Bertus in 1942 from Sri Lanka. The presence of these organisms was found to stimulate production and benefit the health of plants whereas the plants gave low yields when grown in soils deficient of these organisms. The existence of VAM in cardamom in India has been reported recently by Manjunath and Bagyaraj (1982) from the soils of Karnataka. However, no report on the influence of fertility levels on incidence of VAM in this crop is available. The present studies are to fill in this lacunae and aim to show the effect of fertility on incidence and intensity of VAM in cardamom.

Cardamom (*Elettaria cardamom*

MATERIALS AND METHODS

Root samples of cardamom plants of variety Malabar (PV8) type were collected from three plots fertilised with different doses of fertilisers (F_1 :50:25:100, F_2 :100:50:200 and F_3 :150:75:300 kg N:P₂O₅:K₂O per hectare) from CPCRI Research Centre, Appangala, Coorg district in Karnataka. Spacing adopted was 2 × 2 m with total of 2,500 plants per hectare. The crop was planted in September, 1983 and samples were collected after 18 months and 24 months of growth.

Sampling was done from these plots twice: (1) during the month of May, 1985 (pre-monsoon) and (2) during the month of November, 1985 (post-monsoon). Samples were taken 25 cm away from the base of the clump and at a depth of 0-25

cm. One composite sample was obtained by pooling three samples around one plant. Three such plants were thus sampled to get three replicates from each treatment.

Processing of the root samples was done by clearing in 10% KOH solution and staining with trypan blue (Philips and Hayman, 1970). Root slide technique (Giovannetti and Mosse, 1980) was used for assessing the mycorrhizal infection and infection grading in the root. Twenty root segments each of one cm. length were examined for each replicate.

RESULTS AND DISCUSSION

Infection with vesicles and arbuscules characteristic of VAM fungi was observed in all samples. Fungi like *Glomus macrocarpus*, *G. fasciculatus* and



Fig. 1. Vericular arbuscular mycorrhizal infection in cardamom roots.

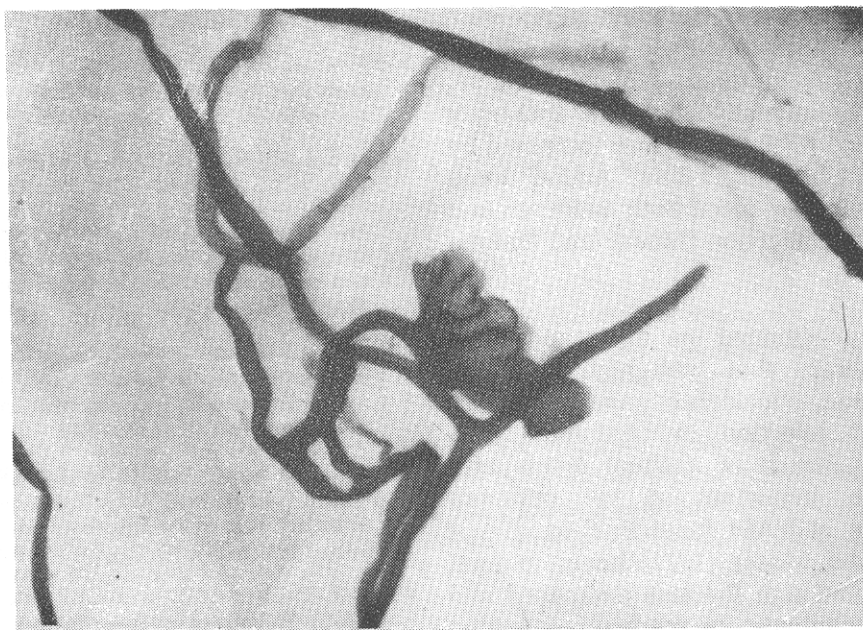


Fig. 2. A young coralloid vesicle.

Gigaspora coralloidea were identified (Figs. 1 and 2).

From Table I, a marked difference in the intensity of percent colonisation of VAM fungi was noticed in pre and post-monsoon samples. Increased infection grading after the rains indicate a spurt of activity of the fungus probably stimulated by enhanced root production and by a favourable climate for microbial growth. The results also indicate that colonisation of roots varied from 40-100 per cent in all the samples from the three treatments. A lower incidence and a lower infection grading was observed in samples collected from high fertiliser level. Root samples from plants grown at minimum fertiliser level showed maximum colonisation followed by plants grown at medium fertiliser level. In other field crops like chickpea, high phosphorus

Table I. *Effect of VAM association as influenced by fertiliser levels in cardamom.*

Dosage of fertilizer given	Pre-monsoon sampling		Post-monsoon sampling	
	Percent colonisa- tion in roots	Infection grading	Percent colonisa- tion in roots	Infection grading
F ₁	100	76.25	94	76.67
F ₂	70	17.25	82	57.67
F ₃	40	4.50	63	30.00

status showed only 10 to 20 per cent colonisation of roots by VAM endophytes and 60 to 80 per cent in roots from soils of low P in Haryana State (Jalali and Thareja, 1985). Similarly Khan (1972) reported that VAM infection in roots of maize decreased with increase of P in soil. *In vitro* studies on the growth of

Endogone in *Trifolium parvifolium* indicated that a low dose (100 mg P/litre medium) gave optimum growth of fungus. However, intensity and not incidence diminished till P levels were increased by addition of 30 mg P/litre. Added doses (260 mg/litre) reduced both incidence and intensity of infection (Mosse and Philips, 1971).

Results obtained in this experiment also indicate that with high levels of fertilisation, incidence and intensity of VAM infection in cardamom was lowered. Status of nutrient levels are, therefore, important to get optimum incidence of VAM fungi in field. Baylis (1967) and Mosse (1971) have, in fact, shown that high P levels decreased and finally eliminate mycorrhizal infection from soils. However, our results show that even at the highest dose of fertilizers administered, VAM colonisation is still found. I would therefore, be worthwhile to exploit such fungi to increase production because cardamom is usually grown on a commercial scale where fertilizer application is quite common.

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A STUDY OF THE RESPONSE IN YIELD AND GROWTH OF RUBBER GROWN IN ASSOCIATION WITH LEGUME AND NATURAL GROUND COVER DURING THE IMMATURE PHASE

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ABSTRACT

The results of two fertilizer experiments on rubber, one grown in association with legume cover and the other with natural cover during the immature phase are presented. The yield data for the first five years of tapping are presented and discussed.

In the legume cover area, the average effect of manuring was significant only during the first year of tapping (1980). There was response to application of 20 kg P_2O_5 /ha and 32 kg K_2O /ha during this period. During 1981 there was response to application of 6 kg MgO /ha in the absence of application of P. There was no response to the main effects during the subsequent years.

In the natural cover area the average effect of manuring was significant during the first two years of tapping i.e., 1980 and 1981. During 1980 (first year of tapping) N application gave response only upto the 40 kg/ha level. But in 1981, 1982 and 1983, N gave response upto 80 kg/ha level. Application of Mg at 6 kg/ha increased yield in 1983 and 1984.

A comparison of the mean yield per hectare per year in the two trial areas showed that the legume cover area gave higher yield during the first three years of tapping. In the subsequent two years a reverse trend was noticed. The cumulative yield obtained during the first three years of tapping in the legume cover area, more than justifies the cost of establishment and maintenance of legume ground cover.

INTRODUCTION

Judicious application of fertilizers has been found to increase and sustain the yield and enhance proper girdling and bark renewal of rubber trees. The mature and degree of response will depend to a large extent on the management practices followed in the estate. Establishment and

maintenance of legume ground covers has been recommended as a very useful agro-nomic practice, since long. Many planters take care to grow legume ground cover in their estate while a few others fail to adopt this practice due to one reason or other. In the latter case natural vegetation of a mixture of various species of

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dicots and monocots take the place of legume cover. Such natural covers are kept under control without assuming the proportion of weeds by periodic slashing during the early immature phase, and later on the heavy shade prevalent in rubber plantation keep the cover in minimal growth.

Studies conducted by the Rubber Research Institutes of India and Malaysia reveal that the fertilizer requirements of rubber grown with legume ground cover and natural ground cover vary considerably during the latter half of immaturity and during the early years of maturity. The higher growth rate of rubber noticed in legume cover areas could be achieved in natural cover areas only with the application of extra doses of nitrogenous fertilizers.

It was considered worthwhile to find out the fertilizer requirements of rubber, during the initial years of tapping, which was differentially grown during the immature phase under legume cover. For this purpose, two field experiments, one with legume cover and the other with natural cover maintained during the immature phase and manured with differential doses of N,P,K and Mg were continued through the mature phase. The observations in yield, soil and leaf nutrient status as influenced by the different fertilizer treatments are brought out and discussed.

MATERIALS AND METHODS

In 1971, two separate experiments were laid out in adjacent fields one with the leguminous ground cover *Pueraria phaseoloides* and the other where only the natural cover was allowed to grow

under controlled conditions. Both the areas were planted with green budded stumps of clone RRIM-600 in 1971. The experiments were located at Central Experiment Station, Chethackal, Ranni.

Both the trials were laid out in Randomised Block Design with split-plot experiment having four replications.

Treatments

Whole plot treatments: Two stages of receipt of regular manuring viz; S₁ and S₂, after which the differential treatments begin.

S₁: 10:10:4:1.5 NPK Mg for 3½ years and then the sub-plot treatments

S₂: 10:10:4:1.5 NPK Mg for 7 years and then the sub-plot treatments.

(Full annual dose of the above fertilizer mixture being 400 kg/ha)

Sub-plot treatments: Two levels each of N,P,K and Mg as follows.

Nutrients	Levels Kg/ha.	
	Legume cover	Natural cover
N ₁	20	40
N ₂	40	80
P ₀	0	0
P ₁	20	20
K ₁	16	16
K ₂	32	32
MgO	0	0
Mg ₁	6	6

(i.e. 2⁴ = 16 factorial combinations (confounded) plus 2 absolute unmanured control plots in each replication.

Plot size: Gross – 49 trees, Net: 25 trees.

Field upkeep: A good leguminous ground cover of *Pueraria phaseoloides* was maintained in the legume trail area till it started dying out from the 5th year onwards due to canopy closing of rubber trees. In the natural cover trial area all the naturally regenerated plants were allowed to grow. Their growth was kept under control by periodical slashing. This natural cover consisted mainly of *Chromolaena odorata*, *Lantana sp.*, *Borreria sp.* and *Panicum sp.* Other management practices were uniformly adopted during the immature and mature phases in both the trial areas. The trees were opened for tapping in 1979.

Recording of observations

Yield was recorded from each plot once every month by the method of cup coagulation. The annual mean yield per tree per tapping for each plot was worked out for the years 1980 to 1984, the year 1980 being considered as the first year of tapping. The data were statistically analysed.

Soil and leaf samples were collected during 1979 and 1983 and the nutrient contents were determined. The percentages of leaf nutrients and the contents of organic carbon and available P, K, Ca and Mg contents were determined and the means presented in Table I to IV.

RESULTS AND DISCUSSION

The results of statistical analysis of the

Table I. Mean Soil Fertility Status, 1979.

A. Natural Cover											
Organic carbon %			Av.P mg/100 g Soil			Av.K mg/100 g Soil			Av.Mg mg/100 g Soil		
No ferti- lizer	40 kg N/ha	80 kg N/ha	No ferti- lizer	No P ₂ O ₅	P ₂ O ₅ 20 kg/ha	No ferti- lizer	16 kg K ₂ O/ha	32 kg K ₂ O/ha	No ferti- lizer	No MgO	6kg MgO/ ha
2.61	2.69	2.62	0.64	1.05	1.28	8.50	7.71	8.28	17.48	10.02	10.19
Mean (Weighted)	2.6		Mean (Weighted)	0.64		Mean (Weighted)	8.50		Mean (Weighted)	10.92	
B. Legume Cover											
Organic carbon %			Av.P mg/100 g Soil			Av.K mg/100 g Soil			Av.Mg mg/100 g Soil		
No ferti- lizer	20 kg N/ha	40 kg N/ha	No ferti- lizer	No P ₂ O ₅	P ₂ O ₅ 20 kg/ha	No ferti- lizer	K ₂ O 16 kg/ kg/ha	K ₂ O 32 kg/ ha	No ferti- lizer	No MgO	MgO 6 ha
2.41	2.35	2.42	0.67	0.84	1.06	5.28	5.31	5.18	7.84	5.33	6.55
Mean (Weighted)	2.39		Mean (Weighted)	0.92		Mean (Weighted)	5.25		Mean (Weighted)	6.15	

Table II. *Mean Leaf Nutrient contents, 1979.**A. Natural Cover*

N%			P%			K%			Mg%		
No ferti- lizer	40 kg N/ha	80 kg N/ha	No ferti- lizer	No P ₂ O ₅	20 kg P ₂ O ₅ /ha ha	No ferti- lizer	16 kg K ₂ O/ha	32 kg K ₂ O/ha	No ferti- lizer	No MgO	6 kg MgO/ ha
3.66	3.75	3.72	0.22	0.23	0.25	1.06	1.08	1.22	0.46	0.46	0.47
Mean (Weighted)	3.73		Mean (Weighted)	0.24		Mean (Weighted)	1.14		Mean (Weighted)	0.46	

B. Legume Cover

N%			P%			K%			Mg%		
No ferti- lizer	20 kg N/ha	40 kg N/ha	No ferti- lizer	No P ₂ O ₅	20 kg P ₂ O ₅ /ha ha	No ferti- lizer	16 kg K ₂ O/ha	32 kg K ₂ O/ha	No ferti- lizer	No MgO	6 kg MgO/ ha
3.88	3.75	3.61	0.29	0.28	0.28	1.26	1.20	1.19	0.59	0.51	0.55
Mean (Weighted)	3.70		Mean (Weighted)	0.28		Mean (Weighted)	1.20		Mean (Weighted)	0.54	

Table III. *Mean Soil Fertility Status, 1983.**N. Natural Cover*

Organic carbon %			Av.P mg/100 g Soil			Av.K mg/100 g Soil			Av.Mg mg/100 g Soil		
No ferti- lizer	40 kg N/ha	80 kg N/ha	No ferti- lizer	No P ₂ O ₅	20 kg P ₂ O ₅ /ha ha	No ferti- lizer	16 kg K ₂ O/ha	32 kg K ₂ O/ha	No ferti- lizer	No MgO	6 kg ha
2.28	2.37	2.37	0.79	1.06	1.41	2.63	3.76	4.78	9.17	5.82	5.63
Mean (Weighted)	2.36		Mean (Weighted)	1.18		Mean (Weighted)	4.09		Mean (Weighted)	6.11	

B. Legume Cover

Organic carbon %			Av.P mg/100 g Soil			Av.K mg/100 g Soil			Av.Mg mg/100 g Soil		
No ferti- lizer	20 kg N/ha	40 kg N/ha	No ferti- lizer	No P ₂ O ₅	20 kg P ₂ O ₅ /ha ha	No ferti- lizer	16 kg K ₂ O/ha	32 kg K ₂ O/ha	No ferti- lizer	No MgO	MgO 6kg/ha
2.33	2.42	2.45	0.83	1.07	1.35	2.64	3.41	3.80	6.26	4.29	4.40
Mean (Weighted)	2.42		Mean (Weighted)	1.17		Mean (Weighted)	3.50		Mean (Weighted)	4.56	

Table IV. *Mean Leaf Nutrient contents, 1983.**A. Natural Cover*

N%			P%			K%			Mg%		
No ferti- lizer	40 kg N/ha	80 kg N/ha	No ferti- lizer	No P ₂ O ₅	20 kg P ₂ O ₅ /ha	No ferti- lizer	16 kg K ₂ O/ha	32 kg K ₂ O/ha	No ferti- lizer	No MgO	6 kg MgO/ ha
3.52	3.61	3.66	0.29	0.28	0.28	1.16	1.22	1.25	0.44	0.42	0.42
Mean (Weighted)	3.62		Mean (Weighted)	0.28		Mean (Weighted)	1.23		Mean (Weighted)	0.42	

B. Legume Cover

N%			P%			K%			Mg%		
No ferti- lizer	20 kg N/ha	40 kg N/ha	No ferti- lizer	No P ₂ O ₅	20 kg P ₂ O ₅ /ha	No ferti- lizer	16 kg K ₂ O/ha	32 kg K ₂ O/ha	No ferti- lizer	No MgO	6 kg MgO/ ha
3.60	3.48	3.52	0.27	0.27	0.78	1.26	1.20	1.23	0.36	0.45	0.46
Mean (Weighted)	3.51		Mean (Weighted)	0.27		Mean (Weighted)	1.22		Mean (Weighted)	0.44	

mean annual yield per tree per tapping of legume and natural cover areas from 1980 to 1984 are presented.

1980: Legume and Natural Cover

Table V indicates that the fertilizer applied plots recorded significantly higher yield compared to un-manured control plots in both the experiments. There was no significant increase in yield either in the legume cover or natural cover area by increasing the dose of nitrogen over 20 kg and 40 kg/ha respectively. Significant increase in yield was noticed by enhancing the doses of P and K in the case of legume cover. No such effect was noticed in the natural cover area. This may be due to the fact that large quantities of N released from dying legume require higher amounts of P and K to keep the

Table V. *Mean Yield per tree per tapping (g).*

Levels of Nutrients	Legume	Cover	Natural	Cover
	S ₁	S ₂	S ₁	S ₂
N ₁	26.0	26.0	23.0	26.1
N ₂	26.3	26.6	26.0	27.1
P ₀	25.5	25.7	24.9	26.4
P ₁	26.8	26.8	24.0	26.8
K ₁	25.2	25.7	24.9	25.6
K ₂	27.2	26.8	24.6	27.7
MgO	25.8	26.7	24.6	26.3
Mg ₁	26.6	25.9	29.4	26.9
Unmanured control	21.7		20.7	
Fertilized	26.2		25.5	
C.D. at 5%	1.68		3.5	
(for comparison between manured & unmanured)				
C.D. for comparison of levels of P and K 1.1				

Table VI. *Mean Yield/tree/tapping (g).*

	No MgO	6 Kg MgO/ha	Mean SE: 0.89 CD: ..
No P ₂ O ₅	39.52	45.70	42.61
20 kg			
P ₂ O ₅ /ha	44.77	43.93	44.35
Mean			
SE: 0.89	42.15	44.82	43.48
CD: 2.56			
For means in the body of the table			SE: 1.25 CD: 3.59

nutrient ratios at optimum levels in plants for higher yields. These results are in agreement with the earlier findings made by the Rubber Research Institutes of India and Malaysia.

1981: Legume Cover

Analysis of the yield data given in Table VI indicates a significant response for Mg and a PxMg interaction. The average effect of Mg showed a significant positive response. But a closer examination of the results shows that there is response to Mg only in the absence of P. When P is applied it also adds Ca to soil by way of Rock Phosphate. This Ca could have an antagonistic effect with Mg. This may be the reason why Mg had response only when P is not applied.

Table VII. *Mean Yield/tree/tapping (g).*

Control (Unmanured)	Manured	Mean
33.07	37.62	37.12
SE: 1.84	0.65	
CD: (5%)	3.96	

There was no difference between the manured and unmanured plots. This could be due to the beneficial effect of the legume ground cover as evidenced by the high nutrient status even in unmanured plots.

1981: Natural Cover

The average effect of manuring was significant as noticed from Table VII. The manured plots gave significantly higher yield compared to unmanured plots. This is because when legume ground cover is not maintained during the immature phase there is definite need for manuring to obtain proper yield.

Table VIII reveals that the effect of N was significant. Application of N at 80 kg/ha gave significantly higher yield compared to 40 kg/ha. In the absence of legume cover there was no enrichment of soil N and hence there was need for a higher level of applied N for optimum yield. Similar results were reported by the Rubber Research Institute of India, Malaysia and Sri Lanka.

1982: Legume Cover

Neither the average effect of manuring nor the simple effect of any of the nutrients was significant. However, the interaction SXMg was significant. It is seen from Table IX that in the absence of Mg application, the treatment application of

Table VIII. *Mean Yield/tree/tapping (g).*

40 kg N/ha	80 kg N/ha	Mean
35.85	39.39	SE : 0.92
		CD :
		(5%): 2.64

Table IX. *Mean Yield/tree/tapping (g).*

	S1	S2	Mean SE: 0.91 CD:
No MgO	39.69	47.63	43.66
6 kg/MgO/ha	43.01	43.73	43.37
Mean	41.35	45.68	43.51
For 'Mg' means in a given level of 'S'			SE: 1.28 CD: 3.67
For 'S' means in a given level of 'Mg' or at different levels of 'Mg'			SE: 1.70 CD: 4.88

NPK Mg mixture upto 7 years (S2) of planting gave higher yield compared to cessation of the same mixture at 3½ years (S1) of planting. This may be due to the favourable effect of Mg accumulated in the S2 treatment. But when Mg was applied there was no difference between S1 and S2. With S2, application of Mg significantly reduced yield whereas with S1 a favourable trend was noticed for applied Mg. The yield depression in S2 plots with Mg application may be due to the role of Mg in inducing early plugging of latex vessels.

1982: Natural Cover

The effect of N alone was significant. Nitrogen at 80 kg level significantly increased yield compared to the 40 kg level.

Table X. *Mean Yield/tree/tapping (g).*

	40 kg N/ha	80 kg N/ha	Mean SE: 1.03 CD: 2.96
	38.67	41.59	40.08

Table XI. *Mean Yield/tree/tapping (g).*

	40 kg N/ha	80 kg N/ha	Mean SE: 0.99 CD: 2.84
	45.16	49.25	47.22

1983: Legume Cover

None of the main effect nor any of the interactions was significant.

1983: Natural Cover

The effect of N was significant. Nitrogen at 80 kg/ha was superior to the 40 kg level in increasing the mean yield (Table XI).

The effect of Mg application also was significant. Table XII) indicates that Mg significantly increased the yield.

1984: Legume Cover

The interaction NP Mg alone was significant. It is seen from Table XIII that when 40 kg N is applied in presence of P and Mg there was significant yield drop compared to 20 kg N level. Similarly the higher level of N also depressed yield in the absence of P and Mg in comparison to the lower level of N in presence of P and Mg. This yield depression could be due to an imbalance of nutrients created by heavy application of N where the favourable effects of previous legume cover already existed.

Table XII. *Mean Yield/tree/tapping (g).*

	No MgO	6 kg MgO/ha	Mean SE: 0.99 CD: 2.84
	45.35	49.06	47.21

Table XIII. *Mean Yield/tree/tapping (g).*

	No MgO		6 kg MgO/ha		Mean SE: 1.18 20 kg
	No	20 kg	P ₂ O ₅ /	No	
	P ₂ O ₅	ha	CD: ...	P ₂ O ₅ /ha	
20 kg N/ha	50.81	50.44	51.00	56.88	52.28
40 kg N/ha	47.18	53.19	50.73	49.24	50.09
Mean					
SE: 1.66					
CD: -	49.00	51.81	50.86	53.06	51.18
For means in the body of the table					SE: 2.35 CD: 6.75

1984: Natural Cover

Table XIV reveals that application of Mg significantly increased the yield. The response to Mg application in the Natural Cover area may be due to a better balance of nutrients within the tree with the application of higher levels of nitrogen.

Comparison of Mean Yield in Legume and Natural Cover areas

Table XV indicates that during the first three years of tapping i.e. 1980, 1981 and 1982 the annual yield per hectare was higher in the legume cover area and a cumulative yield increase of 466 kg was obtained in three years time. But during 1983 and 1984 the Natural Cover area

Table XIV. *Mean Yield/tree/tapping (g).*

No MgO	6 kg MgO/ha	Mean SE: 1.39 CD: 3.99
49.89	55.87	52.88

Table XV. *Mean Yield of rubber in legume and natural cover trial areas (Kg/ha*).*

Year	Legumer Cover	Natural Cover	% Increase in Legume Cover Area
1980	1175	1145	2.62
1981	1948	1685	15.60
1982	1949	1796	8.52
1983	2010	2115	..
1984	2293	2369	..
Cumulative yield (1980 to 1982)	50.72	4626	9.64

*140 tapping days/year and 320 trees/ha.

registered higher yield compared to the Legume Cover area. These results indicate that the beneficial effects of legume ground cover will be visible upto the initial years of tapping. This is in agreement with the finding of the Rubber Research Institute of Malaysia. The increase in yield in 1983 and 1984 in the Natural Cover area might be due to the higher levels of N applied in the Natural Cover area and the diminishing effects of legume in the Legume Cover area.

The additional yield obtained in Legume Cover area for the first three years of tapping more than justifies the cost of establishment and maintenance of the legume cover.

CONCLUSIONS

Based on the results obtained in these experiments the following conclusions may be drawn.

1. While making fertilizer recommendations due consideration has to be given to the history of ground cover maintenance in the plantation.

2. In areas where legume cover is established the additional yield obtained during the initial years of tapping will more than justify the cost of establishment and maintenance of the legume cover.

3. When legume cover is not established there will be need for higher doses of N application during the initial years of tapping to obtain optimum yields.

4. In legume maintained areas there is scope for saving a lot of fertilizers during the initial years of tapping and hence discriminatory fertilizer application should be necessarily followed based on soil and leaf analysis.

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EFFECT OF SUPPLYING NUTRIENTS THROUGH ORGANIC MANURES, INORGANIC FERTILISERS AND THEIR COMBINATION ON ARECANUT CROP*

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ABSTRACT

The source of nutrients supplied did not influence plant growth or yield of the crop. The plots that did not receive organic manures from outside had organic carbon in soil around 0.7%. The level of nutrients supplied per palm per year (100g N, 40g P_2O_5 and 140g K_2O) can be considered adequate for the local cultivar of arecanut as indicated by the build up of P, K and organic carbon in the soil and almost uniform levels of available nitrogen in the soil around root zone.

INTRODUCTION

Arecanut (*Areca catechu* L.) is cultivated in acidic low to medium fertility soils. Under tropical cultivated conditions destruction of soil organic matter is rapid and replenishment is necessary. The organic manure is considered as essential in all intensively cultivated arecanut gardens of Northern Kerala and Coastal Karnataka; where high productive areca gardens are seen. No attempt had been made to study the effect of supplying nutrients solely through fertilisers as compared with the traditional method of applying only organic manures or combination of organic manure and inorganic fertilisers. This paper is the result of this investigation.

MATERIALS AND METHODS

The 'South Kanara' cultivar arecanut seedlings were used in the experiment.

To get maximum uniformity, seedlings raised from nuts of single bunch were used for planting one replication. The experiment consisted of six treatments and four replications. Each treatment, had 8 plants with common border. Square system of planting with spacing of 2.7m was adopted. Seedlings of $1\frac{1}{2}$ year having uniform morphological growth were used. Usual method of digging 1 cm cube pit filling it half and planting was adopted. Adequate drainage was provided during monsoon and irrigation in rainless summer months.

Treatments:

1. Application of organic manures
2. Application of inorganic fertilisers
3. Application of organic manures + inorganic fertilisers
4. Treatment No. 3 + cultivation
5. Treatment No. 1 + cultivation
6. Treatment No. 2 + cultivation

*Contribution No. 544, Central Plantation Crops Research Institute, Kasaragod 670 124, Kerala.

Cultivation means light forking with mammatty fork once in a year in October (after heavy s.w. monsoon). Per palm per year the following nutrients were supplied.

Nitrogen	100 g
P ₂ O ₅	40 g
K ₂ O	140 g

Source of nutrients

a) Fertilisers:

Calcium ammonium nitrate (CAN) to supply N

Super phosphate to supply P₂O₅

Muriate of potash to supply K₂O

b) Organic manures

Combination of green leaf and cattle manure to supply N

Bone meal to supply P₂O₅

Wood ash to supply K₂O

Time, method and rate of application:

The organic manures were applied in one single dose in October. When seedlings were young (up to three years from planting) manuring was done in pits. When the pits were filled basins, 1 m radius to a depth of 20 to 25 cm were opened manures/fertilisers were applied and covered with the soil. The fertilisers were applied in two equal split doses. One in October and the other in January-February. During the year of planting 1/3 the full dose, during the second year 2/3 the full dose and from the third year onwards full dose of nutrients was supplied.

During October, each year annual morphological data i.e. number of leaves, diameter at collar, total height, and number of nodes formed were recorded.

Table I. *Nutrient concentration in Arecanut leaves during different years. Mean values.*

Year	N%	P%	K%
1970	1.69	0.14	0.87
1971	1.80	0.15	0.74
1972	2.00	0.10	1.46
1973	1.94	0.19	1.36
1974	2.40	0.16	0.78
1975	1.88	0.17	0.79
1976	1.92	0.20	0.79
1977	2.15	0.18	0.76
1978	1.87	0.16	0.81
1979	1.97	0.16	0.91
1980	1.86	0.16	0.80

The soil and leaf samples were collected prior to manuring analysed by usual methods.

RESULTS AND DISCUSSION

From 1970 onwards (one year after planting) leaf samples were collected and analysed. During the experimental period (Table I) there were no significant difference between treatments.

The soil samples collected were also analysed every year. There was no significant difference between treatments during any of the years. The mean values for the different years are presented (Table II).

Morphological data recorded annually did not show any significant difference between treatments (Table III).

The first harvest of ripe arecanuts was got in 1973-74. From then ripe bunches were harvested as and when they became fully ripe. The annual yield (June 1 to May 31) was compiled and data

Table II. *Soil analysis data from arecanut basins during different years (Mean values).*

Year	Depth of sample		pH		Organic carbon %		Available N ppm%		Available P ₂ O ₅ ppm		Available K ₂ O ppm	
	0-50 cm	50-100 cm	0-50 cm	50-100 cm	0-50 cm	50-100 cm	0-50 cm	50-100 cm	0-50 cm	50-100 cm	0-50 cm	50-100 cm
1969	6.06	6.02	0.63	0.51	132.9	122.0	5.23	5.36	120.3	122.0		
1970	5.50	5.69	0.68	0.61	122.2	111.9	2.57	4.11	87.6	120.8		
1971	5.94	6.24	1.21	1.30	141.8	142.0	6.54	16.60	56.0	85.0		
1972	5.03	5.51	1.53	1.25	138.0	137.0	13.00	11.66	113.0	150.0		
1973	5.85	5.98	1.05	0.73	159.3	133.1	27.86	13.68	75.1	76.9		
1974	6.09	6.10	1.04	0.79	175.0	163.0	17.80	10.60	123.0	86.0		
1975	6.55	6.18	1.40	0.80	132.5	105.0	50.30	21.00	163.0	85.5		
1976	6.70	6.23	1.29	0.80	131.5	102.9	63.80	21.90	159.4	88.0		
1977	6.64	6.24	1.29	0.79	131.5	103.0	47.80	19.20	160.0	87.8		
1978	6.35	6.16	1.11	0.61	160.0	129.0	66.00	13.00	157.0	100.0		
1979	6.35	6.08	1.43	1.13	143.0	105.0	90.00	22.00	162.0	77.0		
1980	6.54	6.39	1.24	0.86	144.5	110.0	110.0	32.00	193.5	107.3		

examined. Yield differences between treatments were not significant between

Table III. *Morphological data of different years of arecanut palm (Mean values).*

Year	Number of leaves	Girth at collar (cm)	Total height (cm)	Number of nodes
1970	5.08	5.72	184.6	—
1971	6.47	26.64	243.7	3.37
1972	8.41	53.82	357.9	6.35
1973*	8.05	38.30	483.1	12.77
1974**	8.40	40.82	174.1	13.57
1975	9.23	40.46	263.3	16.66
1976	9.40	39.80	342.3	28.02
1977	9.50	40.80	422.0	35.04
1978	9.40	38.30	502.0	39.50
1979	9.80	38.00	622.0	51.50
1980	9.70	40.30	684.0	62.40

Note:

*From 1973 onwards girth at the last exposed node was recorded

**From 1974 onwards the height was measured from a permanent mark given at the base of stem up to the last exposed node

treatments during any of the year. The yield data of ripe arecanuts during different years is presented in Table IV.

The first harvest was taken in the fifth year after planting and minimum variability was obtained in the tenth year. This shows that the 'Vittal' arecanut palms reach yield stability from the tenth year.

Table IV. *The cumulative yield data of ripe arecanuts (Number of arecanuts).*

Year	Yield of ripe fruits (No.)	Number of trees yielded	Mean yield per tree (No. of fruits)	C.V. % for years
1974-75	4759	70	58	91.5
1975-76	18245	145	121.0	39.3
1976-77	52319	175	255.0	23.3
1977-78	35263	181	193.0	27.8
1978-79	34215	178	189.0	25.4
1979-80	62099	187	331.0	20.4
1980-81	52988	184	286.0	21.3

Table V. *Nutrient composition of weed growth and nutrient added per palm per year.*

Nutrient element	Nutrient composition %	Nutrient added per palm per year in 14 kg fresh weed
Nitrogen (N)	1.83	32 g
Phosphorus (P ₂ O ₅)	0.39	7 g
Potash (K ₂ O)	3.00	52 g

The plots receiving organic manures and plots receiving chemical fertilisers showing no significant difference in soil organic matter and soil pH can be explained. To avoid the accounting for the nutrients removed by weed growth we planned scything of weed growth as and when it grew and retained it in situ to decompose and get incorporated to the soil. Because of favoured condition of light and moisture inside the plot there was luxuriant weed growth which was cut and allowed to get incorporated to the plot. This is why there was no significant difference between soil organic carbon content of plots receiving organic manure and those that did not receive. For supplying nitrogen in chemical fertiliser

calcium ammonium nitrate was used which is a non acid forming fertiliser. The application of fertilisers did not bring down soil pH.

During the experimental period of 2 m² area between the palms inside experimental plot was cut and yield of fresh plant growth was weighed. On an average a 2 m² area gave 6.86 kg fresh weed growth. This works out to 17 tonnes per hectare. Assuming only half the area inside the areca garden is available for weed growth (The base of palms, irrigation and drainage channels left out). We have 8.5 tonnes of weed growth in one cutting from one hectare of pure areca garden. From June to October two loppings/cuttings could be got. Thus we have 17 tonnes which gives 14 Kilograms of green matter per palm. The mixed fresh weed growth had 12% dry matter and had the following nutrient content (Table V). Managing the weed growth and getting it incorporated will substantially supply nutrients required by areca palms, besides enriching soil with organic matter. There is no need to eradicate the weeds either by weedicide spray or by hand weeding. These weeds grow luxuri-

Table VI. *Nutrient content and quantity of nutrients added by non marketed produce in arecanut garden (per palm per year).*

Name of the bye-product	Mean dry wt. of biomass Per yr/palm	Nutrient tent%			Nutrient added per yr/palm in grams		
		N	P	K	N	P	K
Arecanut shed leaf	4.0 kg	1.59	0.16	1.01	63.6	6.4	40.4
Leaf sheath	1.7 kg	0.66	0.08	1.51	11.2	1.4	25.6
Arecanut husk	1.7 kg	1.00	0.12	2.40	17.0	2.0	40.0
Arecanut bunch	0.3 kg	1.04	0.07	1.10	3.1	0.2	3.63
Total nutrients added					94.9	10.0	109.63

antly with the rains and cover the soil thus almost completely checking soil erosion.

In any sound crop management and soil fertility, recycling is very important. This implies that we return to the soil as much as possible from the crop harvested. In arecanut cultivation, shed leaves, arecanut husk, arecanut bunches (inflore-

scence after separating ripe arecanuts) are non marketed produce. The nutrient content of these were estimated and the same is given in Table 6.

It is clearly brought out that by incorporating weed growth of areca garden and non marketed produce obtained from the crop, major portion of plant nutrients required by the crop can be met.

GROWTH AND YIELD OF OIL PALM (*Elaeis Quineensis* Jacq) IN RELATION TO LEAF NUTRIENT CONCENTRATION

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ABSTRACT

A study on the relationship between foliar N, P, K, Ca, Mg and Cl with yield and yield attributes was undertaken in oil palm at the Oil Palm Project, Bharatheepuram, Kerala with 3 levels each of N, P and K and 2 levels each of Ca and Mg fitted in a $3^3 \times 2^2$ split plot design. The investigations revealed a general relationship of yield and yield attributes with foliar N, P, K and Cl. The investigations highlighted the relationship of foliar N with P, K, Ca, Mg. The potassium concentration was intimately connected with N, P and Cl. It was observed that there was a two way antagonism between K and Ca + Mg. Similarly, an antagonism of Cl with K was also observed. The role of chlorine in the nutrition of oil palm was also brought out in the present study. A strong relationship was established between anionic concentration with morphological characters. The results signify the importance of cationic concentration for better growth expression and yield in oil palms. A negative interaction of K and Na was also observed possibly caused by K/Na antagonism.

INTRODUCTION

In perennial crops, where responses to fertilizers will take a longer time, foliar analysis can be safely used as an aid for interpretation of agronomic experiments (Hartley, 1977). Foliar analysis can be considered as a tool to understand the pattern of uptake of the plant nutrients and their effect on plant growth and yield. The correlation between foliar nutrient concentrations and their relationship with various growth parameters can be taken as an index of obtainable yield. Keeping in view of the available informations in this regard, an attempt has been made to test its validity in oil palm. Here, an attempt has been made to single out the possible effect of individual applied nutrients on yield, yield attributes, nutrient contents in foliar tissues

individually and in combination. Chapman and Gray (1949), Broeshart (1957), Prevot and Ollagnier (1959); Ollagnier, Ochs and Martin (1970), Tan (1973), Warriar and Piggot (1973), Nair (1981) and Nair and Sreedharan (1983) studied the leaf nutrient concentration in oil palm under various agroclimatic conditions in various parts of the world. The estimation of leaf nutrient concentration can be used for prediction of fertilizer requirements since plants show a 'balancing' phenomenon among various nutrients (Ollagnier et al, 1970). Information of this sort will also be useful for assessing the nutrient balance in palms for effecting remedial measures. But such results are not available under the Indian conditions. Hence, the present investigation was undertaken to understand the

growth and yield of oil palm as influenced by foliar nutrient concentration.

MATERIALS AND METHODS

The investigation was carried out in the plantations of the Oil Palm India Ltd., at Bharathipuram, Quilon District of Kerala State, the palms planted in 1972 (C.V. Tenera) and the fertilizer treatments were super imposed from 1975 onwards. The nutrients tried were three levels each of nitrogen (400, 800 and 1200 g N) as urea; phosphorus (200, 400 and 600 g P_2O_5) as rock phosphate; potassium (600, 1200 and 1800 g K_2O) as muriate of potash and two levels each of Calcium and Magnesium (Zero and 500 g) as Calcium oxide and Magnesium sulphate respectively. The design of the experiment was $3^3 \times 2^2$ confounded split plot. Each main plot consisted of 20 palms and sub plot five palms each; laid out in three blocks of nine major treatments plus one treatment of absolute control.

Calcium and magnesium were applied in March - April. Nitrogen, Phosphorus and Potassium fertilizers were applied in two equal splits during May and October respectively. Biometric observations on rate of leaf production, number of functional leaves, inflorescence production, sex ratio and bunch failure were recorded for 1979 and 1980. Yield record of individual palms was also maintained.

Leaf samples from the 17th leaf of all the palms in a treatment were collected for two years during September 1978 and 1979. The sampling procedure adopted were that described by Poon (1969). Six leaf let from each side of the middle portion of the rachis were taken and

thoroughly cleaned. The mid rib and marginal 2 mm of the laminae were removed. Middle portion of the laminae consisting of 20 - 30 cm was taken and dried at 65°C - 75°C for about 5 hr in a hot air oven and used for estimation of various elements.

Foliar analysis for N, P, K, Ca, Mg, S and Na was carried out from each treatment for September 1978 and 1979 as per the methods given by Jackson (1967).

Correlation coefficients were worked out between leaf nutrient contents with yield and yield attributes (Snedecor and Cochran, 1967).

RESULTS AND DISCUSSION

It is seen from Tables I and II that nitrogen application significantly increased foliar N, P, K, Ca and Mg concentrations. But there was a significant reduction in the foliar chlorine level with increased nitrogen levels. The increase in foliar P by N fertilization is attributed to the general relationship of N and P since both being constituents of plant proteins (Ollagnier et al 1970). The significant reduction in chlorine concentration may be due to the antagonistic effect of N on chlorine (Anonymous, 1974) and the increase in K, Ca and Mg levels in leaf tissues shows the synergistic effect of N.

An antatognism between K and Ca + Mg is noticed, while considering the effect of fertilizers on the cationic elements. An increase in foliar K concentration was resulted consequent to K fertilization (Table I and II). According to Prevot and Ollagnier (1954) the sum of K + Ca + Mg concentration in leaf always

Table I. *Effect of fertilizers on foliar nutrient concentration (%)*.

(September 1978)

	N	P	K	Ca	Mg	Cl
N1	2.314	0.134	0.798	0.639	0.269	0.444
N2	2.415	0.141	0.813	0.746	0.317	0.437
N3	2.586	0.143	0.836	0.742	0.364	0.422
CD	0.223*	0.005*	NS	NS	NS	0.018*
P1	2.339	0.135	0.854	0.662	0.289	0.429
P2	2.500	0.140	0.827	0.710	0.305	0.445
P3	2.476	0.143	0.767	0.756	0.357	0.429
CD	NS	0.005*	NS	NS	NS	NS
K1	2.401	0.137	0.780	0.724	0.369	0.387
K2	2.427	0.142	0.825	0.707	0.299	0.428
K3	2.488	0.139	0.843	0.696	0.289	0.489
CD	NS	NS	NS	NS	NS	0.018*
Ca0	2.459	0.139	0.606	0.701	0.289	0.432
Ca1	2.418	0.139	0.826	0.707	0.345	0.436
CD	NS	NS	NS	NS	0.029*	NS
MgO	2.453	0.140	0.854	0.686	0.282	0.432
Mg1	2.424	0.139	0.774	0.773	0.312	0.436
CD	NS	NS	0.053*	0.068*	0.029*	NS
General mean	2.438	0.139	0.816	0.709	0.312	0.434
Absolute control	1.638	0.129	0.478	0.607	0.212	0.190
Treatment Vs. Absolute control	Sig**	NS	Sig**	NS	NS	Sig**

NS - Not Significant.

* - Significant at 5 per cent level.

** - Significant at 1 percent level

remain at 2%, irrespective of the balance between them. In the present study also, the sum of K + Ca + Mg remains around 2%. Within this level, two way antagonism between the foliar concentration of K and Ca + Mg occurs due to fertilization. It is to be mentioned here that the accepted critical levels of foliar K, Ca and Mg are 1.00, 0.60 and 0.24% respectively in leaf 17 (Ollagnier et al, 1970).

The application of K (as muriate of potash) did not increase the foliar concentration of K. This is due to the antagonism of K $\times$ Ca expressed in the presence of chlorine. According to Ollagnier (1973) the chlorine of KCl decreased the leaf K concentration. Lack of significant increase in foliar K in the present investigation is expected to be due to the antagonism of chlorine on the

Table II. *Effect of fertilizers on foliar nutrient concentration (%)*.

(September 1979)

	N	P	K	Ca	Mg	Cl
N1	2.363	0.138	0.896	0.717	0.298	0.420
N2	2.612	0.139	0.903	0.724	0.304	0.419
N3	2.686	0.145	0.911	0.695	0.323	0.404
CD	0.130**	0.005**	NS	NS	NS	0.015*
P1	2.515	0.136	0.927	0.688	0.297	0.397
P2	2.593	0.141	0.903	0.702	0.307	0.427
P3	2.552	0.144	0.879	0.746	0.320	0.420
CD	NS	0.005*	NS	NS	NS	0.015*
K1	2.546	0.138	0.859	0.717	0.311	0.362
K2	2.564	0.143	0.906	0.717	0.307	0.407
K3	2.551	0.141	0.944	0.706	0.307	0.475
CD	NS	NS	NS	NS	NS	0.015**
CaO	2.527	0.140	0.892	0.695	0.289	0.416
Ca1	2.580	0.141	0.914	0.729	0.328	0.413
CD	NS	NS	NS	0.024**	0.038**	NS
MgO	2.529	0.141	0.911	0.712	0.309	0.412
Mg1	2.579	0.410	0.896	0.712	0.308	0.418
CD	NS	NS	NS	NS	NS	NS
General mean	2.559	0.140	0.903	0.712	0.308	0.415
Absolute control	1.554	0.125	0.627	0.508	0.239	0.197
Treatment Vs. Absolute control	Sig**	Sig**	Sig**	Sig**	NS	Sig**

NS - Not Significant.

* - Significant at 5 per cent level.

** - Significant at one per cent level.

uptake of K. The higher leaf Ca and Mg concentration above the suggested critical levels also substantiates this phenomenon.

CORRELATION STUDIES

The correlation coefficients between foliar nutrients with yield attributes and yield and inter correlation between foliar nutrients are presented in Table III and IV.

Table III reveals that, foliar N is directly correlated with rate of leaf production, number of functional leaves and the weight of fresh fruit bunches (FFB). Foliar N was not found to be correlated with female inflorescence and bunch failure. An increased rate of leaf production and number of functional leaves in oil palm by increased N application is reported by Tan (1973). The application of N also

Table III. *Correlation of yield and yield attributes with foliar nutrient concentration.*

Leaf nutrients	Rate of leaf production	Number of functional leaves	Number of female inflorescences	Bunch failure	Number of bunches	Weight of FFB
N	0.323***	0.396***	0.169	0.1052	0.1740	0.477***
P	0.033	0.226*	0.257**	0.0310	0.205*	0.356***
K	0.134	0.335***	0.158	0.201*	0.231*	0.338***
Ca	0.093	0.117	0.240*	0.036	0.153	0.238*
Mg	0.048	0.24	0.058	0.001	0.037	0.040
Cl	0.192*	0.370***	0.256*	0.129	0.251**	0.471***
N + P	0.412***	0.437***	0.321**	NS	0.461***	0.482***
N + P + Cl	0.465***	0.444***	0.358***	NS	0.510***	0.527***
N + P + Cl + S	0.368***	0.341***	0.287**	NS	0.354***	0.354***
Ca + Mg	0.106	0.079	0.157	NS	0.100	0.231*
Ca + Mg + K	0.185*	0.314**	0.243*	NS	0.252**	0.437***
Ca + Mg + K + Na	0.192*	0.342***	0.321**	NS	0.349***	0.436***

Ns: Not significant

*: Significant at 5 per cent level.

**: Significant at 1 per cent level.

***: Significant at 0.1 per cent level.

Table IV. *Inter correlation between foliar nutrient concentration.*

Nutrients	N	P	K	Ca	Mg	Cl
N	-					
P	0.405***	-				
K	0.494***	0.570***	-			
Ca	0.476***	0.396***	0.145	-		
Mg	0.266***	0.361***	0.141	0.024	-	
Cl	0.473***	0.350***	0.465***	0.392***	0.192*	-
N + P	0.999***	0.430***	0.344***	0.321**	0.148	0.478***
Ca + Mg	0.516***	0.509***	0.131	0.821***	0.650***	0.526***
N + P + Cl	0.978***	0.454***	0.406***	0.369***	0.162	0.644***
Ca + Mg + K	0.672***	0.715***	0.724***	0.621***	0.532***	0.716***
N + P + Cl + S	0.670***	0.311**	0.202*	0.225*	0.161	0.405***
Ca + Mg + K + Na	0.371***	0.375***	0.606***	0.453***	0.340***	0.626***

*: Significant at 5 per cent level.

**: Significant at 1 per cent level

***: Significant at 0.1 per cent level.

increased the foliar P and K concentration. (Table IV).

Foliar P concentration was correlated with number of functional leaves, female inflorescence, number of bunches and

weight of FFB. The increase in the vegetative growth of palms by P application can be attributed to the indirect influence of P on foliar N concentration. The foliar P concentration was positively correlated with all other nutrients. Phosphorus

nutrition thus enabled the palms to absorb large quantities of other nutrient which influenced the yield. A positive effect of P on growth characters of coconut was reported by Manicot *et al* (1979).

Foliar K concentration was seen correlated with number of functional leaves, number of bunches and weight of FFB (Table III). No correlation was noticed between leaf production and number of female inflorescence. This can be attributed to the indirect effect of K on the uptake of N and P (Table IV). Tan (1973) observed favourable effect of K fertilization on growth of palms.

The foliar Cl concentration was correlated with all characters except bunch failure. Among the characters studied foliar chlorine was correlated ($r = 0.471^{***}$) to the maximum extent with FFB. The importance of chlorine nutrition on the growth and yield of oil palm is already brought out by Ollagnier and Ochs (1971). Ollagnier (1973) showed that foliar Cl was most often in positive correlation with cations (six times with K, four times with Ca and once with Mg). Therefore, he suggested that chlorine played an important role in the metabolic functions of oil palms. Ollagnier and Ochs (1971) further reported that higher yields obtained by K Cl application was due to chlorine and not due to potassium. The present investigation also revealed the same results which showed that the 'r' values of coefficient of correlation between foliar chlorine levels and morphological characters and yields are higher than K with the respective characters.

elements to a certain extent in the cell foliar anionic elements, approve the consensus that an increase of the above sap favourably influenced the crop to a certain extent. However, when sulphur is also considered in addition to chlorine, there is a marked decline in the 'r' value (0.354^{***}) which indicates that anionic concentration more than a certain level, may not be desirable for plant growth.

The correlation studies between the leaf cations (individually and in combination) with morphological characters, yield attributes and yield (Table III) have brought out some interesting results. The foliar Ca was observed to be significantly correlated with number of female inflorescence ($r = 0.240^*$) and yield ($r = 0.238^*$) whereas combined effect of Ca + Mg with yield was only $r = 0.231^*$. Foliar Mg gave no relationship to any of the characters. The combination of Ca + Mg gave the same results. The 'r' value for foliar Ca + Mg + K and yield observed (0.437^{***}) was considerably higher than that of Ca + Mg and foliar 'K' alone. With regard to growth characters, foliar K + Ca + Mg + Na gave a much higher 'r' value than K + Ca + Mg. These results signify the importance of cationic concentration for better growth expression and yield in palms. Broeshast (1956) Grunder (1960), Bachy (1963), Ollagnier *et al* (1970), Nair and Sreedharan (1981) and Nair and Sreedharan (1983) reported similar results. It is only the yield which is not influenced by foliar Ca + Mg + K + Na, and can be explained on the basis of K - Na relationship. Even though, the exact possibility of substituting Na for K has not yet been worked out in oil palms, it can be presumed that the K has been able

Further the 'r' values exhibited by the

to express better in presence of Na and as K is involved in fat metabolism this has expressed in terms of yield.

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EFFECT OF DEFOLIATION ON THE PRODUCTIVITY OF COCONUT PALM (*COCOS NUCIFERAL.*) CV. W.C.T.

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ABSTRACT

An experiment was conducted during the period 1977-'81 at the Regional Agricultural Research Station, Pilicode on 55 years old coconut palm cv W.C.T to find out the effect of removal of older functioning leaves on the productivity of the palm and to evaluate the economic feasibility of defoliation. One to three oldest leaves were cut at the base of the petiole on successive or alternate months from January to May. Defoliation involved removal of leaves ranging in numbers from 0,3,5,6,9 to 10 in different treatments. Such moderate to heavy degree of defoliation restricted during summer months of January to May did not significantly affect the total number of functioning leaves per palm which shows the inherent ability of coconut palm to cope up with defoliation treatments. Defoliation treatments did not have any deliterious effect on the coconut palm as reflected by female flower production, setting percentage and nut yield. Cutting two leaves every month from January to May fetched the maximum net profit of Rs.1109 per year. Based on the study, removal of two oldest functioning leaves of coconut palm every month from January to May may be safely recommended as a source of additional income for the farmer without any significant reduction in nut yield.

INTRODUCTION

On an adult coconut palm there are about 30 to 40 functioning leaves (Menon and Pandalai, 1960). Starting from the base of the crown, there are 10 to 12 leaves from the axils of which bunches have already been harvested during the previous 12 months (Patel, 1938). The majority of these leaves are of little value to the tree having past their prime (Sampson, 1923).

During summer months, the older leaves get dried up faster and are shed which in most cases are damaged result-

ing in reduced economic value. If water scarcity is felt, the leaves break at the point of petiole and hang on to the tree. In southern parts of Kerala, there is actually a practice of cutting coconut leaves during summer. Aldaba (1931) reported that the removal of seven to sixteen leaves from a palm does not alter the rate of production of leaves. However, drastic pruning of leaves is definitely harmful to the trees (Nambiar, 1956; Krishna Marar and Padmanabhan, 1970). In a study simulating the damage caused by leaf eating insects, Bailey *et al* (1977) found that after nine months' defo-

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Table I. *The total number of functioning leaves of coconut palm (Cocos nucifera L.) cv W.C.T. as influenced by defoliation treatments.*

Treatments	Year						Mean
	1976	1977	1978	1979	1980	1981	
Control	24.05	21.95	23.30	20.90	21.05	19.79	21.84
One leaf every month	31.70	25.11	23.95	22.10	21.58	19.65	24.02
One leaf alternate month	24.60	24.40	22.85	21.45	22.50	19.95	22.63
Two leaves every month	24.10	24.84	22.21	22.00	21.31	20.77	22.54
Two leaves alternate month	24.05	25.50	23.80	22.30	22.63	21.32	23.27
Three leaves alternate months	24.70	24.95	22.95	21.37	22.74	21.05	22.96
F	0.31	3.46**	0.73	0.34	1.28	1.07	1.74
SEm $\pm$							0.5585
CD (0.05)	NS	NS	NS	NS	NS	NS	NS

Table II. *The female flower production of coconut palm (Cocos nucifera L.) cv W.C.T. as influenced by defoliation treatments.*

Treatments	Year					Mean
	1977	1978	1979	1980	1981	
Control	141.95	165.85	108.75	123.47	132.26	134.46
One leaf every month	160.50	183.75	130.40	113.80	140.10	145.71
One leaf alternate month	141.85	168.85	115.45	121.20	142.05	137.88
Two leaves every month	169.35	149.47	112.82	122.50	152.44	141.32
Two leaves alternate month	166.55	169.45	125.05	134.79	163.16	151.80
Three leaves alternate months	153.20	158.88	127.11	118.68	124.00	136.37
F	0.77	0.81	0.50	0.35	1.03	2.22
SEm $\pm$						4.3774
CD (0.05)	NS	NS	NS	NS	NS	NS

liation, yields declined as the degree of defoliation increased.

The present study was undertaken to find out the effect of removal of older functioning leaves on the productivity of coconut palm and to know the economic feasibility of defoliation.

MATERIALS AND METHODS

The experiment was conducted during the period 1977-'81 55 year old coconut

palms cv W.C.T. in the F Block of Regional Agricultural Research Station, Pilicode, with the following six treatments (Table I-V). One or two oldest functioning leaves were cut every month from January to May involving five cuttings of leaf in each treatment every year. In another set of treatments one, two or three oldest functioning leaves were cut every alternate month from January to May. Here in each treatment, there were three cuttings of leaf every year. Leaves

Table III. *The setting percentage (transformed values) of Coconut palm (Cocos nucifera L.) cv W.C.T. as influenced by defoliation treatments.*

Treatments	Year				Mean	
	1977	1978	1979	1980	1981	
Control	39.72	35.93	33.98	37.25	34.60	36.30
One leaf every month	37.13	35.14	35.29	35.00	34.42	35.40
One leaf alternate month	38.32	37.36	34.91	35.16	36.91	36.53
Two leaves every month	37.77	36.09	35.94	35.06	35.15	36.00
Two leaves alternate month	36.81	37.01	35.34	36.07	34.79	36.00
Three leaves alternate months	38.98	37.76	33.68	36.48	33.46	36.07
F	0.68	0.61	0.34	0.54	0.66	0.66
SEm $\pm$						0.4684
CD (0.05)	NS	NS	NS	NS	NS	NS

Table IV. *The nut yield of coconut palm (Cocos nucifera L.) cv W.C.T. as influenced by defoliation treatments.*

Treatments	Year						Mean
	1973-76	1977	1978	1979	1980	1981	
Control	54.23	56.75	58.15	36.80	45.47	46.26	49.61
One leaf every month	53.60	60.90	63.10	42.80	39.20	49.70	51.55
One leaf alternate month	52.30	55.60	62.80	38.50	41.95	52.55	50.63
Two leaves every month	58.45	65.95	52.90	40.88	41.69	54.50	52.40
Two leaves alternate month	54.08	62.50	62.05	42.15	46.68	55.90	53.89
Three leaves alternate months	52.29	60.35	65.53	40.22	43.42	40.15	50.33
F	0.24	0.31	0.53	0.17	0.28	0.67	1.00
SEm $\pm$							1.5516
CD (0.05)	NS	NS	NS	NS	NS	NS	NS

were cut from the base of the petiole. Besides these five treatments, there was one absolute control where no defoliation treatment was imposed.

Each treatment was allotted randomly on single tree plot basis to twenty palms based on the pre-treatment yield data collected for four years from 1973 to 1976. The experiment was continued upto 1981. Some of the trees in some treatments died during the experimental period.

Therefore, the years were treated as replications for the pooled analysis and the data are presented. Data on the total number of functioning leaves, female flower production, setting percentage and nut yield were collected and statistically analysed. Besides, economics of defoliation in coconut palm was also calculated.

RESULTS AND DISCUSSION

The data on the total number of functioning leaves presented in Table I

Table V. *Economics of defoliation treatments.*

Treatment	Leaves removed (per ha.)	Price of leaves (@ 50 Ps.)	Price of petiole (@ 10 Ps.)	Total price	Cost of removal Rs.	Net profit
Control (No defoliation)	0	0	0	0	0	0
One leaf every month (Jan. to May)	1000.00	500.00	100.00	600.00	41.29	556.71
One leaf alternate month (Jan.-March-May)	600.00	300.00	60.00	360.00	24.77	335.23
Two leaves every month (Jan. to May)	2000.00	1000.00	200.00	1200.00	90.83	1109.17
Two leaves alternate month (Jan.-March-May)	1200.00	600.00	120.00	720.00	54.50	665.50
Three leaves alternate month (Jan-March-May)	1800.00	900.00	120.00	1080.00	90.83	989.17

No. of palms climbed by one person for coconut harvest and defoliation in T1, T2, Te, Tr, T5 and T6 and 60, 55, 55, 50, 50 and 45 respectively.

Wage rate: Rs. 27.25.

show that defoliation treatments have not significantly affected the total number of functioning leaves except in the year 1977. The significant difference found in the total number of functioning leaves in 1977 may be due to factors other than defoliation treatments since the treatments were imposed on the trees from January 1977 and it is too early for the trees to exhibit any pronounced influence on the total number of functioning leaves by the end of December 1977. In fact, studies conducted by Patel (1938) have shown that the time interval required from the primordial initiation stage to the appearance of the fully opened leaf on the crown is thirty months. The defoliation treatments involved the removal of three to ten leaves from each tree in every year. Such a moderate to heavy degree of leaf removal restricted during the summer months of January to May did not significantly affect the total number of functioning leaves per palm. This shows that coconut palm has inherent ability to cope

up with defoliation treatments involving removal of oldest green leaves upto ten during the summer months. This is possibly by increasing leaf production rates. According to Aldaba (1931), rate of leaf production was not altered due to removal of seven to sixteen leaves from a palm. Bailey *et al* (1977) found that the number of new fronds per palm was reduced due to 70 per cent defoliation maintained for twelve months but was little affected by the less severe treatments.

The data on female flower production, setting percentage and nut yield of coconut palm as influenced by defoliation treatments are presented in Tables II-IV. None of the yield attributes were significantly influenced by the defoliation treatments. This shows that defoliation treatments did not have any deleterious effect on the coconut palm as reflected by nut yield, female flower production and setting percentage. In a study conducted for

five years by Krishna Marar and Padmanabhan (1970), removal of all the leaves from the axils of which coconut bunches have been harvested did not have any adverse effect on nut yields. Similar results have been obtained by Mendoza *et al* (1972). However, Bailey *et al* (1977) observed adverse effect on nut yield due to 50 to 70 per cent defoliation.

The economics of defoliation is worked out and is presented in Table V. A tree population of 200 per ha. is assumed. The treatment No. 4 viz., cutting two leaves every month from January to May was found to fetch the maximum net profit of Rs.1109 per year, whereas the treatment No. 3 which involved removal of one leaf in the alternate months from January to May resulted in the lowest net profit of Rs.335. The cost of defoliation varied from Rs.24 per ha due to the removal of one leaf during the alternate months from January to May to a maximum of Rs.90 per ha due to the removal of two leaves every months from January to May.

SUMMARY

Based on the above study, removal of two oldest functional leaves of coconut palm every month from January to May may be safely recommended as a source of additional income for the farmer without any significant reduction in nut yield.

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FORECASTING OF YIELD IN COCONUT BY USING WEATHER VARIABLES

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ABSTRACT

Influence of monthly averages of 11 weather variables viz. max. and min. temperature, vapour pressure (FN & AN) rel. humidity (FN & AN), wind velocity, hours of sunshine, rainfall, evaporation and number of rainy days up to 36 months prior to harvest of nuts was studied for two sets of data at Kasaragod. Based on regression analysis rel. humidity (FN), hrs. of sunshine and vapour pressure (FN) of 17-20 meteorological weeks of the previous year, temperature (Min) of 21-24 weeks, humidity (FN) of 25-28 weeks two years previous and temperature (Min.) of 29-32 weeks three years previous were identified as important for prediction of coconut yield. The prediction model using these variables could explain 91% of the variation in yield.

INTRODUCTION

Forecasting the yield of any crop in advance is important. It is all the more important in coconut, because of the violent fluctuation in production and consequent price rise or fall the country has been experiencing recently. Systematic study to forecast the yield in coconut was first done by Abeywardena (1968) in which he considered 12 rainfall variables during the different periods of the development of coconut. Recently Nair BP (1986) came out with two models to forecast the yield based on the monthly weather variables of one year earlier.

In coconut, the reproductive cycle is very long as each bunch has to go through a long cycle of nearly $3\frac{1}{2}$ years of development from primordial stages upto maturity during which period it has to

face the various weather parameters and their interactions. Hence, studying the effects of weather parameters on yield at least till 3 years prior to the harvest of nuts is important. In the present study such an attempt was made and the variables identified at different stages were made use of for forecasting the yield.

MATERIALS AND METHODS

Meteorological observations collected from the observatory of Central Plantation Crops Research Institute, Kasaragod for the period 1953-79 along with average yield of two plots of the farm, (viz. RS 29: 252 palms and RS 28: 105 palms) for the period 1955-1982 was made use of for the study. The first plot consisted of palms of about 40-45 years and in the second plot palms were of 30-35 years age group at the beginning of the period. The palms

Table I. *Correlation coefficients between weather variables and Yield.*

	Weather variables		Correlation with yield in year		
			i + 1	i + 2	i + 3
Rainfall (TRF)	5-8 weeks	1			
		2			
		3			
	13-16 weeks	1	0.752		
		2	0.628		
		3	0.740		
	17-20 weeks	1		-0.340	
		2		-0.457	
		3		-0.364	
	41-44 weeks	1	-0.454		
		2	-0.549		
		3	-0.550		
Rainy days (TRD)	13-16 weeks	1	0.633		
		2	0.454		
		3	0.400		
	21-24 weeks	1		-0.354	
		2		-0.347	
		3		-0.247	
	25-28 weeks	1	-0.448		
		2	-0.435		
		3	-0.430		
	45-48 weeks	1			-0.368
		2			-0.379
		3			-0.370
Temperature(min) (Tmin)	5-8 weeks	1			-0.456
		2			-0.511
		3			0.476
	21-24 weeks	1		0.499	
		2		0.412	
		3		0.470	
	29-32 weeks	1			-0.339
		2			-0.387
		3			-0.226
	33-36 weeks	1			-0.353
		2			-0.398
		3			-0.366
Hours of sunshine (HRS)	5-8 weeks	1		0.353	
		2		0.385	
		3		0.377	
	17-20 weeks	1	0.475		
		2	0.437		
		3	0.490		
	41-44 weeks	1	0.431		
		2	0.419		
		3	0.440		
	49-52 weeks	1	-0.537		
		2	-0.479		
		3	-0.540		

Rel. Humidity (FN)(HFN)	13-16 weeks	2	0.442		0.443
		2	0.579		0.524
		3	0.500		0.472
	17-20 weeks	1	0.370	-0.631	
		2	0.516	-0.524	
		3	0.390	-0.608	
	25-28 weeks	1		-0.366	
		2		-0.503	
		3		-0.433	
Rel. Humidity (AN)(HAN)	25-28 weeks	1		-0.473	0.429
		2		-0.482	0.333
		3		-0.535	0.418
	29-32 weeks	1	-0.406		
		2	-0.396		
		3	-0.420		
	37-40 weeks	1			-0.341
		2			-0.453
		3			-0.498
	41-44 weeks	1	-0.422		
		2	-0.441		
		3	-0.430		
Vap. pressure (FN)(VPFN)	17-20 weeks	1	0.410		
		2	0.342		
		3	0.400		
	37-40 weeks	1			-0.339
		2			-0.354
		3			0.315
Vap. pressure (AN)(VPAN)	41-44 weeks	1	-0.418		
		2	-0.372		
		3	-0.400		

Note:

- 'i' corresponds to the current year
 1: for yield data from RS 29 block (n = 252)
 2: for yield data from RS 28 block (n = 105)
 3: for weighted average of RS 29 and RS 28 blocks

were grown under rainfed conditions and received recommended doses of fertilizers. Correlations were worked out between four weekly averages of 11 weather variables considered viz. temperature (max. and min.), vapour pressure (FN and AN), rel. humidity (FN and AN), wind velocity, hours of sunshine, total rainfall, evaporation and total number of rainy days with yield of same year, yield one year ahead, yield two years ahead, and yield three years ahead separately for the two plots and

also for the weighted average of these two plots. The variables which had significant correlations with yield in both the blocks were identified as the variables important for prediction of yield. Multiple regression equations were fitted to estimate the yield based on the variables identified to predict the yield in any year based on the weather variables in the preceding one, two and three years.

RESULTS AND DISCUSSIONS

Table I gives the values of correlation

Table II. Regression equations for forecasting yield.

Variables		Week	bj	SE(bj)
Previous Year (i-1)		Eqn-1		
1.	Humidity (FN)	13-16	0.386	0.617
2.	Total rainfall	13-16	0.037	0.063
3.	Total Rainy days	13-16	1.101	0.156
4.	Temp. (min)	13-16	-0.494	1.882
5.	Vapour Pressure (FN)	17-20	1.790	1.237
6.	Rel. Humidity (FN)	17-20	0.188	0.189
7.	Hrs. of Sunshine	17-20	1.588	1.892
8.	Hrs. of Sunshine	49-52	-1.253	1.936
9.	Rel. Humidity (AN)	29-32	-0.345	0.515
10.	Rel. Humidity (AN)	41-44	-0.044	0.269
11.	Hrs. of Sunshine	41-44	0.342	1.614
12.	Total Rainy days	25-28	-0.694	0.483
Constant			29.662	
R ²			0.805	
Two years earlier (i-2)		Eqn. 2		
1.	Total Rainfall	17-20	0.007	0.016
2.	Total Rainy days	21-24	0.093	0.227
3.	Temp. (Min.)	21-24	3.118	2.032
4.	Hrs. of Sunshine	5-8	2.528	3.938
5.	Rel. Humidity (FN)	17-20	-0.949	0.510
6.	Rel. Humidity (FN)	25-28	-0.795	0.771
7.	Rel. Humidity (AN)	25-28	-0.719	0.591
Constant			168.750	
R ²			0.586	
Three years earlier (i-3)		Eqn-3		
1.	Total Rainy days	45-48	-0.352	0.345
2.	Temp (Min.)	5-8	-2.193	1.460
3.	Temp. (Min.)	29-32	0.664	1.246
4.	Temp. (Min.)	33-36	-1.710	1.625
5.	Rel. Humidity (FN)	13-16	1.408	0.595
6.	Rel. Humidity (AN)	25-28	1.395	0.416
7.	Rel. Humidity (AN)	37-40	-0.147	0.398
8.	Vapour pressure (FN)	37-40	-5.061	2.469
Constant			13.979	
R ²			0.739	

coefficients when they are significant for both the plots. This is done so as to choose only those weather variables which had consistent effects. Results and discussions are based on the correlations worked out for the weighted average yield of these two plots. It is seen from

the table that 13-20 weeks (late March – mid May) is the important period as number of weather variables during this period had significant correlations with next year's yield. While rainfall, no. of rainy days and rel. humidity (FN) of 13-16 weeks had significant positive correla-

Table III. *Regression equations for forecasting yield.*

Previous Year (i-1) Variables	Equations					
	4 Weeks bj	SE(bj)	5 bj	SE(bj)	6 bi	SE(bj)
1. Total Rain fall	13-16	0.101*	0.038	-	-	-
2. Rel. Humidity (FN)	17-20	0.375**	0.128	0.479**	0.103	0.524**
3. Hrs of sunshine	17-20	3.045*	1.103	4.426**	0.778	4.046**
4. Vapour Pressure	17-20	1.884	1.018	1.466	0.875	1.384*
Two years earlier (i-2)						
1. Temp. (min.)	21-24			3.832**	0.982	3.881**
2. Rel Humidity (FN)	25-28			-0.713	0.412	-0.600+
Three years earlier (i-3)						
1. Temp. (Min.)	29-32					-3.101**
Constant term	-42.27		-76.36		-15.51	
R ²	0.74		0.82		0.91	

+ Significant at 10% level

*Significant at 5% level

**Significant at 1% level

tion, temperature (max.) of this period had near significant negative correlation. Importance of summer rains had been also brought out by earlier workers like Patel (1938) Balasubramanian (1956), Prasada Rao (1982) and Mathew *et al* (1986). Similarly hours of sunshine, humidity (FN) and vapour pressure (FN) of 17-20 weeks had significant positive correlation with yield one year ahead. Rel. humidity (FN) and rainfall during 17-20 weeks were found to have significant negative correlation with yield two years ahead.

Efforts were made to build up models to predict yield based on weather variables one year, two years and three years preceding the year of harvest. The 12 significant variables (1st set) preceding one year of the harvest could explain 81% of the variation in yield. Similarly, the significant variables considered two years (7 in number) and three years prior to

harvest (8 in number) could explain 59% and 74% of the variation in yield respectively (Table II).

Stepwise Regression analysis was carried out to eliminate 'non contributing' variables in the 1st set. It was seen that four variables viz. TRF 13-16, HFN 17-20, HRS 17-20 and VPFN 17-20 only could explain 73% of the variation in yield. To these variables the significant variables preceding two years and three years were added one by one to see additional contribution (Table III). Finally, six weather variables viz. three variables preceding one year, two preceding two years and one preceding three years were selected.

Total rain fall of 13-16 weeks which had the highest correlation with yield one year ahead got deleted in the final stage. The actual and predicted yield (based on equation 6) for the years from 1958 to 1982 have shown close agreement excep-

ting for two years viz. 1974 and 1982. The average deviation however for this period was less than 5% from the actual value. The studies have thus shown that by the middle of May, a forecast can be given for the next year's yield with a good precision.

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INFLUENCE OF WEATHER ON NUT DEVELOPMENT IN COCONUT

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ABSTRACT

The monthly variation in nut development of three different coconut hybrids viz., T × CDO, CDO × T and CDO × LO was studied at the Regional Agricultural Research Station, Pilicode during 1985-86. The mean husked nut weight of CDO × T was higher (538 g/nut) than those of the other two cultivars T × CDO (498 g/nut) and CDO × LO (504 g/nut). T × CDO, in contrast had higher (149 g/nut) copra content as compared to CDO × T (131 g/nut) and CDO × LO (123 g/nut). The maximum copra content was noticed in summer (March – May) in all the hybrids.

The influence of weather elements on the second phase of nut development was also studied. The second phase (5 – 8 months after female flower fertilization) of nut development of all the cultivars was seen influenced by the heat units

$$(H U = \text{Max. temp } (^{\circ}\text{C}) + \text{Min. temp } (^{\circ}\text{C}) - 10^{\circ}\text{C}).$$

The other weather elements had ²no significant influence on phase II. A quadratic regression equation using the heat units during the second phase of nut development was worked out.

The equation had a multiple correlation coefficient of 0.8689 for CDO × T, 0.8443 for T × CDO and 0.7977 for CDO × LO.

INTRODUCTION

After fertilization, it takes about eleven to twelve months for the female flower of coconut to develop into a mature nut. During the period of development commencing from fertilization to nut ripening, the coconut bunches are fully exposed to the microclimate around the crown and the variation in nut size within a variety is believed to be a function of the weather changes. Generally, big sized nuts and higher yields are obtained during the summer months and small sized nuts and lower yields in the North-East monsoon period (Krishna Marar and Pandalai, 1957; Vasudevan Pillai and Satyabalan, 1960; Bhaskaran and Leela, 1983). Though the process of nut development is

confined to a twelve-month weather cycle, the weather changes during the critical phase of development if of great importance. Nambiar *et al.* (1969) pointed out that any abnormal weather factor coinciding with the critical phase of development (4-7 months after fertilization) adversely affected the rate of growth and final size of the nut and copra content. In order to elucidate more information on these aspects, a study was conducted at the Regional Agricultural Research Station, Pilicode to study the effect of weather on nut development in coconut hybrids.

MATERIALS AND METHODS

Five palms each of three coconut

Table I. *Husked nut weight (g/nut) and Copra content (g/nut) of coconut hybrids during January 1985 - January 1986.*

Month	C.D.O × T		T × C.D.O		C.D.O × L.O.	
	Husked nut weight (g/nut)	Copra content (g/nut)	Husked nut weight (g/nut)	Copra content (g/nut)	Husked nut weight (g/nut)	Copra content (g/nut)
January 1985	1042	-	611	-	820	-
February	696	155	663	190	720	163
March	733	200	700	206	700	183
April	650	200	673	185	675	166
May	700	111	708	201	530	134
June		Not available				
July	407	121	433	130	280	76
August	366	66	366	108	300	62
September	244	93	383	122	325	100
October	304	91	320	108	350	87
November	330	110	333	113	385	100
December	410	126	373	133	466	133
January 1986	581	172	420	146	500	154
Mean	538	131	498	149	504	123

hybrids CDO × T, T × CDO and CDO × LO in block N. VI of the farm formed the material for the study. The palms were of uniform age (12 years) and were grown under unirrigated conditions. Three fully matured nuts were collected at random every month from each tree from January 1985 to January 1986 to record monthly observations on nut size and copra yield. The nut weight was recorded after husking. The kernal was dried to six percent moisture before recording the copra weight.

The daily data on weather parameters were gathered from the agrometeorological station attached to the farm. The correlations between different weather elements during the second phase of nut development (5-8 months after fertilization) and the husked nut weight were worked out. The relationship between the

husked nut weight and the temperature during the second phase of nut development was also worked out using the heat unit concept (Azpiázee *et al.* 1971).

$$HU = \frac{T_{\max} + T_{\min}}{2} - T_t$$

Where HU = heat unit, T max = maximum temperature in °C, T min = minimum temperature in °C and T_t = minimum thresh hold temperature in °C. The minimum thresh hold temperature for coconut has been assumed as 10°C.

RESULTS

The data on mean monthly husked nut weight and copra content of the three hybrids are presented in Table I. The hybrid CDO × T registered higher (538 g/nut) nut weight than T × CDO (498 g/nut) and CDO × LO (504 g/nut). In

Table II. *Husked nut weight (g/nut) and Copra content (g/nut) during different seasons in 1985.*

Variety	Summer (Mar.-May)		South west monsoon (June-Sept.)		Post monsoon (Oct.-Nov.)		Winter (Dec.-Feb.)	
	Husked nut weight (g/nut)	Copra content (g/nut)	Husked nut weight (g/nut)	Copra content (g/nut)	Husked nut weight (g/nut)	Copra content (g/nut)	Husked nut weight (g/nut)	Copra content (g/nut)
CDO × T	694	170	339	93	317	100	716	140
T × CDO	693	197	394	120	326	110	549	161
CDO × LO	635	161	301	79	367	93	668	148

contrast, T × CDO recorded relatively more copra content (149 g/nut) than CDO × T (131 g/nut) and CDO × LO (123 g/nut).

The seasonal variation in nut size and copra content could be clearly seen in the data presented in Table II. All the three hybrids recorded higher nut weight and

copra content in the summer months of March, April and May. There occurred a slight reduction in the weight of copra in winter months (Dec. to Feb.). The fall in nut weight and copra yield was conspicuous in the rainy and post rainy periods.

Table III. *Correlation coefficients between different weather elements during the second phase of nut development and the husked nut weight of coconut hybrids.*

Weather parameter	Variety		
	CDO×T	T×CDO	CDO×LO
Max. Temp.	-0.78**	-0.54	-0.84*
Min. Temp.	-0.43	-0.67***	-0.24
Rainfall	+0.35	-0.07	+0.45
Number of rainy days	+0.34	-0.05	+0.46
Sunshine hours	-0.44	-0.04	-0.55
R.H.(%) at 7.30 AM	+0.83*	+0.74**	+0.76**
R.H.(%) at 2.30 PM	+0.50	+0.15	+0.64***

*Significant at 0.001 level

**Significant at 0.01 level

***Significant at 0.02 level

Table III presents the correlation coefficient between the husked nut weight and the different weather elements during the second phase of nut development. Among the weather parameters, the maximum temperature and the relative humidity in the morning showed significant influence on nut weight.

The data on total heat units during the second phase of nut development and nut weight of the three hybrids are summarized in Table IV. The data indicate a negative relationship between the heat units and the husked nut weights. There was a marked decline in nut size from July to December in response to an increase in total heat units, indicating that total heat units above 2100 were not congenial for nut development.

Table IV. *Total heat units during the second phase of nut development and husked nut weight of coconut hybrids.*

Month	Heat units (°C) during the second phase of nut development	Hybrid		
		CDo × T (g/nut)	T × CDO (g/nut)	CDO × LO (g/nut)
Jan.	2018	1042	611	820
Feb.	2040	696	663	720
Mar.	2040	733	700	700
Apr.	2018	650	673	675
May	2040	700	708	530
June		Not available		
July	2077	407	433	280
Aug.	2184	366	366	300
Sept.	2259	244	383	325
Oct.	2285	304	320	350
Nov.	2219	330	333	385
Dec.	2219	410	373	466
Jan.	2033	581	420	500
Correlation coefficient between heat units and husked nut weight (r) =		-0.83*	-0.82*	-0.72**

*Significant at 0.001 level

**Significant at 0.01 level

Based on the relationship between the total heat units during the second phase of nut development and the husked nut weight, the following quadratic equations have been worked out for estimating the nut weight of the test varieties.

$$Y(T \times CDO) = 26493.2094 - 23.1107x + 0.0051x^2 \quad (R^2 = 0.87)$$

$$Y(CDO \times t) = 47656.2579 - 42.2450x + 0.0094x^2 \quad (R^2 = 0.84)$$

$$Y(CDO \times LO) = 55053.404 - 49.7958x + 0.0113x^2 \quad (R^2 = 0.80)$$

Where x = total heat units during the second phase of nut development.

DISCUSSION

The process of nut development

commencing from fertilization of female flower to ripening takes place in three distinct phases covering a total duration of eleven to twelve months. During the first phase (0-4 months), the growth is slow. The next phase of rapid growth lasts for four months. There is a decline in growth after the second phase. Of all the parameters of weather studies, the total heat units during the second phase of nut development only has a distinct influence on the final nut size. High ambient temperature during the active growth phase adversely affects the rate of growth of the nut with a consequent decline in nut weight. For example, the small size of nut in CDO × T harvested in the month of September is attributable to the adverse effects of high total heat

units on the critical phase of nut development during the period February to May. The relationship between the total heat units during the second phase of nut development and the final nut size is negative and significant. The concept can be used for estimating the nut size in coconut. However, more studies are required in this direction to confirm the results.

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CROP YEAR VERSUS CALENDAR YEAR AS BASIS FOR COMPILING ANNUAL YIELD IN COCONUT

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ABSTRACT

Coconuts are harvested throughout the year at an interval of about 30-60 days and the annual yield is the number of nuts obtained in a 12 month period. Two different methods of compilation of annual yield data showed that the year to year variation is more pronounced in the case of calendar year tabulation, as compared to agricultural years. When two year averages were taken, these differences were found to come down. With the help of experimental data, it has been shown that conclusions drawn can be different depending on the method of compilation of annual yield data. Analysis of mean yield for two consecutive years is suggested to overcome this problem.

INTRODUCTION

In coconut, the annual yield is taken as the number of nuts harvested at 30-60 days interval, in a 12 month period. In the past, many research workers have tried to discuss the annual and seasonal variations in the yield of coconut (Menon and Pandalai, 1958; Satyabalan *et al.* 1968, 1969; Abeywardena, 1971; Thampan, 1981). In some cases, they have considered for analysis the yields obtained in a calendar year, while in some other cases, the crop year or agricultural year (viz. July to June) yields have been considered. For official statistics also, while agencies like FAO and APCC present the data on calendar year basis, some other agencies like Directorate of Economics and Statistics (Ministry of Agriculture, Government of India) publish the figures on crop year

basis. While presenting experimental results in research publications also, both these methods of tabulations have been noticed. In this paper, an attempt has been made to study the variations that may arise by adopting the two different methods of compilation.

MATERIALS AND METHODS

At Central Plantation Crops Research Institute, Kasaragod, coconuts are harvested almost regularly at an interval of about 30 days and palm-wise, harvest-wise data are available for the past many years. For this study, the yield data of a total of 375 West Coast Tall palms, from four different locations in the farm, for the period from July 1978 to December 1984 were considered. Mean annual yield of nuts, for the the data tabulated on the basis of calendar years and crop years,

Table I. *Mean annual yield of coconut for crop years and calendar years.*

Year	Annual Data				Two year moving averages			
	Plot 1 (n = 42)	Plot 2 (n = 39)	Plot 3 (n = 194)	Plot 4 (n = 100)	Plot 1	Plot 2	Plot 3	Plot 4
1978-79	77.4	99.1	61.7	37.5				
1979-80	65.3	44.1	39.1	38.7	71.3	71.6	50.4	38.1
1980-81	73.2	67.6	43.7	39.3	69.3	55.9	41.4	39.0
1981-82	82.9	72.1	65.8	74.4	78.1	69.9	54.8	56.8
1982-83	87.4	82.3	69.8	73.9	85.2	77.2	63.8	74.1
1983-84	76.2	63.3	66.5	82.6	81.8	72.8	63.2	78.3
Mean	77.1	71.4	57.8	57.7	77.1	69.5	54.5	57.3
1979	84.8	85.2	64.3	45.9				
1980	57.3	37.1	23.0	31.2	71.1	61.1	43.7	38.6
1981	90.5	91.4	74.4	60.8	73.9	64.2	48.7	46.0
1982	65.2	48.4	49.3	68.6	77.8	69.9	61.9	64.7
1983	102.3	105.3	93.2	92.6	83.8	76.9	71.8	80.6
1984	67.1	38.4	40.1	73.7	84.7	71.7	66.7	83.2
Mean	77.9	67.6	57.4	62.1	78.3	68.8	58.5	62.6

for the different plots are presented in Table I. All the palms were growing under rainfed conditions. While the palms in Plot 1 were around 40-50 years old during this period, others were much younger, the years of planting being 1959, 1965 and 1968 respectively for Plots 2, 3, and 4. The palms in Plot 4 are the non-experimental border palms of an irrigation experiment, while in Plot 3, both the experimental and the non-experimental border palms of a regular fertilizer trial were considered together. Two-year moving averages for these plots have also been presented in Table I.

To illustrate the possible effects of these two methods of tabulation on the analysis and interpretation of experimental data, the yield records of a well laid out genotype-cum-fertiliser trial from CPCRI, Kasaragod was considered. This

experiment was laid out in 1965 on newly planted seedlings, with nine treatments, representing the factorial combinations of three genotypes and three levels of fertilizer mixture, all replicated thrice, in a randomized block design with six-tree plots. The analysis of the annual data was carried out for the years 1979 to 1984 in the case of calendar years and for 1978-79 to 1983-84 in the case of crop years and the summary of the analysis of variance table is presented in Table II. Pooled analysis of data for the six year period was also carried out, as suggested by Patterson (1939) (Table III).

RESULTS AND DISCUSSION

The data presented in Table I clearly show that the year to year variation is more pronounced in the the case of calendar year tabulation, as compared to

Table II. *Genotype-cum-Fertilizer Trial - Analysis of annual data - Summary of ANOVA (M.S.S.) and Table of means*

a) *Crop year data*

Source	df	1978-79	1979-80	1980-81	1981-82	1982-83	1983-84
Replications	2	165.4	9.5	1010.0	321.2	222.1	498.8
Genotypes	2	1236.6++	451.2+	663.9	1842.9++	473.7	1373.6++
Fertilizers	2	10603.9++	4291.7++	3196.2++	6258.9++	7805.7++	5436.7++
Geno. × Fert.	4	167.7	129.2	275.5	99.4	341.8	143.2
Error	16	129.8	87.4	228.8	223.6	209.7	212.8
Genotype 1		49.2	29.0	33.0	48.1	72.4	56.3
Genotype 2		69.3	41.8	46.0	73.4	86.1	79.0
Genotype 3		48.8	30.1	29.8	49.1	75.1	59.3
Fertilizer 1		17.0	8.8	14.7	26.6	44.6	36.5
Fertilizer 2		68.3	42.2	44.7	68.5	88.7	79.9
Fertilizer 3		82.1	49.9	49.4	75.4	100.4	78.2
Mean		55.8	33.6	36.3	56.8	77.9	64.9

b) *Calendar year data*

Source	df	1979	1980	1981	1982	1983	1984
Replications	2	49.5	2.6	2499.1	1401.5	982.7	1259.6
Genotypes	2	3943.4++	28.0	4536.4++	523.5	7319.9++	416.5+
Fertilizers	2	11853.8++	841.7+	11558.7++	1625.1++	14580.3++	1501.2++
Geno. × Fert.	4	572.6	41.9	920.9	696.2	998.2	234.1
Error	16	280.2	44.9	371.2	245.3	360.0	86.6
Genotype 1		46.3	17.2	53.3	45.7	89.1	35.4
Genotype 2		83.3	14.1	91.7	32.4	139.5	23.7
Genotype 3		47.9	17.1	52.3	45.6	91.2	35.5
Fertilizer 1		17.6	6.3	24.6	26.2	60.2	17.8
Fertilizer 2		75.3	16.6	82.9	45.6	128.1	33.5
Fertilizer 3		84.6	25.6	89.8	52.0	131.5	43.4
Mean		59.2	16.1	65.8	41.2	106.6	31.5

+ Significant at $P = 0.05$ ++ Significant at $P = 0.01$

agricultural year. Distinct ups and downs could be seen in alternate years, when the data was tabulated on the basis of calendar years, and these differences were found to reduce when the data were considered on crop year basis. Slight differences observed between plots can

be attributed to the age differences and the effect of irrigation in the adjoining plots. However, when two-year moving averages were taken, these differences, between years as well as between the methods of tabulation, were found to narrow down. This is because, during the

Table III. *Genotype-cum-Fertilizer Trial Pooled analysis of data – Summary of ANOVA (M.S.S.) Table.*

Source of variation	df	Crop-year data (1978-79 to 1983-84)	Calendar year data (1979 to 1984)
Replications	2	894.77	1338.50
Genotypes	2	5571.17++	4651.59++
Fertilizers	2	35990.72++	32474.39++
Geno. × Fert.	4	833.35	778.95
Error (a)	16	667.61	620.90
Years	5	7717.16++	27168.90++
Geno. × Years	10	94.15	2423.23++
Fert. × Years	10	320.46+	1897.27++
Geno. × Fert.			
× Years	20	64.67	537.01++
Error (b)	90	105.05	244.34

++ Significant at $P = 0.01$

period under consideration, a two year cycle was observed for peak yields.

These methods of tabulation of data were found to affect the conclusions that can be drawn from experimental data. While the variance-ratios for the annual data showed only marginal differences under the two methods of tabulation (Table II), a perusal of the treatment means showed that some of the genotypes which behaved in a steady manner when the data were tabulated on agricultural year basis, were found to behave in an erratic manner, for the calendar year data. This was confirmed in the pooled analysis also. Genotype × years and genotype × fertilizer × years interactions, which were not significant when the data were considered on agricultural year basis, turned out to be highly significant, when the data were tabulated on the basis of calendar years (Table III). Based on the analysis of agricultural year

data, while conclusions can be drawn about the consistent behaviour of the genotypes over the years, the same is not possible for calendar year data.

Half yearly yield data of these palms were critically examined to ascertain the reasons for these differences, when the same data were tabulated in two different ways. Menon and Pandalai (1958) has pointed out that about 60% of the nuts harvested in any year is from the months of January to June. A more-or-less similar trend was noticed in the present study also, in years of both high and low yields (Table IV). However, in lean years, the actual number of nuts harvested during January to June is lower than that obtained during July-December of the preceding or succeeding year of high yield. When yield data are considered on the basis of crop years, one half year of high yield is combined with a preceding or succeeding half year of low yield, and vice versa, or the two half years coming together are of medium yield, thus

Table IV. *Half-yearly yield obtained for different genotypes.*

Year	Period	Genotype		
		1	2	3
1978	July-December	20.2	16.8	17.4
1979	January-June	29.3	51.9	31.6
	July-December	17.5	29.2	16.6
1980	January-June	11.9	11.8	13.8
	July-December	5.5	2.7	3.6
1981	January-June	27.5	43.7	25.9
	July-December	25.9	46.8	26.1
1982	January-June	22.5	24.4	23.4
	July-December	23.7	7.3	23.0
1983	January-June	50.0	78.7	52.6
	July-December	40.3	59.3	38.7
1984	January-June	16.4	18.2	21.1
	July-December	19.1	5.4	15.1

reducing the year to year fluctuations. But, in the case of calendar years, two half years of high yield, or two half-years of low yield are coming together, thereby increasing the year to year variations.

The present study has shown that coconut yield data, when tabulated on the basis of calendar years, tend to fluctuate more widely between years, than when it is considered on crop year basis. Depending on the method of tabulation, the conclusions drawn from experiments may also turn out to be different. Whatever be the method of tabulation, since the differences narrow down when two year averages are taken, analysis of mean yield for two consecutive years is to be preferred to analysis of annual yield. Jacob Mathew and Vijaya Kumar (1984) had earlier pointed out that pooling of data of consecutive years reduces the error variance, thereby helping to detect treatment differences more precisely.

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FIELD PLOT TECHNIQUE FOR EXPERIMENTS WITH COCONUT

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ABSTRACT

The present study deals with certain plot techniques for conducting field experiments on adult coconut palms. Coconut being a perennial crop, presents additional problems in both statistical design and analysis of the data. Pointing out various difficulties in identifying uniform experimental material (Coconut palms) for designing experiments several methods are tried. Achieving greater homogeneity between plots within a block by creating greater heterogeneity within plots is found to be the best design approach. Similar techniques are suitable for adoption to other perennials especially plantation crops with long gestation period and high genetic variability.

Perennial plants and fruit trees are, in general, considerably different from annuals or field crops in that they need special statistical methods for experimentation. This is mainly because of their longevity in bearing, sensitivity to variation in fertility status, susceptibility to various mishaps, long gestation period etc. Because of their large size and long life the individual tree is of considerable interest to the Scientist than a group of trees in a stand. In other words, the individual is more important than a group of individuals. This greater attention on individuals has resulted in a greater importance being attributed to genetic or biological rather than environmental or positional variation. Normal experience with perennials is that the experimental error is considerably large compared to annuals because of the presence of greater biological variation among them. The statistical analysis and interpretation of experimental data are largely depen-

dent on the design of the experiments. A major difficulty in laying out statistically well designed experiments with them is thus the lack of uniformity in the experimental material.

Coconut is an important plantation crop of Kerala. The experimenter often faces the problem of getting uniform experimental material (Coconut palms) on account of the biological variation present among the individual palms. This lack of uniformity in the experimental palms leads to unsatisfactory conclusions from field experiments on them. It is desirable to get biologically homogeneous palms with respect to the character 'yield' to design experiments on them. Coconut is a crop which shows biennial tendency though it is not severe as in some other perennial fruit crops. So it is a practice to use the totality of yields over an even number of successive years as an index of its performance. Even with

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this criteria of selection for homogeneity the problem of getting uniform experimental palms still remains. The present study deals with certain considerations in designing experiments on biologically heterogeneous material like coconut by applying a well known result in sampling methodology.

MATERIALS AND METHODS

Experimental lay out is very important in conducting any experiment. The general method of laying out experiments by taking compact blocks does not appear to be feasible in experiments with adult coconut palms because of the high variability in yield of individual trees, irrespective of whether the experiments are to be laid out in experimental plantation specially established or in cultivators fields. The present practice followed in designing experiments on coconut is to form blocks having uniform yield suggested by Shrikande (1957), the real aim being to reduce the within block variation. One can think of methods which reduce the between plot variation by increasing the within plot variation, following the methods applied in selecting cluster samples.

In experiments with perennials, an experimental unit is an individual plant or a group of plants. In general, there is practical difficulty in getting uniform experimental material in designing experiments with them because of the presence of biological or genetical variation among them. Coconut being a perennial crop is often subjected to this biological variation. The usual practice is to choose a uniform set of experimental palms with respect to the important

"measured character", namely yield over an even number of consecutive years to eliminate biennial periodicity. Such a procedure often introduces a significant positive correlation between plants within plots because of which variation between plants within plots is reduced. This reduction however leads to unsatisfactory consequences of increasing between plot variation within a block. A procedure by which such a positive correlation between plants within a plot is avoided will have a more satisfactory impact on the choice of the experimental design. Best results can however be achieved if a marked negative correlation between palms within a plot can be created. In sample survey methodology it is a well known fact that clusters formed with negative intra-class correlation i.e. with units within the same cluster heterogeneous, are relatively most efficient (Sukhatme and Sukhatme, 1970).

The widely adopted techniques of planting configurations in coconut are the square and triangular methods. Six types of plot configurations were tried with a plot size of three and these have been designated as Methods I, II, III, IV, V and VI. The first three methods are based on the geographical contiguity of palms, method IV is based on a random selection of the palms and methods V & VI are based on calibrating 'yield' over a period of two consecutive years.

Method I

The adjacent palms in a row are grouped together to form contiguous plots of size three.

Method II

Three palms in a diagonal direction are considered for plot formation.

Method III

The palms are taken in a triangular fashion

In the above three methods the distance between two neighbouring palms remain constant.

Method IV

The plots are formed with a random selection of palms from the whole area under consideration.

Method V

The palms are arranged in ascending (descending) order of yield performance over an even number of consecutive years. The ordered palms are divided into three groups of equal size, having palms with low, medium and high yield. A palm is chosen at random from each of these groups as a member of a plot. So the three palms in a plot are heterogeneous in yield performance.

Method VI

The palms are ordered in the same way as in Method V. Then the first three palms are grouped to form the first plot, the next three palms to form the second plot and so on. So the three palms constituting a plot are homogeneous in yield performance.

In the last three methods a plot is not at all formed by a group of contiguous palms.

The above methods were illustrated with yield data pooled over the period 1968 and 1969, 1970 and 1971 and 1972 and 1973 relating to 108 palms. These

yield data were recorded from palms of age 50 years from Regional Agricultural Research Station, Kerala Agricultural University, Pilicode. Though some of these palms were subjected to some fertiliser treatments during the period 1972 and 1973 the data from them were also treated as uniformity trial data because the effect of fertiliser application is known to manifest on yield only 3 to 4 years after their application.

Since the total yield for a unit plot is of ultimate interest the plot means, plot variances and coefficients of variation were calculated. The intra-class correlation coefficients were worked out for Table I. *Plot Means and standard deviations (in nuts).*

Methods	Years		
	1968 & 1969	1970 & 1971	1972 & 1973
	Block 'C'		
I	63	68	87
II	55	64	92
III	56	66	100
IV	54	52	67
V	30	40	52
VI	105	88	118
Mean	316	277	244
	Block 'D'		
I	60	57	75
II	61	52	78
III	63	52	78
IV	32	51	72
V	25	38	41
VI	94	71	99
Mean	229	217	170
	Block 'E'		
I	57	64	74
II	62	54	78
III	59	48	78
IV	52	40	63
V	25	35	60
VI	84	63	103
Mean	358	343	301

Table II. *Coefficient of variation (in percentage) for plot yields totalled over two years.*

Methods	1968 and 1969	1970 and 1971	1972 and 1973	1968 and 1969	1970 and 1971	1972 and 1973	1968 and 1969	1970 and 1971	1972 and 1973
	Block 'C'			Block 'D'			Block 'E'		
I	19.83	29.64	32.93	21.78	26.46	21.90	22.86	26.87	24.52
II	17.52	27.98	25.96	22.93	24.01	22.87	24.96	32.08	25.82
III	17.78	28.80	27.78	22.71	24.09	22.80	23.72	28.39	25.91
IV	16.98	22.55	18.77	20.77	23.44	20.92	23.73	35.50	27.53
V	9.82	17.52	14.63	8.93	17.63	12.00	10.07	20.60	20.02
VI	33.24	38.63	32.93	34.04	36.99	28.98	39.98	37.23	34.20
Single tree plots	33.54	44.44	39.45	34.44	40.35	34.92	40.08	51.15	42.63

each method of plot formation and also for all year-pairs.

RESULTS

The yield data pooled over a period of two consecutive years were used to form 36 plots of size 3, relating to 108 palms each from Block C, D & E of Regional Agricultural Research Station, Kerala Agricultural University, Pilicode. The plot means, plot variances and Coefficients of variation for plots with respect to each method of plot configurations were calculated and presented in Tables I and II.

The standard deviation of yield was less for method V compared to the other methods, its magnitude has increased during the year-pairs 1970 and 1971 and 1972 and 1973. But again it remained less for method V. It ranged from 30 to 52 nuts in Block C while this range was observed to be 52 to 100 nuts for the other methods. Similar results can be observed from Blocks D and E also.

The Coefficients of variation on single tree basis for Blocks, C, D and E during

the year-pair 1968 and 1969 was of order 33.5, 34.4 and 40.1 per cent respectively. In all the three Blocks the Coefficients of variation during the period 1970 and 1971 was higher compared to the earlier period 1968 and 1969. It is 44.4 in Block C, 40.4 in Block D and 51.2 percent in Block E. The years 1972 and 1973 showed lesser variation compared to 1970 and 1971 but somewhat more compared to 1968 and 1969.

The C.V. was of order 9.8, 17.5 and 14.6 percent for Method V compared to 17.0, 22.6 and 18.8 per cent for method IV. The C.V. was of the same order for method VI as compared to single tree plots during 1968 and 1969 in all Blocks. There was a slight reduction in C.V. during the consecutive year groups 1970 and 1971, and 1972 and 1973 for this method. The reduction in the C.V. has been quantified as a decrease of 13 to 17 percent for 1970 & 1971 and 1972 & 1973 year-pair respectively for Block C and 8 to 18 percent respectively in Block D, and 20 to 27 per cent in Block E.

Intra-class correlation Coefficients (ρ)

Table III. *Intra-class correlation Coefficients for different methods of plot formation.*

Method	Year		
	1968 & 1969	1970 & 1971	1972 & 1973
Block 'C'			
I	0.0341	0.1780	0.0760
II	0.0823	0.1051	0.1497
III	0.2249	0.1404	0.2545
IV	0.1072	0.1056	0.1529
V	-0.3808	-0.3736	-0.2886
VI	0.9737	0.6417	0.5541
Block 'D'			
I	0.1104	0.1553	0.1003
II	0.1242	0.0408	0.1421
III	0.1630	0.0442	0.1499
IV	0.0555	0.0156	0.0480
V	-0.3964	-0.2071	-0.3185
VI	0.9663	0.4880	0.5418
Block 'E'			
I	0.0029	0.0776	0.0056
II	0.0918	0.0998	0.0602
III	0.0402	0.0308	0.0643
IV	0.0357	0.2330	0.1364
V	-0.4028	-0.2511	-0.1617
VI	0.9924	0.3049	0.4753

were worked out for each method of plot formation in all the Blocks and also for all periods of year-pairs. These values are presented in Table III. ρ was high for method VI in all blocks and for all year groups. For the first year-pair it varied from 0.966 to 0.992. In the subsequent year-pairs the magnitude of ρ was low compared to the first year-pair, ranging from 0.305 in Block E for 1970 and 1971 and 0.642 in Block C for the same period. But all these Coefficients were significant. The estimates of ρ were the smallest for Method V, being negative in all Blocks and for all year-pairs. This is the only method where negative intra-

class Correlation Coefficients were obtained. The value of ρ ranged from -0.162 in Block E for the year-pair 1972 and 1973 to -0.403 in the same Block for the year-pair 1968 and 1969. Though ρ was positive for all year-pairs in all blocks it was not significant in the first four methods. In methods V and VI ρ was significant though its magnitude did not remain constant for different year-pairs of the same block.

DISCUSSION

The layout is very important in conducting an experiment and to draw meaningful inferences from them. The usual method of forming blocks on the basis of geographical contiguity is often not found to be efficient in plantation crops. It is important that the high variation among individuals trees should be taken into account in designing experiments with perennials like coconut and the design must be practicable and statistically sound. It may be useful to have uniform experimental palms both within and between plots in a block. However, there are practical constraints in achieving this objective. So long as this objective is not fully achieved, to that extent we suffer from design defects. The high variation in yield from plant to plant necessitates a search for other techniques of grouping experimental palms. The main purpose of a blocking system is to reduce the experiment into convenient units to control positional variation. If the variation is only due to a random cause, contiguity considerations can be given full weight. In perennials the blocks can be formed on the basis of pre-recorded observation on some measurable characteristics like yield i.e. by calibration.

Six methods of forming plot configurations are tried in designing experiments with coconut. The first three methods are similar, except further distinctions are made in respect of the procedures followed for adopting contiguity. Method V is aimed at reducing the between plot variation by increasing the within plot variation. There is likely to be greater heterogeneity within plots but greater homogeneity between plots. No consideration need be taken of the type of design to be adopted.

The plot mean yield were found to be substantially low during the year-pair 1970 and 1971 in all the blocks. This may be due to the low rainfall (499 mm) recorded during the year 1969. During the other periods of study the rainfall ranged from 752 mm to 900 mm. In coconut the present yield is always affected by previous rainfall. The plot S.D. of yield was less for method V in all the blocks.

Coefficient of variation is a measure of reliability or consistency of the data. In all the three blocks C.V. during the period 1970 and 1971 was higher compared to the earlier periods 1968 and 1969. The years 1972 and 1973 showed lesser variation compared to 1970 and 1971 but somewhat more compared to 1968 and 1969.

When the plots are formed with more than one palm per plot (being three in the present case) there was substantial reduction in C.V. in respect of all the methods. When the contiguous trees are grouped C.V. is reduced to 35 to 50 percent. A further substantial reduction of 50 to 75 per cent has been achieved by grouping palms of heterogeneous yielding capacity.

In Block C, Method I was inferior to Method II and III. During the period 1968 and 1969 C.V. is reduced by 41 percent by Method I while in Methods II and III the decrease is respectively 40 to 47 percent compared to single tree plots. This reduction was less during the subsequent periods of study. In Block D and E also Method I was shown to be inferior to methods II and III. The reduction in C.V. was more or less of the same magnitude in Methods II and III. Method IV was found to be superior to the first three methods. C.V. reduced by 49 to 42 per cent in Blocks C, 40 to 42 per cent in Block D and 39 to 44 per cent in Block E.

Method V gave substantially lower C.V. compared to all the methods, in all the Blocks for each year-pair. C.V. reduced by 71 per cent in year-pair 1968 and 1969, 61 per cent in 1970 and 1971 and 63 per cent in 1972 and 1973 compared to single tree plots in Block C. This reduction in C.V. was of similar order in Blocks D and E. Considering all the blocks together Method V is found to be the best.

In Method V greater heterogeneity is created among units in a plot while in Method VI greater homogeneity is created among units in a plot. Method V where the intra-class correlation coefficient is negative, is found to be the superior one. This result is in agreement with the result of cluster sampling that clusters formed with heterogeneous elements will be more efficient. So, for experiments with heterogeneous genotypes like coconut Method V is the suitable one to reduce the experimental error. Also no consideration need to be taken of the type of design to be adopted.

SUMMARY

A major problem in designing experiments with adult coconut palms is the lack of uniformity in the experimental material. This problem is examined in the present study. The present field plot technique with adult coconut palms is to group the palms having similar yields for an even number of periods prior to the start of the experiment. An alternative grouping of palms having marked yield differences is suggested. This method is based on the principle of negative intra-class correlation present among the experimental units within a plot. This method is found to reduce the within block variation by increasing the within plot variation. Even a completely randomised design will be sufficient for experiments with adult palms with this method of plot formation. This method will solve the problem of getting uniform experimental palms and will lead to successful experimentation with adult

coconut palms. Various field plot configurations like (i) Contiguity of palms, (ii) random allocation of palms and (iii) relatively homogeneous palms are also tried but none of these are found to be superior to the method in which heterogeneous palms are used for plot configuration.

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OPTIMUM PLOT SIZE FOR W.C.T. COCONUT PALMS FROM FERTILIZER TRIAL YIELD DATA

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ABSTRACT

The yield data of an NPK fertilizer experiment conducted at CPCRI, Kasaragod were made use of for studying the coefficients of variations of plots of different sizes and shapes, after converting to a uniformity trial data by eliminating treatment effects on the yield of individual palms. Not much variations in C.V. were observed for plots of different shapes of the same size. The C.V. decreased with the increases in plot size. Smith's Law (1938) was found to give a satisfactory fit to the underlying relationship between CV and plot size. The per unit decreases in CV were found minimum, when the plot size exceeded 8 palms/plot. With fixed experimental resources, smaller plots were found more efficient. The efficiency decreased with increase in block size.

INTRODUCTION

In recent years a number of investigations on uniformity trials have been published, particularly on cereals and other short duration crops. In perennial tree crops only few uniformity trials seem to have been conducted. Compared to annual short duration crops such investigations on perennial tree crops require relatively longer period. Since experiments on perennial crops are conducted for a long time, care should be taken in their planning and lay out. As the material is costly, economy in the lay out reduces the total cost of experiment. Hence the size and shape of plots for experiments on perennial crops are important.

Normally size and shape of plots for a particular crop is investigated to obtain a

proper experimental unit for agricultural experiment. For studying the optimum plot size for a particular crop, coefficients of variations from plots of various sizes and shapes are calculated on the yield data from uniformity trial. The optimum size and shape of plot is the one which gives least CV for a given cost and also relatively less variation due to soil fertility. After conducting uniformity trial on coconut, optimum plot size of 18-20 trees per plot was reported from Sri Lanka (Joachim, 1937). In India no such uniformity trial has been conducted so far to work out the optimum plot size for coconut. Unlike annual crops, it is difficult to conduct a uniformity trial on perennial tree crops, mainly due to the large area required, long pre-bearing period and the time taken for the stabilisation of yield. Encouraging results obtained from a study of optimum plot

size for D × T coconut palms from the yield data of an NPK fertilizer experiment (Nambiar, 1986) has prompted for a similar study on WCT palms.

MATERIALS AND METHODS

The yield data of the NPK fertilizer experiment on WCT coconut conducted at CPCRI, Kasaragod were made use of for this study. The experiment was started during 1965 with 27 treatment combinations of N, P and K laid out in a factorial confounded design with 3 blocks in a single replication. The palm wise yield data for 1981-82 and 1982-83 for 197 palms were used for this study. The method is to convert the yield data of the fertilizer experiment to a uniformity trial data by eliminating treatment effects, from the yield of individual palms as suggested by Ray, (1973). This technique will hold good only when the number of palms/plot is constant and the yield figures are available palmwise. In this way the entire yield data was converted to a uniformity trial data and the CVs were worked out by forming plots of different sizes and shapes, taking individual palm as the ultimate unit for ana-

lysis. The analysis was carried out for individual years as well as for the pooled data.

RESULTS AND DISCUSSION

For the pooled data of two years the average CVs of different shapes of the same size were plotted against the plot size 'x' (Fig. 1). The CVs decreased with the increase in plot size for the individual years as well as for the pooled data. Fairfield Smith equation $y = a x^{-g}$ (Smith, F. 1938) gave a good fit for the data, where 'y' is the average CV, 'x' is the plot size of x units and 'g' is the soil heterogeneity coefficient. The fitted equation for the pooled data was $y = 35.72 x^{-0.61}$ with an R^2 value of 0.98. The per unit decreases in CV were minimum when the plot size exceeded 8 palms/plot. The value of 'g' explains the pattern of variability in the field and its value lies between 0 and 1. Lower values of 'g' indicates soil heterogeneity and higher values indicates soil homogeneity.

Block size and minimum number of replications

When there are large number of treatments under factorial type of experiments, use of smaller blocks will become necessary adopting confounding system or incomplete blocks. The efficiency of blocks of 'm' plots relative to block of 'n' plots is defined by the ratio $RE (m/n) = \frac{n(n-1)(1-n^{-8})}{m(n-1)(1-m^{-8})}$. Smaller blocks are found to be more efficient than bigger blocks, which indicates that the adoption of confounded or incomplete block design will increase the efficiency. In the planning of field experiments one of the main points

Fig 1 COEFFICIENT OF VARIATION IN RELATION TO SIZE OF PLOT

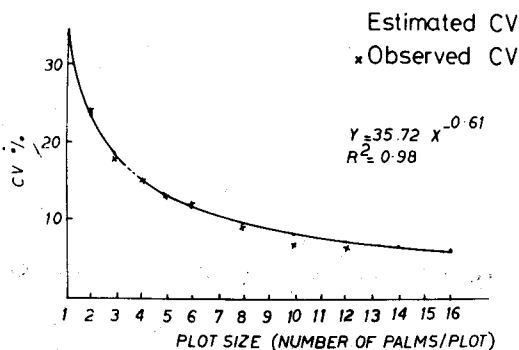


Table I. Plot size and CV under different block sizes and the minimum number of replication (*r*) required for 5% standard error of treatment mean.

Plot size (x)	4 plot block		6 plot block		8 plot block	
	CV %	r	CV %	r	CV %	r
1	29.95	36	26.55	28	31.06	38
2	20.53	17	17.36	12	16.06	10
3	16.47	11	13.54	7	10.92	5
4	14.08	8	11.35	5	8.31	3
5	12.47	6	9.90	4	6.72	2
6	11.29	5	8.85	3	5.65	—
8	9.65	4	7.42	—	4.30	—
10	8.55	3	6.47	—	3.47	—
12	7.74	—	5.79	—	2.92	—

Blank space indicates that replication has not been worked out due to less d.f.

to be considered is the number of replications to be provided, which depends upon the total variability and the amount of precision desired. The CVs under different block size and the minimum number of replications required for 5% SE of mean are given in Table I and the efficiencies of different block size are given in Table II. The number of replications required for a given level of accuracy for a fixed block size decreased with the increase in plot size.

Optimum plot size under cost consideration

To relate the cost of experimentation with the plot size Fairfield Smith (1938) recommended a general cost function given by $Cx = Co + Cl x$, when Co is that portion of the cost which is independent of the size of plot and Cl is the contribu-

tion of the cost by a unit increase in the plot size. The optimum value of x is that which minimises the cost per unit information viz., $(Co + Cl x) Vx$ where $Vx = VI/x^g$.

Assuming Smith's Law, for a fixed variance, the optimum plot size x_{opt} is given by $\frac{g}{1-g} \frac{Co}{Cl}$ (Sardana, *et al*, 1967).

Optimum plot size obtained on cost consideration from the above formula (2) is given in Table III for value of 'g' ranging from 0.1 to 0.8 and $\frac{Co}{Cl}$ from 4 to

8. For 'g' ranging from 0.5 to 0.6 and $\frac{Co}{Cl}$ from 4 to 8, the optimum plot size ranges from 4 to 12 palms/plot.

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Table II. Efficiency of different block sizes.

Block size (Plots/Block)	4	6	8	20
Relative efficiency	1.16	1.11	1.07	1

Table III. *Optimum plot size under cost consideration.*

g	Co/Cl				
	4	5	6	7	8
0.1	0.44	0.56	0.67	0.78	0.89
0.2	1.00	1.25	1.50	1.75	2.00
0.3	1.71	2.14	2.57	3.00	3.43
0.4	2.67	3.33	4.00	4.67	5.33
0.5	4.00	5.00	6.00	7.00	8.00
0.6	6.00	7.50	9.00	10.50	12.00
0.7	9.33	11.67	14.00	16.33	18.67
0.8	16.00	20.00	24.00	25.00	32.00

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FORECASTING OF CASHEW YIELD FROM PLANTATIONS

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ABSTRACT

A method to forecast the cashew yield from large plantations based on biometrical characters/yield attributes from small sample of trees was attempted. For this purpose, data collected during 1982 and 1983 from Cashew Plantations at Muliya and Perla and during 1982, 1983 and 1984 from Periya belonging to the Plantation Corporation of Kerala were made use of. A double sampling procedure was used to get a ratio estimate by which a small sample (n) is used for detailed observations and a large sample (n') is used for recording an easily observable character. In gardens ranging between 100 to 300 cashew trees a maximum of 200 trees for recording the character condition of flowering graded 0 to 5 and a sub sample of 20 trees for recording the canopy area and estimated number of nuts at all stages of maturity are sufficient to give an yield estimate of the garden with 20 per cent deviation at 5% level of significance. Double sampling was relatively two to three times efficient than simple random sampling. This methodology can be safely adopted to forecast the total yield from large plantations by subdividing the area into blocks of 150 to 300 trees considering the natural boundaries and selecting a small sample of such blocks, according to any suitable sampling design.

INTRODUCTION

The harvest of cashew extends to 3-4 months and it is rather difficult to collect the yield data from a large number of trees over a large area. George and Vijayakumar (1979) developed a forecasting method for estimating cashew yield from any tree based on sample observations taken on different occasions during the flowering phase. George *et al* (1982) observed that the yield from any cashew tree can be forecast by a single snap observation made during the peak flowering period (Feb-March). The present study was intended to refine the forecasting methodology for individual

trees and to utilize this procedure to estimate the total yield from large plantations/estates from only a small sample of trees.

MATERIAL AND METHODS

A study was carried out for three years during 1982-84 at three centres viz., Periya, Perla and Muliya cashew estates in Kasaragod District belonging to the Plantation Corporation of Kerala. Observations on the canopy area (Mohapatra *et al* 1973), condition of flowering (graded 0 to 5) and the estimated number of nuts at all stages of maturity were collected from all the trees in blocks of 314 trees

Table I. *Correlation coefficients of biometrical characters with Yield in the three locations*

Characters	Perla		Muliya		Periya		
	1982 (145)	1983 (138)	1982 (112)	1983 (106)	1982 (305)	1983 (286)	1984 (292)
Canopy Area	0.64**	0.41**	0.58**	0.62**	0.29**	0.29**	0.40**
Est.no.of nuts	0.72**	0.67**	0.75**	0.73**	0.79**	0.71**	0.73**
Cond. of flowering	0.81**	0.82**	0.75**	0.64**	0.79**	0.83**	0.81**

Figures in the parenthesis give the number of trees considered for the analysis.

from Periya, 146 trees from Perla and 114 trees from Muliya during the peak flowering phase (Feb-March). The yield data from all these trees were collected by daily harvest and average weight of

nuts was worked out. The above observations were collected for three years from Periya and two years each from Perla and Muliya. The correlations between these biometrical characters and yield were

Table II. *Multiple regression equations for forecasting cashew yield based on biometrical characters*

Centre	Year	b0	Canopy area b1	Estimated No. of nuts b2	Condition of flowering b3	R ²
Muliya	1982	-2.441	0.028** (0.005)	0.007** (0.001)	0.763** (0.149)	0.74**
	1983	-4.282	0.050** (0.007)	0.012** (0.002)	0.851** (0.215)	0.71**
Pooled over years (Eliminating year effect)		-3.275	0.039** (0.005)	0.008** (0.001)	0.795** (0.135)	0.69**
Perla	1982	-1.327	0.020** (0.003)	0.006** (0.001)	0.615** (0.063)	0.81**
	1983	-0.980	0.009** (0.003)	0.005** (0.001)	0.891** (0.079)	0.75**
Pooled over years (Eliminating year effect)		-1.089	0.014** (0.002)	0.005** (0.001)	0.751** (0.050)	0.77**
Periya	1982	-0.894	0.006** (0.003)	0.007** (0.001)	0.730** (0.059)	0.76**
	1983	-0.417	0.003 (0.002)	0.008** (0.001)	0.646** (0.040)	0.75**
	1984	-2.417	0.020** (0.004)	0.009** (0.001)	0.985** (0.075)	0.75**
Pooled over years (Eliminating year effect)		-1.217	0.010** (0.002)	0.008** (0.001)	0.790** (0.035)	0.73**
Pooled over the Locations		-1.644	0.017** (0.001)	0.008** (0.0004)	0.775** (0.033)	0.70**

Figures in the parenthesis are the S.E.'s

worked out centre-wise and year wise (Table I).

Based on the individual tree observations on the canopy area, estimated number of nuts and condition of flowering, regression equations were worked out to forecast yield for each location after eliminating the year effect and then the over all regression equation eliminating the location effect (Table II).

In order to estimate the minimum number of sample trees required to estimate the population (garden) mean for a given cost with minimum variance, a double sampling procedure was used to get a ratio estimate by which a small sample (n) is used for detailed observations and a large number (n') is used for recording the easily observable character viz., condition of flowering. The cost ratio used was 1:30 where 1 is the cost (i.e. time in minutes) for recording the condition of flowering in one tree and 30 is the cost (time in minutes) for recording the detailed observations. The estimates of mean, variance and relative efficiency were worked out as per Sukhatme & Sukhatme (1977) and as modified by Dalakrishnan and Jose (1985). Estimates of yield (Y) was made using the formula $Y = N \cdot \bar{Y}_n \cdot \frac{\bar{x}_n'}{\bar{x}_n}$ where

$\bar{Y}_n$ is the mean yield of n trees $\bar{x}_n$ is the mean of the auxiliary variable (condition of flowering) for n trees, $\bar{x}_n'$ is the mean of the auxiliary variable (condition of flowering) for n' trees and N is the total number of trees flowered in that block (garden). The relative efficiency of the double sampling procedure was compared with simple random sample (Table IV).

RESULTS AND DISCUSSION

The correlation coefficients of canopy area, estimated number of nuts and condition of flowering with yield showed that all these three characters were highly correlated with yield (Table I), confirming the results obtained by George *et al* (1982). Multiple regression equations for forecasting the individual tree yields based on the above characters for the different years and locations, as well as the pooled regression values eliminating the year effect and the over all regression were given in Table II. It can be seen that the estimates were all relatively precise ($R^2 > 70\%$) using the prediction equation

$$Y = -1.644 + 0.017 x_1 + 0.008 x_2 + 0.775 x_3$$

(0.001) (0.0004) (0.033)

($R^2 = 0.70$)

where x_1 , x_2 and x_3 are the observed values for the canopy area, estimated number of nuts and condition of flowering respectively for estimating the total yield (Y) in kg of that tree. This equation is a refinement over the earlier one developed by George *et al* (1982) as in the present study a larger number of trees were sampled and observations repeated in three locations for a period of three years.

Further, the minimum number of trees required to be observed for the auxiliary variable viz. condition of flowering (n') and for the detailed observation (n) for estimating the population mean with a deviation of 20% at 5% level of significance is given in Table (III). From a block of 300 trees or less, a large number (n') of about 200 trees or the actual number of trees whichever is less are required for recording the easily observable character, viz. condition of flowering. But for recording detailed observations, only

Table III. *Number of sample trees required for detailed and auxiliary observations*

Location	Year	No. of trees in the garden	No. of trees to be sampled		
			For auxiliary observation	For detailed observation	
				Number	Percentage
Muliyar	1982	112	112	32	29
	1983	108	108	31	29
Perla	1982	145	145	19	13
	1983	138	138	14	10
Peiya	1982	305	211	21	.7
	1983	286	214	14	5
	1984	292	163	13	4

about 20 trees (n) are required in a garden with normal heterogeneity, and about 30 trees when the trees are highly heterogeneous. Estimates obtained by double sampling ratio estimate were very close to the actual value, except for the year 1982 for Periya which may be due to sampling fluctuations (Table IV). The relative efficiency of double sampling ratio estimate was always more than 150% and in some cases up to 389% in comparison with simple random sampling procedure. This methodology, is highly useful in estimating the total yield from large plantations. The total plantations/estates can be subdivided into blocks of 150-300 trees considering the natural boundaries. The required number of such

blocks can be selected according to any sample survey design and the estimates of the total yield from those selected blocks can be worked out by observing a maximum of about 200 trees from each selected blocks for the condition of flowering and taking detailed observation from a sub sample of 20-30 trees and counting the total number of flowered trees (N). By this method it has become possible to take up large scale sample surveys and work out reliable estimates of cashew production scientifically.

ACKNOWLEDGEMENT

The authors are grateful to the Managing Director, General Manager

Table IV. *Efficiency of Double Sampling Ratio estimates*

Location	Year	Estimated Average yield based on		Actual average yield (whole popn.) kg/tree	Efficiency of of double sampling compared to S.R.S.
		S.R. sampling on n trees kg/tree	Double sampling kg/tree		
Muliyar	1982	3.51	3.37	3.40	1.93
	1983	3.97	4.23	4.27	1.59
Perla	1982	1.92	1.82	1.84	3.34
	1983	3.23	2.60	2.52	2.65
Periya	1982	3.51	3.18	2.69	2.49
	1983	3.66	1.97	1.82	3.89
	1984	3.01	3.26	3.10	3.20

(Cashew) and Superintendent Cashew estates Muliya, Plantation Corporation of Kerala, for giving all the facilities for conducting this trial, to Dr. K.V. Ahamed Bavappa, Director, CPCRI for his keen interest and guidance, to Shri Jacob Mathew HD (Statistics) for his valuable suggestions and to Shri Jose Abraham, Scientist who was associated with this work in the initial stages.

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PLENARY SESSION

SESSION I: BIOTECHNOLOGY AND PLANT PHYSIOLOGY

Dr. M.R. Sethuraj in his lead paper strongly advocated the importance of defining and delimiting the scope of the bio-technology instead of clumping all conventional methodologies in this newly emerged branch of science. He opined that it will be ideal to import costly and potent enzymes and other fine chemicals rather than investing heavily on the infrastructure for the manufacture of these chemicals in our own country. He made a strong plea to revive the earlier plan to have a centre of biotechnology for plantation crops exclusively. Dr. Sethuraj expounded the areas in which he felt there is immense scope for biotechnological investigations with particular reference to plantation crops. These areas of investigation include micro-propagation, somatic embryogenesis, soma-clonal variation, somatic cell hybridization and recombinant DNA technology.

Following the lead paper nine other contributed papers were presented. Among those two pertain to tissue culture techniques dealing with oil palm and eucalyptus. Among the other papers four dealt with coconut, and one paper each on tea, coffee and arecanut. The feasibility of inducing somatic embryos from the calli originated from foliar veins and recovering plantlets in oil palm were discussed in the first paper. Second one dealt with the employment of embryonal tissues to recover plantlets either through axillary bud proliferation or differentiation from callus in *E. camadulensis*. The

advantage of two commercial formulations to enhance productivity in mature seedling teas formed the theme of the third paper. The economic benefits of using NAA sprays to prevent the premature button shedding in coconuts was brought out in the next talk. Based on certain biochemical parameters three coffee selections out of the seven screened were found to be drought tolerant which opened the possibility of utilising these characteristics, in future screening and selection programmes. The next paper dealt with attempts to define the chemical make up of vascular sap from the inflorescence of healthy and wilt diseased coconut palms so that medium can be defined in which the mycoplasma like organisms may be reared. The influence of management practices on the physiology of root wilt affected coconut palms was discussed in the next paper. The penultimate paper discussed the role of ammonium in enhancing the induction of nitrate reductase activity by nitrate under both light and dark conditions in coconut leaves. In the last paper it was disclosed that only 27% of the photo-synthetically active radiation penetrated through the arecanut canopy and crops like banana, coffee, cocoa, clove and pepper could thrive under this reduced sunlight intensity in the multiple tier cropping system of cultivation.

P.K. RAMAIAH
Chairman

SESSION II: PROCESSING, PRODUCT DIVERSIFICATION AND EQUIPMENT

Eight papers were presented in this Session including the lead paper on

processing, product diversification and equipment development. Besides the lead paper, there were two papers on tea, two on spices and three on equipments dealing with coffee, coconut and arecanut. The present status of the processing and marketing of spices and coconut was reviewed in the lead paper. The processes developed for improving the marketability of value added products were discussed at length. Attempts were made to convert spices like pepper and chillies into value-added items namely oil or oleoresin. Super critical extraction of oils at low temperature has been identified as an efficient process – a means to make the extract economically viable. It was also mentioned that some of the processes developed indigenously are being practised on a commercial scale. Coconut products like coconut cream, partially defatted coconut grating and coconut water are some of the processes ready for commercial exploitation.

Isolation of curcumin from turmeric powder was described in a paper indicating that further work is needed to commercialise the process. Lipophytic profile of fat extracted from nutmeg was presented in the next paper. Two papers were presented on tea, one highlighting the modification processes required to produce black tea with improved liquor characteristics and keeping quality and the other on the role of gallic acid in relation to high temperature during drying. Effect of fluid bed drying on the formation of this chemical constituent was the main theme of the paper. For more rational grading and marketing of tea it was felt that it would be worth to evolve standards for tea grading

nomenclature. A paper on a modified pulper cum washer for processing coffee, claimed that the new machine can reduce water consumption by 80 to 90% without affecting the quality of coffee. Designing and development of a simple and cheap drier using agricultural waste as fuel was described in the next paper. This drier is suitable for drying copra and arecanut. An electronic moisture meter designed and developed at CPCRI was found to be suitable for estimating moisture content of copra. The instrument operating within the range of 5 to 40% of moisture level. The Session recommended that research on product improvement and product diversification should receive more attention than at present. The Regional Research Laboratory, Trivandrum (CSIR) should evolve schemes to have greater involvement in the field of product improvement of all plantation crops as they have better infrastructure for such work.

A.G. MATHEW

Chairman

SESSION III: MARKETING, EXTENTION AND COST OF PRODUCTION

In this Session though there were 5 papers including the lead paper only three were presented. Dr. Das in his lead paper on the cost of production, market stability and remedial measures for plantation crops highlighted the problems both in production and marketing. Capital cost of establishing new planting or re-planting are extremely high. As a result, replanting and rejuvenation programme have been seriously affected. Due to low productivity and high input

cost, the price competitiveness of Indian plantation commodities in the international market has been lost. The real price of plantation commodities have tended to decline even though the absolute prices are substantially increased. The paper brought about the facts that apart from weather uncertainties, the frequent changes in important and export policies and taxation policies have contributed to the instability in the price of plantation commodity. There has been a tendency of over dependence on non-quota markets.

The only paper on extension was on the impact of the training programme – V.P. tea nursery management in the Nilgiris. The paper compared the relative performance of the nurseries raised by trained and untrained persons. The training resulted in the production of over 10 million clonal tea plants per year of which 65% is sold to the outsiders and around 25% was used for infilling of existing vacancies in mature tea fields and the balance for new planting. The training programme undertaken by the UPASI Krishi Vigyan Kendra has resulted in creating awareness in the scientific crop husbandry techniques, providing self-employment opportunities, meeting the demand for the supply of required planting material, generation of income leading to the investment of land, house and transport vehicles and also establishing contact with developmental agencies. The paper on rubber wood market emerging changes indicated that the wood based industries consume about 93,000 cubic metre of rubber wood; the plywood unit alone accounts for 49,000 cubic metre of rubber wood. The rubber-wood is supplying about 68% of

the requirement of small wood based industries in Kerala. The main centres of these units are located in Quilon, Cannanore, Calicut, Trichur and Kottayam. Since the Rubber Board is planning for a big replanting programme, the optimum utilisation of rubber wood would go in a big way in checking the de-forestation.

The recommendations of these Sessions are: (1) emphasis should be made for price stabilisation through international agreements, increasing effective demand through market promotion and product diversification, (2) development of economically viable technologies for reducing the cost of production as well as marketing and creating value added products, (3) the experience gained through UPASI-K.V.K. should be followed by the other agencies involved in transfer of technologies, (4) the large scale availability of wood produced in plantation sector should be used profitably by converting them into value added products, (5) while the transfer of technology in crops like tea, coffee and rubber could make an impact on the production, it is not so in the case of crops like coconut, arecanut, cocoa, pepper, cardamom and cashew. This calls for a review of the existing system of transfer of technology for these crops and re-orientation to meet the anticipated production targets.

P. RETHINAM
Chairman

SESSION IV: PEST MANAGEMENT

There were 12 papers presented in this Session. Among the 12 papers on pests, four were on biological control, three on

integrated pest management, one each on chemical control, vertebrate pest control, insecticide application techniques and herbicide application techniques. In the lead paper on pest management in plantation crops almost all aspects of pest management were covered. The need for considerable improvement in pesticide application techniques was emphasised. The possibilities of using biotechnology in pest management, was discussed and adequate scope was identified.

Integrated management of red palm weevil – *Rhynchophorus ferrugineus* – in coconut garden resulting in considerable reduction in pest infestation was explained in the next paper. Improved adult attractant techniques using leaf petiole bits, yeast and toddy was discussed. By adoption of all the proven methods of weevil control in an integrated manner, the pest infestation could be brought down near zero level and maintain the garden free of fresh infestation. Biological suppression in the population of coconut rhinoceros beetle – *Oryctes rhinoceros*, in Minicoy and Lakshadweep by releasing beetles infected with *Oryctes baculovirus* was described in the next paper.

Integrated management of coconut blackheaded caterpillar *Opisina arenosella* in Tamil Nadu, using various parasites and trunk injection of systemic insecticide during summer was described in another paper. Manipulation of sex ratio of parasites with Altosid and parasite mass production techniques were described in the next paper. The authors cautioned about the uncontrolled use of tree injection of systemic

insecticide by non-experts. A Government agency to check such practices was solicited.

Short acting organophosphorus and synthetic pyrethroid insecticides were found to be effective in suppressing the population of shot-hole borer of tea in the mid-cycle chemical control. Application of long acting organo-chlorine insecticides did not help in reducing the infestation.

The pupal parasitoid of *Opisina arenosella* *Xanthopimpla punctata* of *Opisina arenosella* suppressed the population of the pest in waterlogged areas.

Egg, larval and pupal parasites of *Homona coffearia* was recorded in the tea fields at Anamallais, effecting varying degrees of control.

Life history and population dynamics of *Micromus timidus*, a predator of tea aphid *Toxoptera aurantii* was presented in the next paper. The maximum number of prey consumed during the life time of the predator was found to be 309 plus or minus 49.17.

Integrated management of coffee green scale, *Coccus viridis* using the white hollow fungus *Verticillium lecanii* and sub-toxic level of insecticide fenthion resulted in considerable reduction of the pest. The effectiveness was increased when surfactant Tween 20 and humectant Glycerol were added to the spore suspension. It was suggested that 5% of the crop may be left totally free from pesticide for the survival of the pest to support the natural enemies.

From the evaluation of the insecticide application methods for the control of *Coccus viridis* on coffee, it was found that the stem implantation of monocrotophos and dimethoate is effective in reducing the pest population in young plants, but ineffective on older plants. Spraying of these insecticides gave better control than trunk implantation. Moreover, in trunk implantation in young plants these insecticides were phytotoxic.

The black rat, *Rattus wrougtoni*, an important pest of coconut and cocoa was found to prefer the bait mixed with fumarin to those mixed with warfarin in laboratory studies. The peak mortality was achieved on fifth day for warfarin and seventh day for fumarin. On evaluation of herbicide applications in rubber, it was concluded that the controlled droplet application sprayers effect considerable saving in spray volume and man days, compared to high volume sprayers.

K. JAYARATHNUM

Chairman

SESSION V: DISEASE MANAGEMENT

The lead paper on integrated disease management in plantation crops in India highlighted the multi-prong integrated approach with a specific emphasis on phytosanitation, cultural practices, varietal resistance, nutrient vs. diseases, biological and chemical control. The successful disease management adopted in root (wilt) affected coconut gardens and katte disease affected cardamom plantations was cited as typical examples. The necessity of assessment of crop losses was stressed to objectively utilise the information in the disease

management. The importance of improved spraying technologies, the timing and coverage of sprays was discussed. The standardisation of methodology for estimation of yield losses in various plantation crops was called for.

Of the remaining 12 papers presented, two each were on coffee, cardamom, rubber and oil palm, and one each on tea, cocoa, pepper and turmeric. In coffee, the leaf rust disease management strategy to maximise productivity taking into account the biological, climatological and economic factors were highlighted. Out of the two fungicides tested namely Bavistin and Captafol the latter provided adequate control of coffee blight.

The importance of application of organic fungicides with systemic action in the integrated spraying schedule to combat the tea blister blight disease effectively and efficiently at economic levels was reported in the paper on 'Tea blister blight control'.

The susceptibility of cocoa pods in relation to their maturity to infection of *Colletotrichum gloeosporioides* was presented and the cork borer method of inoculation was found to be ideal for screening for disease resistance.

In 'katte' disease of small cardamom, application of insecticides to control the vector of the virus was found ineffective. On the contrary certain insecticides increase the disease incidence and this warrants further critical investigations to establish the finding. In the spread of 'katte' the infection log foci and the distance play a major role in determining the spread. The importance of self-sown

seedlings and bringing the plants from outside sources also contributed to the internal spread.

A spray volume of 3000 litres per hectare effectively controlled the abnormal leaf fall on rubber. The economic viability of crown budding with clones resistant to *Phytophthora* needs further investigation.

The etiology of spear rot complex of oil palm warrants thorough investigations to plan effective control measures. The importance of quarantine regulations in importing oil palm seeds was called for in view of the proposed increase in oil palm area.

The strategy for rejuvenation of wilt affected pepper gardens needs further investigation. A survey on the root-knot infestation in turmeric and the nature of damage under field conditions was suggested.

During the discussion, urgency for both internal and external quarantine measures to effectively check the spread of diseases of plantation crops was emphasised. In a crop like oil palm which is of recent introduction, eradication of diseased palms has to be carried out very scrupulously.

The General Chairman Dr. Krishnamoorthy pointed out the incidental decrease of shot-hole borer incidence in tea with high dose of potash application. Thus it was stressed, in general, to adopt judicious and integrated management practices to combat the diseases of plantation crops for optimum returns.

P.K. KOSHY
Chairman

SESSION VI: GERMLASM

This is the first time in the history of PLACROSYM that a session on germplasm has been held. It indicates the importance of conservation of plant genetic resources in plantation crop improvement. Apart from the lead paper on plantation crop genetic resources research in India, there were two papers on coffee and one each on rubber, tea and cardamom. The following recommendations emerged from the deliberations. (1) There is an urgent need to collect and conserve the germplasm of all plantation crops both indigenous and exotic, with special reference to the place of origin of respective crops. This is of special significance because of fast depletion of virgin forests on a global scale. (2) An action plan for germplasm collection of plantation crops should be chalked out such that all the important gene resources available are conserved by 2000 A.D. (3) The statutory plant quarantine regulations should be scrupulously followed and available quarantine techniques adopted not only by the scientists but also by the commercial organisations authorised to bring in materials to India. An off-shore quarantine station should be established to facilitate effective quarantine inspection. Due importance should be given to post-entry surveillance in nursery for diseases and pests before field planting. (4) Internal quarantine measures are to be enforced when indigenous collections are made. Spread of pest and diseases can be controlled if proper measures are taken before distribution of planting materials from nursery. Such discipline is warranted for the effective internal quarantine since

there are rarely any definite regulation on this or where is any agency to enforce even the existing one. (5) In view of the obvious difficulty in field maintenance of this group of crops, newer techniques like embryo preservation and limited growth technique have to be thought of in addition to long term storage. For this, basic work must be initiated and required facilities made available to the concerned centre. (6) Minimum descriptor list should be devised for basic characterisation of the introduction and collection. (7) Proper evaluation techniques including statistical design have to be evolved for meaningful evaluation and immediate utilisation for commercial exploitation wherever possible. (8) Alternate centres for collections are to be recommended to guard against any loss due to unforeseen calamities. (9) A catalogue for all the available plantation crops germplasm listing readily identifiable oleogenic characters should be prepared for effective utilisation of the material. (10) A joint exploration for indigenous collection of plantation crops is to be recommended. (11) Efforts should be made to establish a National Gene Bank for all the plantation crops.

M.K. NAIR

Chairman

SESSION VII: CROP VARIETAL IMPROVEMENT

In Session "Crop Varietal Improvement" seven papers were presented in addition to the lead paper. In the lead paper it was brought out that though the achievements made so far in varietal improvement has been substantial, future strategies will have to

be on a highly interdisciplinary basis for the total exploitation of the available genetic variability, induction of new variability and identification of genotypes resistant or tolerant to pest, diseases and stress situations. Quality aspects of plantation crops were also highlighted for consideration for achieving both high yields as well as the various qualitative requirements. It was suggested that the future breeding programmes should have multi-disciplinary approach involving Physiologists, Biochemists, Agronomists, Soil Scientists and Plant Protection Scientist.

Out of the seven papers presented, cropwise, two each were on coffee and rubber, one each on small cardamom and large cardamom and arecanut. In the paper on genetic variability on growth and yield characteristics in coffee the role played by dwarfing gene of San Ramon in drought tolerance and high yield has been brought out. The papers on early performance testing and test tapping on seedlings of rubber showed that clonal differences do exist with regard to major characters and it is possible to detect their differences well in advance.

The paper on arecanut selection formulated a vigour index by regressing four selected variables on the yield and a selection criterion is proposed to select elite areca palms using yield and vigour index.

The male sterility in some species of coffee was explained due to blocking of nutrients to the generative tissues, suppression of androecium and tapetal hypotrophy leading to the break down of sporogenous tissue. A scheme for

utilising male sterility to exploit hybrid vigour in coffee was suggested.

The paper on polyploidy breeding in cardamom brought out the meiotic stability of induced tetraploids and also high percentage of fertility. The discussion clearly brought out the significance of polyploids in cardamom breeding.

There was in depth discussion on breeding programme for drought tolerance and various parameters that could be possibly used both in the laboratory and in the fields for identifying drought tolerant lines. The need for using statistical designs in breeding experiments was also brought out. Arising out of the presentation of papers as well as discussions it appears that there is a need to develop broad based breeding approaches for plantation crops. It is recommended that a sub group consisting of at least one researcher from each crop may be constituted to go into this and develop a broad and sub frame for each of the crop for adoption.

K.V.A. BAVAPPA

Chairman

SESSION VIII: CROP HUSBANDRY

In crop husbandry 16 papers were presented out of which one was the lead paper on nutrition management of plantation crops. One paper each on coffee, tea, rubber, arecanut, cashew and oil palm, two on cardamom and seven on coconut were presented. The lead paper dealt on the nutrition management of

plantation crops in relation to various factors and future strategies. The importance of initiating nutrient balance studies in plantation crops, agro-ecosystems, standardisation of new techniques such as EUF method of analysis for refining fertilizer usage, recognition of micronutrient flux in soils cropped to plantation crops was discussed at length.

In the paper on cardamom the cationic relationship of leaf K, Ca and K/Ca ratio on the incidence of *Chenthai* disease was indicated. Increase in dose of fertilizer to cardamom tended to decrease the intensity and incidence of VAM population in soil and roots.

The paper on rubber emphasised that when legume cover crops are grown there is a possibility of reducing the level of nitrogen. Suitable extractants to determine the level of available manganese status in soils was brought out in the paper on coffee.

The disadvantages and detrimental effects of centering of tea plants in the nursery was emphasised in the paper on tea. Growth and yield of oil palm in relation to leaf nutrient composition was brought out in a paper on oil palm. In arecanut, the importance of supplying nutrients through organic and inorganic sources in combination for the productivity was brought out. The importance of zinc nutrition on yield of coconut in a zinc deficient soil was emphasised.

Removal of the oldest leaves of coconut palms every month from January to May was found to be desirable and profitable.

Forecasting the yield in coconut and cashew using weather parameters and biometrical characteristics respectively was discussed. The influence of weather on nut development was brought out in another paper on coconut. With the aid of experimental data, another paper on coconut explained that the conclusion drawn can be different, depending on the method of compilation of yield data based on calendar year or crop year. To overcome this problem, analysis of mean yield for two consecutive years is suggested. Use of statistical techniques in field experimentation with reference to the optimum plot size and design was emphasised in two of the papers on coconut.

The following points emerged out of the discussions. (1) Importance of inorganic nutrition in cardamom. (2) Application of zinc as a foliar spray in increasing the crop productivity. (3) Level of nutrients for plantation crops for sustenance of yield as well as to increase the yield to the targetted level. (4) Use of organic amendments to increase the soil productivity. (5) Studies on potash nutrition with relation to disease resistance in plants. (6) Mycorrhiza studies in plantation crops and (7) Understanding the various soil characteristics for crop productivity.

K.K. KRISHNAMOORTHY

Chairman

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