

PROCEEDINGS OF THE SIXTH SYMPOSIUM ON PLANTATION CROPS

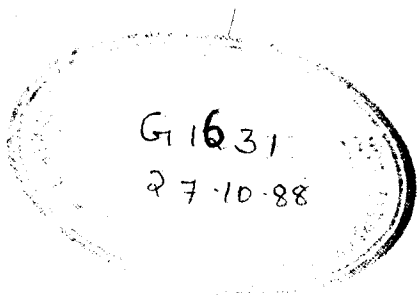
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PROCEEDINGS OF THE SIXTH SYMPOSIUM ON PLANTATION CROPS

Held at

**RUBBER RESEARCH INSTITUTE OF INDIA
(RUBBER BOARD) KOTTAYAM, INDIA
16 to 20 December, 1984**

On
Crop Botany
Plant Protection
Agronomy and Soils
Economics, Marketing, Statistics
Extension & Technology

PLACROSYM VI

(All Disciplines)

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FOREWORD

This volume comprises the full text of papers presented at the sixth symposium on plantation crops research held at Kottayam in December, 1984. Fifty one research contributions covering all disciplines are discussed in six sessions.

Session I is devoted to Crop Botany in which 11 research papers are presented and discussed. Sessions II and III of this volume consist of 15 research contributions on Plant Protection of various plantation crops. The next two sessions are on the Agronomy of Crops such as coconut, cocoa, rubber, tea and coffee, and contain 18 scientific papers. The last session is devoted to the Economics, Marketing, Statistics, Extension and Technology and presents results of seven scientific investigations.

The PLACROSYM brings together scientists of all disciplines of plantation crops so that they can discuss the results in a common forum. Like the earlier ones PLACROSYM VI also has generated a lot of valuable information on plantation crops research for transfer to farmers.

M.R. SETHURAJ
General Chairman, PLACROSYM VI

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S.N. POTTY
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KEY NOTE ADDRESS

M.R. SETHURAJ

YIELD AND BIOMASS PRODUCTION

Crop improvement through breeding occupies the most important position in the field of agricultural research. In cereals 40 per cent of the increased crop production is due to varietal improvements whereas use of fertilisers, irrigation, pesticides, mechanisation and other improved cultural practices together account for 60 per cent of the increases.

The economic yield (Y) of any crop can be expressed by the formula.

$$Y = \frac{W_p \cdot C}{X}$$

where

W_p = total dry matter production ($\text{ha}^{-1} \text{a}^{-1}$)

C = harvest index

X = times of energy value as compared to that of carbohydrate

Y = economic yield ($\text{ha}^{-1} \text{a}^{-1}$.)

In annuals, where breeding successes have gone much ahead of perennials, varietal improvements have been mainly due to improvements in harvest indices. Improvements in total biomass (dry matter) production have been very little, though this component can also have significant contribution towards yield improvement. Theoretically the value of X cannot be changed.

In case of wheat the attained maximum harvest index is 0.5 and the potential attainable value is 0.62 for a potential yield increase of 26 per cent. This could be achieved by reducing the stem

and sheath dry weights by 50 per cent. There is very little scope for increasing the harvest index beyond the above values. Thus further yield increases can be achieved only through increasing the biomass production.

With regard to plantation crops also there is considerable scope for improving the economic yields as the present average productivities of these crops are very low (Table 1). The potential yield increases which can be achieved by increases in biomass alone in major plantation crops is depicted in Table 2. Yields of 5.8, 6.0, 9.8 and 5.5 tonnes $\text{ha}^{-1} \text{a}^{-1}$ are achievable for coconut, oil palm, cocoa and rubber respectively. However, assuming a potential biomass production of 60 tonnes $\text{ha}^{-1} \text{a}^{-1}$ and further improvements in harvest indices the theoretical values of economic yields achievable are given in Table 3. Though harvest indices of 0.5 have been reported for certain selections of coconut and oil palm, the values for rubber and cocoa can be further improved. That the assumed values of biomass production and harvest index are not far from what is really possible is evident from the figures in Table 4 for coconuts of different yielding capabilities. For the super palms the annual biomass production is 62.8 tonnes ha^{-1} and the harvest index for high yielding palms is 0.49.

In the case of *Hevea* rubber the biomass production per annum is 39.83 tonnes ha^{-1} when the tree is untapped. However, in *Hevea*, unlike in other plantation crops there is an unaccounted inhibition of biomass production when the trees are exploited by tapping. The reductions in biomass production under different intensities of exploitation are given in Table 5. Though the harvest index is significantly increased under a daily tapping system this is more than offset by the severe reductions in biomass production. Thus in *Hevea* attempts to improve the yields must be by increasing the dry rubber yields per tap and by increasing the total biomass production. More studies have to be undertaken to elucidate the mechanism of unaccounted biomass loss and to minimise this loss.

Future studies must be aimed at both improving the harvest indices and biomass production. For biomass production photosynthetic rates are very important. The energy conversion efficiencies for majority of the crops are very low at present, ranging

Table 1. Area, production and productivity of plantation crops in India

Crop	Area (000's ha)	Production (000's t)	Yield (kg ha ⁻¹)	% of world production
Arecanut	183	195	1066	90.0
Cardamom	94	3.3	62	23.5
Cashew	481	196	407	—
Coconut	1088	4200 ^x	3460*	12.0
Coffee	227	100	785	2.9
Ginger	41	80	2122	62.0
Pepper	109	29	266	24.0
Rubber	308	175	860	4.2
Tea	382	589	1542	33.0
Turmeric	86	168	1953	70.0

^x5600 million nuts.

*5164 nuts.

Table 2. Crop growth rate and yield—potential and actual

Crop	Potential		Commercially actual		Average yield t ha ⁻¹ a ⁻¹
	Dry matter* t ha ⁻¹ a ⁻¹	Yield t ha ⁻¹ a ⁻¹	Dry matter t ha ⁻¹ a ⁻¹	Yield t ha ⁻¹ a ⁻¹	
Coconut	44	5.8	24	2.5	1.15
Oil palm	51	6.0	29	5.0	—
Cacao	56	9.8	20	2.0	—
Rubber	46	5.5	26	2.0	0.86

*Corley, 1983.

^xAssuming HI of 0.25 and taking energy values of the product into consideration.

Table 3. Yield achievable at different harvest indices assuming biomass production of 60 t ha⁻¹ a⁻¹

Crop	Harvest indices			
	0.1	0.25	0.5	0.75
Coconut	3.145	7.86	15.72*	23.586
Rubber	2.85	7.13*	14.25	21.38
Oil palm	2.85	7.13	14.25*	21.38
Cacao	3.30	8.26*	16.52	24.77
Tea	6.00	15.0	30.0	45.0

*Observed values of HI.

Table 4. Total dry matter increment, yield of copra and harvest index of coconut under varying situations

	Nature of the palm			
	Low	Medium	High	Super
Total dry matter (t ha ⁻¹ yr ⁻¹)	10.3	18.1	25.4	62.8
Copra yield (t ha ⁻¹ yr ⁻¹)	1.2	3.7	6.6	15.4
Harvest index	0.23	0.39	0.49	0.46
Low — 7000, nuts	Medium	—	19,443 nuts	
High — 30,520 nuts	Super	—	82,425 nuts	

Table 5. Biomass production, dry rubber yield, harvest index and efficiency of solar energy conversion at different exploitation systems in Hevea

Exploitation system	Biomass t ha ⁻¹ a ⁻¹	Yield t ha ⁻¹ a ⁻¹	HI	% Ec
S/4 d/2	25.01	2.30	0.19	1.89
S/4 d/2 + E	24.99	2.62	0.21	1.94
S/2 d/2	24.77	2.47	0.20	1.90
S/1 d/2	12.56	2.08	0.29	1.09
No tapping	39.83	—	—	2.46

from 1–2 per cent. Table 6 gives the potential dry matter production figures which could be achieved at different increased energy conversion efficiencies. Such increases could be achieved by

- increased crop growth rates where feed back inhibition of photosynthetic rates occur.
- improved canopy architecture and subsequent improvements in light penetration resulting in increased net assimilation rates
- improved partitioning assimilates, etc.

Another component of biomass production which has not received the deserving attention is dark respiration. In tropical trees 75 to 85 per cent of the fixed carbon is lost by respiration

(Table 7). Whereas the synthesis respiration is independent of temperature and species the maintenance (basal) respiration is dependent on both. Considerable research has to be done to find out ways to reduce the high dark respiration in tropical trees. The possible increases in dry matter production by reducing respiration are as given in Table 8.

I have attempted to present only a few examples to illustrate the importance of sustained biomass increase capability in maintaining higher yield levels in perennial plantation crops. I wish that the delegates here would take note of this theme in their future breeding efforts.

*Table 6. Potential annual production at different efficiencies of solar energy conversion ($t\ ha^{-1}$)**

	Efficiency of solar energy conversion (%) ^x				
	1*	3	5	7	9
Annual dry matter production	18	55	92	128	165

*Annual energy input = $170\ k\ cal\ cm^{-2}\ yr^{-1}$.

^xAssuming 1 g of dry matter = 4.2 k cal.

Table 7. Respiratory loss in perennial tropical crops

Tropical rain forest spp.	=	75% (Kira et al., 1967)
Tea	=	85% (Hardfield, 1974)
Oil palm	=	80% (Corley, 1976)

Table 8. Potential increases in dry matter by assumed reductions respiration

Gross productivity	$70\ g\ m^{-2}\ d^{-1}$			$50\ g\ m^{-2}\ d^{-1}$		
	30%	50%	75%	30%	50%	75%
Respiration						
Net dry matter ($t\ ha^{-1}\ a^{-1}$)	179	128	64	128	92	46

SESSION I

CROP BOTANY

Chairman : Dr. K.V. Ahmed Bavappa
Rapporteurs : Mr. V.C. Markose
Dr. K. Purushottam

ISOLATION OF *PYTHIUM* TOLERANT GINGER BY TISSUE CULTURE

D.D. KULKARNI, S.S. KHUSPE and A.F. MASCARENHAS

ABSTRACT

Cell suspensions of callus isolated from healthy sprouting buds of ginger cultivar varieties (cv) Mahim and Poona local were grown in liquid tissue culture medium containing 10 per cent and 20 per cent culture filtrates (CF) of the fungus *Pythium aphanidermatum*. Fifty per cent inhibition of colony formation was found in media containing 10 per cent CF and total inhibition in 20 per cent CF. The morphogenetic potential of the callus cultures decreased with every successive subculture on media with 20 per cent CF. The rooting of shoots regenerated on a medium with and without 10 per cent CF was 80 to 90 per cent respectively. Only three rhizome samples out of 114 of cv Mahim obtained from a callus grown with 10 per cent CF were tolerant to *Pythium*, whereas all rhizome samples such as 86 of cv Poona local were susceptible to it. The yield of rhizomes of tissue culture cv Mahim and Poona local isolated from controls and medium with 10 per cent CF indicated that there is no loss in yield after CF treatment.

INTRODUCTION

India is the largest producer and exporter of ginger (*Zingiber officinale*) to more than 50 countries, its production being nearly half of the total world's production (Venkataraman, 1980). The most serious problem facing ginger production is the "rhizome-rot" caused mainly by the fungus *Pythium aphanidermatum*. The heavy crop loss caused by this disease could be avoided if a

Pythium tolerant variety of ginger could be developed.

One of the potential applications of plant tissue culture has been for the isolation of mutants or variants tolerant to different stress conditions. Dutreouq (1977) pointed out that *in vitro* techniques using cultures of embryos, calluses, anthers, somatic cells or protoplasts also open up new opportunities for breeding and vegetative propagation of plants for the selection of individuals which are resistant or tolerant to plant diseases especially to those which are induced through the mediation of toxins secreted by pathogens.

As pointed out by Skirvin (1978), mutations in tissue culture can be induced using X-rays, ultra-violet rays or gamma-rays or chemicals such as ethylmethyl sulphonate etc., or by drastic changes in temperature or by bacterial or fungal filtrates and cultures.

Initiation of cell culture, selection of desirable cell phenotype, regeneration of mutant cells into whole plants and field testing are the stages involved for selection of mutants through tissue culture. Mutants resistant to disease have been generally isolated by growing plant tissues either on a medium containing toxins produced by the pathogens, or by using the culture filtrates on which the organisms were grown (Binding et al., 1970).

From various studies, it was also demonstrated (Evans, 1983) that the reactions of tissue cultured plant cells to fungal pathogens are very similar to whole plant responses to these pathogens. *In vitro* culture thus provides an excellent system for investigating specific aspects of plant diseases and disease-resistance mechanisms. Successful isolation of *Pythium* tolerant samples of rhizome from ginger cultivar Mahim, from cells cultured in a medium containing culture filtrate of the pathogen is reported here.

MATERIALS AND METHODS

The media and methods used for the isolation of callus and regeneration of plantlets was according to the procedure described earlier (Nadgauda et al., 1980). The media used were

MS-1 : M&S + CM (10 per cent) + 2,4-D (1.0 mg/l) + Sucrose (2 per cent)

MS-2 : M&S + CM (10 per cent) + Kn (0.1 mg/l) + BAP (0.2 mg/l) + Sucrose (2 per cent).

The sterile culture filtrate (CF) used in the studies was obtained by millipore filtration (0.22) of the corn liquid medium (Ohh et al., 1978) on which *Pythium aphanidermatum* cultures was grown as a static culture for seven days at 30°C.

Experimental

ISOLATION OF VARIANTS

Callus isolated from healthy sprouting buds of ginger cvs Mahim and Poona local and grown on MS-1 agar medium was used. The cell suspension was prepared by taking 5.0 g of callus in a Petri dish, gently breaking it up with a pair of forceps and transferring it to 25 ml MS-1 liquid media in 100 ml conical flasks. The flasks were incubated on a rotary shaker (125 rpm) at 25°C for 25 days. A cell suspension consisting of free cells and cell aggregates in clumps of up to 50 cells was obtained by filtration through stainless steel wire mesh (105/ μ). Five ml of this filtrate was then subcultured to 20 ml MS-1 liquid medium containing 10 and 20 per cent CF. Controls were run without CF. These flasks, 20 from each set, were then incubated on a rotary shaker (125 rpm) at 25°C for 25 days. The cell suspension from the respective sets of flasks, namely, controls and with CF (10 and 20 per cent) were pooled separately and centrifuged at 500 rpm for 15 minutes. The different pellets were re-suspended in 5 ml MS-1 liquid media. Approximate cell counts of this high density cell suspension from the respective pellets were made using a Haemocytometer and then appropriately diluted with the melted semi-solid MS-1 agar media alone or with CF (10 and 20 per cent) at 40°C to get a final cell density of 1.25×10^5 cells/ml. This melted agar media containing the cell suspension was then poured (5 ml/plate) into plates (diameter 9 cm). These plates were sealed with parafilm and incubated in the dark at 25°C. Fifteen plates were incubated with media without CF, 10 with 10 per cent and six with 20 per cent CF for both cv Mahim and Poona local.

After 25 days it was observed that two to four colonies/plate were produced for cv Mahim and four to six colonies/plate for cv Poona local on MS-1 medium containing 10 per cent CF. The corresponding number of colonies/plate on control plates was eight to 10 and 10 to 14 respectively. Total inhibition was obser-

ved with 20 per cent CF.

The cell colonies grown on MS-1 media with and without 10 per cent CF which were approximately 1.0 mm in size were picked up and transferred to the same media in plates and incubated in the dark at 25°C. These colonies, when they had grown to a size of 5 to 7 mm were then subcultured twice to the same media in tubes at intervals of 25 to 30 days to obtain sufficient callus. From the fourth to the seventh passage, control callus was inoculated into 10 tubes whereas callus grown on 10 per cent CF was inoculated into 15 tubes for obtaining shoot formation.

CAULOGENESIS

The medium MS-2 used for caulogenesis that is, shoot regeneration contained Kn (0.1 mg/l) and BAP (0.2 mg/l) instead of 2,4-D (1.0 mg/l) as in MS-1 used for growing of callus.

Callus from controls and 10 per cent CF which had undergone three subcultures was transferred to MS-2 in tubes with and without 10 per cent CF and incubated in light (1000 lux) with a photoperiod of 18 h light at 25°C. After 25 days, callus grown on MS-2 media with 10 per cent CF produced two to five shoots per culture whereas callus without CF produced six to eight shoots per culture.

RHIZOGENESIS

These regenerated shoots were separated individually and then transferred to tubes containing White's liquid media with filter paper support. The concentration of CF in the medium was maintained as the same as that used for shoot formation. These cultures were incubated in light (1000 lux) with the same photoperiod as that used for shoot formation, for 14 days at 25°C for regeneration of a healthy root system. This process, as described above for regenerating shoots and rooted plants on the two media, was continued with callus cultures as inoculum up to the seventh subculture for both the cultivars.

Thus, with every subculture plantlets were obtained from callus grown with and without CF as described in Table 1 for cv Mahim and Table 2 for cv Poona local. These plantlets were grown in pots containing a sterile mixture of soil and vermiculate (1:1) for two weeks in a glass house and later transplanted to the field. These results are summarised in Tables 1 and 2.

Table 1. Shoot and plantlet regeneration from ginger callus cv Mahim

Subculture No.	Control (10 culture tubes)				CF (15 culture tubes)			
	Total No. of shoots	Total number of rooted plants	No. of plantlets in glass house	No. of potted plantlets in field	Total No. of shoots	Total number of rooted plants	No. of plantlets in glass house	No. of potted plantlets in field
S ₄	63	56	53	46	60	51	40	37
S ₅	68	59	53	50	60	47	38	31
S ₆	58	53	50	49	54	41	32	29
S ₇	65	58	51	47	42	34	28	17

Table 2. Shoot and plantlet regeneration from ginger callus cv *Poona local*

Subculture	Control (10 culture tubes)				CF (15 culture tubes)			
	Total No. of shoots	Total No. rooted plants	No. of plantlets in glass house	No. of potted plantlets in field	Total No. of shoots	Total No. of rooted plants	No of plantlets in glass house	No of potted plantlets in field
S ₄	64	56	52	49	60	46	34	29
S ₅	59	52	48	44	49	41	32	25
S ₆	68	57	50	46	34	30	24	19
S ₇	61	55	50	45	32	24	18	13

FIELD STUDIES

All the plantlets regenerated totalling 192 and 184 for controls and 114 and 86 for the CF tolerant plants from cv Mahim and Poona local respectively, were planted in the field.

Screening of the rhizomes for tolerance of pythium

After maturity the plants were harvested and the rhizomes from each plant were collected separately. A systematic method was followed for screening of these rhizomes for tolerance to *Pythium*.

Rhizomes from each sample of both the cultivars were infected with sporulating *Pythium aphanidermatum* cultures in 10 replicates and incubated in sterile sand for 10 days at 30°C. The sand was kept moist throughout the incubation period. Softening of the rhizomes was taken as the symptom of the rhizomes-rot, that is, *Pythium* infection. After 10 days of incubation the rhizomes were screened and data on the degree of softening of the rhizomes were collected. Five rhizome samples out of 114 from cv Mahim and six rhizome samples out of 86 from cv Poona local from plantlets regenerated after CF treatment showed tolerance to *Pythium*. All the rhizome samples, that is, 192 from cv Mahim and 184 from cv Poona local from the control plants showed very clear symptoms of rhizome-rot.

The 11 uninfected samples from the two cultivars were reinfected and screened after 10 days of incubation in moist sand at 30°C. This procedure of screening was repeated twice for the uninfected rhizome samples at each stage.

By this repeated screening procedure, finally three samples, only from plants of cv Mahim regenerated with CF treatment were found to be tolerant to *Pythium*. These three tolerant samples of rhizomes from cv Mahim have been replanted in the field in June 1984. The rhizomes obtained from these plants will be screened after harvesting in February 1985.

Callus has also been isolated from these three tolerant samples and its tolerance to *Pythium* culture filtrate is being tested *in vitro*.

DISCUSSION

Using culture filtrates of *Pseudomonas phaseolicola* Bajaj and Saettler (1970) observed 77 per cent inhibition in the growth of

bean callus. Carlson (1973) reported that tobacco callus was isolated using methionine sulfoximine in medium and plants regenerated from this callus showed different degrees of resistance to wild-fire disease. Heinz (1973) reported regeneration of sugar cane plants resistant to eye-spot disease and that 15 to 20 per cent of the regenerated plants were resistant to this disease. Krishnamurthy and Tlaskal (1974) regenerated sugar cane plants from callus resistant to Fiji disease and found that resistance could be maintained through several generations. Gengenback et al. (1977) observed that plants regenerated from maize callus resistant to culture filtrate of *Helminthosporium maydis* after four selection cycles were toxin resistant. The resistance was inherited through female and not male plants. Behnke (1979) isolated potato callus resistant to a culture filtrate *Phytophthora infestans* and reported that the plants obtained did not lose resistance through regeneration and induction of new callus. In 1980, he reported isolation of potato callus resistant to culture filtrates of *Fusarium oxysporium*. Latun de Dada and Lucas (1983) reported that the regenerated plants of *Medicago sativa* were resistant to *Verticillium* wilt. Bhagyalaxmi et al. (1984) found in screening experiments conducted under field conditions in downy mildew sick plots that only a few pearl millet plants did not express disease symptoms in all three seasons although the control plants did.

In the present investigation, it was found that: (1) there was about 50 per cent inhibition of colony formation on media containing 10 per cent CF as compared to the controls with both varieties and total inhibition of cell growth was observed on media with 20 per cent CF; (2) the morphogenetic potential of the callus cultures decreased with every successive subculture on media with 20 per cent CF, whereas it remained nearly the same in the controls; (3) the rooting of shoots regenerated on a medium with and without 10 per cent CF was 80 and 90 per cent respectively; (4) only three rhizome samples out of 114 of cv Mahim obtained from a callus grown with 10 per cent CF were tolerant to *Pythium*, whereas all rhizome samples, that is, 86 of cv Poona local were susceptible to it; (5) the ratio of tolerant plants to the number of cells inoculated on media with 10 per cent CF works out to be 3: (6.25×10^6) for cv Mahim; and (6) the yield of rhizomes for plantlets of cv Mahim and Poona local

isolated from controls and medium with 10 per cent CF respectively indicating no loss in yield after CF treatment.

The advantage of the method developed lies in the fact that isolation of mutants through tissue culture was carried out with approximately 6.25×10^6 cells of cv Mahim within a span of seven to eight months in the laboratory. Assuming the totipotency of plant cells it would have required 1.8 ha of land and uncertain climatic conditions to screen this number of plants. Further studies will be conducted with rhizomes of tolerant plants of cv Mahim obtained from the second generation to investigate whether this resistance trait is stable and can be genetically transferred.

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DISCUSSION

Q : In the field study, only limited number of plants were planted. Then, how did you arrive at yield/ha?

Ans: Yield/ha has been estimated based on the yield of individual plants.

Q : The yield of 100 tonnes for variety Poona local and 150 tonnes for Mahim appears to be fantastic by any standards reported. Since the scope of the experiment is on Pythium tolerance, it is suggested that yield estimates can be deleted?

Ans: Yes.

Q : Why you have not used other varieties of ginger for your study?

Ans: The emphasis of this study is on the standardisation of tissue culture techniques. Therefore we limited the study to two varieties.

Q : Were the conditions of incubation ideal for infection?

Ans: Yes. Softening of rhizomes were seen except in tolerant ones which shows that conditions of incubation were optimum.

GENETIC CONVERGENCE AND DIVERGENCE AMONG SELECTED CULTIVARS OF ARABICA COFFEE (*COFFEA ARABICA* L.)

V.S. SRINIVASAN and V. SUBBALAKSHMI

ABSTRACT

Genetic relationships were studied among seventeen *Coffea arabica* selections of Indian and exotic origin using Mahalanobis' D^2 statistic involving 11 morphological characters. The selections could be grouped into five clusters with cluster I consisting of nine varieties, cluster II with three varieties, clusters III and IV with two varieties each and cluster V with a single variety. Divergence between clusters II, III, IV and V was maximum and hence the varieties in these were suggested for hybridisation. The characters internodal length, number of nodes and total length of primary, leaf area, fruit volume and weight were found to be more important for distinguishing varieties.

INTRODUCTION

In coffee, studies on the classification of varieties based on morphological characters have been reported (Leon, 1962; Orozco and Nieto, 1972; Fournier, 1973). However, no attempt appears to have been made at quantifying the genetic diversity among a set of varieties with a view to identify the divergent genotypes for utilisation in breeding. The present study was conducted with this objective.

MATERIALS AND METHODS

Seventeen *Coffea arabica* selections of diverse origin were taken for the study. A brief description of each selection is given in Table 1. During 1981 and 1982, the following characters were

Table 1. Selections taken

1. Indian	: Kents, 948, 795, 1934, Sln. 5, 6, 7.2, 7.3, 9, 11.
2. Portuguese	: 1) Hibrido-de-Timor and its crosses 2794, 2800, 2803. 2) Caturra cross (3827).
3. Ethiopian	: Cioccie, Tafarikela.

studied on ten competitive plants in each selection: (1) total length of longest primary (cm); (2) number of nodes on longest primary; (3) internodal length of longest primary (cm); (4) length (cm); (5) breadth (cm); (6) area (cm²) of 10 largest leaves; (7) length (cm); (8) breadth (cm); (9) thickness (cm); (10) volume (cm³); and (11) weight (g) of 100 bilocular fruits.

Statistical analysis

The data were subjected to D² analysis following the procedure given by Rao (1952) and Singh and Chaudhary (1977). The grouping of varieties into clusters was done following Tocher's method given by Rao (1952).

RESULTS

The seventeen selections could be grouped into five clusters based on the 11 morphological characters (Fig. 1). Cluster I was the largest, having nine selections (S. 795, S. 948, S. 1034, Kents, Tafarikela, Sln. 5, S. 2794, S. 2800 and S. 2803); cluster II had three selections (Cioccie, Sln. 6 and Sln. 10), clusters III and IV had two selections each (Sln. 7.2 and 7.3 in cluster III and Sln. 8 and 9 in cluster IV) while cluster V had a single selection (Sln. 11).

Intra- and intercluster D² values are presented in Table 2.

Divergence was maximum between clusters IV and V followed by divergence between clusters II and V. Cluster I was closely related to all other clusters.

Character means of the clusters are given in Table 3. Cluster

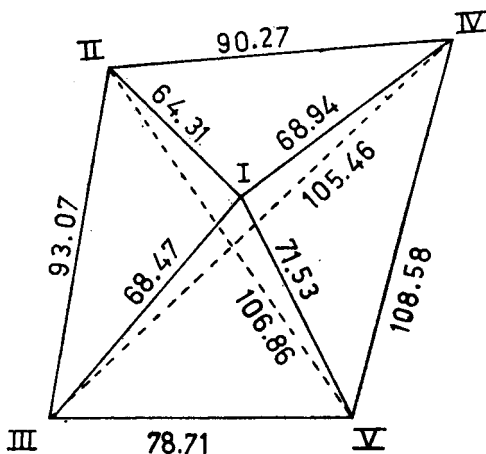


Fig. 1. Cluster diagram. The values are $\sqrt{D^2}$.

IV consisting of selections eight and nine showed higher mean values for most of the vegetative characters (total length and number of nodes on longest primary, length, breadth and area of largest leaves), while selections in cluster II (Cioccie, Sln. 6 and Sln. 10) were characterised by longer internodes, bolder fruits and higher fruit weight. Cluster V constituting a single selection (Sln. 11) was characterised by smaller leaves and fruits.

The characters, total length of longest primary, number of nodes and internodal length on longest primary, maximum leaf area, fruit volume and fruit weight were found to be more important for distinguishing selections as measured by their ranking in relation to total divergence (Table 4). The rest of the characters like maximum leaf length and breadth, fruit length, breadth and thickness were relatively less important.

DISCUSSION

The grouping of 17 *Coffea arabica* selection into five clusters is indicative of considerable genetic diversity prevailing among them. While cluster I was the largest comprising nine cultivars, the remaining eight cultivars diverged into four clusters. This apparently shows that the cultivars in cluster I could be considered nearer to the typical *arabica* phenotype while the rest of the cultivars are deviating from it to different degrees. Considering Hibrido-de-Timor (Sln. 8) and its crosses, the cross with Bour-

Table 2. Average and range of intra- (underlined>) and intercluster D^2 values

Cluster	I	II	III	IV	V
I	1907.96 <u>(376.22-</u> 4501.33)	4135.55 <u>(1857.20-</u> 8661.50)	4688.21 <u>(1669.84-</u> 6764.30)	4752.70 <u>(1341.02-</u> 8724.30)	5115.95 <u>(3042.91-</u> 7004.76)
II		<u>1978.53</u> <u>(874.89-</u> 2641.34)	8663.22 <u>(6420.83-</u> 11465.39)	8148.48 <u>(5247.94-</u> 11863.77)	11419.78 <u>(10016.42-</u> 13615.13)
III			<u>1389.00</u> <u>(1389.00)</u>	11120.96 <u>(8219.78-</u> 14868.73)	6195.72 <u>(5758.63-</u> 6632.82)
IV				<u>2163.23</u> <u>(2163.23)</u>	11789.60 <u>(8415.68-</u> 15163.53)
V					<u>0.0000</u> <u>(0.00)</u>

Table 3. Character means of clusters

Cluster	1	2	3	4	5	6	7	8	9	10	11
	Length of primary (cm)	Number of nodes	Internodal length (cm)	Leaf length (cm)	Leaf breadth (cm)	Leaf area (cm ²)	Fruit length (cm)	Fruit breadth (cm)	Fruit thickness (cm)	Fruit volume (cm ³)	Single fruit weight (g)
I	141.88	29.33	4.89	19.11	8.05	97.00	1.50	1.30	1.17	2.34	1.51
II	121.60	20.47	5.98	19.12	8.79	106.23	1.63	1.43	1.22	2.83	1.76
III	92.00	32.60	4.01	16.54	8.55	88.91	1.49	1.32	1.21	2.37	1.48
IV	194.80	37.20	5.24	21.50	8.98	121.68	1.53	1.38	1.20	2.51	1.75
V	144.60	32.60	4.44	15.04	5.79	54.86	1.50	1.25	1.03	1.93	1.19
Grand mean	138.98	30.44	4.91	18.26	8.03	93.74	1.53	1.34	1.17	2.40	1.54

Table 4. Contribution of each character to divergence

Character	Length of primary nodes	Number of nodes	Inter-nodal length	Leaf length	Leaf breadth	Leaf area	Fruit length	Fruit breadth	Fruit thickness	Fruit volume	Fruit weight	Total
No. of times appearing first in ranking	25	27	32	—	1	27	—	—	—	14	10	136
Per cent contribution	18.38	19.85	23.53	—	0.74	19.85	—	—	—	10.29	7.35	100.00

bon, Geisha and S. 12 Kaffa converged under cluster I while the cross with Tafarikela (Sln. 9) alone grouped with it in cluster IV. This shows that Sln. 9 is more like Sln. 8 compared to other crosses with Hibrido-de-Timor.

High divergence was found between clusters II, IV and V indicating the existing scope for further improvement of *Coffea arabica* through hybridisation among selections from these clusters. The character means of these clusters were also superior. The total of six varieties (Cioccie, Sln. 6, 8, 9, 10 and 11) constituting these clusters may be crossed in diallel to fashion to evaluate their combining ability and study the extent of heterosis.

Fournier (1973) considered a number of characters for distinguishing *arabica* cultivars. Orozco and Nieto (1972) found that the branch angle, size of fruit disc, number of fruits per glomerule and leaf size were more important for distinguishing varieties. The present study shows that the important characters for distinguishing varieties are length of primary, number of nodes and internodal length, leaf size, fruit volume and weight.

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PATH COEFFICIENT ANALYSIS FOR YIELD IN EAST COAST TALL COCONUT

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ABSTRACT

Path coefficient analysis was carried out in a population of East coast cultivar of coconut to identify characters which have direct and indirect influences on yield. Among the 12 characters studied, positive direct effects of a number of functional leaves, number of branches with nuts and number of leaflets on yield indicate the importance of these characters in the selection programme in East Coast Tall Coconut.

INTRODUCTION

Heritability estimates in different yield groups of coconut have indicated that the parameters were high for the number of female flowers, yield of nuts and percentage set (Nambiar and Nambiar, 1970). Analysis on the pattern of genetic variation for reproductive characters and its impact on yield potential have shown that selection of genotypes with low variance of distribution of female flowers, and greater number of spikes with one female flower tend to reduce instability in production and increase productivity (Nambiar et al., 1970; Nambiar and Ravindran, 1974). A study on the phenotypic and genotypic variability in 25 cultivars and hybrids has shown that the number of leaves per year, number of leaves on the crown, number of spathes per year, number of female flowers per palm, setting percentage and

number of nuts have a high genetic advance and these characters were recommended for exercising selection (Louis, 1981). Path coefficient analysis for yield of nuts during stabilised period of yield showed that the major contributing characters which influenced yield directly or indirectly are the average number of female flowers, number of functioning leaves at 19 years and internodal distance at a fixed mark. These characters influenced the yield indicating their value in selection (Sukumaran et al., 1981).

An attempt has been made in this paper, to identify the characters which have direct and indirect effects in influencing the nut yield in "East Coast Tall" cultivar of coconut which is traditionally grown in Tamil Nadu with the objective of making use of them as reliable criteria for selection of mother palms.

MATERIALS AND METHODS

Coconut gardens in farmers' holdings were selected at ten locations in Thanjavur district. The age of the palms ranged between 25 and 40 years. Five palms were chosen at random in each location and observations were recorded on the following characters.

- X : Number of nuts/palm/annum
- X1 : Number of functional leaves
- X2 : Number of bunches with buttons
- X3 : Number of bunches with nuts (above size)
- X4 : Length of petiole (cm)
- X5 : Length of leaflet bearing portion of leaf (cm)
- X6 : Number of leaflets on one side
- X7 : Length of middle leaflet (cm)
- X8 : Girth of trunk 1 m above ground (cm)
- X9 : Mean length of inflorescence (cm)
- X10 : Mean length of spikelet (cm)
- X11 : Number of spikelets
- X12 : Number of female flowers/spadix

Phenotypic correlation coefficients were worked out, and the direct and indirect effects of different characters on the nut yield were assessed.

RESULTS AND DISCUSSION

Phenotypic correlation coefficients are presented in Table 1.

Table 1. Phenotypic correlation coefficients in coconut

Characters	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	Y
X1	-0.125	0.438**	0.322*	0.309*	0.069	0.22	0.145	0.334*	0.201	0.120	-0.133	0.375**
X2		-0.427**	0.025	0.048	0.204	0.007	-0.024	-0.134	0.894**	-0.072	0.262	0.123
X3			0.198	0.077	0.001	0.301*	0.142	0.377**	-0.070	0.277*	-0.398**	0.237
X4				0.466**	0.321*	0.282*	0.239	0.357**	0.464**	0.277*	0.177	0.214
X5					0.483**	0.629**	0.381**	0.253	0.176	0.058	0.216	0.139
X6						0.387**	0.132	0.179	0.249	-0.185	0.115	0.214
X7							0.333**	0.323*	0.089	0.110	0.142	0.084
X8								0.385**	0.107	0.093	0.093	0.045
X9									0.411**	-0.069	-0.897**	0.109
X10										-0.071	0.149	0.054
X11											-0.010	0.255
X12												0.173

*Significant at 0.05 level. **Significant at 0.01 level.

Among the characters studied, nut yield was found to be associated with the number of functional leaves, the value of r being 0.375. All other characters did not show significant relationship with nut yield. The number of functional leaves was found to be associated with: (a) number of bunches with nuts; (b) length of petiole; and (c) length of leaflet-bearing portion of leaf indicating the importance of the number of functional leaves in the selection programme.

Other characters which showed significant and positive correlation were:

1) Number of bunches with buttons associated with length of spikelets;

2) Number of bunches with nuts associated with length of middle leaflet, length of inflorescence and number of spikelets;

3) Length of petiole associated with length of leaflet-bearing portion of leaf, number of leaflets on one side, length of middle leaflet, length of inflorescence, length of spikelets and number of spikelets;

4) Length of leaflet-bearing portion of leaf associated with the number of leaflets on one side, length of middle leaflet and girth of trunk at 1 m height;

5) Number of leaflets on one side associated with length of middle leaflet;

6) Girth of trunk associated with the length of inflorescence; and

7) Length of inflorescence associated with length of spikelets.

Significant negative correlations were observed between the number of female flowers per spadix on one hand and the number of bunches with nuts, and, the length of inflorescence on the other hand.

Correlation coefficients indicate an existing relationship between two different traits and the correlated response in selection programmes when one of them is considered for selection. However, selection of genotypes is likely to be influenced by simultaneous responses in the positive and negative directions of all the component characters with which the yield or any other dependent trait is associated. The path analysis suggested by Dewey and Lu (1959) is one of the best methods used by different workers to predict the effect of selection based on an independent character with reference to its dependent character.

Table 2. Direct and indirect effects of different characters on nut yield of coconut (phenotypic values)

Character	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	Total correlation with yield
X1	<u>0.353</u>	-0.023	0.128	-0.205	-0.012	0.019	-0.048	-0.005	0.015	-0.015	0.027	-0.044	0.375
X2	-0.044	<u>0.183</u>	-0.125	-0.002	-0.002	0.056	-0.002	0.001	-0.006	-0.006	-0.016	0.086	0.123
X3	0.155	-0.078	<u>0.293</u>	-0.013	-0.003	0.001	-0.066	-0.005	0.017	0.005	0.061	-0.130	0.237
X4	0.113	0.005	0.058	-0.064	-0.017	0.089	-0.061	-0.009	0.016	-0.034	0.061	0.058	0.214
X5	0.109	0.009	0.023	-0.028	-0.039	0.133	-0.137	-0.012	0.012	-0.013	0.013	0.071	0.138
X6	0.024	0.037	0.0002	-0.021	-0.019	<u>0.276</u>	-0.084	-0.004	0.008	-0.018	-0.023	0.037	0.214
X7	0.070	0.001	0.009	-0.018	-0.025	0.107	-0.217	-0.010	0.015	-0.007	0.024	0.047	0.084
X8	0.052	-0.044	0.042	-0.018	-0.015	0.036	-0.072	-0.032	0.014	-0.008	0.021	0.031	0.045
X9	0.117	-0.025	0.110	-0.023	-0.010	0.049	-0.070	-0.010	<u>0.046</u>	-0.030	-0.015	-0.032	0.109
X10	0.071	0.017	-0.021	-0.030	-0.007	0.069	-0.019	-0.004	0.019	-0.074	-0.016	0.049	0.054
X11	0.043	-0.013	0.081	-0.018	-0.002	-0.030	-0.024	-0.003	-0.003	0.005	<u>0.221</u>	-0.003	0.255
X12	-0.047	0.048	-0.117	-0.011	-0.008	0.031	-0.031	-0.003	-0.004	-0.011	-0.002	<u>0.328</u>	0.373

Note: Underlined figures are direct effects.

Direct and indirect effects of different characters on nut yield of coconut are presented in Table 2. Among the 12 independent characters studied, direct effects of the characters, number of functional leaves (0.353), number of bunches with nuts (0.293), number of leaflets on one side (0.276), and number of female flowers per spadix (0.328) were positive and high indicating the importance of these characters in the selection programme of coconut (East Coast Tall cultivar). The character, number of bunches with nuts was found to have an increasing effect on all the other characters. Thus, the direct effect of the character number of functional leaves (0.353) has been enhanced to result in a correlation value 0.375. Similarly the character, number of leaflets on one side also had an increasing effect on different characters. Hence in a selection programme in East Coast Tall coconut, it would be worthwhile to consider the characters: (1) number of functional leaves; (2) number of bunches with nuts; and (3) number of leaflets on one side. Though the character number of female flowers per spadix exerted a positive direct effect, its effect through many other characters is negative, thus resulting in a reduction of its strength of association with nut yield.

Among the twelve characters studied, four traits namely: (1) length of petiole; (2) length of leaflet-bearing portion of leaf; (3) length of middle leaflet; and (4) length of spikelets, tend to reduce the positive effects of other traits indirectly besides exerting considerable negative direct effects on nut yield and hence will be disadvantageous.

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DISCUSSION

- Q : Are morphological characters useful in selection programme?
- Ans: In this experiment I have correlated the morphological characters with the nut yield so as to arrive at selection indices.
- Q : Have you recorded the various parameters from a well planned experiment?
- Ans: No. The observations were recorded from farmer's field.
- Q : Were all the trees observed of the same age group?
- Ans: No. Age was different. I have studied the direct and indirect effect on the nut yield only.

ALLOPOLYPLOIDISATION IN A SPONTANEOUSLY DOUBLED HYBRID OF TWO DIPLOID SPECIES OF *COFFEA*

A.G.S. REDDY, K.V.V.S. RAJU and P.S. DHARMARAJ

ABSTRACT

A spontaneously doubled hybrid (S. 2464) of *Coffea liberica* and *C. eugenioides* has regular bivalent formation with some quadrivalents and secondary association of bivalents. Genome homology of the genus *Coffea* and self-fertility in relation to tetraploidy has been discussed. The amphidiploid named 'Ligenioides' is suggested to be related to the progenitor of *C. arabica* and as such of interest for breeding of *C. arabica*.

INTRODUCTION

Spontaneous interspecific hybrids involving tetraploid ($2n=44$) and diploid species ($2n=22$) (Cramer, 1957; Windle, 1933; Ramanathan et al., 1951; Vishweshwara and Govindarajan, 1970) and between the diploid species of *Coffea* (Sybenga, 1960; Singh et al., 1963) have been on record in Brazil, India and Indonesia. The origin of such allotetraploid hybrids involving *C. arabica* ($2n=44$) as one of the parents has been attributed to the participation of unreduced gametes in fertilisation (Sybenga, 1960). A few hybrids both at diploid level as 'congusta' (Cramer, 1957) and at tetraploid level as 'Devamachy' and 'Hibrido-de-Timor' (HDT) (Ramanathan et al., 1951; Vishweshwara and Govindarajan, 1970), are productive and promising.

Natural allotetraploids from diploid species are not documented in *Coffea*, and even if found in nature they might have escaped notice (Singh et al., 1963). A single instance, however, of a natural allotetraploid from the diploid hybrid (F_1) of *C. liberica* and *C. eugenioides* has been recorded in India (Narasimhaswamy and Vishweshwara, 1961, 1967). Its morphology, cytology and fruiting pattern in detail are presented here.

MATERIALS AND METHODS

The hybrid under study is the first generation clonal progeny of the original tetraploid sucker found on a diploid F_1 of two diploid species, *C. liberica* and *C. eugenioides* at CCRI, Chickmagalur and maintained under major selection No. 11 as S. 2464. Contrasting features of the two species and their F_1 (C. 1721) have been recorded elsewhere (Reddy, 1976; Reddy and Narayan, 1981). The performance of this hybrid is under observation at the Regional Coffee Research Station, Raghavendranagar, Andhra Pradesh, where the material was introduced in 1976 in a 0.25 ha plot.

Microsporogenesis in the hybrid was induced in the flower buds on cut twigs during February, 1982 following the usual procedure (Reddy, 1976). The anthers at 41 and 42 h after moisture treatment were fixed in farmer's fixative for diakinesis and metaphase-I respectively. Meiotic chromosome preparations were obtained by adopting the procedure described earlier (Reddy, 1976).

Data on cytomorphology of *C. liberica*, *C. eugenioides* and their F_1 (Reddy, 1976; Reddy and Narayan, 1981) have been presented for comparison.

RESULTS AND DISCUSSION

A spontaneous allotetraploid, 'Campinas 387' originated from *C. arabica* and *C. dewevrei* ($2n = 22$) (Krug et al., 1950), was found to have one genome of *arabica* and two of *dewevrei* and was self-sterile. In Indonesia, natural tetraploid hybrids between *liberica* and *arabica* (Cramer, 1957) had apparently a double set of *liberica* chromosomes and were relatively fertile. General morphological appearance of these hybrids was stated to be

intermediate between the parents. The present material (S. 2464), has originated from somatic duplication of highly infertile diploid F_1 ($2n = 22$) of the two morphologically and geographicaly distinct, diploid and cross-fertile species *liberica* and *eugenioides*. The phenotype of the hybrid appeared like an enlarged *eugenioides* to be more towards *C. arabica* in qualitative and quantitative characters of leaf, flower and fruit (Table 1).

The hybrid exhibited regular bivalent and some quadrivalent formation in 43.08 per cent of the cells at diakinesis (Table 2), whereas only 45.94 per cent of the cells showed chromosome pairing through bivalents in the diploid F_1 (Reddy, 1976). The occurrence of a quadrivalent in as many as 43.08 per cent of 130 cells clearly indicates that there is enough homology between the two species to lead the homologous chromosome association (Elci and Sybenga, 1976). There was a considerable rise in the number of cells with univalent pairs and some increase in the frequency of bivalents at metaphase-I with a corresponding reduction in cells showing quadrivalents.

The frequency of chiasmata at diakinesis and metaphase-I sometimes reached four in a bivalent (Table 3). Bivalents with four chiasmata were also observed in *liberica* (Reddy, 1976; Reddy and Narayan, 1981).

Secondary associations of two bivalents were invariably noticed in 79.79 per cent of the cells at diakinesis and pro-metaphase indicating genome homology between the diploid parent species. This agrees well with the general genome homology observed within the genus *Coffea* (Reddy and Narayan, 1981).

Pollen sterility almost corresponded with the per cent meiotic abnormalities (19.80 per cent) and resembled that of *liberica* (Table 4). Fruit fertility of the hybrid however reached 54.9 per cent (Reddy et al., 1981). This shows that S. 2464 is less balanced as an allopolyploid, unlike *arabica* with reduced incidence of multivalents and at regular meiosis (Chinnappa, 1968). Since the observations pertain to the first generation of the clonal progeny of S. 2464, it remains to be seen whether full fertility is obtained in advanced generations. The fertility observed constitutes both self-fertility and cross-fertility with *C. arabica* and diploid *robusta*. On reciprocal crosses, the fertility of the hybrid was found between 40.2 to 52.0 per cent and 37.0 per cent respectively (unpublished data). Self-fertility in the hybrid was

Table 1. Morphological characters of S-2464 in relation to its parents and in comparison with *C. arabica*

Morphological characters	<i>C. liberica</i> (2n = 22)	<i>C. eugenioides</i> (2n = 22)	<i>C. 1721</i> (2n = 22) (F ₁)	<i>Allotetraploid</i> S. 2464 (2n = 44)	<i>C. arabica</i> var. 'Agaro' (2n = 44)
Leaf length (cms)	26.5 (21.8-29.5)	7.2 (6.2-8.0)	13.5 (12.7-16.0)	14.0 (9.5-17.6)	15.9 (13.0-19.5)
Leaf breadth (cms)	12.3 (9.6-15.0)	2.53 (2.2-3.0)	5.4 (5.0-6.0)	5.9 (3.4-8.0)	6.5 (5.0-7.5)
Base angle (o)	90.3 (72-112)	60.7 (52-70)	73.0 (62-82)	77 (51-103)	75.3 (62.0-90.0)
Shape and texture of leaf	Elliptical obovate obtuse-entire sub- wavy glabrous sub- coriaceous	Linear-elliptical obovate sub- acute tip sub- wavy to entire subcoriaceous	Linear-elliptical obovate sub-acute apex, entire sub- wavy sub-coria- ceous	Elliptical with sub-acute leaf- tip wavy mar- gin sub-coria- ceous	Elliptical to obovate sub- acute leaf-tip wavy margin- glabrous sub- coriaceous
Leaf-tip length (cms)	—	0.8 (0.7-0.9)	0.55 (0.5-0.6)	1.35 (0.5-2.1)	1.31 (0.5-2.0)
Flower spread (cms)	4.95 (4.29-5.60)	2.78 (2.23-3.32)	4.0 (3.8-4.2)	2.2 (1.8-2.5)	2.48 (2.0-3.0)
Pistil length (cms)	3.13 (2.57-3.69)	2.13 (1.64-2.62)	3.07 (3.0-3.14)	1.7 (1.2-2.1)	2.58 (2.0-3.0)
Flower length (cms)	3.64 (3.18-4.11)	2.10 (1.72-2.48)	3.16 (3.00-3.22)	2.2 (1.6-2.5)	2.40 (1.8-2.7)
Flowers/node	26 (8-44)	6 (1-12)	8 (1-15)	9 (1-26)	16 (8-22)
Fruits/node	6 (5-8)	5 (2-8)	—	7 (5-10)	5 (2-9)
Fruit wall colour	Red-yellowish red	Red to red- yellow-red	Red, red-yellow- red	Orange red	Dark orange red

ALLOPOLYPLOIDISATION IN COFFEA

Fruit volume	3.34	0.5	1.5	0.93	1.34 (0.61-1.59)
Both colour	Yellow	Yellow-green yellow	Yellow-green yellow	Green-yellow	Light yellow green
Petiole length (mm)	20.5 (16.2-24.8)	5.1 (3.0-7.2)	10.1 (9.0-11.2)	6.0 (3-11)	6.3 (3-15)
Internode length (cms)	10.05 (7.4-12.7)	4.0 (3.3-4.7)	7.1 (5.2-9.0)	4.0 (2.5-5.5)	4.21 (2.8-5.8)
Pollen fertility	63.38	90.63	15.46	(40.88-70.0)	65.28 (64-75.0)

() value in parentheses denote range.

Table 2. Chromosome associations at different meiotic stages in *S. 2464*

Association	Univalents		Bivalents		Quadrivalents		Total cells scored
	Range (Mean)	Per cent cells	Range (Mean)	Per cent cells	Range (Mean)	Per cent cells	
Diakinesis	0-4 (2)	15.38	16-22 (19)	41.54	0-3 (1.5)	43.08	130
Metaphase I	0-4 (2)	40.00	18-22 (20)	42.70	0-1 (0.5)	17.30	110

Table 3. Range and mean distribution of chiasmata and its pattern in different meiotic stages of *S. 2464*

Meiotic stage	Number of Bivalents with				Number of univalent pairs	Total cells scored
	1-Chiasmata	2 Chiasmata	3-Chiasmata	4-Chiasmata		
Diakinesis	3-16 (9.06)	6-16 (11.19)	0-3 (1.45)	0-1 (0.05)	0-2 (0.25)	73
Metaphase I	8-17 (12.4)	1-13 (8.4)	0-2 (0.7)	—	0-2 (0.5)	73

Table 4. Abnormalities at meiotic and post-meiotic stages in *S. 2464*

Stage	Abnormalities (%)	Number of cells scored
Meiosis I*	21.83	600
Meiosis II*	30.00	400
Pollen **	19.80	300
Pollen sterility	22.8—59.1	4675

*Anomalies such as univalent pairs, division of univalents, non-disjunction, laggards and persistent bivalents at AI, TI and interphase.

Unequal distribution, precocious movements, laggards in A II and their persistence in T II.

**Occurrence of monads, triads, pentads and polyads.

found to an extent of 34.7 to 39.6 per cent (Reddy et al., 1981). Self-fertility has invariably been found in all spontaneous and evolved tetraploid hybrids (Sybenga, 1960; Reddy et al., 1981). In view of the great morphological resemblance and seasonal reproductive stability of this 'Ligenioides' (*Liberica eugenioides*) hybrid, it may be closely related to the primitive allopolyploid, from which *C. arabica* has developed, as such it is likely to be promising for introducing new genetic variability into *C. arabica*.

The 'Ligenioides' hybrid studied is yet another sure pointer to the fact that alloploidy rather than autopoloidy has played a significant role in the origin and speciation of new coffee forms with higher chromosomes.

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DISCUSSION

Q : Do you think that self-fertility in relation to tetraploidy is useful?

Ans: Yes, because it has played a significant role in the origin of coffee.

ESTIMATION OF LEAF AREA IN ONE-YEAR-OLD CARDAMOM PLANTS

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K. VIJAYA KUMAR and S. BHAGAVAN

ABSTRACT

The area (P) of any individual leaf of a one-year-old cardamom seedling can be estimated by a linear function $P = 0.813B + 0.657 L.B.$ ($R^2 = 0.984$) where L and B are the length and breadth of the leaf. The total functioning leaf area (Y) of a tiller with 'n' leaves can be estimated by a linear function $Y = -3.168 L + 33.464 n b$ ($R^2 = 0.976$) where 'n' is the total number of functioning leaves in the tiller and L and B are the linear measurements of median leaf. Further, the total functioning leaf area (A) of a whole clump consisting of several tillers can be estimated by a linear function. $A = 11.935 L + 22.3 N.B$ ($R^2 = 0.979$) where 'N' is the total number of leaves in the clump and L and B are the linear measurements of the median leaf of tiller having the maximum number of leaves.

INTRODUCTION

The importance of leaf area concept in crop physiology is well known. Due to the cumbersome and destructive nature of the procedure for leaf area measurements, which also involves destroying the leaves, non-destructive estimation procedures have been suggested in several crop plants (Krishnamarar and Pappachan, 1964; Palaniswamy and Gomez, 1974; Tejwani et al., 1957; Spencer, 1962; Narasimhayya and Murthy, 1977; Arkel, 1978). In this paper a non-destructive method to estimate leaf

area in cardamom is proposed, based on linear measurements of a leaf.

MATERIALS AND METHODS

Twenty, one-year-old clumps of Malabar cultivar of cardamom with a total of 55 tillers were used for this study. The number of leaves per tiller varied from four to ten. The actual areas of individual leaves were measured using a Li-COR model electronic area meter. Four different regression equations of the form:

$$P_i = b_1 L + b_2 B$$

$$P_i = b_1 L + b_2 L.B.$$

$$P_i = b_1 B + b_2 L.B.$$

$$P_i = b_1 L + b_2 B + b_3 L.B.$$

were fitted to estimate the individual leaf area of any leaf. L and B refers to the usual notations of length and breadth, P_i denotes the estimated leaf area and b_1 is the regression coefficient.

In order to study the positional effect of the leaves, separate regression equations were fitted for the first five leaf positions from the top and were tested for parallelism. The pooled regressions were also worked out for any leaf position.

To estimate the total leaf area (TLA) (A) of any tiller and total leaf area (TLA) (Y) of the whole clump based on linear measurements of any specified leaf, the following regression equations were fitted separately for tillers and clumps:

$$TLA = b_1 n + b_2 L$$

$$TLA = b_1 n + b_2 B$$

$$TLA = b_1 n.L + b_2 B$$

$$TLA = b_1 n.B + b_2 L$$

$$TLA = b_1 n + b_2 L.B.$$

In the case of TLA (A) for tillers, 'n' refers to the total number of leaves in the tiller, and L and B are the linear measurements of the median leaf of the tiller, whereas in the case of TLA (Y) for clump, 'n' refers to the total number of leaves in all the tillers of the clump and L and B the linear measurements of the median leaf of the tiller having the maximum number of leaves. $\frac{n}{2}$ th leaf or $\frac{(n+1)}{2}$ th leaf from the top is

considered as the median leaf, depending on whether the number of leaves (n) is even or odd.

RESULTS AND DISCUSSION

A perusal of Table 1 shows that the area of any individual leaf from any position can be estimated with a high degree of precision by measuring its length and breadth (R^2 varying from 0.938 to 0.995). The regressions for different leaf positions were found parallel except in the first case where linear measurements of L and B alone were considered (Table 2). Pooling the regression equations (Table 3) the area of any individual cardamom leaf from any position can be estimated with reasonably good precision (0.984). It is seen from Tables 1 and 3 that all the three sets of regressions have almost the same degree of precision in estimating the leaf area (P) and hence there is no additional gain in taking the three variables, namely L , B and $L.B$. Any of the variables L or B and its products were found to give an equally precise estimate of the leaf area.

The total functioning leaf area of any tiller TLA (Y) can be estimated by counting the number of leaves (n) in the tiller, measuring the length (L) and breadth (B) of the median leaf and using the equations given in Table 4. The equation TLA (Y) = $-3.168 L + 33.464 n B$ gives a very precise ($R^2 = 0.976$) estimate of the total leaf area of any tiller with n leaves.

Further, the total functioning leaf area TLA (A) of a whole clump consisting of several tillers can be estimated by counting the total number of leaves (n) in all the tillers of a clump, measuring the length and breadth of the median leaf from the tallest tiller (the tiller having the maximum number of leaves in the clump) and using the equations given in Table 5. A perusal of the Table 5 indicates that TLA (A) of a clump can be estimated reasonably precisely (R^2 0.97) simply by measuring the length or breadth of one leaf (median leaf from the biggest tiller) and counting the total number of leaves in the whole clump; even though the remaining equations give slightly more precise estimates, from the point of view of rapidity in estimation one might choose this equation (Table 5). Total leaf area TLA (Y) of the tiller can be estimated with a reasonably good degree of precision using the equation TLA (Y) = $67.099 n + 148.798$

Table 1. Multiple regression equations for estimating the leaf area (P) with length (L) and breadth (B) of the leaves

Equations	Leaf position					
	I	II	III	IV	V	
$A = b_1L + b_2B$	b_1	3.1455	2.4277	2.9384	-0.5278	-0.0650
	b_2	6.1009	12.5030	10.7239	35.2939	34.5447
	R^2	0.938	0.949	0.966	0.969	0.977
$A = b_1L + b_3LB$	b_1	-0.6311	0.1918	-0.1479	-0.2595	0.2090
	b_2	0.7534	0.6488	0.6969	0.7079	0.6556
	R^2	0.970	0.964	0.987	0.994	0.995
$A = b_1B + b_3LB$	b_1	-0.0254	6.5442	0.8401	-3.6135	0.4232
	b_2	0.6581	0.5176	0.6569	0.7469	0.5754
	R^2	0.969	0.966	0.987	0.994	0.995
$A = b_1L + b_2B + b_3LB$	b_1	-0.9441	-0.6508	-0.2463	0.1177	0.3546
	b_2	2.1885	7.8113	1.3198	-4.4705	-2.2703
	b_3	0.7438	0.5828	0.6818	0.7484	0.6807
	R^2	0.970	0.967	0.987	0.994	0.995

Table 2. Summary of anova table (M.S.S.) of pooling regressions over the five different leaf positions

Source	Equation			
	$Y = b_1L + b_2B$	$Y = b_1L + b_2L.B.$	$Y = b_1B + b_2L.B.$	$Y = b_1L + b_2B + b_3L.B.$
Combined				
Reg.	2	4857671.69	5011270.46	5011156.04
Diff. of				
Reg.	8	12141.25*	329.62	919.31
Combined				
Res.	253	1469.55	628.82	611.08
				df
				3
				12
				248
				3341346.28
				659.51
				614.18

*Significant at 1 per cent level.

Table 3. Pooled regressions for estimating the leaf area (P) of any leaf of a cardamom plant

Equations	Regression Coefficients			R^2
	b_1	b_2	b_3	
$P = b_1L + b_2L.B$	-0.1138	0.6909	—	0.984
$P = b_1B + b_2L.B$	0.8127	0.6568	—	0.984
$P = b_1L + b_2B + b_3L.B$	-0.2828	1.6913	0.6776	0.984

Table 4. Regression equations for estimating TLA (Y) in cm of a tiller with length (L) and breadth (B) of the median leaf (in cm)

Sl. No.	Equations	R ²
1.	TLA (Y) = 88.839 n + 18.751 L	0.911
2.	TLA (Y) = 67.099 n + 148.798 B	0.919
3.	TLA (Y) = -16.907 B + 4.928 nL	0.970
4.	TLA (Y) = -3.168 L + 35.464 nB	0.976
5.	TLA (Y) = 14.444 n + 4.3214 LB	0.969

n is the number of leaves in the tiller.

Table 5. Regression equations for estimating TLA (A) in cm² of a clump with length (L) and breadth (B) in cm of the median leaf of the tiller with maximum number of leaves

Sl. No.	Equations	R ²
1.	TLA (A) = 151.991 n + 18.948 L	0.970
2.	TLA (A) = 149.528 n + 128.809 B	0.970
3.	TLA (A) = 3.387 n.L + 85.347 B	0.977
4.	TLA (A) = 22.300 n.B + 11.935 L	0.979
5.	TLA (A) = 147.567 n + 2.692 L.B.	0.975

n is the total number of leaves in the clump.

B (R² = 0.919) (Table 4) when a little precision can be sacrificed for a quick estimate of the TLA (Y) with just one linear measurement, namely the breadth of the leaf. The above procedure can be very well extended for estimating the leaf area and the total functioning leaf area of other zingiberaceous plants (turmeric, ginger and *Amomum acrepelus*).

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DISCUSSION

Q : When leaf area meter is available, why one should go in for a comprehensive method like this?

Ans: This is a method to find out the leaf area by measuring length and width when there are practical difficulties in using leaf area meter.

Q : What is the practical utility of this experiment?

Ans: This non-destructive method gives total leaf area with reasonable degree of precision. The methodology can be extended to other plants of Zingiberacea.

VARIABILITY AND ASSOCIATION OF CERTAIN BARK ANATOMICAL TRAITS IN *HEVEA BRASILIENSIS* MUELL. ARG.

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JOSEPH G. MARATTUKALAM

ABSTRACT

Bark anatomical traits of 10 rubber clones (*Hevea brasiliensis* Muell. Arg.) were used to estimate various genetic parameters as well as association between them. The PCV estimates were generally higher than the corresponding GCV values. Heritability was high for all the traits. Genetic advance ranged from very low to high. Based on the genetic parameters suitable breeding methods could be adopted for improvement of the tree.

INTRODUCTION

The latex producing capacity of the para rubber tree (*Hevea brasiliensis*) is influenced by the quantity of laticiferous tissue. The number of latex vessel rows, density of latex vessels per row per unit circumference, diameter of latex vessels and the girth of the tree are factors influencing productivity.

Genetic parameters, as well as the intercharacter association of yield and yield attributes, in the para rubber tree have received attention only recently (Huat, 1981; Alike and Onokpise, 1982; Hamzah and Gomez, 1982). Of the anatomical traits, bark thickness and the number of latex vessel rows have been studied by various workers (Bobilioff, 1923; Gomez et al., 1973; Narayanan and Ho et al., 1973). In the present paper an attempt has

been made to study the intercharacter association and genetic parameters of certain anatomical traits influencing yield.

MATERIALS AND METHODS

Data were collected from 30 trees involving ten clones of *Hevea brasiliensis* planted in a randomised block design with three replications. Samples of virgin bark at a height of 150 cm from the bud union were collected from trees at the age of nine and fixed in FAA. Sections (80 μ m thickness) in the tangential plane were cut from the soft bark region, stained in Sudan III and observed under light microscope. The characters studied were ray height, ray width, ray density, latex vessel density per row per unit circumference of the tree, latex vessel diameter and number of anastomeres per unit length. Genotypic and phenotypic coefficients of variation (GCV and PCV) were estimated. The heritability and genetic advance were calculated as per the standard procedures. Genotypic and phenotypic correlations among the various traits were estimated as per the method of Al-Jibouri et al. (1968).

RESULTS AND DISCUSSION

The estimates of genetic parameters for the different traits are presented in Table 1. The PCV estimates were higher for all the traits than the corresponding GCV values. Among the various traits studied, ray height had the highest GCV and PCV estimates, followed by density of ray groups and latex vessel diameter.

The comparatively high PCV signifies the involvement of environment in the expression of these traits. Heritability (broad sense) was very high for all traits except for ray width for which it was medium. The genetic advance ranged from 0.243 for density of ray group to 103.65 for ray height at 5 per cent selection intensity. Except for ray height all other traits had low or moderate genetic advance along with high heritability estimates. This indicates the predominant involvement of non-additive gene effects in the expression of these traits, whereas the variability for ray height be due to additive gene effect (Johnson et al., 1955; Allard 1960).

The genotypic and phenotypic correlation coefficients are

Table 1. Mean, genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability and genetic advance for certain yield attributes in rubber (Hevea brasiliensis)

Characters	Mean	Genotypic variance	Phenotypic variance	GCV	PCV	Heritability (%)	Genetic advance (5 % selection intensity)
Ray height	336.23	3260.45	4161.10	17	19	78.36	103.65
Ray width	46.71	20.41	42.82	10	14	47.67	6.43
Latex vessel diameter	20.18	9.17	11.06	15	17	82.93	5.68
Number of connection for unit length	7.12	0.857	1.47	13	17	58.4	1.46
Density of vessel	27.16	3.41	5.28	7	8	64.6	3.06
Density of ray group	25.69	17.36	18.38	16	17	94.4	0.243

Table 2. Genotypic (rg) and phenotypic (rp) correlation coefficients among certain yield attributes (anatomical) in rubber (*Hevea brasiliensis*)

Ray height	Ray width	Latex vessel diameter	No. of connections per unit length	Density of vessel	Density of ray group
Ray height (rg)	0.280	0.09	-0.05	-0.27	-0.98**
(rp)	0.320	-0.33	0.08	-0.37	0.60
Ray width (rg)		0.38	-0.13	-0.89**	-0.54
(rp)		0.18	-0.10	-0.74*	-0.39
Latex vessel diameter (rg)			-0.28	0.12	0.12
(rp)			-0.17	-0.09	-0.87**
No. of connections per unit length of vessel (rg)				0.23	0.003
(rp)				-0.14	-0.007
Density of vessel (rg)					-0.37
(rp)					0.61

*p = 0.05. **p = 0.01.

presented in Table 2. Ray height had significant negative association with density of ray group at the genotypic level. Ray width also had negative association with density of ray group though not significant. But this trait had significant negative association with density of the vessel both at the genotypic as well as phenotypic levels. Latex vessel diameter had significant negative correlation with density of ray group at the phenotypic level. Thus it emerges that the density of the latex vessel was considerably affected by the ray width. Similarly latex vessel diameter was also significantly affected by the density of ray group. It was also revealed that the number of connections per unit length of the vessel were independent of the density as well as diameter of the latex vessel. Similarly, the latex vessel diameter was also independent of the density of the vessel. The negative association of ray width with the density of the latex vessel might be due to the effect of ray width on the running direction of the latex vessel. It may therefore be possible to select clones simultaneously for high density as well as greater diameter of latex vessels. Since ray width and density of ray group have a negative association with latex vessel density, selection for higher latex vessel density will naturally reduce the former traits leading to more straight laticifers. The negative association of vessel diameter with density of ray groups is also a desirable relationship. Higher vessel diameter will also contribute the laticiferous tissue per unit area.

However, since all the traits studied except ray height had shown a predominant influence of non-additive genetic variance, it would be advisable to exploit heterosis or utilise recombination breeding to improve rubber clones for these traits.

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DISCUSSION

Q : Can polyploidy be used for improvement of *Hevea* clones for the traits studied?

Ans: All the traits studied, except ray height, had shown predominant influence of non-additive genetic variation. So we cannot expect any change by alteration of gene dosage. So polyploidy has little breeding value as far as the traits studied.

FOLIAR ANATOMY OF SOME SPECIES AND HYBRIDS OF COFFEE

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M.S. SREENIVASAN

ABSTRACT

Foliar anatomical characters in 14 species of *Coffea* L. namely, *C. arabica* L., *C. canephora* Piere ex-Frochner, *C. congensis* Frochner, *C. liberica* Bull. ex-Hiern., *C. excelsa* Chev., *C. dewevrei* De Wild. et. Durand, *C. stenophylla* G. Don, *C. racemosa* Lour., *C. zanguebariae* Lour., *C. salvatrix* Swynn. et. Phil., *C. kapakata* Hirsch., *C. bengalensis* Roxb. ex-Heyne, *C. khasiana* Hook., *C. travencorensis* Weight et. Arnott; and two hybrid lineages, SLN 3 and SLN 7 of *arabica* were described. Universal presence of Kranz syndrome in these materials was recorded. Differences in mesophyll thickness and degree of development of Kranz were explained as adaptations of evolutionary significance.

INTRODUCTION

A perusal of literature revealed that the earlier work on the foliar anatomy in the genus *Coffea* L. (Chevalier, 1947; Metcalfe and Chalk, 1957; Dedeca, 1957) is mostly centred on the midrib. Finer details of the reticulate veins are available only for *C. canephora* and *C. arabica* (Orzocco and Cassalet, 1974). These aspects assume great importance as the leaf is the site of photosynthetic processes. Differential adaptive value of foliar anatomical syndrome and its importance to photosynthesis in tropical plants is known (Laetsch, 1968, 1974; Downton, 1971; Evans, 1971). The

present study deals with the foliar anatomy of some species and hybrids of coffee.

MATERIALS AND METHODS

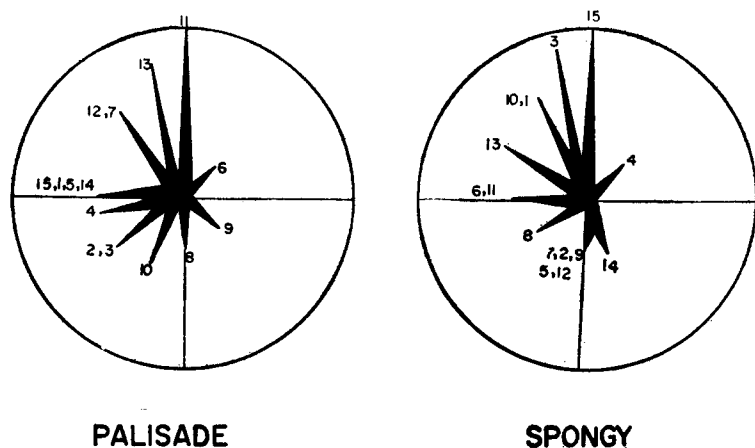
Fully expanded first and fourth pairs of leaves were collected from the parents and progenies of two selections of *C. arabica* L (SLN 3 and SLN 7—geneology chart) and the species: *C. canephora* Pierre ex-Frochner, *C. congensis* Frochner, (*Erythrocoffea*), *C. liberica* Bull. ex-Hietn., *C. excelsa* Chev., *C. dewevrei* De Wild et. Durand (*Pachycoffea*), *C. stenophylla* G. Don (*Melano-coffea*), *C. racemosa* Lour., *C. zanguebariae* Lour., *C. salvatrix* Swynn. et. Phil., *C. kapakata* Hirsch. (*Mozambicoffea*), *C. bengalensis* Roxb. ex-Heyne, *C. khasiana* Hook and *C. travencorensis* weight et. Arnott (*Paracoffea*), and were fixed in FAA. Further processing was done by the customary paraffin method (Johansen, 1940). Serial sections cut at 8–15 μ were stained in safranin-anilin blue and the slides were made permanent in a xylol-alcohol series (Johansen, 1940).

Comparative observations on the first and fourth pairs were taken only with reference to the differentiation of Kranz while all other observations pertain to the fourth pair of leaves. Observations were taken on the thickness of mesophyll components, number of cell layers, average diameter of palisade, spongy and Kranz cells, average number of chloroplasts per cell of spongy and Kranz cells and interveinal distance and lateral cell count. Observations on the thickness of spongy and palisade parenchyma layers were subjected to F-test (Sundararaj et al., 1972).

RESULTS

Species of *Coffea* In all the species studied, the differentiation of Kranz is similar in the first and fourth pairs of leaves. The arrangement of leaf tissues is dorsiventral and did not show any xerophytic characters. The midrib vascular strand is an open arc in the species *C. congensis*, *C. racemosa* (narrow leaves type NL), *C. travencorensis* and *C. khasiana*, whereas it is cylindrical in the rest of the species studied. Small accessory bundles were present towards the wings. It is interesting to note the anatomical features similar to the Kranz type (Moser, 1934; Naidu and Das,

1981) in the reticulate veins. A well-developed bundle sheath was present with chloroplasts in its cells. The shape and size of these chloroplasts were similar to those in the mesophyll cells. A tendency towards centripetal arrangement of chloroplasts was noted in the bundle sheath of *C. stenophylla* while in all other species it is centrifugal.



Scheme 1. Variability of mesophyll components species
 1. *C. excelsa*; 2. *C. liberica*; 3. *C. dewevrei*; 4. *C. canephora*; 5. *C. congensis*; 6. *C. stenophylla*; 7. *C. racemosa* BL; 8. *C. racemosa* NL; 9. *C. zanguebariae*; 10. *C. salvatrix*; 11. *C. kapakata*; 12. *C. bengalensis*; 13. *C. khasiana*; 14. *C. travencorensis*.

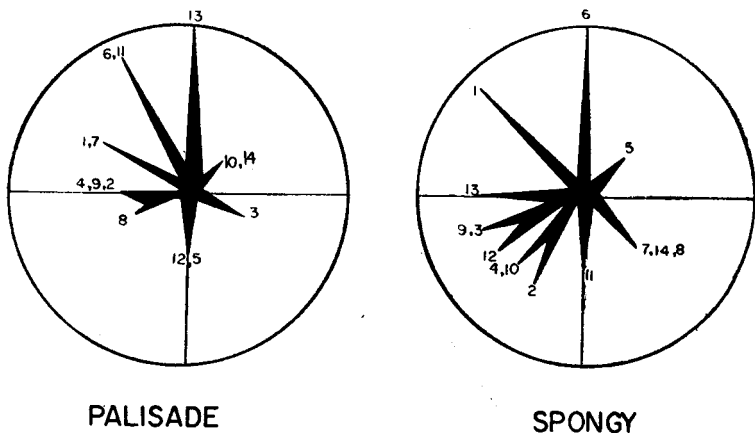
Significant variations in the thickness of mesophyll tissues were noted ($P < 0.01$). Palisade and spongy mesophyll exhibit independent variations among species (Table 1, Scheme 1). Two types of arrangement of spongy parenchyma tissue were observed among the species studied. In *C. canephora*, *C. congensis*, *C. dewevrei*, *C. stenophylla*, *C. racemosa* (broad leaved type BL), *C. salvatrix*, *C. kapakata* and *C. zanguebariae*, the spongy parenchyma is loosely arranged and the individual cells tend to produce arm-like outgrowths. The second group is characterised by a compact arrangement of more or less isodiametric parenchyma cells as in *C. liberica*, *C. racemosa* (NL), *C. bengalensis* and *C. travencorensis*. A somewhat intermediate condition of compact parenchyma with a tendency to produce arm-like outgrowths was observed

Table 1. Anatomical characters of some species of Coffea

Species	Mesophyll thickness (μ) (No. of cell layers)		Average cell diameter (μ)		Average No. of chloroplasts per cell		Intervinal distance (μ) (Lateral cell count)
	Palisade	Spongy	Palisade	Spongy	Kranz	Spongy	
<i>C. canephora</i>	7.11 (1 or 2)	15.88 (8.40)	2.12	2.73	2.47	11.00	13.02 (5.4)
<i>C. congensis</i>	5.23 (1 or 2)	7.17 (4.20)	2.26	2.32	2.38	7.80	16.87 (7.3)
<i>C. stenophylla</i>	11.05 (2)	28.98 (10.20)	2.21	3.44	2.88	7.20	13.55 (5.00)
<i>C. zanguebariae</i>	7.11 (1)	17.35 (8.20)	1.62	2.82	2.21	8.40	19.17 (8.30)
<i>C. kapakata</i>	10.70 (2)	13.41 (5.00)	2.15	3.29	3.29	15.20	33.08 (11.50)
<i>C. salvatrix</i>	3.59 (1)	15.11 (7.60)	1.65	2.21	1.91	27.20	22.87 (15.20)
<i>C. racemosa</i> (Broad leaf)	8.58 (1)	12.35 (6.00)	1.73	2.85	2.76	14.40	9.70 (3.70)
<i>C. racemosa</i> (Narrow leaf)	6.64 (1 or 2)	11.64 (4.60)	1.35	2.59	1.99	6.80	6.20 (3.70)
<i>C. liberica</i>	6.94 (2)	14.58 (9.00)	1.82	3.29	2.50	6.80	8.11 (4.50)
<i>C. deweyrei</i>	4.70 (1 or 2)	18.23 (9.20)	1.59	2.91	2.88	6.40	7.23 (1.09)
<i>C. excelsa</i>	8.41 (2)	25.28 (9.60)	1.88	3.50	2.70	8.80	9.53 (8.20)
<i>C. travencorensis</i>	3.53 (1)	12.05 (6.00)	1.53	2.50	1.85	7.80	6.82 (4.40)
<i>C. bengalensis</i>	5.47 (1 or 2)	17.16 (8.60)	1.88	3.18	2.85	6.20	11.11 (4.60)
<i>C. khasiana</i>	12.99 (2)	22.40 (7.60)	3.47	3.41	3.35	11.40	19.20 (5.70)
C.D. at 1%	1.95	4.54					

in *C. excelsa* and *C. khasiana*. The number of chloroplasts of Kranz cells was more than that of spongy cells in *C. stenophylla*, *C. excelsa*, *C. zanguebariae* and *C. bengalensis* while it was more or less equal in *C. racemosa* (NL), *C. liberica*, and *C. dewevrei* and it was less in others.

Hybrids of *Coffea*: Results in this section are pertinent to *arabica* types. Kranz differentiation in the first and fourth pairs of leaves was similar as among the species. Thickness of mesophyll has shown significant variations (Scheme 2). However, the pattern of arrangement is similar to that of the first group of species described earlier. Arm-like outgrowths of spongy cells are common features in all these hybrids. The number of chloroplasts of the Kranz cells is generally less than that of the spongy cells. However, equality of chloroplast numbers between Kranz cells and spongy cells was noted in S. 3755 and S. 3584.



Scheme 2. Variability of mesophyll components hybrids.

1. kents; 2. S. 288; 3. S. 26; 4. S. 474; 5. S. 795; 6. S. 1404; 7. S. 1934; 8. San Ramon; 9. Agaro; 10. Cioccie; 11. S. 2044; 12. S. 2491; 13. S. 2498; 14. S. 3584; 15. S. 3755.

Other characters such as interveinal distance, lateral cell count average diameter of palisade, spongy and Kranz cells did not show any large variations among either the species (Table 1) or hybrids (Table 2) studied.

Table 2. Anatomical characters of some hybrids of coffee (*C. arabica*)

Hybrid	Mesophyll thickness (μ) (No. of cell layers)		Average cell diameter (μ)		Average No. of chloroplasts per cell		Interveinal distance (μ) (Lateral cell count)
	Palisade	Spongy	Palisade	Spongy	Spongy	Kranz	
S.26	5.76 (1 or 2)	30.63(11.00)	2.15	3.76	3.53	5.32	13.73 (5.20)
S.288	5.97 (1)	21.46(8.20)	1.88	3.29	4.94	5.02	14.46(10.00)
Kents	6.41 (1)	26.34(9.40)	1.71	4.15	3.76	6.45	14.99 (4.40)
S.474	5.97 (1)	18.17(6.80)	1.71	3.56	3.06	6.18	13.47 (4.40)
S.795	6.73 (1)	20.93(7.40)	1.65	3.59	3.06	5.44	12.94 (4.30)
S.1404	4.88 (1)	23.46(7.40)	2.03	3.62	4.35	7.22	14.17 (6.30)
S.1934	7.35 (1)	21.58(7.00)	1.99	3.79	3.29	6.24	16.46 (4.80)
San Ramon	5.29 (2)	22.28(8.60)	1.94	3.88	2.65	4.50	10.29 (3.00)
Agaro	4.97 (1)	21.05(8.20)	1.94	3.70	2.94	6.44	16.85 (4.90)
Cioccie	5.97 (1)	26.52(9.00)	2.18	3.91	2.35	6.64	13.64 (5.60)
S.2044	10.29 (1)	23.46(7.40)	1.94	3.47	2.88	6.88	11.17 (3.60)
S.2491	7.41 (1)	20.82(6.80)	1.94	3.62	3.41	8.36	10.94 (3.10)
S.2498	7.70 (1)	25.23(9.20)	1.79	3.85	3.29	6.69	15.52 (4.40)
S.3755	6.73 (1)	31.52(9.80)	1.97	3.85	2.88	8.20	9.23 (3.00)
S.3584	6.73 (1)	20.23(7.00)	1.82	3.82	3.47	7.24	15.17 (3.50)
C.D at 1%	1.31	4.21					

DISCUSSION

Foliar anatomical characters in the species and hybrids of *Coffea* appear to be very homogeneous, as no large variations are encountered among the characters, interveinal distance, lateral cell count, average diameter of palisade, spongy and Kranz cells. This accounts for the relative homology of genetic structure within the genus (Carvalho and Monaco, 1967; Charrier, 1978). Adaptations are expressions of genes controlling specific characters in the appropriate environments (Ford, 1964). Certain anatomical characters observed can be explained as adaptations as follows:

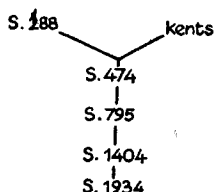
Variations observed in the thickness of mesophyll components are lacking taxonomic conformity or continuity. However, individual species in different subsections/sections of the genus *Coffea* have shown a tendency towards greater thickness of mesophyll components, which is a trend leading to succulent nature. This is an adaptation to the tropical environments in which coffee is grown. Therefore, it is logical to infer that the tendency to be succulent has occurred independently in different groups.

Kranz type anatomy of the reticulate vasculature observed in all species and hybrids is an interesting feature. Overall anatomical features observed in the various materials of the present study closely resemble those observed in *Mollugo verticillata* (Kennedy and Laetsch, 1974) which are intermediate between Kranz and non-Kranz species. The expression of Kranz is known to be an adaptive character in the tropical plants (Downton, 1971; Evans, 1971; Berry, 1974; Mansfield and Jones, 1976) and is a highly mutable condition susceptible to be triggered by a particular combination of environmental factors (Downton, 1971; Etherington, 1975). Thus, the presence of Kranz in these mesophytic plants can be an adaptation to the tropical climates where intermittent aridity generally prevails.

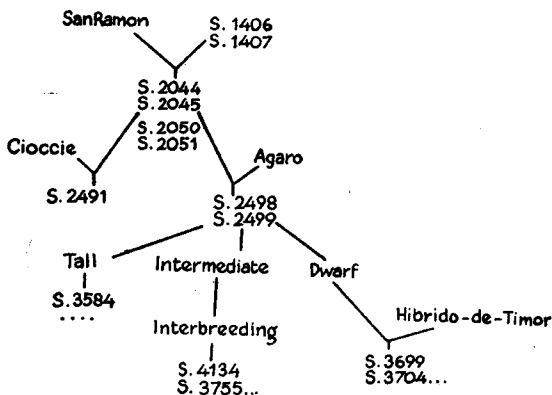
Coffee is classified to be a C_3 plant based on the effects of light, temperature and water stress on photosynthesis (Maestri and Barros, 1977; Kumar and Tieszen, 1980 a and b). But the Kranz seems to be a 'constitutive' character in the genus and offers the possibility of being exploited for producing types with greater photosynthetic productivity, as the Kranz species generally possess the C_4 carbon fixation pathway (Nobel, 1970; Slack, 1971; Bjorkman, 1971; Evans, 1971; Troughton, 1975; Mansfield and Jones,

1976). Specialisation of mesophyll cells associated with Kranz anatomy was reported by Kemp et al. (1983) in the grasses; similar specialisation was also observed in the present study. This is believed to be an adaptation for the efficient conductance of photosynthetic intermediates in the leaf tissues (Kemp et al., 1983).

Genealogy of SLN 3



Genealogy of SLN 7



The present data on the degrees of difference in the expression of Kranz in terms of the number of chloroplasts in Kranz cells among the species suggest an evolutionary trend as follows: Generally, well developed Kranz cells possess a larger number of chloroplasts than their mesophyll counterparts (Naidu and Das, 1981; Shrivastava et al., 1983). This condition is present in *C. stenophylla*, *C. excelsa*, *C. zanguebariae* and *C. bengalensis*. A condition approaching the above but with equality of chloroplast numbers was found in *C. dewevrei*, *C. liberica* and *C. racemosa*

(NL). The rest of the species possess a poorly developed Kranz. It is pertinent to state that hybrids did not possess a well developed Kranz anatomy even though a few of them show a tendency towards the equal number of chloroplasts in the Kranz and spongy cells.

The existence of different degrees of expression of Kranz syndrome in species and hybrids of coffee revealed in the present study offers the possibility of selecting types which are more efficient photosynthetically.

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DISCUSSION

Q : Does this study gives any information on the evaluatory trend?

Ans: Yes. In terms of number of chloroplast in krang cells.

Q : Is there any variation in differentiation of krang cells among hybrids and their parents?

Ans: No.

ROLE OF MAINTENANCE FOLIAGE IN TEA (*CAMELLIA* SPP.)

N. SATYANARAYANA and V.S. SHARMA

ABSTRACT

The effect of different depths of maintenance foliage on the yield of two tea cultivars was studied. A positive indication of an optimal depth of the foliage for higher productivity was obtained. This is likely to have practical implications in formulating plucking policies.

INTRODUCTION

Plucking systems in different tea-growing areas are so devised as to add leaves at periodic intervals to the maintenance foliage already left at the time of tipping, to compensate for the progressively ageing and senile leaves in the lower tiers (Rahman, 1975; Wettasinghe et al., 1981; Sharma, 1983). The newly added leaves maintain the photosynthetic efficiency at a level to meet the nutrient requirements of the growing crop shoots, as also to enrich the carbohydrate reserves to be used in times of stress (Barua, 1961; Tubbs, 1961; Sanderson and Sivapalan, 1966; Manivel, 1980; Manivel and Hussain, 1982). In a canopy of overlapping tiers of leaves, the rate of photosynthesis depends to a large extent on the amount of solar radiation received by leaves at different depths (Meyer and Anderson, 1952). Light intensity decreases exponentially with the depth of foliage in the canopy (Hadfield, 1975) and the reduction in the radiation down the profile is so much that in bushes, particularly with a flat leaf

pose, lower tiers do not receive adequate light for efficient assimilation. Large numbers of such mature, self-shaded, photosynthetically ineffective leaves, the contribution from which productivity is uncertain, are carried on the bush. Increased yield due to defoliation of the lower tiers (Kilavuka and Magambo, 1979) and exactly contrary results (Pethiagoda, 1971; 1974) reported, confound the issue. A positive information in this regard has a practical value in formulating a plucking policy that is likely to contribute to a higher productivity of the bush. The results of an experiment to study the effect of different depths of maintenance foliage on productivity and if possible, to optimise the former, are discussed in the paper.

MATERIALS AND METHODS

The experiment was of random block design; there were six treatments and five replicates, with five bushes in each replicate. Two clones, TRI-2024 with large, nearly flat and horizontal leaf and UPASI-15 with small, slightly keeled and semi-erect leaf pose, were chosen for the experiment. The bushes were in their fourth year from pruning, with 32 cm and 37 cm deep maintenance foliage in TRI-2024 and UPASI-15, respectively at the time of imposing the treatments mentioned below:

- 1) Untreated standard.
- 2) Same as treatment 1, but with the addition of leaf litter to the ground in plots at the rates as in treatment 4.
- 3) Retention of only the top 10 cm of the maintenance foliage; manual defoliation and discarding the foliage below.
- 4) Same as treatment 3, but with the retention of the removed foliage on the ground in respective plots (leaf litter at the rate of 2.8 and 1.9 mt per hectare to the plots of TRI-2024 and UPASI-15, respectively).
- 5) Retention of only the top 20 cm of the maintenance foliage; manual defoliation and discarding the foliage below.
- 6) Same as treatment 5, but with the retention of the removed foliage on the ground in respective plots (leaf litter at the rate of 1.6 and 1.3 mt per ha to the plots of TRI-2024 and UPASI-15, respectively).

The treatments were imposed on April 8, 1981. Crop shoots comprising three leaves and a bud were harvested, plot-wise, at

weekly intervals and fresh weights recorded on the spot. The yield data were subjected to analysis of variance and presented as averages of five replicates, over a year. The fresh weight of shoots and the number of shoots per unit area of the plucking surface were recorded at bi-monthly intervals.

The experimental plots were pruned at 65 to 70 cm in April 1982 and the fresh weight of the prunings was recorded. The bushes recovering from pruning were tipped two leaves above the pruned level during July/August 1982; the fresh weight of the tipped material was recorded.

RESULTS AND DISCUSSION

In the clone TRI-2024, retention of the maintenance foliage only up to a depth of 10 cm and its removal below depressed the yield indicating the inadequacy of the amount of maintenance foliage in sustaining the productivity of the bush. On the other hand, retention of the maintenance foliage up to a depth of 20 cm increased the yield by 13 per cent; an addition of leaf litter equivalent to the amount of the foliage removed increased the yield by 27 per cent (Table 1). Generally, the same trend was

Table 1. Effect of partial defoliation of the maintenance foliage on yield

Treatments	Yield* in kg green leaf per plot	
	TRI-2024	UPASI-15
1. Standard	6.221	5.838
2. Standard + leaf litter	5.604 (-10)	5.729 (-2)
3. Maintenance foliage 10 cm	5.588 (-10)	5.636 (-3)
4. Maintenance foliage 10 cm + leaf litter	5.837 (-6)	5.232 (-10)
5. Maintenance foliage 20 cm	7.019 (+13)	6.262 (+7)
6. Maintenance foliage 20 cm + leaf litter	7.879 (+27)	6.061 (+4)
C.D. at P = 0.05		0.640
= 0.10		0.539
= 0.20		0.420

*Mean of five replicates.

Figures in parentheses indicate percentage increase or decrease over standard.

observed in the clone UPASI-15 also, but the quantum of increase in yield due to the treatments was lower. The addition of leaf litter to the plots in UPASI-15 depressed the yield compared to the corresponding treatments without the addition of leaf litter (Table 1). This crop depression due to the leaf litter is inexplicable and needs further confirmation and also, it would be interesting to investigate whether auto-allelopathy exists in certain tea cultivars.

An increase in the number of shoots and their weight, apparently contributed to the enhanced yields in the concerned treatments, while the yield depression in the other treatments was due to the reduced numbers of shoots as also their weight (Table 2).

*Table 2. Effect of partial defoliation of maintenance foliage on yield components**

Treatments	No. of shoots per plot per year		Fresh weight of shoots (g)	
	TRI-2024	UPASI-15	TRI-2024	UPASI-15
1. Standard	7586	7390	0.82	0.79
2. Standard + leaf litter	6918	7345	0.81	0.78
3. Maintenance foliage 10 cm	6898	7134	0.81	0.79
4. Maintenance foliage 10 cm + leaf litter	7206	6708	0.81	0.78
5. Maintenance foliage 20 cm	8257	7765	0.85	0.81
6. Maintenance foliage 20 cm + leaf litter	9056	7576	0.87	0.80

*Mean of six observations.

Recovery from pruning in terms of tipping weights was the same under all the treatments, indicating that removal of mature leaves in the lower layers did not affect the health of the bush.

It is evident from this study that the bushes under the current plucking practices carry a larger head of maintenance foliage than is required, indeed or is desirable. A firm indication in this regard was obtained in the clone TRI-2024; more significant data should emerge with regard to UPASI-15, if further studies with more treatments of varying depths of maintenance foliage and their effect on yield are made. An interaction between the

cultivars and the treatments was noticed in this investigation, which may be partly responsible for the earlier contradictions (Pethiagoda, 1971, 1974; Kilavuka and Magambo, 1979). The clonal variation in response to the defoliation of the maintenance foliage in the lower tiers may be due to the variation in the degree of light penetration to the lower layers because of the leaf types (Hadfield, 1975).

It was established that a mature leaf once it becomes a net exporter never imports the carbohydrates again (Sanderson and Sivapalan, 1966; Manivel and Hussain, 1982). The depression in the yield of bushes with an abundance of the foliage more than required, hence, cannot be attributed to the withdrawal of assimilates by the lower, mature and senile leaves from, and the consequent depletion of, the 'source'. The factors responsible for the crop inhibition, in this context, should be identified for a better appreciation of the physiology of the tea bush under plucking and its possible application.

The practical implications of the findings out of this investigation are obvious. Large foliage canopies are not only less efficient due to the lack of light penetration to the lower layers of maintenance leaves as contended by Visser (1960) and Hadfield (1963), but also, seem to be detrimental to the productivity of the bush. This is reflected in the virtual stagnation or even decline of yields in the four-year-old bushes from pruning with a large amount of maintenance leaf canopy. There seems to exist an optimum depth of maintenance foliage to sustain a higher productivity, which should be quantified in terms of total leaf area or leaf area index for different cultivars with different leaf types. Once this is established, it is possible to maintain the necessary depth of the maintenance foliage by adjusting the plucking policy (Sharma, 1983).

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INFLUENCE OF CERTAIN GROWTH REGULATORS ON SPROUTING IN PRUNED TEAS

K. RAMAN

ABSTRACT

The effect of external application of some growth regulators and their commercial formulations on recovery of bushes from pruning with vigorous and numerous bud sprouts was monitored in mature seedling teas. Of the naturally occurring regulators adenine and triacntanol proved to be the best in terms of inducing more shoots ready for tipping, heavier shoots more pluckable shoots and increasing the yield. With regard to the other chemicals and formulations, thiourea (500 ppm) followed by Miraculan, proved highly beneficial. Pruned bushes treated with these two chemicals regenerated with faster and heavier growing bud sprouts, which ultimately led to a higher yield compared to those not sprayed with chemicals.

INTRODUCTION

Successful pruning in tea is gauged by the rapidity with which the bushes recover, endowed with a rich crop of orthotropic shoots which are tender, heavy and fast growing without any casualties among the pruned bushes. Endogenous plant growth substances are known to influence all the growth and development processes of the plants (Bidwell, 1974; Jacobs, 1979; Nickell, 1982). Cytokinins, auxins and gibberellins have been implicated in the differentiation of shoot buds, acceleration of axillary bud development and other physiological and biochemical

activities (Steward and Krikorian, 1971; Nickell, 1982; Thomas, 1982; Letham and Palni, 1983). Recently, triacontanol a long chain primary alcohol, has also been reported to influence an array of developmental processes in plants (Ries and Houtz, 1983). In addition, it has been demonstrated that roots are the site of synthesis for a variety of naturally occurring growth substances which are translocated to the aerial portions where they regulate or modify many physiological and biochemical functions (Crozier and Reid, 1971). In the light of the above, the present trial was undertaken to explore the role of any of the effects of external application of a number of synthetic and endogenous plant growth regulators on the pruning recovery of the mature seedling teas.

MATERIALS AND METHODS

The trial was conducted on mature seedling teas planted in 1962. The bushes were pruned in the second week of May 1982 at a height between 60 and 65 cm which left few mature basal maintenance leaves. The chemicals were sprayed till run off within 24 hours of the completion of pruning. The first tipping was done 13 weeks following pruning and the second one was carried out after four weeks. After about 20 weeks of pruning, the bushes were ready for the initial plucking (though only a few with two and/or three leaves and a bud were mature) and two more pluckings were done within the subsequent three weeks. The tipped-in shoots were counted and the fresh weights of these from each bush recorded. The same exercise was repeated for the first three pluckings as well. The tipping and plucking styles were performed as per the departmental suggestions.

The plant growth regulators not soluble readily in water were initially dissolved in very small quantities of weak acidic organic solvents and made up to the desired volume by distilled water. It required about 100 to 150 cc per bush to adequately drench the same. Each treatment contained 10 bushes and observations were recorded separately for each of these bushes.

RESULTS

Of the endogenously occurring substances attempted in this

study, except gibberellic acid and ascorbic acid, all other treatments enhanced the number of shoots tipped, weight of these tipping-in materials, the number of buds generated on the pluckings surface and the yield (fresh weights) in the initial three pluckings (Tables 1 and 2). Among the treatments, adenine followed by triacontanol elicited the maximum beneficial response, with regard to the above parameters, while gibberellic acid and ascorbic acid at the concentrations attempted in this exercise were not useful compared to the untreated control.

The result from studies on the effect of externally applied synthetic growth regulators and formulations are presented in Figs. 1 and 2. The number of shoots that came up for tipping was highest with Thiourea at 500 ppm while all the other treat-

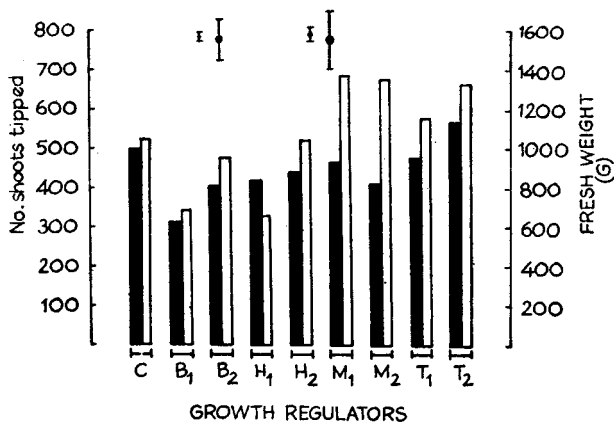


Fig. 1. Influence of spraying various analogous and growth regulator formulations following pruning on the number of shoots came up for tipping (solid bars) and the fresh weight (empty bars) of these tipping-in materials.

- C = Control
 B₁ = Benzylaminopurine 1.0 ppm H₁ = Hormonol 0.5 ppm
 B₂ = Benzylaminopurine 10.0 ppm H₂ = Hormonol 1.0 ppm
 M₁ = Miraculan 0.25 ppm T₁ = Thiourea 250 ppm
 M₂ = Miraculan 0.5 ppm T₂ = Thiourea 500 ppm

On the top, the left side pair indicates the Minimum (0.6) and Maximum (3.7) standard error of the mean the number of shoots tipped, and the right side one (0.45 and 6.1) of the fresh weights of the tipping-in materials.

Table 1. Effect of external application of naturally occurring growth substances on pruning recovery

Treatment	No. shoots tipped \pm SE	Tipping wt \pm SE (g)	Unit weight (g)
Control	500 \pm 0.9	1051.7 \pm 3.1	2.10
Ascorbic acid: 100 ppm	422 \pm 3.7	876.6 \pm 2.0	2.10
Ascorbic acid: 250 ppm	411 \pm 1.4	898.4 \pm 0.45	2.17
Giberellic acid: 50 ppm	416 \pm 0.8	1003.5 \pm 1.5	2.41
Triacantanol: 0.1 ppm	642 \pm 0.4	1453.5 \pm 2.8	2.26
Triacantanol: 1 ppm	688 \pm 0.9	1626.5 \pm 5.8	2.36
Folic acid: 62.5 ppm	594 \pm 0.7	1293.5 \pm 6.1	2.18
Folic acid: 125 ppm	562 \pm 1.2	1262.5 \pm 2.8	2.25
Folic acid: 62.5 ppm + Cysteine: 62.5 ppm	461 \pm 0.6	1038.0 \pm 4.3	2.25
Folic acid: 62.5 ppm + Cysteine: 125 ppm	512 \pm 0.7	1090.5 \pm 4.3	2.13
Adenine: 50 ppm	796 \pm 0.6	1712.5 \pm 3.1	2.15

Table 2. Effect of external application of naturally occurring growth substances following pruning on the yield of green leaf (first three pluckings)

Treatments	No. shoots plucked (3 pluckings) \pm SE	Yield in fresh wt (3 pluckings) \pm SE	Unit weight (g)
Control	542 \pm 1.3	1162.2 \pm 1.86	2.14
Ascorbic acid: 100 ppm	469 \pm 0.9	989.6 \pm 1.35	2.10
Ascorbic acid: 250 ppm	414 \pm 0.8	941.4 \pm 1.86	2.27
Gibberellic acid: 50 ppm	426 \pm 1.2	1030.0 \pm 2.30	2.42
Triacantanol: 0.1 ppm	686 \pm 0.8	1580.0 \pm 2.69	2.30
Triacantanol: 1 ppm	759 \pm 1.1	1794.0 \pm 2.85	2.36
Folic acid: 62.5 ppm	645 \pm 1.2	1391.5 \pm 2.82	2.16
Folic acid: 125 ppm	615 \pm 1.0	1357.0 \pm 2.30	2.21
Folic acid: 62.5 ppm + Cysteine: 62.5 ppm	528 \pm 1.0	1199.0 \pm 1.63	2.27
Folic acid: 62.5 ppm + Cysteine: 125 ppm	555 \pm 1.0	1182.5 \pm 1.87	2.85
Adenine: 50 ppm	812 \pm 1.7	1836.0 \pm 3.54	2.26

ments fared less than the control. However, the fresh weights of the tipped-in shoots as well as the pluckings were higher from those bushes treated with miraculan and thiourea. In either of these, both the concentrations proved beneficial. Hormonol and benzylaminopurine, on the other hand, were ineffective in hastening the bud breaks or producing any other beneficial response.

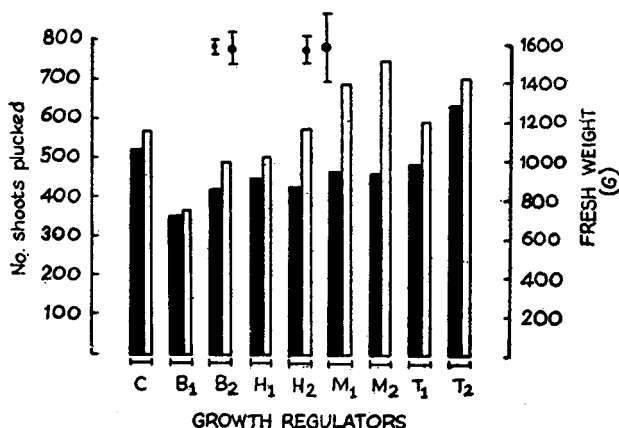


Fig. 2. Influence of spraying various analogous and growth regulator formulations following pruning on the number of shoot buds plucked (solid bars) and plucking weights (empty bars) during the initial three pluckings after the two tipplings (for description of growth regulators, see legend for Fig. 1)

The pairs of standard errors of the mean represent the minimum and maximum of the number of buds plucked (0.8 and 1.7) and the fresh weight of the pluckings (1.63 and 3.54).

DISCUSSION

This preliminary investigation, reveals a number of fundamental and applied aspects of the physiology of pruning recovery. The critical factor that controls the pruning recovery of the tea bushes is the amount of carbohydrates available to the pruned frame, which are stored as starch granules in the root system (Eden, 1976). This stored starch has to be hydrolysed before it is translocated to the aerial portions and utilised for differentiation, initiation, development and growth of shoot buds. For the

hydrolysis of starch, either *de novo* synthesis or the activation of already present repressed hydrolytic enzymes (for example, amylases) have to be triggered. It is irrefutably demonstrated that plant growth substances are involved in the induction of enzymes (Glasziou, 1969; Key, 1969; Lesniak and Ries, 1983). Either enzyme kinetics or the substrate levels at various periods was not monitored during the pruning recovery; however such a parallel biochemical and physiological developmental pathway can be visualised.

The application of adenine, triacontanol and folic acid enhanced the number of shoots tipped-in, the weight of those tipping-in shoots, the number of two and/or three leaves and a bud plucked and the fresh weight of these pluckings. In practical terms, these treatments increased the intensity as well as the density of bud sprouts on the pruned frames, which ultimately led to the generation of more pluckable shoots earlier, on the plucking surface. More significantly, there are indications to conclude that these treatments also helped in enhancing the unit weights of the pluckings. Earlier investigations have revealed that foliar application of triacontanol stimulates generation of more buds on teas under plucking (Raman, 1981). Similarly a formulation containing folic acid is reported to be beneficial for mature teas.

In spite of numerous reports on the effects of adenine in promoting shoot buds in a number of *in vitro* and *in vivo* systems, this is first study to demonstrate its shoot bud generating potential in tea. The preliminary investigations in this laboratory indicated that adenine in the medium has a promotive influence in the differentiation of shoot buds of tea callus cultures (Raman, unpublished).

Quite unexpectedly, gibberellic acid and ascorbic acid did not appear to be beneficial for any of the morphogenic phenomena monitored in this study. This was very surprising, since both these compounds have been reported to cause earlier flushing and more bud breaks in mature teas (Bhattacharya, 1980). It is quite possible that the optimal concentrations of these chemicals at this particular developmental phase may be different, or the timing of application not appropriate for eliciting any favourable response in the present study.

Miraculan is a formulation with triacontanol as one of its

active ingredients. Miraculan, like other long-chain-alcohol-based formulations, has been earlier reported, to enhance the yield in mature clonal and seedling teas (Raman, 1982 a, b, c and 1983).

Kaska (1979) had reported that thiourea is being employed in temperate orchard crops to induce earlier bud breaks. Similarly, though not at very significant levels, thiourea increased the yield in two mature South Indian clonal teas as well (Raman, 1983; Ranganathan et al., 1983).

Hormonol, a formulation containing a mixture of auxins, cytokinins and gibberellins had enhanced the yield in mature seedling teas (Raman, 1983). However, neither hormonol, nor the synthetic cytokinin, benzylaminopurine were beneficial in enhancing the intensity and density of bud sprouts, or the rejuvenation of buds on the plucking surface; rather these compounds were slightly inhibitory. At present, no logical explanations could be offered for such a negative impact, since cytokinins initiate cell divisions and induce the shoot bud differentiation in several situations (Letham, 1978). This is especially intriguing when one viewed the promotory influence of adenine observed in this study, even though the potency of these synthetic and natural cytokinins vary in different experimental systems and plants. It is possible that analogous substances may be biosynthesised in the root apices and translocated to the aerial portions at various stages of development. For example, in *Perilla*, following floral induction, the cytokinin export from roots increased more than five times (Beever and Woolhouse, 1973). Similarly, root tips have been shown as active sites of gibberellin and auxin synthesis (Carr and Reid, 1968; Crozier and Reid, 1971). Recently, higher levels of triacontanol have been detected in the xylem sap of sugar maples, during the spring bud sprouts (Houtz and Ries, 1983).

It is too premature to conclude whether the negative effect following treatment with gibberellic acid and/or benzylaminopurine is due to the supraoptimal levels attained in the aerial tissues resulting from the root-exported endogenous gibberellins and cytokinins along with these externally applied substances. This possibility, though remote, could not be discounted as the xylem sap of tea bushes also contains similar growth regulatory substances (Kathiravetpillai and Kulasegaram, 1981).

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DISCUSSION

Q : Do you think that the data is sufficient to conclude the negative effect of GA on yield?

Ans: Further research is needed on this line.

Q : Can these growth regulators be recommended for large-scale use?

Ans: Information on the long term effects have to be generated before recommending their use on an extensive scale.

Q : Have you monitored enzyme kinetics and substrate levels during the course of the study?

Ans: No.

NITRATE REDUCTASE AND SPECIFIC LEAF WEIGHT OF COCOA AND LIGHT PROFILES IN ARECANUT-COCOA MIXED CROPPING

D. BALASIMHA and N. SUBRAMONIAN

ABSTRACT

The pattern of light penetration through arecanut canopy and its effect on specific leaf weight (SLW), chlorophyll content and nitrate reductase (NR) activity of cocoa in six different spacings of arecanut-cocoa mixed cropping was studied. The PAR was maximum under wider arecanut spacings. The cocoa leaf NR activity and SLW also were higher over the season in such spacings. The chlorophyll content however did not show any definite trend.

INTRODUCTION

Some tropical crop plants like coffee, cocoa and tea need to be grown under the shade of taller trees. Cocoa is traditionally planted under forest trees in West Africa and South America. However, cocoa was introduced in India as an intercrop under the canopy of taller trees of arecanut and coconut (Shama Bhat and Bavappa, 1972). In an arecanut garden, 37 to 50 per cent sunlight is reported to pass through the canopy which can be utilised for the growth of other perennial or annual crop species tolerant to shade (Sannamarappa and Muraleedharan, 1982).

An experiment laid out in 1970 to study the effect of different

spacing of cocoa and arecanut as a mixed crop with six treatments showed that the yield of arecanut and cocoa were maximum in 3.3 × 3.3 m spacing (Sannamarappa and Muraleedharan 1982). There is no data available on the physiological aspects in such multiple cropping systems, namely, light profiles and other physiological responses. Hence, a seasonal study on the changes in some physiological parameters affected by light intensity was studied and is reported in this paper.

MATERIALS AND METHODS

Samples was collected from the agronomy experiment laid out in 1970 with arecanut (*Areca catechu* L. var. South Kanara) and cocoa (*Theobroma cacao* L. var. Foresterio). There were six spacing treatments as shown in Table 1. Fertilisers were applied in the recommended dosage. The soil is lateritic. Mature leaves (third to fifth) were taken as samples at 10 ha randomly from different parts of individual trees and pooled for analyses. Specific leaf weight (SLW) was estimated from a known leaf area after oven drying

Table 1. PAR profile under arecanut and cacao canopies*

Treatment	Spacing	Canopy	PAR μ Einstein M ⁻² Sec ⁻¹		
			9.00	12.00	15.30 h.
T-1	2.7 × 2.7 m	Areca	100**	240	266
	5.4 × 5.4 m	Cacao	15	42	28
T-2	3.3 × 3.3 m	Areca	80	1410	307
	3.3 × 3.3 m	Cacao	7	64	103
T-3	3.9 × 3.9 m	Areca	43	950	600
	3.9 × 3.9 m	Cacao	29	22	45
T-4	2.7 × 2.7 m	Areca	133	285	127
	2.7 × 5.4 m	Cacao	10	28	22
T-5	2.7 × 2.7 m	Areca	73	470	135
	2.7 × 2.7 m	Cacao	18	42	14
T-6	1.8 × 5.4 m	Areca	206	1510	255
	3.6 × 5.4 m	Cacao	16	33	35
Total sunlight intensity			650	1710	810

*Measurement taken on 23rd March.

**Average of 5 readings in each treatment and variation was within 10 per cent of mean values.

to constant weight. Nitrate reductase (NR) activity was assayed by *in vivo* procedures (Jaworski, 1971). The assay medium (5 ml) contained in final concentration 0.1 M KNO₃, 0.02 M K-phosphate buffer pH 7.5 and 0.3 per cent n-propanol. Chlorophyll was extracted in 85 per cent (v/v) acetone and determined on an ECIL spectrophotometer (Association of Official Analytical Chemists, 1975).

The photosynthetically active radiation (PAR) was measured with a LI-COR quantum radiometer at two levels in an arecanut garden, (1) under arecanut but above cocoa canopy; and (2) below cocoa canopy. Measurements of light intensity in any open area were also noted.

RESULTS AND DISCUSSION

For the optimum growth and yield of cocoa, 50 per cent shade was reported to be the best (Murray, 1964). The yield of cocoa was found to be maximum in 50:50 arecanut and cocoa combination at 3.3 × 3.3 m spacing. The PAR profile at different times of day is given in Table 1. The mid-day light profile revealed a maximum PAR in treatments T-2 and T-6. However, in the afternoon, the PAR was maximum in T-3. This partly explains the higher yields obtained in T-2 (Sannamarappa and Muraleedharan, 1982). Very little PAR penetrated the cocoa canopy, maximum being in T-1 having wider cocoa spacing.

The seasonal changes in SLW, NR activity and total chlorophyll contents were measured (Table 2). The SLW and NR activity generally showed higher values in T-1 and T-6 followed by T-2. The other treatments showed lower activity and SLW in cocoa leaves. The chlorophyll content did not show any definite trend though marginally higher in T-3 on most of the sampling dates.

The environmental factors especially of light intensity have a profound influence on leaf morphology and physiological functions (Cooper and Qualls, 1967; Barnes et al., 1969; Pearce et al., 1969). Leaves developed under shade are thinner having lower SLW than those receiving higher light intensity (Boardman, 1978, Pearce et al., 1969). The results obtained in cocoa conform to these earlier reports. Higher SLW was associated in cocoa grown at spacing allowing maximum light intensity namely T-2 and

T-6. The higher SLW in T-1 may possibly be due to lesser self-shading of cocoa canopy due to wider spacing of cocoa plants.

Table 2. SLW, NR activity and chlorophyll content in cocoa leaves in different spacings

Treatment	Months						
	Feb	Apr	Jun	Jul	Sep	Oct	Jan
	SLW (mg/cm ²)						
T-1	5.89	7.14	5.91	7.34	7.69	—	6.58
T-2	6.23	5.77	5.90	6.48	6.97	4.93	6.28
T-3	4.54	4.19	4.68	4.54	7.11	5.60	4.59
T-4	4.25	5.21	4.35	6.01	4.70	4.89	5.86
T-5	5.00	4.16	4.71	4.46	5.57	4.98	4.04
T-6	5.72	5.82	5.58	5.81	7.38	5.47	5.44
SE	0.26	0.39	0.36	0.39	0.49	0.42	0.47
	NR activity (μ M No ₂ ^{-g} fresh weight h ⁻¹)						
T-1	6.8	14.0	9.8	7.8	9.0	—	5.0
T-2	5.9	9.1	10.9	6.2	5.6	13.3	5.3
T-3	7.0	5.8	3.4	3.8	7.8	11.6	4.2
T-4	6.4	7.8	4.0	5.4	5.6	11.6	—
T-5	5.7	7.7	5.0	4.4	7.0	11.6	5.0
T-6	5.7	9.1	7.0	6.3	6.4	9.9	5.4
SE	0.25	1.15	1.32	0.52	0.56	0.43	0.28
	Total chlorophyll (mg g ⁻¹ fresh weight)						
T-1	1.71	1.29	1.62	2.15	2.67	—	2.55
T-2	1.41	1.01	1.66	2.05	2.37	2.35	1.86
T-3	2.17	1.49	1.88	1.98	2.91	2.51	2.02
T-4	1.90	1.25	1.67	2.56	3.05	1.60	2.12
T-5	1.69	1.00	1.75	2.56	3.05	2.23	1.80
T-6	1.61	0.76	1.90	2.21	2.61	2.05	1.90

Similarly NR activity was enhanced in T-1, T-2 and T-6 (Table 2). This key enzyme of nitrate assimilation is markedly influenced by light (Beevers and Hageman, 1969) and reduced light intensity either by artificial or natural shading decreased the activity in corn (Hageman et al., 1961). Thus, the study of morphological and physiological parameters is very vital in multiple cropping with arecanut, as these parameters are ultimately expressed in terms of yield. The study of light penetration pat-

tern and physiological performances of various crop species with respect to their shade tolerance characteristics and optimum spacing combinations is imperative in future research.

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DISCUSSION

Q : Why were all the physiological parameters not estimated in the study?

Ans: This study was limited to nitrate reductase activity, specific leaf weight and chlorophyll content under the different light profiles in a mixed cropping system.

IN VIVO NITRATE REDUCTASE ACTIVITY IN THE LEAVES OF APPARENTLY HEALTHY AND ROOT (WILT) AFFECTED COCONUT PALMS

V. RAJAGOPAL, K.D. PATIL and B.S.K. AMMA

ABSTRACT

The *in vivo* nitrate reductase activity (NRA) was studied in apparently healthy and root (wilt) diseased coconut palms. The enzyme activity was more in the leaves of the middle whorl, followed by those of the outer whorl, than either in the spindle leaf or the first fully open leaf. In all the leaves studied, the diseased palms had higher activity than in the apparently healthy palms.

The enzyme activity was influenced by the light intensity. Irrespective of the palm condition the NRA was higher at high light intensity (1250 to $1400\mu\text{E m}^{-2}\text{s}^{-1}$) than that at low light intensity (250 to $500\mu\text{E m}^{-2}\text{s}^{-1}$). Again, the activity of enzyme in apparently healthy palms was less than that in the diseased palms.

With increase in the level of nitrogen application there was increase in NRA both in apparently healthy and diseased palms, the latter recording relatively high activity. The response of palms to simulated stress indicated that the enzyme was adversely affected in both the palms. The study thus revealed disturbed nitrogen metabolism caused by the root (wilt) disease.

INTRODUCTION

Several physiological and biochemical changes have been observed in the root (wilt) affected coconut palms. The leaves of

diseased palms had a higher respiration rate than those of apparently healthy palms (Michael, 1978). The content of sugars was relatively high in the diseased palms (Chacko Mathew, 1977). As compared to healthy palms, the diseased palms showed variations in different fractions of proteins (Padmaja et al., 1981). However, detailed investigation on the nitrogen assimilation is lacking. The first rate limiting enzyme in nitrogen assimilation is nitrate reductase (NR), which catalyses the reaction between nitrate and nitrite. Nitrate reductase activity is inducible both by light and the substrate (Beevers et al., 1965; Travis et al., 1970; Sawhney and Naik, 1972; Vijayaraghavan et al., 1979). Though some aspects of NRA had been studied in coconut (Shivasankar and Rajagopal, 1983; Shivasankar and Ramadasan, 1983), the activity of the enzyme in relation to the root (wilt) disease has not been investigated earlier. The present paper reports certain aspects of the enzyme activity in the apparently healthy and diseased palms.

MATERIALS AND METHODS

Coconut palms (*Cocos nucifera* L. var. West Coast Tall) were grown in the Institute Farm with the usual cultural and agronomic practices. The palms were supplied with the recommended doses of N : P : K (500 : 320 : 1200 g/palm/year). In one of the experiments, palms grown with a higher level of nitrogen (750g) were also studied. Palms of uniform age (15 to 20 years) were selected in the two categories, namely apparently healthy (disease index less than 10 per cent and middle diseased palms (disease index 25 to 35 per cent).

Three experiments were designed, so that the first one was concerned with the determination of NR activity in the leaves of different maturity. In the second experiment the influence of light intensity on NRA was studied. Determination of enzyme activity in palms with two levels of nitrogen supply formed the third experiment. In addition, the effect of simulated stress (with PEG, MW 6000, 20 per cent) on the activity of NR both in apparently healthy and diseased palms was investigated.

The *in vivo* nitrate reductase was assayed in accordance with the method described by Klepper et al. (1971) and nitrite estimation by Evans and Nason (1953). In the preliminary experi-

ments, the quantity of leaf material, the substrate concentration required for the optimum activity, the time of incubation and the aliquot used for colour development were standardised (data not presented now). Based on this, all the assays were carried out. Details pertaining to each experiment are described in Tables 1, 2 and 3.

RESULTS AND DISCUSSION

The activity of NR was higher in the middle leaves than in other leaves irrespective of the palm condition (Table 1). Shivasankar and Ramadasan (1983) also observed increase in NR activity with maturity up to 14 leaves followed by a decline. Since the leaf water content differs between the apparently healthy and diseased palms, the enzyme activity is also expressed on unit dry weight basis. The trend in NRA remained the same on both unit fresh and dry weight bases. There was relatively high activity both in young and mature leaves of diseased palms as compared to healthy palms. For instance, the spindle leaf of diseased palms had 88.7 per cent higher NRA than that in the apparently healthy palm (dry weight basis).

Table 1. NR activity in the leaves of different whorls of apparently healthy and root (wilt) affected coconut palms. Values are mean of six palms

Leaf position	NRA—n. moles g ⁻¹ fwt h ⁻¹		NRA—n. moles g ⁻¹ dwt h ⁻¹	
	App. Healthy	Diseased	App. Healthy	Diseased
Spindle	52.5	60.2	214.6	405.1
First whorl	58.3	81.2	168.9	260.0
Middle whorl	123.7	126.8	323.3	332.6
Outer whorl	73.1	101.7	185.3	235.7

The enzyme activity was determined during 'cloudy' (250 to 500 $\mu\text{E m}^{-2}\text{s}^{-1}$) and 'bright' (1250 to 1400 $\mu\text{E m}^{-2}\text{s}^{-1}$) days (Table 2). Irrespective of the palm condition and leaf position, the NRA was less under low than under high light intensity. Under both light intensities, diseased palms had higher enzyme activity (59.1

per cent and 46.9 per cent, and 86 per cent and 6 per cent in the first and middle leaves respectively) than the apparently healthy palms. Variations in NR activity in coconut between the 'summer' and 'wet' seasons were also observed (unpublished). The influence of light on NR activity is well established in many crops (Beevers et al., 1965; Sawhney and Naik, 1972). NRA had also exhibited diurnal and seasonal fluctuations in different species (Rajagopal et al., 1977; Steer, 1974; Shivashankar and Ramadasan, 1983). These indicate the relationship between the enzyme activity and photosynthesis. Maximum activity of NR in coconut leaves treated with nitrate exposed to light was reported recently (Shivashankar and Ramadasan, 1983).

Table 2. Effect of light on the NR activity in the leaves of apparently healthy and diseased palms. The samples were collected on a 'cloudy' and 'bright' day and the light measurement was determined with a steady state porometer attached with a light sensor between 930 and 1130 AM. Values are means of six palms

Light, $\text{Em}^{-2}\text{s}^{-1}$	Leaf position	NRA - n. moles g^{-1} dwt h^{-1}	
		App. Healthy	Diseased
250-500	First whorl	63.5	101.0
	Middle whorl	59.2	110.1
1250-1400	First whorl	439.0	645.0
	Middle whorl	297.0	383.0

The response of the enzyme to nitrogen level was determined both in the apparently healthy and diseased palms (Table 3). An increase in nitrogen supply from the normal level of 500 g to 750 g per palm resulted in enhanced enzyme activity in young and mature leaves of both apparently healthy and diseased palms. A two-fold increase in the enzyme activity was observed in both the leaves of diseased and in the matured leaves of apparently healthy palms, while the increase was over three-fold in the first leaves of apparently healthy palms. Enhanced activity with a high level of nitrogen supply could be attributed to substrate induction, as NR is a substrate inducible enzyme (Beevers et al., 1965).

As observed in the previous cases, diseased palms had always higher enzyme activity than the healthy palms. Influence of different levels of nitrogen supply on the NRA of sorghum varieties was reported (Rajagopal et al., 1976), which showed that there are genotypic variations to nitrogen response. While some genotypes exhibited increase in NR activity with increase in nitrogen supply from 50 to 200 kg ha⁻¹, other genotypes had the opposite trend.

Table 3. Effect of nitrogen levels on the NR activity in the leaves of apparently healthy and diseased palms. Values are means of six palms

N. levels, g/palm	Leaf position	NRA—n. moles g ⁻¹ dwt h ⁻¹	
		App. Healthy	Diseased
N1, 500	First whorl	190.8	463.7
	Middle whorl	342.1	375.6
N2, 750	First whorl	675.9	851.9
	Middle whorl	602.7	775.3

The consistent observation of relatively high NRA in the leaves of diseased palms as compared to healthy palms shows that at least the first step in nitrogen assimilation is not adversely affected as a result of root (wilt) disease. This might indicate that the nitrate supply from the roots to leaves is maintained at a high level in the diseased palms. This perhaps is possible through a high transpiration stream, which is characteristic of root (wilt) affected palms (Rajagopal et al., 1984). Though the nitrate reduction step in diseased palms is above the normal level of apparently healthy palms, there is variation in different protein fractions (Padmaja et al., 1981). Increase in non-protein nitrogen content with a concomittant fall in water-soluble nitrogen and protein nitrogen in the leaves of diseased palms was reported (Varkey et al., 1969). Pillai and Shanta (1965) reported accumulation of acidic amino acids and their amides in the leaves of diseased palms.

Significantly high levels of sugars in the diseased levels (Chacko Mathew, 1977) could also have caused higher NR activity.

Recently, Shivashankar and Rajagopal (1983) showed the activity of NR during different times of the day following the same trend as that of the total sugar level. This suggests a possible role of sugars in the regulation of NRA. Thus, an above-normal supply of nitrate and high level of sugars might have favoured relatively high activity in the leaves of diseased palms.

Moisture stress adversely affected the enzyme activity in the leaves of both apparently healthy and diseased palms (Table 4). It is interesting to note that though the diseased palms had maintained higher NRA under normal conditions, imposition of stress resulted in greater loss of activity of NR in the diseased palms. (64 per cent reduction on 'control') than in the apparently healthy palms (30 per cent reduction on 'control'). This indicates the poor stability of the enzyme in the diseased compared to apparently healthy palms. NR activity has been shown to be highly sensitive to moisture and salt stress in different crops (Balasubramanian et al., 1974; Sinha and Rajagopal, 1975, 1977).

Table 4. Effect of simulated stress on the NR activity in the middle leaves of apparently healthy and diseased palms. The leaflets from the middle whorl were excised and kept in half the strength of Hoagland's nutrient solution or 20 per cent polyethyleneglycol, 6,000 prepared in nutrient solution for 24 hours in the laboratory near the window under diffused light. At the end of the treatment, NR activity was determined both in the control and stressed leaflets. Representative samples were kept for dry weight. Values are mean of five palms

Treatment	NRA - n. moles g ⁻¹ dwt h ⁻¹	
	App. Healthy	Diseased
Control	143.4	183.0
Stressed	100.2	61.1
Percentage of control	69.9	35.7

It is evident from the foregoing discussion that the root (wilt) disease greatly affects the nitrogen metabolism of coconut palms. Though the reduction of nitrate is maintained at a high level,

further steps in the nitrogen assimilation appears to have been greatly hindered in the diseased palms, as exemplified by accumulation of certain amino acids (Pillai and Shanta, 1965) and by large variations in protein fractions (Padmaja et al., 1981). This would mean that other enzyme systems involved in the protein synthesis are probably affected by the disease. Thus, the overall effect of root (wilt) disease is reflected on the disturbed nitrogen metabolism.

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SESSION II

PLANT PROTECTION 1

Chairman : P.N. Radhakrishna Pillay

Rapporteurs : R. Kothandaraman

N. Ramachandran

INVESTIGATIONS ON THE INTEGRATED CONTROL OF ROOT (WILT) DISEASE OF COCONUT

C. MATHAI, G. INDRASENAN and U. MOHAMED KUNJU

ABSTRACT

Results of investigations conducted on the integrated control of root (wilt) disease of coconut employing a fungicide, bactericide, nematocide and different plant nutrients indicated that the disease is incited by an organism or entity which is unaffected by a nematocide, bactericide or a fungicide. It is also indicated that the deficiency of Ca, Mg or Zn pre-disposes the palms to infection by root (wilt) pathogen. The various treatments further failed to show any effect on the incidence of leaf rot disease, the ratings of which were higher in palms with high root (wilt) disease index.

INTRODUCTION

Studies so far conducted on the cause of root (wilt) disease of coconut, present a complex situation, wherein more than one biological agents are involved. As such no specific measures for the control of the disease have been evolved. The disease symptoms were reproduced under field conditions and controlled conditions by sap transmission from diseased palms as well as by incorporation of roots of diseased palms in the soil substrata. Soil fungi like *Rhizoctonia* sp. are found to be associated with the root damage. A strain of TMV was isolated from diseased coconut tissue and also from healthy material. A bacterium iden-

tified as *Pseudomonas* sp. was found to be associated with the rotted roots. Plant parasitic nematodes belonging to 23 genera occur in the root zone of the coconut palm. Investigations on soil and nutritional factors suggested the possible role of Ca and Mg deficiency in soils in pre-disposing the palm to root (wilt) disease. The present study aims to have an integrated approach, accounting for all these factors controlling the disease.

MATERIALS AND METHODS

The investigations on the integrated control of root (wilt) disease were conducted at the regional Agricultural Research Station, Kumarakom, Kerala during the period from 1976 to 1984 in a randomised replicated field trial with 11 treatments. The following were the treatment combinations: (1) Control; (2) NPK + Ca + Mg + Zn; (3) NPK + Ca + Mg; (4) Tr. 2 + Dasanit; (5) Tr. 3 + Dasanit; (6) Tr. 2 + Agrimycin-100, (7) Tr. 3 + Agrimycin-100; (8) Tr. 2 + Benlate, (9) Tr. 3 + Benlate; (10) Tr. 2 + Dasanit + Agrimycin-400 + Benlate; and (11) Tr. 3 + Dasanit + Agrimycin-100 + Benlate. All the treatments including control were given the following common pre-treatments: (1) each planting pit was burned with trash; and (2) the coconut seedlings of variety WCT were dipped for 15 minutes in 1000 ppm nemagon solution before they were planted. The application of treatment was started three months after planting and continued for five years. NPK was applied at the recommended dosage for ordinary WCT palms. Ca was applied as slaked lime at the rate of 12 kg/tree and Mg as Magnesium sulphate (commercial) at the following rates: (1) first year of planting 1 kg/palm; (2) second year 2 kg/palm; and (3) from the third year onwards 3 kg/palm. Zn was given as zinc sulphate (0.2 per cent) foliar spray. Dasanit was treated after opening the basin when the soil was moist, and used at 100 g for seedlings up to three years and afterwards at the rate of 300 g/palm. Treatment of Agrimycin-100 was carried out as foliar spray (500 ppm) once in a month for six months per annum. Benlate was applied at the basin twice a year at the rate of 40 litres of 0.1 per cent solution up to three years and 70 litres/palm afterwards. Benlate was made to dissolve in acetone and 3 per cent Hcl before it was diluted with water and warmed for six hours. Observations on

the intensity of root (wilt) disease were recorded from 1979 at half-yearly intervals based on standard methods of indexing, evolved by George and Radha (1973). The number of leaves showing leaf rot was also recorded for the above period.

RESULTS AND DISCUSSION

Results of statistical analysis of the data on intensity of root (wilt) disease (Table 1) and the number of leaves affected by leaf rot (Table 2) are presented.

Root (wilt) disease

The treatment effects are not statistically significant when the observations on individual years are analysed except that of 1979 and 1981. Root (wilt) disease intensity was lowest in plots treated with NPK + Ca + Mg + Zn both for 1979 and 1981. But pooled analysis of the data for six years from 1979 indicated that combined application of NPK + Ca + Mg + Zn have significant effect in reducing root (wilt) disease syndrome. However, the treatment effects of NPK + Ca + Mg with Agrimycin or with Benlate or with a combination of Dasanit, Agrimycin and Benlate were on par. The investigations lead us to the conclusion that treatment with a nematicide bactericide or fungicide was not effective to check the occurrence of root (wilt) disease in coconut. It may therefore be presumed that neither a nematode, bacterium nor a fungi is involved in the development of the disease. Perhaps it leads us to infer that root (wilt) disease is incited by an organism or entity which is unaffected by a nematicide, bactericide or fungicide. On the other hand, the results reveal that there is a reduction in the intensity of the root (wilt) disease due to the application of Ca, Mg or Zn. It may also be indicated here, that deficiency of Ca, Mg or Zn plays a vital role in pre-disposing the palms to infection by the root (wilt) pathogen. Investigations carried out by earlier workers suggested the possible role of Ca and Mg deficiency in soils in pre-disposing the palms to root (wilt) disease. According to Robert Cecil (1975) the Ca and Mg contents of root (wilt) diseased palms are lower than that of healthy palms. Ramadasan (1964) attributed foliar yellowing which is part of root (wilt) disease syndrome due to Mg deficiency. Mathai and Vasudevan Nair (1978) observed

Table 1. Mean root (wilt) disease index

Tr. No.	1979	1980	1981	1982	1983	1984	Mean of pooled data
1	26.77	25.57	27.99	43.98	41.35	41.66	34.55
2	9.46	9.05	6.84	30.43	31.51	21.05	18.05
3	25.99	26.98	16.79	41.62	35.22	28.85	25.56
4	29.12	23.70	28.07	49.12	36.18	34.49	33.45
5	26.20	25.07	20.45	43.78	46.65	36.49	28.04
6	17.76	16.33	17.49	29.57	45.67	35.28	27.02
7	20.94	19.72	21.53	21.95	28.99	26.63	23.79
8	21.77	20.35	15.27	33.59	38.77	37.22	27.83
9	17.14	14.04	10.59	38.56	33.07	31.80	22.23
10	14.10	12.05	28.20	27.57	37.68	29.37	24.82
11	8.88	10.16	17.45	19.80	33.62	22.44	18.18
CD (P = 0.05)	12.75	N.S	12.38	N.S	N.S	N.S	

CD (P = 0.05) for comparison between treatments: 7.32.
(Pooled Mean).

significant beneficial effect on the yield with the application of Zn. Thus the results obtained in the present study substantiate the observations made by the earlier workers.

Leaf rot disease

Statistical analysis of the pooled data as well as the observations for individual years on the number of leaves affected by leaf rot disease for the period from 1979 to 1984 (Table 2) does not reveal any significance between treatments. There was no significant effect for the different treatments in reducing the number of leaves affected by leaf rot disease. However the trend was that its incidence was higher in palms with high root (wilt) disease index and *vice versa* as observed by Mathai (1980). The widespread occurrence of leaf rot disease in the root (wilt) affected tract and its limited incidence in healthy areas as reported by Radha and Lal (1968) confirm the relationship obtained in the present study.

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DISCUSSION

Q : What was the basis for fixing the dose of lime? Did you take lime requirement into consideration?

Ans: The dose of lime was fixed based on general lime requirement of the area.

Q : What was the organic matter status of the soil?

Ans: Not tested.

Q : Under waterlogged conditions, the Al and Mn level play a significant role. Have you estimated them?

Ans: No. Estimation of these nutrients is not envisaged in this trial.

Q : Incidence of disease is much lower in plots under treatment T₂. But the same treatment with insecticides did not show such a trend. Please comment?

Ans: The effect observed in treatment T₂ was found to be satisfactory on par with T₇, T₉, T₁₀ and T₁₁. The values under these treatments are only numerically higher.

Q : What is the level of Mg in root wilt affected palms?

Ans: The level of Mg varies with intensity of yellowing.

Q : It is stated that the etiology of the disease is not known. But as early as 1983, MLO has been observed to be associated with root wilt disease. Please comment?

Ans: The etiology of the disease is not proved beyond doubt by employing Koch postulates.

Q : Have you worked out the cost involved in integrated control of root wilt disease?

Ans: No.

THANJAVUR WILT OF COCONUT: ITS OCCURRENCE, SPREAD AND MANAGEMENT

R. BHASKARAN, T. RAMANATHAN and M. RAMIAH

ABSTRACT

A wilt disease was first observed in coconut palms in the coastal areas of Thanjavur district during the year 1952 and named as Thanjavur wilt. The survey conducted during the years 1965-66 showed that the disease was confined to the coastal districts of Tamil Nadu. However, the 1978-80 survey revealed that the disease has spread to all the coconut-growing districts of the State and the incidence is high in coastal districts particularly in Thanjavur (5.0 per cent). Within a garden, the disease generally spreads to adjacent palms in all directions and the spread is slow, a healthy palm adjacent to a diseased palm contracting the disease in a period of six to 14 months.

An experiment on the management of the disease revealed that application of manganese sulphate (225 g per palm per year) reduced the disease intensity when compared to control. Combined application of Bordeaux mixture (40 litres of 1 per cent solution), tank silt (100 kg) and green leaves (50 kg) also reduced the disease severity. There is also clear indication that the disease is contained to a great extent when aureofungin-sol (2 g) + copper sulphate (1 g) in 100 ml of water is given as stem injection in the initial stage of symptom appearance combined with soil drenching of 40 litres of 1 per cent Bordeaux mixture, the treatments being given four times at quarterly interval.

INTRODUCTION

A lethal disease of coconut was first observed in Thambikkottai

and Muthupet areas of Thanjavur district in Tamil Nadu after the cyclones of 1952 and 1955. As the etiology of the disease was unknown, the malady was named as Thanjavur wilt. The disease is characterised by the oozing of a reddish brown viscous fluid from the basal portions of the stem, drooping of leaves and death of the palms in the final stages (Bhaskaran et al., 1982). Available evidence indicates that *Ganoderma lucidum* (Leys) Kart. may have a major role in the cause of the disease. In the present paper, results of the survey conducted on the occurrence and spread of the disease and certain management practices to contain the disease are reported.

MATERIALS AND METHODS

Survey

A random survey was conducted in the various districts of Tamil Nadu during 1965-66 to assess the incidence and intensity of the disease. Again the survey was repeated during the years 1978-80 to assess the extent of spread of the disease. An area of one acre was selected at random for every 200 acres of coconut and the percentage incidence of the disease was assessed. Details regarding age of the palms, soil type and cultural practices followed in the garden were also recorded.

Epidemiology

To study the spread of the disease in a garden from the first focus of infection, three gardens of two acre each with less than 5 per cent disease incidence were selected and all the palms in the gardens were mapped. At monthly intervals, fresh infection, if any, was marked and the experiment was continued for three years.

Management of the disease

Four field experiments were conducted on the management of the disease, namely: (1) effect of coconut husk treatment; (2) effect of micronutrients on disease intensity; (3) effect of fungicides in combination with organic manures and fertilisers; and (4) effect of fungicides and organic manure on Thanjavur wilt intensity (treatment details as given in Tables 1 to 4). In all these experiments, if it is organic manures, fertilisers or micro-

nutrients treatments, they were applied once in a year and if it is fungicide and/or antibiotic treatment, it was given four times at quarterly intervals. The first three experiments were conducted for a period of five years and the last experiment over a period of three years. Disease intensities in all these experiments were worked out according to the formula given by Vijayan and Natarajan (1975).

RESULTS AND DISCUSSION

The survey conducted during 1965-66 revealed that the disease was confined to the coastal areas of Tamil Nadu namely, the districts of Thanjavur (10.8 per cent), Kanyakumari (6.3 per

Table 1. Effect of coconut husk/treatment on Thanjavur wilt intensity and yield of palms (Mean of five years)

Treatments*	No. of trees wilted	Disease index	Yield/palm/year
Husk treated adult palms	0	24	56
Control adult palms	1	127	66
Husk treated young palms	1	105	**
Control young palms	1	123	**

*Five palms in each treatment.

**Palms have not come to regular bearing.

Table 2. Effect of micronutrients on disease intensity and yield of Thanjavur wilt affected palms (Mean of five years)

Treatments	No. of palms wilted	Disease index	Yield/palm/year
Borax	0	16.9	46
Copper sulphate	1	16.7	56
Manganese sulphate	0	2.8	86
Zinc sulphate	2	41.5	59
Ferrous sulphate	2	18.7	33
Ammonium molybdate	1	50.4	56
Control	1	33.0	46

Table 3. Effect of fungicide in combination with organic manures and fertilisers on wilt intensity and yield (Mean of five years)

Treatments*	No. of palms wilted	Disease index	Yield/palm/year
1. 1 per cent Bordeaux mixture (BM) + farm yard manure (FYM) + ash	2	28.7	45
2. BM + Husk	1	60.4	32
3. BM + Palmyrah leaves	1	60.1	50
4. BM + FYM + NPK + Green leaves	1	54.0	56
5. BM + Tank silt + Green leaves	1	15.0	42
6. Control	3	75.2	20

*Bordeaux mixture was applied at 40 litres per palm, farm yard manure 160 kg, ash 40 kg, coconut husk 300 numbers, palmyrah leaves 20 numbers, green leaves 50 kg, tank silt 100 kg and NPK fertilisers 0.23, 0.23 and 0.34 kg per palm.

Table 4. Effect of fungicides and organic manure on Thanjavur wilt intensity (1982-84)

Treatments	Disease index (Mean of three replications)
Aureofungin-sol (AF)	9.6
Bordeaux mixture (BM)	17.1
AF + BM	2.8
Neem cake (NC)	10.9
AF + BM + NC	8.5
Control	48.0
C.D. (P = 0.05)	24.1

AF = Aureofungin-sol 2 g + 1 g copper sulphate in 100 ml of water given as stem injection.

BM = 40 litres of 1 per cent Bordeaux mixture as soil drench.

NC = 5 kg of neem cake.

cent), Trichirapalli (4.0 per cent), Ramanathapuram (4.0 per cent), South Arcot (3.5 per cent) and Chingleput (3.3 per cent). The survey results of 1978-80 indicated that the disease has spread to almost all the districts of Tamil Nadu, although the intensity was maximum in the coastal areas. In some of the seve-

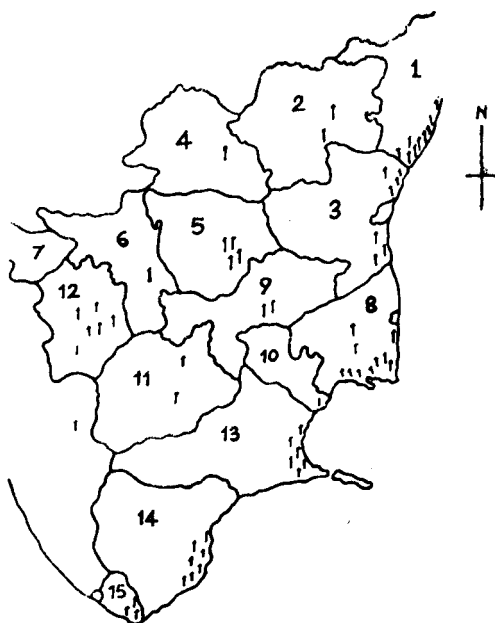
rely infected gardens in Thanjavur district, the incidence was as high as 30 per cent. An analysis of the particulars gathered during the survey revealed that, in general, the disease was more prevalent in coastal sandy or sandy loam soil where coconut is grown under rainfed conditions and in poorly managed gardens. Lack of soil moisture during the summer months, water logging in rainy weather, presence of old infection in the garden and neglect of the cultural operations were found to be conducive to the spread of the disease. Trees in the age group of 10 to 30 years are more susceptible to the disease (43 per cent) than younger trees (17 per cent).

When the spread of the disease in a garden from the first focus of infection was studied, it was found that the disease generally spreads to adjacent palms in all directions and the spread was very slow, healthy palms adjacent to the diseased palms contracting the disease in a period of six to 14 months. However, in a garden, independent infections can occur far away from the original focus of infection and the source of primary communication for such infection could not be ascertained as to whether it is from the soil or from air-borne spores.

In the experiment on the effect of coconut husk treatment (500 numbers per palm), it was found that burying coconut husk in trenches around the adult palm (20 to 25 years old) reduced the disease intensity, whereas in young palms (less than 12 years old), the treatment had no effect (Table 1). When the effect of individual micronutrient application namely, borax, copper sulphate, manganese sulphate, zinc sulphate, ferrous sulphate (each 225 g) and ammonium molybdate (2 g) was tested, it was found that manganese sulphate gave minimum disease intensity and higher yield than control palms (Table 2).

In the experiment on the efficacy of combined application of fungicides, fertilisers and organic manures, combined application of Bordeaux mixture, tank silt and green leaves gave a low disease index of 15.0 as compared to 75.2 in control (Table 3).

The results on the efficacy of the antifungal antibiotic aureofungin-sol revealed that application of the antibiotic either alone or in combination with Bordeaux mixture and *neem* cake gave significant reduction in disease intensity. Even though the different treatments, except control, were on par in this experiment, the combined application of AF + BM as well as AF + BM



+ NC gave a lower disease index than the other treatments (Table 4).

The results presented in this paper thus clearly indicate that Thanjavur wilt of coconut is spreading in all the districts of the State, though the spread is slow. Although the etiology of the disease could not be established, the disease can be contained by management practices especially when the treatments are given in the initial stage of the disease itself.

ACKNOWLEDGEMENT

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DISCUSSION

Q : Under what type of soil was the experiment conducted?

Ans: Sandy loam soil.

Q : As aeration is not a problem in sandy loam soil what is the benefit of ploughing?

Ans: The results of experiments conducted on manuring, irrigation and cultural practices go to show that ploughing definitely influences yield of coconut palms.

Q : The cost benefit ratio are 0.42, 0.40 and 0.39 for control, herbicide and cultural practices respectively. How does the author conclude that ploughing is the best treatment?

Ans: Though there was not much difference in cost/profit ratio, a significantly higher yield of 21.2% over control was obtained in this treatment as against 16.8% in herbicide treatment. Hence the conclusion.

Q : Do the farmers adopt the control measures recommended?

Ans: Yes.

Q : What are the optimum environmental variables that are responsible for the spreading of the disease?

Ans: High temperature during summer, low organic matter content of soil and moisture stress in soil are the factors responsible for spread of this disease.

Q : Zinc sulphate has been found to reduce root wilt disease in Kerala while in the work at Tanjore, the application of zinc sulphate has increased the disease incidence. What could be the reason?

Ans: The difference may be due to the difference in soil type.

EFFECT OF NATURAL INFECTION OF 'KATTE' ON YIELD OF CARDAMOM: A CASE STUDY

M.N. VENUGOPAL and R. NAIDU

ABSTRACT

Studies on crop loss due to natural infection indicated that virus affected plants yield 38 per cent, 62 per cent and 68 per cent less cardamom in the first, second and third year of infection respectively. The quantity of crop loss is related to the duration over which the plant had been infected. The yield of a well-maintained plot was affected considerably from the very first year of infection. Production of cardamom in the disease-affected plot, experienced a loss of 16 per cent at 37 per cent infection level, 44 per cent at 84 per cent infection level and 59 per cent at 98.5 per cent infection level respectively in the first, second and third year of infection.

INTRODUCTION

In India, cardamom (*Elettaria cardamomum* (L.) Maton) occupies over 93,947 ha (Anon, 1984) with an annual production ha of 2600 to 3000 (metric) tonnes. Widespread occurrence of 'Katte' or 'Mosaic' or 'Marble' disease has been recognised as the major threat to this perennial spice crop (Mayne, 1951; Alexander, 1967; George, 1967; Venugopal and Naidu, 1981). Buchanan (1807) estimated the yield of a healthy garden as 59.0 kg/ha while that of a diseased plantation as only a few kg of dry capsules per ha. Varma (1962) studied the effect of simultaneous infection of

'Katte' on arecanut-based cardamom plantation and reported losses ranging from 10 to 98 per cent. This communication presents the extent of crop loss caused by natural infection of 'Katte' virus under forest-based pure, well-managed cardamom plantation.

MATERIALS AND METHODS

This trial was conducted for four years in Sunticoppa Estate, Sunticoppa. The plantation is located at an altitude of 950 m and receives an average annual rainfall of 125 to 175 cm. The selected plot comprised 1976 planting and gap filled in 1978. Planting material used in this block was seedling progeny of Malabar type. The experimental area was quite isolated and a 'U' shaped coffee plantation encloses this block. Initially all the 'Katte' affected plants which were present in two spots were rogued out in July 1979. A bench survey was conducted in June 1980 and all the 'Katte' affected and healthy plants were marked. As the number of plants was inadequate to continue with this study for two more years, a total of 345 plants of 1978 gap fills which attained a yielding stage were included in this experiment from 1981 onwards. A total of 36 to 10 plants died in 1981 and 1982 respectively.

Fresh surveys were repeated in June 1981 and June 1982 to locate new infections. Infections as on June 1980 and new infections that occurred from 16th June 1980 to 15th June 1981, and 16th June 1981 to 15th June 1982, and healthy clumps were marked in corresponding years. Yields of two treatments in 1980, three treatments in 1981 and four treatments in 1982 were taken separately in six to seven rounds of picking. The block received recommended organic and inorganic (NPK 75:75:150 kg/ha) fertilisers applied in two split doses; irrigation in dry period and two rounds of 1 per cent Bordeaux mixture and four rounds of insecticides to keep major diseases and pests under check.

RESULTS AND DISCUSSION

Comparison of yield data presented in Table 1 and Fig. 1 reveal that the 'Katte' infection on productive clumps reduces the yield to the extent of 38 per cent in the same year of infection, 62 per cent in the second year of infection and 68.7 per cent in the third

Table 1. Effect of 'Katte' disease on the yield of cardamom during different years

(a) Yield of green capsules in 1980

Treatments	No. of plants	Total yield (kg)	Mean yield/plant	% of reduction over healthy
1. Infection as on 15th June 1980	679	557.400	0.820	35.4
2. Healthy	824	1046.200	1.270	—
3. Total plants in the block	1503*	1603.600	1.070	16.0

*Yield of an additional 345 plants of 1978 gapfills was not considered in 1980.

(b) Yield of green capsules in 1981

1. Infection as on 15th June 1980	674	166.370	0.240	65.75
2. Infection from 16th June 1980 to 15th June 1981	849	375.300	0.440	38.73
3. Healthy	289	209.630	0.730	—
4. Total plants in the block	1812	751.300	0.410	43.84

(c) Yield of green capsules in 1982

1. Infections as on 15th June 1980	671	127.700	0.190	68
2. Infections from 16th June 1980 to 15th June 1981	843	202.760	0.240	59
3. Infections from 16th June 1981 to 15th June 1982	261	92.650	0.385	39
4. Healthy	27	15.850	0.587	—
5. Total plants in the block	1802	438.960	0.242	59

year of infection. Hence it is evident that 'Katte' causes a considerable amount of loss on cardamom and a reduction in yield is related to the duration over which the plant has been diseased. Varma (1962) reported crop losses of 10 to 68 per cent in the

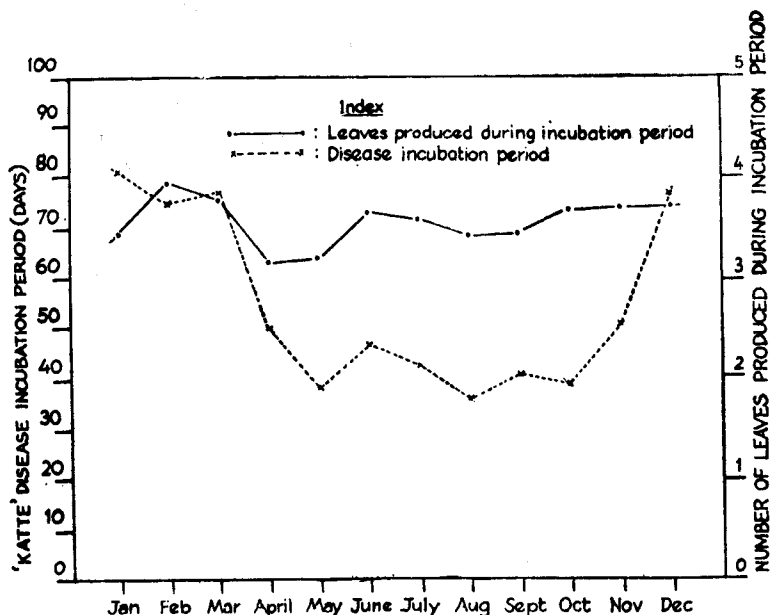


Fig. 1. 'Katte' disease incubation period in relation to number of leaves produced during different months of inoculation

first year of yielding, 26 to 92 per cent in the second year and 82 to 98 per cent in the third year owing to 'Katte' infection. The present study confirms the magnitude of crop loss caused by 'Katte' virus. Basically, the spread of 'Katte' disease follows a compound interest pattern and once it enters, it spreads slowly and centrifugally (Deshpande et al., 1972). There are no reports which ascribe the effect of a centrifugal spread on the total productivity of this perennial crop. This four year study reveals that cardamom production in the affected plot suffered a loss of 16 per cent at 37 per cent incidence level, 44 per cent at 85 per cent incidence level and 59 per cent at 98.5 per cent incidence level respectively in the first, second and third year of infection (Fig. 1). The results obtained from the present yield trial show that it is not economical to keep a diseased plant in the garden, firstly because it yields less, and secondly it serves as a source of inoculum for secondary spread.

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EPIDEMIOLOGY OF 'KATTE' VIRUS DISEASE OF SMALL CARDAMOM. I. DISEASE INCUBATION PERIOD AND ROLE OF DIFFERENT HOST PARTS AS A SOURCE OF INOCULUM IN DISEASE SPREAD

R. NAIDU and M.N. VENUGOPAL

ABSTRACT

The incubation period of 'Katte' virus disease was studied by inoculating grown up clumps under field conditions over a period of three years. The disease incubation period varied from 20 to 114 days during different months of incubation. However, the number of leaves produced during the incubation period remain more or less constant. Symptom expression was directly influenced by the growth of plants as indicated by early expression in the active growing period (May to November) and late expression in dry period (December to April). Higher transmission of the virus was obtained when young growing parts were used as a source of inoculum as against low transmission with mature and old parts. The old leaf sheaths which are the natural breeding sites of the vector were found to be a poor inoculum source. The various forms of aphid found naturally colonising on the old drying parts may not play a significant role in disease spread.

INTRODUCTION

'Katte' or Mosaic disease of cardamom has been responsible for low yields in South India (Mayne, 1951; Varma, 1962). Experimental transmission of the disease through banana aphid was first established by Uppal et al. (1945). The disease spreads pri-

marily through rhizomes used for propagation. Secondary spread in the field occurs through aphid vector. Deshpande et al. (1972) made pioneering efforts to understand epidemiological factors involved in the spread of this disease. They observed negative correlation between the vector population and disease incidence. Their conclusions suffered mainly due to lack of information on the disease incubation period which is essential for predicting and for critical analysis of new outbreaks. Knowledge on the disease incubation period in different seasons, the role of inoculum factor and various forms of aphid naturally colonising on an infected plant, in disease spread is essential to evolve realistic disease management strategy. Since no published information is available on these aspects the following investigations were undertaken.

MATERIALS AND METHODS

Disease incubation period

The incubation period for the disease was defined as the number of days between inoculation of a healthy plant by viruliferous aphid and the appearance of visible symptoms in the newly emerged leaf. To study 'Katte' disease incubation period, inoculations were conducted for three years (1980 to 1982) in an isolated block situated in CPCRI, Research Centre, Appangala farm. The experimental block was located at 1,000 m MSL and receives an annual rainfall of 3,200 mm. Nearly 80 per cent of the rain precipitates in the months of June, July and August. The temperature also varied considerably in different months. The lowest and the highest temperatures under field conditions were 8° C (December) and 32° C (March), respectively. Grown up clumps of five years were inoculated in the first week of every month in 10 replications. The inoculation was done through viruliferous aphids of four to five leaf stage young tiller. Apterate adults of *Pentalonia nigronervosa* f. *caladii* Van der Goot reared on cardamom plants were used for inoculation. Initially aphids were starved for two hours, then fed for 30 minutes on young symptomatic leaves of cardamom carrying local 'Katte' isolate (K-1). Viruliferous aphids were released in groups of 25 per funnel made by rolling and the tying of two youngest leaves. After overnight inoculation access the aphids were killed

by spraying with 0.05 per cent Quinalphos. Data on the number of days taken to express visible symptoms and the number of leaves produced during the incubation period were recorded.

Role of inoculum factor on natural spread of disease

Different host parts namely, unopened leaf, young opened leaf, mature leaf (fourth leaf), old leaf (sixth to eighth leaf from the top), lower-most old leaf, leaf sheath, inflorescence, young capsule, mature capsule, ripe capsule, young suckers (seven to nine cm length), young symptomatic pseudostem and partially dried pseudostem were collected from two-year-old 'Katte' infected plants. These host parts were tested separately as a source of inoculum through adult alate aphids as described earlier. Healthy cardamom seedlings raised in insect-proof conditions were used as test seedlings.

Role of various forms of vector naturally colonising on 'Katte' infected clumps

Partially drying pseudostems harbouring natural colonies were collected from two-year-old 'Katte' affected plants. The aphids in different stages of development namely, nymphs of one to two instar, nymphs of three to four instar, apterate and alate adults were collected and released separately in groups of 10 per test plant. After four hours of inoculation access the inoculants were sprayed with 0.05 per cent Quinolphos to kill the vector. The inoculated test plants were kept in a green house for observations.

RESULTS AND DISCUSSION

'Katte' disease incubation period

It is clear from Table 1 that the effect of climatic variation is profound on the 'Katte' disease incubation period which varied from 20 to 114 days during different months. An early expression of symptoms was seen in the active growing season (May to November) and it took more time during the dry months (December to April). The incubation period is directly influenced by the temperature, soil moisture and other edaphic factors. In spite of variations, the number of leaves produced during the incubation period in different months of inoculation remain

*Table 1. 'Katte' disease incubation period under field condition
(Mean of 10 replications)*

Months	Number of leaves produced during incubation period (Mean for three years)	Number of days taken for symptom expression (Mean for three years)
January	3	81
February	4	75
March	4	77
April	3	50
May	3	39
June	4	47
July	4	42
August	3	37
September	3	41
October	4	39
November	4	51
December	4	77

more or less constant. Symptoms first appear as chlorotic flecks in the fourth leaf produced after the inoculated leaf. The succeeding leaves show granular mosaic followed by clear mosaic. This pattern of symptoms expression remains clear till the inoculated pseudostem dries up (more than one year). This character can be taken as a key in predicting latent infections in epidemiological studies.

Deshpande et al. (1972) tried to correlate the vector population and activity and new outbreaks of disease in corresponding observations. Our studies have shown that actual infection occurs much earlier and it will be under incubation for a considerable period. By using the information on the disease incubation period in different months the correct assessment between vector population and new infections can be worked out.

Roguing has been suggested as a practical measure to manage 'Katte' disease of cardamom (Varma, 1962; Deshpande et al., 1972; Naidu and Venugopal, 1982; Naidu, 1983). The success of roguing has been attributed to locating infected plants at an early stage of disease. Data obtained in the present investigations are of practical value in fixing the interval and frequency of inspection during the plant sanitation operation.

Role of inoculum factor in the spread of disease

A higher transmission was recorded with the young leaves and a lower transmission was observed when the old and matured plant parts were used as inoculum source (Table 2). It is interesting to note that the old leaf sheaths which normally harbour an aphid colony are a poor source of inoculum. These results show that even non-symptomatic young host parts like panicles and capsules can also serve as a source of inoculum. In the light of the above results it is more appropriate to use young leaves to obtain higher transmission in screening trials for 'Katte' disease resistance.

Table 2. Effect of different host parts as a source of inoculum of transmission of 'Katte' disease

Sl. No.	Host part used for acquisition	No. of test seedling		Transmission per cent
		Inoculated	Infected	
1.	Unopened leaf	18	4	22.22
2.	Young opened leaf (1st leaf from top)	25	23	92.00
3.	Mature leaf (4th)	21	11	52.38
4.	Old leaf (6th-8th)	15	5	33.33
5.	Lower-most old leaf	20	2	10.00
6.	Leaf sheath (unopened)	13	1	7.69
7.	Inflorescence	14	1	1.14
8.	Young capsule (peanut size)	20	3	15.00
9.	Mature capsule	20	2	10.00
10.	Ripe capsule	20	0	0.00
11.	Young suckers (7-9 cm)	19	3	15.79
12.	Young pseudostem symptomatic	20	2	10.00
13.	Partially dried pseudostem	25	0	0.00

Role of various forms of aphid found colonising on 'Katte' affected plant

The results presented in Table 3 indicate that aphids colonised on the old leaf sheaths of 'Katte' affected plants play a negligible role in the disease spread. Under natural conditions, aphids are found in colonies of 30 to 50 comprising nymphs, apterate and alate adults. These colonies are formed in between the pseudostem

and loose leaf sheaths especially of old partially decayed, drying or damaged plants. The migration of aphids occurs only when the pseudostem starts drying and becomes unsuitable for food and shelter. This study suggests that aphids migrating from natural breeding sites may not be viruliferous and intermittent migration and probing on young host parts may be responsible for the natural spread of the disease. This study also indicates the low concentration of virus in the older parts which is a common feature in virus affected plants (Bartels, 1954). As there are remote chances of spread with the old parts, the prevailing disposal procedure can be simplified. Instead of disposing the entire 'Katte' infected clump as suggested by Deshpande et al. (1972) and Rao (1977) the aerial portion can be detopped and placed gently around the basin and only the rhizome portion can be eliminated, so that the labour involved in the roguing operation can be minimised.

Table 3. Role of various forms of vector naturally colonising on diseased clumps in transmission of the disease

Sl. No.	Form of aphid vector tested	No. of test seedlings		Transmission per cent
		Inoculated	Infected	
1.	Nymphs (1-2nd instar)	150	0	0.00
2.	Nymphs (3-4 instar)	146	1	0.68
3.	Apterous adults	150	0	0.00
4.	Alate adults	40	0	0.00
Total		486	1	0.20

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DISCUSSION

- Q : What is the effect of shade trees on the spread of Katte disease?
- Ans: Studies on this aspect have not been conducted so far.
- Q : How does agro-ecological conditions affect the spread of the disease?
- Ans: The disease spreads at faster rate under condition of low rainfall, higher temperature and lower altitude. Higher vector population and their migratory activity are noticed under these conditions.
- Q : Why is that the capsules are not affected by the Katte disease?
- Ans: Katte virus does not affect capsules. The affected capsules act as symptomless carriers of the virus.

COLLATERAL HOSTS OF *CORYNEBACTERIUM* SP. CAUSING CHENTHAL DISEASE OF CARDAMOM

MATHEW GEORGE and N.P. JAYASANKAR

ABSTRACT

Corynebacterium sp. is reported to be involved in the blight of cardamom and symptoms characteristic of chenthal disease were observed on certain wild species of *zinziberaceae*. The host range of the bacterium was studied with respect to eight species after spraying the bacterial suspension. *Curcuma angustifolia* did not exhibit any symptoms. Mild infection was noted on *Alpinia galange*. Water soaked lesions were observed on *Aframomum malequeta* and *Zingiber officinale*.

INTRODUCTION

The blight of cardamom, familiarly known as chenthal disease is characterised by the appearance of initially water-soaked lesions of varying sizes on the abaxial surface of young leaves which later turn brown to dark in colour with a pale yellow halo. As the withering of leaves progresses the pseudostems wilt. The involvement of *Corynebacterium* sp. in the blight of cardamom has been reported (George et al., 1976). A survey of the cardamom growing tracts of the Western Ghats revealed the spread and factors influencing the disease (George and Jayasankar, 1979). The characteristic symptoms of chenthal disease observed during the survey on certain wild *Zingiberaceae* plants prompted a study to be made on the host range of this bacterium.

MATERIALS AND METHODS

Eight *Zingiberaceae* plants were raised in earthen pots holding 15 kg soil by planting pieces of underground stem. These pots were maintained in a glasshouse. The *Corynebacterium* isolate from cardamom was multiplied in nutrient broth. After 24 hours incubation the inoculated broth was centrifuged at 6000 rpm and the bacterial cells were sedimented and resuspended in saline. The turbidity of the suspension was adjusted to contain approximately 10^7 cells/ml (O.D. 0.7 to 0.9). The potted plants were covered with polythene bags and inside of polythene cover was sprinkled with water to maintain increased relative humidity. The plants were sprayed with the bacterial suspension after 12 hours using an atomiser both on the adaxial and abaxial surface of the leaves. Polythene covers were sprinkled with water periodically on the subsequent days. The abaxial surface of the leaves were observed for the water-soaked lesions characteristic of *Corynebacterium* infection in chenthal disease. Bits of leaf showing water-soaked lesions were washed in several turns of sterile water and plated on nutrient agar to reisolate the pathogen. The bacterium encountered was compared to the original isolate.

RESULTS AND DISCUSSION

The intensity of symptom expression by the different plants sprayed upon with the pathogen is expressed in Table 1. Among the *Zingiberaceae* plants tested, *Curcuma angustifolia* failed to exhibit any reaction to inoculation with *Corynebacterium* whereas in *Aframomum malegueta* and *Zingiber officinale* characteristic water-soaked lesions were observed after 60 hours. Even though only mild infection was noticed in *Alpinia galanga*, the water-soaked lesions turned to brown spots within 60 hours. Except in *Alpinia galanga* in all other plants the water-soaked lesions persisted as such, for four to five days and disappeared later with no further progression of symptoms. On planting, the bits of leaf showing water-soaked lesions, the pathogen was reisolated. Chenthal causing *Corynebacterium* and its host cardamom prefers to thrive better in comparatively cooler weather conditions. One of the reasons for failure of a symptom development in these plants may be attributed to the higher temperature of the plains

Table 1. Intensity of water-soaked lesions on spraying with *Corynebacterium* sp.

Plant	Observations	
	24 h	60 h
1. <i>Curcuma angustifolia</i> , Roxb.	Nil	Nil
2. <i>Alpinia galanga</i> , Willd.	+	Developing brown spot
3. <i>Hedychium coronarium</i> , Koen.	+	as such
4. <i>Zingiber zerumbet</i> , Smith.	+++	as such
5. <i>Curcuma longa</i> , Linn.	+++	as such
6. <i>Aframomum malegueta</i> , K. Sch.	Nil	++
7. <i>Amomum muricatum</i> , Beddome	+++	as such
8. <i>Zingiber officinale</i> , Rosc.	Nil	+

where the study was conducted. The same reason holds good for the non-occurrence of this disease on the *Zingiberaceae* plants growing on the plains. But characteristic symptoms were observed on *Alpinia malaccensis*, a wild species of *Zingiberaceae* growing in the border of a certain cardamom estate. Symptoms were also observed on *Hedichium coronarium*, *Aframomum malegueta* and *Alpinia calcarata* maintained in the farm of cardamom research station, Pampadumpara. The record of chenthal symptoms on *Hedichium coronarium* may be of importance as *Hedichium* sp. is used for intergeneric hybridisation of cardamom—an attempt to build up resistance against 'Katte' disease of cardamom.

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DISCUSSION

Q : Could you isolate the *Corynebacterium* from the artificially inoculated plants which took infection?

Ans: Yes.

Q : Did you observe the association of *Cercospora* spores with Chenthal disease?

Ans: Similar symptoms were found to be caused by *Cercospora* in Malabar variety.

ELETTERIA CARDAMOMUM—A NEW HOST FOR *PHYTOPHTHORA PALMIVORA* (BUTLER) BUTLER

T.P. MANOMOHAN and ABI CHEERAN

ABSTRACT

During the course of an investigation to find out the collateral hosts of *Phytophthora palmivora* (Butler) in pepper gardens, cardamom was also found to harbour this pathogen. The cultural and morphological characters of the isolate of *P. palmivora* from cardamom were identical with those from arecanut, coconut, cocoa, pepper, and rubber. When cross inoculated on the above hosts the cardamom isolate of *P. palmivora* gave positive results.

INTRODUCTION

The ravages caused by *Phytophthora palmivora* (Butler) have been reported from a number of cash crops in Kerala. It causes bud rot in coconut, fruit rot or 'mahali' in arecanut, black pod in cocoa, quick wilt or foot rot in black pepper and abnormal leaf fall and pod rot in rubber. The warm and humid climate of Kerala is highly favourable for this pathogen.

During the course of an investigation to identify the collateral hosts of *P. palmivora* in pepper gardens, cardamom was also found to harbour this pathogen. The cardamom capsules showing rotting symptoms collected from a garden in Wynad district yielded *P. palmivora* on isolation. The association of *Phytophthora* species with cardamom was reported by several earlier workers.

Menon et al. (1972) had identified *Phytophthora* sp. as the causative organism of 'azhukal' disease of cardamom. Later, Thankamma and Pillai (1973) identified this *Phytophthora* sp. as *P. nicotianae* Breda de Haan var. *nicotianae* waterhouse. Nair and Menon (1980) also successfully isolated *Phytophthora* sp. from all parts of cardamom showing azhukal infection and identified as *P. nicotianae* var. *nicotianae*. Even though Radha and Joseph (1974) had reported that capsule rot (azhukal) of cardamom may also be caused by *P. palmivora* or its strains or variety, its association with cardamom has not been recorded so far.

RESULTS AND DISCUSSION

The morphological characters of the *Phytophthora* sp. isolated from cardamom capsules during the present investigation were found almost agreeing with Butler's (1907 and 1919) descriptions of *P. palmivora*. The growth on carrot agar produced very sparse aerial mycelium. Mycelium was hyaline and coenocytic. The hyphae measure 4.00 to 6.00 μm (mean 4.96 μm) in thickness. Sporangiohores arose from the somatic hyphae and their tip became swollen which developed into sporangia. The sporangiohores were of indeterminate growth measuring 35.00 to 255.00 μm (mean 119.30 μm) long. Mature sporangia were ovoid to limoniform with a round base and well pronounced papillae. They were borne terminally on the sporangiohores in a simple sympodial fashion and were caducous. Deciduous sporangia measured 35.00 to 42.50 \times 25.00 to 32.50 μm (mean 39.15 \times 27.50 μm) and had short and thick stalks filled with semitransparent plugs of 2.00 to 5.00 μm (mean 3.24 μm) long. The L/B ratio (length by breadth ratio) of the matured sporangia ranged from 1.23 to 1.70 (mean 1.42) (Table 1, Figs. 1 and 2).

Deciduous sporangia germinated in the presence of free water giving rise to a mass of zoospores through the papillae. They rested for a while at the mouth of the sporangium and then motile zoospores got separated from the mass and swarm away in the film of water. After a short while, the swarming zoospores came to rest and got encysted. The encysted zoospores were more or less spherical measuring 8.00 to 10.00 μm in diameter. They later germinated by means of a germtube (Table 1, Fig. 3).

The fungus produced chlamydospores in abundance in old cul-

Table 1. Morphological characters of *P. palmivora* isolate from cardamom

Morphological character	*Mean	*Mode	*Range
Breadth of hypha, μm	4.96	5.00	4.00-6.00
Length of sporangiophore, μm	119.30	—	35.00-255.00
Length of sporangium, μm	39.15	37.50	35.00-42.50
Breadth of sporangium, μm	27.50	27.50	25.00-32.50
L/B ratio of sporangium	1.42	1.36	1.23-1.70
Length of pedicel, μm	3.24	3.00	2.00-5.00
Diameter of zoospores, μm	8.85	9.00	8.00-10.00
Diameter of chlamydozoospores, μm	8.90	9.00	7.00-11.00
Diameter of oospores, μm	33.22	30.00	27.00-42.00

*of 50 observations.

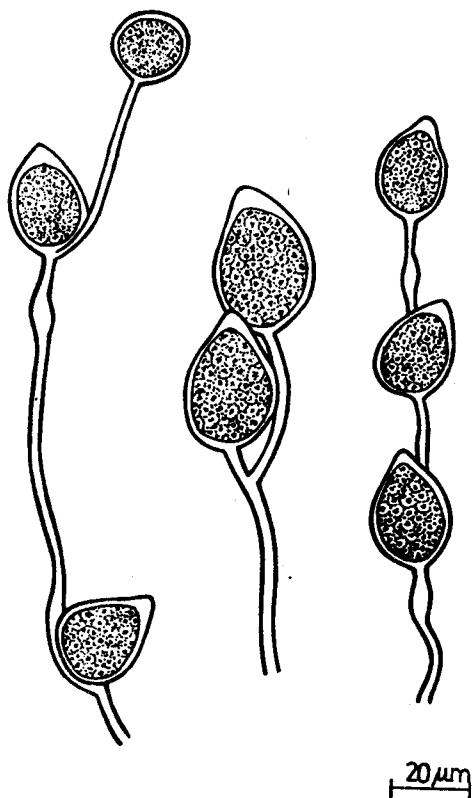


Fig. 1. Sporangial ontogeny of *P. palmivora* cardamom isolate on carrot agar.

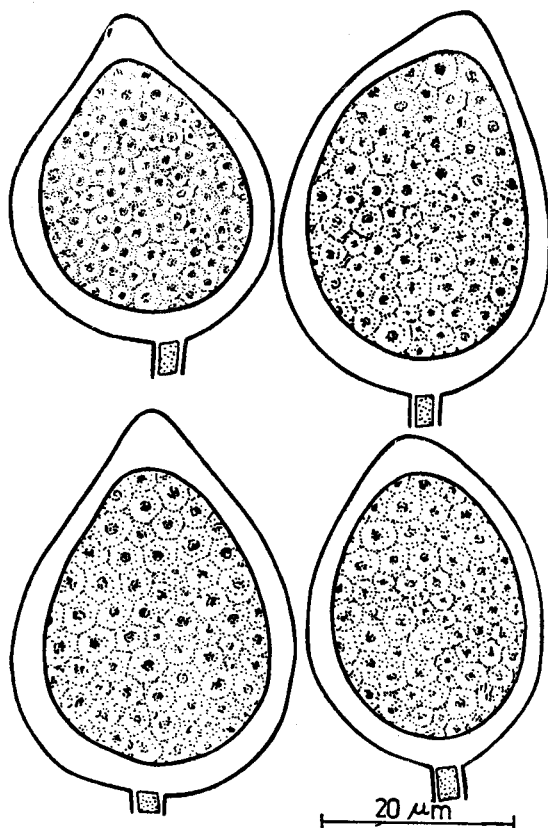


Fig. 2. Sporangia of *P. palmivora* cardamom isolate.

tures in oat meal agar. They were intercalary, slightly coloured and more or less spherical measuring 7.00 to 11.00 μm in diameter. Oospores were also observed abundantly in monoculture. The spherical oospores measured 27.00 to 42.00 μm (mean 33.22 μm) in diameter (Table 1).

The cultural and morphological characters of this isolate of *P. palmivora* were identical with those isolated from arecanut, coconut, cocoa, pepper and rubber. When cross-inoculated on arecanut, coconut, cocoa, pepper and rubber it yielded positive results. The symptoms developed on these hosts were similar to those produced by the isolates from the host proper.

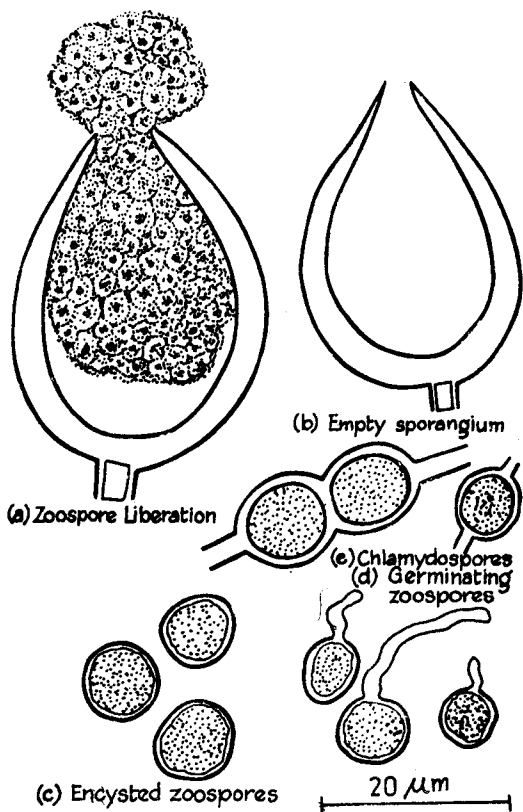


Fig. 3. *P. palmivora*: Germination of encysted zoospores.

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DISCUSSION

- Q : How many zoospores were observed in a single sporangium?
- Ans: In carrot agar medium the zoospores in a sporangium varies from 50-100.
- Q : Have you isolated *P. palmivora* from plant parts other than cardamom capsules?
- Ans: Yes.

EVALUATION OF FUNGICIDES FOR THE CONTROL OF *PHYLLOSTICTA* LEAF SPOT OF GINGER

T. PREMANATHAN and C.K. PEETHAMBARAN

ABSTRACT

Leaf spot, caused by *Phyllosticta zingiberi* causes extensive foliar destruction in ginger. Twelve fungicides were tested in the laboratory. One per cent Bordeaux mixture was found to be efficient and the best, followed by Difolatan and Antracol. Field trial for the disease control was conducted with six fungicides and Cuman, Bordeaux mixture, Panolil and Difolaran, respectively recorded a minimum disease index.

INTRODUCTION

Ginger is an important seasonal spice crop contributing nearly 13 per cent of the total spice export from India, Kerala, with an area of 12,700 ha of land under ginger, producing 33,000 tonnes of dry ginger per year accounts for over 40 per cent of the total production in our country. The crop is subject to a number of diseases resulting in varying degrees of yield reduction. While soft rot caused by *Pythium* spp. continues to be the most serious disease of ginger, leaf spot caused by *Phyllosticta zingiberi* Ramakr. has assumed serious proportions causing extensive foliar destruction and thereby considerable reduction in yield.

The present study was conducted to evaluate the efficacy of different fungicides for the control of the disease.

MATERIALS AND METHODS

Laboratory evaluation of fungicides was conducted by the poisoned food technique (Zentmeyer, 1955) using potato dextrose medium. Details of the fungicides used are given below:

1. Antracol	Zinc-propylene-bis-dithiocarbamate
2. Bavistin	2-(methoxy-carbamoyl)-benzimidazole
3. Bayer 5072	P-Dimethyl amino-benzene diazo-sodium sulfonate
4. Bordeaux mixture	Basic copper sulphate
5. Cuman	27 per cent Zinc dithiocarbamate
6. Difolatan	N-1, -1, 2, 2-tetrachloroethyl thio-cis-4-cyclohexene-1, 2-dicarboximide.
7. Dithane M-45	75 per cent co-ordination product of zinc ion and manganous ethylene bis-dithiocarbamate
8. Dithane Z-78	75 per cent ethylene bis-dithiocarbamate
9. Fycop A	40 per cent copper oxychloride
10. Hinosan	O-ethyl-S, S-diphenyl dithiophosphate
11. Kitazin	48 per cent O-O-diethyl-S-benzyl thiophosphate
12. Panolil	Guazatine-40 per cent W/V. (Guandated 9-aza-1, 17-diamino-heptadecane acetate salt)

All the fungicides except Bordeaux mixture were tested at concentrations of 100, 250, 500, 1,000 and 2,000 ppm using poisoned food technique incorporating the fungicides in potato dextrose agar medium. Bordeaux mixture was tested at 1 per cent concentration. Twenty ml of potato dextrose agar was taken in a culture tube, sterilised and the required quantity of fungicide added from the stock solution to the molten medium, mixed, well and poured into a sterilised Petri dish. A disc (5 mm) cut out from a seven-day-old culture of the fungus was placed in the centre of the Petri dish aseptically and incubated at room temperature. The medium without fungicide was taken as control. Four replications were maintained for each treatment. Observations on

the growth of the fungus were noted on the sixth day of incubation, when the growth in check reached the outer edge of the Petri dish. The per cent inhibition of fungal growth in fungicide incorporated medium was calculated by the formula (Vincent, 1927). For bio-assay in liquid medium, the required quantity of fungicide was added into 100 ml of sterilised potato dextrose broth in a conical flask (250 ml). A fungal disc of 5 mm diameter as mentioned above was transferred aseptically into the flask and incubated at room temperature. Potato dextrose broth without any fungicide was kept as control. Three replications were used in all experiments. The dry weight of mycelium after 15 days growth was noted after filtering the fungal mat through a previously weighed Whatman No. 1 filter paper and oven drying at 60°C till a constant weight was obtained.

Field trial for the control of the disease was conducted in randomised block design with seven treatments and four replications using the cultivar, Maran. The cultivation was done as per package of practices recommendations (Anonymous, 1978). Five fungicides found significantly effective in checking the growth of the fungus in bio-assay studies and Fycop (reported effective against the fungus elsewhere) were used at concentrations given below:

<i>Fungicide</i>	<i>Concentration per cent</i>
Antracol	0.2
Bordeaux mixture	1
Cuman	0.1
Difolatan	0.2
Fycop	0.25
Panolil	0.05

The fungicides were sprayed three times at six week intervals starting from three months after planting, when the leaf spots appeared in the field. Observations were recorded at three week intervals using a score card having nine grades as given below:

<i>Grade</i>	<i>Intensity of the disease (Per cent leaf area infected)</i>
0	No infection
1	less than 2 (1 or 2 spots)
2	less than 5 (3 to 5 spots)
3	less than 10 (6 to 9 spots)
4	11 to 20

5	21 to 35
6	36 to 60
7	61 to 85
8	More than 85

Twelve clumps from each replications were tagged and all the leaves from each clump were graded. The disease index was calculated by a modified method of McKinney's scale (1923) as follows:

Disease index =

$$\frac{(\text{grade} \times \text{number of leaves})}{\text{Total number of leaves}} \times \frac{100}{\text{Maximum disease score}}$$

RESULTS AND DISCUSSION

Bio-assay studies

In solid medium, Panolil induced 100 per cent inhibition, at 1,000 ppm. Complete inhibition was noticed with Antracol and Bayer 5072 at 2,000 ppm and 1 per cent Bordeaux mixture (Table 1). On comparing the efficacy of different fungicides, 1 per cent Bordeaux mixture was found to be the best, followed by Difolatan and Antracol. Panolil was found to be the best in concentrations above 500 ppm. There were significant differences among the different concentrations of the same fungicide.

The extent of inhibition in fungicide incorporated liquid medium was more than that in the solid medium. Bordeaux mixture completely inhibited the growth of the fungus. Bayer 5072 and Cuman also completely inhibited the growth at 2,000 ppm. On comparing the efficacy of the fungicide in inhibiting the growth based on the mean mycelial weight, Bordeaux mixture was found to be superior to all other fungicides followed by Cuman and Bavistin which were on par (Table 2). The fungistatic activity of Bordeaux mixture on pycniospores of *Phyllosticta prunicola* was reported by Ristanovic (1972). Prasad et al. (1978) observed that Difolatan even at the lowest dose (25 ppm) was inhibitory to the pathogen of cardamom leaf spot, *Phyllosticta elettariae*. In the present study, in solid medium, a similar result was obtained. However, complete inhibition of the fungal growth was not obtained even at the highest concentration in both solid and liquid media. In liquid medium Bavistin 2,000 ppm and Cuman 500

Table 1. Effect of different fungicides in potato dextrose agar medium on the growth of *Phyllosticta zingiberi*

Treat- ment No.	Fungicide	Per cent inhibition of growth of the fungus in fungicide incorporated medium						Mean
		100	250	500	1000	2000		
		Concentrations in ppm						
1.	Antracol	72.34	78.27	87.80	88.10	100.00	85.30	
2.	Bavistin	0.00	0.00	5.95	11.90	19.35	7.44	
3.	Bayer 5072	0.00	19.94	65.48	89.88	100.00	55.06	
4.	Cuman	29.76	66.96	85.42	90.18	97.02	73.87	
5.	Difolatan	92.86	93.15	93.45	93.75	94.05	93.45	
6.	Dithane M-45	68.45	71.73	79.76	83.33	83.33	77.32	
7.	Dithane Z-78	36.90	42.56	55.06	74.11	86.99	59.11	
8.	Fycop	0.00	23.81	38.99	74.11	83.33	44.05	
9.	Hinosan	63.10	64.58	69.05	70.44	78.57	69.11	
10.	Kitazin	19.34	55.36	73.51	84.23	84.52	63.39	
11.	Panolil	0.00	77.38	100.00	100.00	100.00	75.48	
12.	Bordeaux mixture 1 per cent						100.00	

(The data were analysed after angular transformation).

CD (0.05) between fungicides excluding Bordeaux mixture: 2.23.

CD (0.05) for comparing Bordeaux mixture with other fungicides: 3.87.

CD (0.05) between concentrations within fungicides: 0.50.

12 5 1 11 6 4 9 10 7 3 8 2

Table 2. Effect of different fungicides in potato dextrose broth on the growth of *Phyllosticta zingiberi*

Treatment No.	Fungicide	Dry weight of mycelium (in mg) in fungicide incorporated medium						Mean
		100	250	500	1000	2000		
		Concentrations in ppm						
1.	Antracol	169	139	136	111	67	124.40	
2.	Bavistin	105	95	73	73	62	81.60	
3.	Bayer 5072	432	105	82	73	62	150.80	
4.	Cuman	144	71	65	63	63	81.20	
5.	Difolatan	150	130	118	93	77	113.60	
6.	Dithane M-45	171	126	109	108	110	124.47	
7.	Dithane Z-78	195	158	107	83	82	125.13	
8.	Fycop	603	283	148	105	98	247.40	
9.	Hinosan	207	118	112	96	77	122.00	
10.	Kitazin	107	94	76	70	69	83.20	
11.	Panolil	185	132	95	83	73	113.73	
12.	Bordeaux mixture 1 per cent						62.00	
13.	Control						808.00	

(Dry weight of the fungal disc used = 62 mg).

CD (0.05) between fungicides excluding Bordeaux mixture: 1.95.

CD (0.05) for comparing Bordeaux mixture with other fungicides and control with fungicides: 3.38.

CD (0.05) between concentrations within fungicides: 4.37.

12 4 2 10 5 11 9 1 6 7 3 8

ppm and above, gave 100 per cent inhibition of growth of the fungus though they supported some growth of the fungus in solid medium. This can be attributed to the uniform dispersal of the fungicides in liquid medium than in solid medium.

Field studies

The pre-treatment and post-treatment disease indices are presented in Table 3. The pre-treatment disease indices were statistically on par. The observations from three weeks onwards showed that plots treated with Cuman recorded minimum disease index followed by Bordeaux mixture, Panolil and Difolatan throughout the experimental period (Table 3).

The efficacy of different fungicides against the disease was compared by taking the mean disease index of observations. Cuman (8.54) was superior to all other fungicides followed by Bordeaux mixture (10.62). All the fungicide treatments were significantly superior to an untreated set. Cuman and Bordeaux mixture were found to be effective in controlling the disease throughout. Ramakrishnan (1942) and Sohi et al. (1973) have recommended the spraying of Bordeaux mixture against the disease.

Effect of fungicide treatment on the yield of green ginger

The effects of different treatments on the control of *Phyllosticta* leaf spot, and thereby on the rhizome yield of ginger was worked out. The per cent decrease in disease index over the control was worked out based on the disease index, three weeks after the third spray. The maximum decrease was obtained in Cuman sprayed plots (49.23) followed by those treated with Bordeaux mixture (39.53). Similarly from the yield data, the average yield per plot and the per cent increase of yield over the control as a result of fungicide application was calculated and is presented in Table 3. The average rhizome yield per plot was not statistically significant. However, the yield per plot was directly proportional to the efficacy of the fungicide on the disease control. Cuman treated plots gave the maximum average yield (31,640 kg) followed by Bordeaux mixture (29,960). The maximum per cent increase in yield over the control was obtained in Cuman treated plots (34.98) followed by Bordeaux mixture (27.82) and Difolatan (27.30).

Table 3. Efficacy of different fungicides for the control of Phyllosticta leaf spot of ginger

Treatment No.	Fungicide	Disease index			Average yield per plot in kg	Percentage increase over control
		Pre-spraying	Three weeks after third spray	Percentage decrease over control		
1	Antracol	1.16	32.74	13.20	28.240	20.48
2	Bordeaux mixture	2.07	22.81	39.53	29.960	27.82
3	Cuman	1.32	19.15	49.23	31.640	34.98
4	Difolatan	0.94	29.71	21.24	29.840	27.30
5	Fycop	1.72	31.85	15.56	24.600	4.95
6	Panolil	1.59	26.32	30.22	28.000	19.45
7	Control (no fungicide)	1.94	37.72	—	23.440	—

CD

NS

2.14

NS

3 2 6 4 5 1 7

The study emphasises the need for giving prophylactic spray of fungicides, Cuman or Bordeaux mixture which are found to be very effective against the disease.

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DISCUSSION

Q : Why some of the fungicides effective in liquid medium were excluded from the field trial?

Ans: Fungicides like Bavistin (2000 ppm) though effective in liquid medium, were not effective in solid medium. Moreover, cost of fungicides was also taken into consideration while selecting fungicides for the field trial.

MODULATION OF LEAF SURFACE pH AND BLISTER BLIGHT DISEASE CONTROL IN TEA

B. CHANDRA MOULI and R. PREMKUMAR

ABSTRACT

Laboratory studies have shown that the basidiospores of *Exobasidium vexans* Masee, the causal fungus of the blister blight disease of tea, failed to germinate at and below pH 3 while maximum germination occurred at pH 8 and 8.8. In a field experiment the possibility of controlling blister blight by modulating pH of the leaf surface was investigated. Excellent disease control was obtained by daily spraying of acid water (pH 1.3), whereas with a similar spray application of alkaline water (pH 8 and 9) disease infection was either at the level of or even greater than the untreated disease control. Treatments were not phytotoxic and they did not impair the quality of the processed tea. But in acid with water treatment imposed at a two day interval, the infection was high under continuous wet weather conditions and low when the weather was mild. Longer intervals of three, five and seven days of acid treatment were found to be inferior.

INTRODUCTION

Prevention of spore germination, thereby precluding infection by plant pathogenic fungi, by adverse pH on the leaf surface could be a novel approach to disease control. Two factors influenced us in undertaking the investigation reported in this paper: (1) the observation that basidiospores of *Exobasidium vexans* Masee germinated poorly at low pH (Venkata Ram, 1979);

and (2) the report by Cloughley and Ellis (1980) that modification of leaf pH to the range 4.5 to 4.8 during fermentation increased the theaflavin content and decreased the level of thearubigins in black tea, thereby improving quality. Several species of basidiomycetes have been recorded to be favoured by pH range 5.0 to 8.5 for spore germination, with the optimum close to 7.5 (Kauffman, 1934) and in this respect *E. vexans* behaves similarly in that the optimum pH for germination is 7.0 to 8.8 (Venkata Ram, 1979). At pH 3.1 germination of *E. vexans* basidiospores is completely inhibited. The occurrence of *Aureobasidium pullulans* on the phyllosphere is antagonistic to *Helminthosporium sativum* due to pH effect; cultural filtrate of the former was shown to inhibit germination of *H. sativum* due to low pH (4.0) (Diem, 1969). In studies on the effect of atmospheric pollution on leaf surface microflora Saunders (1971) showed that fungi may be adversely affected by deposition of sulphuric acid, and other acids; only 30 per cent of conidia of *Diplocarpon rosae*, the causal pathogen of black spot disease of rose, germinated in 100 ppm sulphuric acid, whilst this concentration had no injurious effect on the host plant. An experiment was performed to explore the possibility of obtaining adequate control of blister blight disease by modification of leaf surface pH with dilute acid sprays to prevent spore germination, the results of which are reported here.

MATERIALS AND METHODS

Plots of 30 bushes, planted at 120×75 cm in 1965, in a blister susceptible clone (TES-34) were marked in a tea field at the Research Institute. Aqueous sprays of nitric acid, 3 ml concentrated HNO₃ in 1 litre of water (pH 1.26) and alkaline sprays made with 0.1 N sodium hydroxide to give pH 8.0 and 9.0, were applied to the tea plants in the appropriate treatments with a hand atomiser fitted with a Bray 000 nozzle, adjusted to a spray volume of 175 l/ha. Dilute nitric acid was sprayed at intervals of one, two, three, five and seven days, whereas dilute sodium hydroxide sprays were applied daily.

Percentage incidence of blister blight recorded at each of the 16 weekly samplings in the acid and alkali spray treatments, compared to the control, is given in Fig. 1; data relating to disease

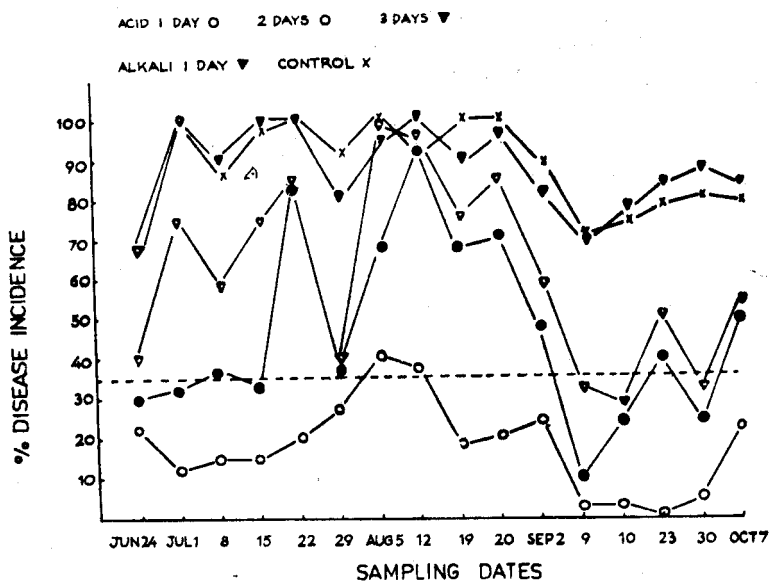


Fig. 1. Per cent of incidence of blister blight disease after acid and alkali treatment.

incidence in acid spray imposed at five and seven days intervals are not included, because in these treatments infection was all through the above critical 35 per cent level. Results with alkali spray at pH 9.0 only are given since the trend and level of disease incidence at both pH 8.0 and 9.0 were almost identical.

RESULTS AND DISCUSSION

Blister blight infection in the untreated control and in the alkali treatment was throughout very high, reaching 100 per cent in some of the assessments. It is apparent that alkali spray caused increase in blister blight incidence over the control, while acid spray treatment gave interesting results in regard to application intervals. Daily sprays checked blister infection very efficiently and with the exception of two assessments (August 5th and 12th) in all the other 14 samplings disease incidence was well below the critical level of 35 per cent; from September 9th to October 7th, infection was extremely low. At two day intervals blister incidence was below the critical level in six of the assessments, but infection increased to very high levels on July 22nd and

August 12th; this treatment could be considered satisfactory in reducing disease incidence only in the early part, and towards the end of the period of disease occurrence. Acid spray at three days intervals was unsatisfactory from the beginning of the treatment until September 2nd, thereafter in three assessments infection dropped to below the critical level and it again increased in two assessments.

In Fig. 2 the average disease incidence over the duration of the experiment, in the seven treatments, and the control, is presented. Only with acid spray at one day interval the percentage blister infection was well below the critical threshold of 35 per cent; in all other acid spray treatments at intervals of two, three five and seven days, disease incidence was 50 per cent or above. In the alkali spray treatment at both pH 8 and 9 per cent, the disease incidence was very high and it was comparable to the untreated control.

It is observed from Table 1 that rainfall was excessively heavy, and sunshine hours very few in June and August, whereas in

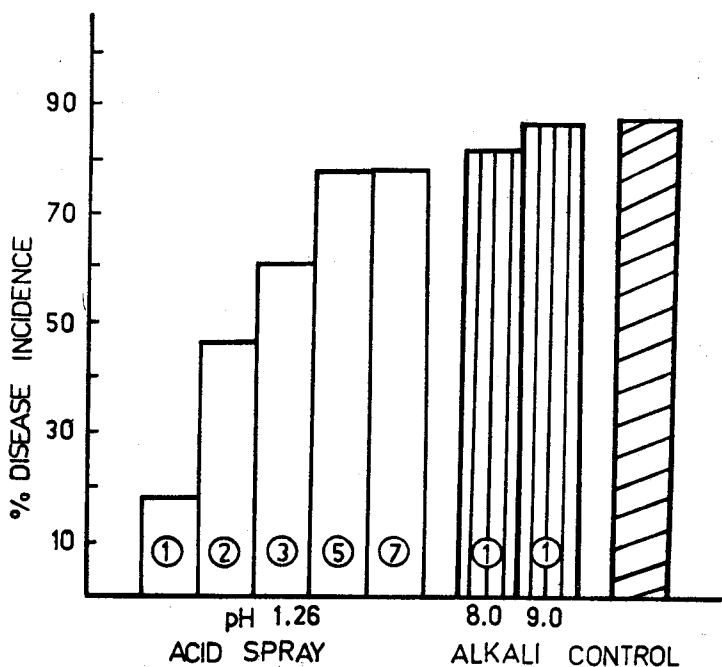


Fig. 2. The average disease incidence after treatment.

Table 1. Meteorological data recorded during the period of experiment (1981)

Month	Jun.	Jul.	Aug.	Sep.	Oct.
Rainfall (mm)	1552.4	923.2	1017.8	869.9	286.1
Sunshine (hours)	28.5	70.0	34.5	81.5	113.5

July and September despite moderately heavy rainfall the sunshine hours were 70 and 81.5, respectively. This weather pattern is reflected in the incidence of blister blight in the acid spray treatment imposed at two and three day intervals. Early in the blister blight season the infection pressure is low because of comparatively less inoculum load in the atmosphere and in such situations application of acid spray at two day intervals controlled the disease to below the critical level. The air temperatures, mean maximum and mean minimum, as well as percentage relative humidity, were throughout conducive for blister blight infection.

Valuation of black tea processed from the leaves under the different treatments, compared to the control, is given in Table 2. As expressed in terms of currency (local) value, organoleptic assessment for quality showed that with acid sprays the teas improved in comparison to the untreated control. The difference in quality was significant in acid spray treatment at one day interval in the samples processed in August and September. In the

Table 2. Effect of treatments on the quality of manufactured tea

Treatment	pH	Spray Interval (Days)	*Valuation (Rs per kg tea)
Acid	1.26	1	14.60
Acid	1.26	2	14.20
Acid	1.26	3	14.20
Acid	1.26	5	14.10
Acid	1.26	7	13.65
Alkali	8.00	1	13.50
Alkali	9.00	1	13.85
Control		Untreated	13.50

*Average of five assessments.

average value of the five samples, tea in the acid treatment at one day interval was significantly superior in quality to that in the five day, and seven day acid spray treatment and in the two alkali treatments, but teas in the one day, two, three and five day acid treatments were not significantly different. Valuation was significantly higher for teas in the acid treatment at one, two and three day intervals, compared to the two alkali treatments.

Results of the field experiment showed that the incidence of blister blight was significantly reduced by the daily application of 0.3 per cent aqueous HNO_3 spray throughout from June to October; however, in the peak infection period of the first two weeks in August infection crossed the critical threshold limit (Fig. 1). Disease incidence was significantly lower by the acid spray treatment at two day intervals when the infection pressure in the early period of blister epidemic was low, and again when weather conditions were relatively mild in September (Table 1); but in August, infection could not be contained within critical threshold limits because of heavy rainfall and very little sunshine. Acid sprays applied at three day intervals were generally unsatisfactory in reducing blister blight incidence to economic levels of control (Webster and Park, 1959), except over a short period in September under mild weather conditions but this treatment was greatly superior to acid spray treatment at five day and seven day intervals and to alkali sprays (Fig. 1); at five day and seven day intervals acid spray treatment was comparable and the reduction of blister incidence was poor (Fig. 2). Differences between the alkali spray at daily interval and the control were negligible and overall less disease incidence was recorded with acid spray at seven days interval than in the daily alkali spray treatments (Fig. 2). The effect of 0.3 per cent HNO_3 spray on the causal pathogen is one of inhibition of spore germination at low pH, as shown by Venkata Ram (1979) with 0.1 HCl *in vitro* studies on germination of *E. vexans* basidiospores. Similar observations have been reported on sulphuric acid droplets deposited on leaf surface in reducing germination of conidia of *Diplocarpon rosae* (Saunders, 1971). It was shown that 100 ppm concentration of H_2SO_4 (sulphuric acid) had no visible effect on the host rose plant, the concentration of which was inhibitory to the conidia. In investigations on pathogen-saprophyte interactions Diem (1969) attributed low pH of *Aureobasidium pullulans* cultural

filtrate to be inhibitory to germination and growth of *Helminthosporium sativum*; low pH was considered to be the reason for the control of grey mould of tomato and strawberries by *Cladosporium* and *Aureobasidium pullulans* (Newhook, 1957; Bhatt and Vaughan, 1962). However, the use of other dilute acids (H_2SO_4 and HCl) had similar effect on reducing blister blight incidence, and hence the mode of action of the acid spray is one of low pH. Indeed, *Diplocarpon rosae* conidia were found to be less tolerant to sulphuric acid (Saunders, 1971). Treatment with dilute NaOH aqueous spray adjusted to pH 8.0 and 9.0 has very little influence on blister blight incidence and this observation corroborates the data on germination of *E. vexans* basidiospores at neutral and alkaline pH (Venkata Ram, 1979).

Daily spray application is neither pragmatic nor economical on a field scale, excepting in homestead farms where the area under tea is small. However, the influence of the acid sprays on quality of the processed tea (Table 2) may tilt the balance from the angle of overall economics. There was a significant improvement in organoleptic evaluation with acid sprays at one, two, three and five day intervals which in specific marked situations of demand for quality teas, could produce added value to more than justify the cost of frequent spray treatment. The improvement in organoleptic evaluation is a direct pH effect as shown by Cloughley and Ellis (1980) who recorded an increase in the aflavins content and reduction in thearubigins levels by adjusting the pH of fermenting tea leaf to pH 4.5 to 4.8 by sprays of 0.2 M of orthophosphoric acid. It may be argued that the higher organoleptic evaluation for teas in acid spray treatment, compared to the untreated control could be due to the fact that the leaf material in the former had considerably less blister affected leaf, compared to a high percentage in the control, since severely blistered tea shoots are known to make poor quality tea (Venkata Ram, 1964). This is negated by the overall higher organoleptic evaluation of tea under treatment with alkali spray at pH 9.0 (Table 2), although the incidence of blister blight was very similar to that in the untreated control. Although the crop record of the plots in the experiment was not maintained, the tea bushes in the acid spray treatment at one, two and three day intervals appeared healthier and more vigorous than those in the other treatments and the control. Acid spray application on

basidiomycetes that have neutral or alkaline pH requirement for spore germination could be a promising approach for the control of certain leaf diseases in plants.

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DISCUSSION

Q : Has the author looked into the economic aspects involved in the treatment?

Ans: This aspect will be considered at the recommendation stage.

Q : Will it be possible to spray acid solution daily?

Ans: I fully agree that spraying acid daily is cumbersome.

Q : What will be the effect of acid spray on soil microflora and fertility?

Ans: These aspects were not studied.

Q : Have you used any sticker or spreader?

Ans: No.

EFFICACY OF FUNGICIDES TO CONTROL THREE VIRULENT ISOLATES OF *COLLETOTRICHUM GLOESPORIOIDES* ON COCOA

R. CHANDRA MOHANAN and K.M. KAVERIAPPA

ABSTRACT

The widespread occurrence of *Colletotrichum* disease of cocoa in India warrants the study on the control of the disease. Symptomatology of this disease revealed that besides pod rot, there are three kinds of foliar symptoms namely, blight, shot hole and irregular spot caused by *Colletotrichum gloeosporioides* Penz. The relative efficacy of nine fungicides on the growth of three virulent isolates of *C. gloeosporioides* causing blight, shot hole and irregular spot symptoms on cocoa leaves was studied in the laboratory. Out of the nine fungicides tested *in vitro* Carbendazim (Bavistin WP=0.05-0.10 per cent) mancozeb (Dithane M-45=0.20 and 0.30 per cent) and ziram (Liquid Cuman=0.3 per cent) inhibited the growth of all the three isolates completely. There was considerable variation in growth among the three isolates at different concentrations of the various fungicides tested.

The effect of the above three fungicides in controlling the foliar infection caused by the three isolates, when applied as pre- and post-inoculation sprays was studied. In both pre- and post-inoculation sprays, the leaf blight and irregular spots caused by the respective isolates were controlled effectively by Bavistin WP (0.05 per cent) followed by Dithane M-45 (0.2 per cent) whereas the shot hole symptom was effectively controlled by Dithane M-45 followed by liquid cuman (0.3 per cent). Thus Bavistin WP and Dithane M-45 were found to be promising fungicides to control *C. gloeosporioides* disease of cocoa.

INTRODUCTION

Until recently *Colletotrichum* disease was not a major problem on cocoa (*Theobroma cacao* L.). However, with the recent expansion in the cultivation of cocoa the disease has become widespread in the cocoa growing areas in India. It has also been observed in greater intensities in certain regions. In India, *Colletotrichum gloeosporioides* Penz. has been reported to have caused rotting of immature pods and three kinds of foliar symptoms namely, blight, shot hole and irregular spot (Chandra Mohanan and Kaveriappa, 1983). Studies on the pathogenicity of the isolates of *C. gloeosporioides* collected from the cocoa gardens of Kerala, Karnataka and Tamil Nadu states showed a great variation in pathogenicity among the isolates. Thus it has become necessary to find suitable control measures for the disease. The present investigation was undertaken to find out the relative efficacy of certain fungicides on three virulent isolates of *C. gloeosporioides*.

MATERIALS AND METHODS

A total of 299 pathogenic isolates of *C. gloeosporioides* were collected from different cocoa growing areas of Kerala, Karnataka and Tamil Nadu states. The most virulent isolates TNI/139, KeII/55 and KaIII/9 (Isolate No.) among the isolates causing blight, shot hole and irregular spot symptom on cocoa leaves respectively, were selected for the present studies.

In vitro studies

The relative efficacy of nine fungicides on the growth of the three isolates TNI/139, KeII/55 and KaIII/9, was studied in the laboratory by poisoned food technique (Nene, 1971). The fungicides tested were:

Bavistin WP (Carbendazim) (Methyl-1H-benzimidazol-2-ylcarbamate)

Kitazin (S-Benzyl-O, O-diisopropyl-phosphorothioate)

Calixin (Tridemorph) (N-Tridecyl-2, 6-dimethylmorpholine)

Dithane M-45 (Mancozeb) (Manganese ethylenebisdithiocarbamate plus zinc ion)

Dithane Z-78 (Zineb) (zinc ethylenebisdithiocarbamate)

Foltaf (Captafol) (cis-N-(1, 1, 2, 2-Tetrachloroethylthio)-4-cyc-

lohexene-1, 2-dicarboximide)

Liquid cuman (Ziram) (zinc dimethyldithiocarbamate)

Daconil 2787 (Chlorothalonil) (Tetrachloroisophthalonitrile)

Of the above Bavistin, Kitazin and Calixin are systemic fungicides. The test concentrations of fungicides are given in Table 1. The fungicides were mixed thoroughly in sterile distilled water and added to a known quantity of PDA medium cooled at 45°C to get the required concentration. The medium was gently shaken to ensure proper and uniform distribution of the fungicide. Fifteen ml of the medium was then poured into each of the sterile plates. Mycelial discs of 6 mm diameter were cut from the periphery of 10-day-old cultures of each isolate growing on PDA and placed in the centre of the plates containing the poisoned medium at the rate of one disc per plate. The plates were incubated at room temperature ($28 \pm 2^\circ\text{C}$) for 10 days. Three replications were maintained for each treatment and the plates without fungicide served as control. Radial growth of the fungus in each plate was recorded on the 10th day by measuring the diameter of the colony in two directions at right angles to each other. The average colony diameter was recorded and the per cent inhibition of growth was calculated by using the equation given by Vincent (1927). The data were statistically analysed.

In vivo studies

Based on the results of *in vitro* tests, three fungicides namely Bavistin WP, Dithane M-45 and liquid Cuman were selected for *in vivo* studies. They were tested at concentrations of 0.05 per cent, 0.2 per cent and 0.3 per cent respectively. These concentrations were selected on the basis of *in vitro* studies, as well as the earlier reports of their effect in controlling *Colletotrichum* disease of other crops. Cocoa seedlings were raised and eighteen day old healthy seedlings of uniform size were selected for the trial. Bavistin WP, Dithane M-45 and Liquid Cuman were separately mixed with distilled water to make 0.05 per cent, 0.2 per cent and 0.3 per cent concentrations respectively. They were applied as pre- and post-inoculation sprays. The inoculum was obtained from five day old cultures of the isolates, TNI/139, KeII/55 and KaIII/9 on oat meal agar medium. The seedlings were inoculated with a suspension of conidia and mycelia of each isolate separately in tap water.

Table 1. Effect of different concentrations of fungicides on the growth of the three selected isolates of *C. gloeosporioides*

Fungicides	Conc. (%)	*Percentage inhibition of growth					Mean of three isolates
		TNI/139 (3)	KelII/55 (4)	KaIII/9 (5)	(6)		
Bavistin WP	0.025	90.00 (100)	90.00 (100)	90.00 (100)	90.00 (100)	90.00 (100)	
	0.05	90.00 (100)	90.00 (100)	90.00 (100)	90.00 (100)	90.00 (100)	
	0.10	90.00 (100)	90.00 (100)	90.00 (100)	90.00 (100)	90.00 (100)	
Kitazin	0.05	58.37 (72.50)	61.00 (76.50)	62.38 (78.50)	60.00 (75.88)	60.00 (75.88)	
	0.1	65.65 (83.00)	66.04 (83.50)	67.62 (85.50)	66.44 (84.02)	66.44 (84.02)	
	0.2	68.45 (86.50)	72.54 (90.99)	71.59 (90.02)	70.86 (89.25)	70.86 (89.25)	
Calixin	0.05	56.48 (69.50)	47.00 (53.50)	53.43 (64.50)	52.30 (62.61)	52.30 (62.61)	
	0.1	59.02 (73.50)	49.89 (58.50)	54.94 (67.00)	54.62 (66.47)	54.62 (66.47)	
	0.2	64.16 (80.99)	54.63 (66.50)	60.67 (75.99)	59.82 (74.73)	59.82 (74.73)	

Dithane M-45	0.10	90.00 (100)	90.00 (100)	41.55 (43.99)	73.85 (92.26)
	0.20	90.00 (100)	90.00 (100)	90.00 (100)	90.00 (100)
	0.30	90.00 (100)	90.00 (100)	90.00 (100)	90.00 (100)
Diithane Z-78	0.10	34.45 (31.99)	19.82 (11.49)	12.23 (4.49)	22.17 (14.23)
	0.20	35.67 (33.99)	23.58 (15.99)	22.38 (14.49)	27.21 (20.91)
	0.30	90.00 (100)	27.62 (21.49)	22.79 (14.99)	46.80 (53.15)
	0.05	49.60 (57.99)	62.03 (77.99)	62.38 (78.50)	58.00 (71.92)
	0.10	54.94 (66.99)	63.79 (80.50)	63.79 (80.50)	60.84 (76.26)
Captaf	0.20	56.79 (69.99)	65.65 (83.00)	64.89 (81.99)	62.44 (78.59)
	0.10	51.35 (60.99)	58.05 (71.99)	58.69 (72.99)	56.03 (68.78)
	0.20	58.05 (71.99)	62.03 (77.99)	66.82 (84.50)	62.29 (78.39)
	0.30	63.43 (79.99)	65.65 (83.00)	90.00 (100)	73.03 (91.48)

(Contd.)

Table 1 (Contd.)

(1)	(2)	(3)	(4)	(5)	(6)
Liquid	0.1	65.24 (67.50)	90.00 (100)	66.82 (84.50)	70.69 (89.06)
Curman	0.2	67.22 (85.01)	90.00 (100)	90.00 (100)	82.41 (98.25)
	0.3	90.00 (100)	90.00 (100)	90.00 (100)	90.00 (100)
Daconi	0.1	37.76 (37.49)	35.37 (33.49)	21.97 (13.99)	31.69 (27.61)
	0.2	45.86 (51.50)	49.31 (57.50)	31.94 (27.99)	42.37 (45.42)
	0.3	48.16 (55.50)	51.35 (60.99)	40.68 (42.49)	46.73 (53.02)
Mean		64.84 (81.92)	64.64 (81.66)	61.76 (77.61)	—

CD ($P=0.05$) for isolates 0.16
 for treatments 0.48
 for isolates \times
 treatments 0.83

*After arcsine transformation.
 Values in parentheses are original mean.

In the pre-inoculation fungicidal application, seedlings were sprayed with the respective fungicides separately and inoculated with the three isolates separately on the same day. In the post-inoculation application, the seedlings were inoculated with the three isolates separately and two days later the fungicides were sprayed. Twenty-five seedlings were used for each treatment. Seedlings inoculated separately with each isolate and maintained without fungicidal sprays served as control. In all the cases the seedlings were covered immediately after inoculation with polythene bags containing wet cotton pads for 72 hours to provide high humidity. The seedlings were kept under observation for eight days and the disease intensity was recorded on the eighth day. The disease intensity caused by each isolate was assessed by using grades of severity based on the leaf area affected. A quantitative index of severity was calculated based on these ratings (McKinney, 1923).

RESULTS AND DISCUSSION

The per cent inhibition of growth of each isolate in different concentrations of fungicides is given in Table 1. Out of the nine fungicides tested Bavistin WP (0.025-0.10 per cent), Dithane M-45 (0.20 and 0.30 per cent) and Liquid Cuman (0.3 per cent) inhibited the growth of all the three isolates completely. Dithane M-45 at 0.1 per cent concentration completely inhibited the growth of TNI/139 and KeII/55, whereas only 44 per cent inhibition of growth was found in isolate KaIII/9 at this concentration. Liquid Cuman at 0.2 per cent concentration inhibited the growth of the isolate KeII/55 and KaIII/9 completely, and there was only 85 per cent inhibition of TNI/139. The growth of KeII/55 was completely inhibited even at 0.1 per cent concentration of Liquid Cuman. But the other two isolates showed tolerance at this concentration. In the presence of Dithane Z-78 (0.3 per cent) only one isolate, (TNI/139) showed complete inhibition of growth. All the three isolates showed growth at 0.1 and 0.2 per cent concentrations of this fungicide. Dithane Z-78 at 0.4 per cent concentration has been reported to be very effective in reducing the incidence of inflorescence die-back of arecanut and is being recommended for commercial application (Reddy et al., 1978). In the presence of Captaf (0.3 per cent) also the growth of only one isolate KaIII/9 was completely inhibited. The growth of C.

gloeosporioides causing inflorescence die-back of arecanut has been reported to be completely inhibited in the presence of Thiram (0.25 per cent), Phenyl mercury Urea (0.1 per cent) and Captan (0.25 per cent) (Saraswathy et al., 1975). There was no complete inhibition of growth of any of the isolates at any of the concentrations of Foltaf, Kitazin, Calixin and Daconil tried. Among these, Daconil gave the least inhibition of growth of all the three isolates in all the concentrations tested. Thus there was considerable variation in growth among the three isolates at different concentrations of the various fungicides tested.

Since Bavistin (0.025-0.1 per cent), Dithane M-45 (0.2 and 0.3 per cent) and Liquid Cuman (0.3 per cent) were found to completely inhibit the growth of all the three isolates, these fungicides were selected for *in vivo* studies. The results of the effect of Bavistin (0.05 per cent), Dithane M-45 (0.2 per cent) and Liquid Cuman (0.3 per cent) in controlling the foliar infection caused by the three isolates when applied as pre- and post-inoculation sprays are presented in Table 2.

In both pre- and post-inoculation sprays leaf blight and irregular spot symptoms caused by TNI/139 and KaIII/9 respectively were controlled effectively by Bavistin followed by Dithane M-45. Spraying cocoa trees with maneb 30 per cent WP, Zinc ion-maneb complex 80 per cent WP, thiram 80 per cent WP, Zineb, Trifuncit 75 per cent WP and perenox was reported to be effective in reducing the leaf blight incidence in Ghana (Dakwa and Danquah, 1978). But comparative studies on the effect of these fungicides in controlling the leaf blight incidence are not available. In the pre-inoculation spray shot hole symptoms caused by KeII/55 were controlled effectively by Dithane M-45 followed by Liquid Cuman and Bavistin. In post-inoculation spray also the control of shot hole symptom was significantly high in Dithane M-45 treated seedlings. It was followed by Liquid Cuman. The fungicidal trial on cocoa seedlings in Costa Rica revealed that Difoltan and Dithane M-45 were quite effective in controlling *Colletotrichum* leaf spot (Newhall and Diaz, 1967). Dithane Z-78, copper oxide, fermate and DNC were reported to be effective in controlling anthracnose on young cocoa plants caused by *C. theobromicum* in Colombia and Dithane Z-78 was found to be superior to other fungicides tested (Mazorra, 1954). Dithane Z-78 has also been reported to be effective in controlling the in-

florescence die-back of arecanut (Saraswathy et al., 1975). But in the present investigation, in *in vitro* tests Dithane Z-78 at 0.3 per cent concentration (the highest concentration tested) showed complete inhibition of growth of only leaf blight isolate (TNI/139) and hence was not included for the *in vivo* evaluation. Bavistin was thus found to be superior in controlling leaf blight and irregular spot caused by TNI/139 and KaIII/9 respectively, whereas Dithane M-45 was most effective in controlling shot hole symptoms caused by KeII/55. The infection was controlled more effectively when fungicides were applied as pre-inoculation spray.

From both *in vitro* and *in vivo* studies, Bavistin and Dithane M-45 were found to be the promising fungicides to control *C. gloeosporioides* infection on cocoa seedlings. Therefore these fungicides may be used for large scale field trials to control *C. gloeosporioides* disease of cocoa.

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DISCUSSION

Q : Will it be economical to carry out fungicide application using costly fungicides in view of the prevailing low price for cocoa?

Ans: The economics of the treatment has not been worked out.

Q : Have you investigated the possibility of the three different isolates of *C. gleosporioides* being three different strains of the fungus?

Ans: No.

SEASONAL VARIATION IN MICRO- FLORA OF STORED BLACK PEPPER

S. ESTELITTA and ABI CHEERAN

ABSTRACT

In all the seasons, association of microflora was observed with different grades of stored black pepper and there was no change in the type of micro-organisms. Only the population of micro-organism was found to be varying in different grades in different seasons. The ground pepper samples showed more microbial population than the whole samples of different grades of black pepper. The microbial population was minimum in whole samples of garbled pepper and it was maximum in ground samples of light pepper.

It was found that eight species of fungi, belonging to five genera, and one gram negative bacterium were associated with all the grades of black pepper in all the seasons of the year. All the grades of sorted black pepper examined in different seasons yielded *Aspergillus* spp. (four species), *Penicillium* sp., *Curvularia* sp., *Fusarium* sp., and *Rhizopus* sp. and one type of gram negative bacterium.

INTRODUCTION

Pepper is harvested during December to February in Kerala while pepper trade is a continuous process throughout the year. Therefore it involves the process of storage for a long time. Even properly dried and stored pepper is subjected to quality deterioration due to microbial attack even though the process is very slow.

One of the oldest methods of preservation is drying and stor-

ing, and this has a direct consequence of removal or binding of moisture, without which the micro-organisms cannot grow. For nearly half of the year, a highly humid condition is existing in this part of the country, hence there is every chance for the black pepper stored in godowns to absorb moisture from atmosphere and facilitate microbial activity. Very little attention has been given to the studies on quality deterioration of stored black pepper. The present study was designed to assess the periodical variations in the occurrence of microflora associated with the stored black pepper.

MATERIALS AND METHODS

Four different grades of black pepper namely garbled, ungarbled, light pepper and pinhead were collected from export centres of Cochin during four seasons of 1979 namely cool dry (January), warm dry (April), south west monsoon (July) and north west monsoon (October).

Single colony isolation of the fungal flora developed in the dilution plate method were cultured in potato-dextrose-agar and the morphological characters were studied by slide culture technique (Ainsworth, 1968). Bacterial colonies developed in the dilution plate method were streaked in nutrient agar. Grams' method (1984) was employed for the identification of bacteria.

RESULTS AND DISCUSSION

Microbial population of ground and whole samples of four different grades of stored black pepper were estimated in four different seasons namely cool dry period, warm dry period, cool moist period and warm moist period of the year 1979. Isolation of different micro-organisms, namely fungi, bacteria and actinomycetes was done with specific media (that is for fungi-Martins Rose Bengal streptomycin in agar, for bacteria-nutrient agar and for actinomycetes-Kuster's agar) for each group of micro-organisms.

Bacterial and fungal populations were present in all the grades of stored black pepper during all the seasons while actinomycetes were absent. There was no variation in the type of microflora associated with the stored black pepper in seasons. The results of the population estimates of fungi and bacteria in different

grades of stored black pepper in different seasons are presented in (Tables 1 and 2).

The results reveal that ground samples yielded more number of fungal colonies in all the grades during all the seasons. The fungal populations in whole and ground samples of light pepper and pinhead grade were not much pronounced when compared to that of garbled and ungarbled grades (Table 1).

The results indicate that in the whole samples of all grades of stored black pepper, the minimum fungal population was observed in the garbled grade (26163 colonies/g) followed by pinhead (28488 colonies/g), ungarbled (35488 colonies/g) and light pepper (42608 colonies/g). In the case of ground sample the minimum count was found in pinhead (38285/g) followed by the garbled grade (41888/g) and the maximum was for the light pepper (51463/g).

The results reveal that there was much fluctuation in fungal population in all grades of stored black pepper in different seasons. In all the grades, the minimum fungal population was observed. For both whole and ground samples during the warm dry period of the year (April) and the maximum fungal population in all the grade was observed during the cool moist period of the year (July). During the cool dry period and warm moist period the fungal population was found to be less than in the cool moist period, but it was found higher during the warm moist period when compared to that of the cool dry period (Table 1).

The results show that bacterial colonies were more in ground samples of each grade in different seasons when compared to whole samples of all grades of stored black pepper. The whole and ground samples of garbled grade yielded less number of bacterial colonies (7427500 colonies/g and 8765000 colonies/g respectively) than light and pinhead grade (8703000 colonies/g and 104963000 colonies/g respectively). There was not much difference between light and pinhead grades which yielded a population of 10472500 colonies/g and 11518300 colonies/g respectively.

The variation in the occurrence of bacterial population in different grade of stored black pepper in different seasons of the year was much pronounced. The minimum population for both whole and ground samples was obtained in all the grades during the warm dry period of year (April) and the maximum bacterial population in all the grades was obtained for the cool moist period of

Table 1. Mean fungal population ('000) in different grades of stored black pepper in different seasons of the year 1979

Seasons	Grades of black pepper							
	Garbled		Ungarbled		Light pepper		Pinhead	
	Whole	Ground	Whole	Ground	Whole	Ground	Whole	Ground
January	27.00 (4.4314)	38.25 (4.5827)	31.15 (4.4935)	44.50 (4.6484)	37.83 (4.5778)	48.95 (4.6897)	29.25 (4.4661)	36.00 (4.5563)
April	13.50 (4.1303)	29.25 (4.4661)	22.50 (4.3522)	33.75 (4.5282)	27.00 (4.4314)	31.50 (4.4983)	15.75 (4.1973)	22.50 (4.3522)
July	31.15 (4.4935)	55.00 (4.7404)	50.60 (4.7042)	61.60 (4.7896)	57.20 (4.7575)	70.40 (4.8476)	37.40 (4.5729)	50.60 (4.7042)
October	33.00 (4.5185)	45.05 (4.6537)	37.70 (4.5763)	55.63 (4.7483)	48.40 (4.6848)	55.00 (4.7404)	31.50 (4.4983)	44.00 (4.6435)

MICROFLORA OF STORED BLACK PEPPER

Mean	26.163 (4.5176)	41.888 (4.6221)	35.488 (4.5501)	48.870 (4.6890)	42.608 (4.6295)	51.463 (4.7115)	28.488 (4.4547)	38.285 (4.5031)
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Figures given in parentheses are logarithmically transformed values.

	<i>Whole</i>	<i>Ground</i>
Garbled pepper	-0.2337	0.18
Ungarbled pepper	-0.27	0.21
Light pepper	-0.253	0.20
Pinhead pepper	-0.17	0.17

CD (0.05) for season

Table 2. Mean bacterial population ('00000) in different grades of stored black pepper in different seasons of the year 1979

Seasons	Grades of black pepper							
	Garbled		Ungarbled		Light pepper		Pinhead	
	Whole	Ground	Whole	Ground	Whole	Ground	Whole	Ground
January	66.25 (6.8212)	72.00 (6.8573)	68.98 (6.8387)	84.55 (6.9272)	96.10 (6.9827)	102.35 (7.0103)	98.50 (6.9934)	103.50 (7.0170)
April	49.50 (6.6946)	60.75 (6.7836)	62.50 (6.7959)	76.50 (6.8837)	79.00 (6.8976)	87.75 (6.9432)	81.60 (6.9117)	92.25 (6.9652)
July	96.80 (6.9859)	114.40 (7.0584)	113.20 (7.0539)	134.20 (7.1277)	127.80 (7.1066)	143.00 (7.1553)	129.50 (7.1123)	138.60 (7.1418)
October	84.55 (6.9272)	103.45 (7.0149)	103.45 (7.0149)	124.60 (7.0955)	116.00 (7.0645)	127.00 (7.1059)	119.26 (7.0766)	122.00 (7.0864)

MICROFLORA OF STORED BLACK PEPPER

Mean	74.275 (6.8709)	87.650 (6.9427)	87.030 (6.9396)	104.963 (7.0212)	104.725 (7.0199)	115.183 (7.0615)	107.215 (7.0302)	114.088 (7.0573)
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Figures given in parentheses are logarithmically transformed values.

	<i>Whole</i>	<i>Ground</i>
Garbled pepper	-0.04	0.13
Ungarbled pepper	-0.04	0.09
Light pepper	-0.014	0.079
Pinhead pepper	-0.014	0.06

CD (0.05) for season

the year (July) as shown in Table 2. The variation of bacterial population in different seasons differed significantly in all grades, both for whole and ground samples.

In the whole samples of garbled pepper, the bacterial population differed significantly from one season to another and the maximum occurred during the cool moist period, followed by the warm moist period, the cool dry period and least in the warm period. But in case of ground samples of garbled grade, the maximum population was observed during the cool moist period even though being on par with the warm moist period. It differed significantly from that of the cool dry period and warm dry period, while the latter two were on par. The whole and ground samples of all other three grades namely ungarbled, light pepper and pinhead showed exactly the same trend as that of the garbled grade.

The fungi isolated and identified were four species of *Aspergillus*, (*Aspergillus niger*, *A. candidus*, *A. nidulans* and *A. versicolor*), *Curvularia lunata*, *Penicillium citrinum*, *Fusarium moniliforme* and *Rhizopus nigricans*. The morphological characters of these fungi were studied and identified by slide culture technique. A cursory observation of Tables 1 and 2 reveals that the four samples of all grades of black pepper in all seasons yielded more microbial growth when compared to the whole samples. This might be due to the increased surface area of the black pepper when it was ground. This finding is in conformity with the earlier works of Moreno-Martinez (1970) and Martinez and Christensen (1973).

There was much variation in the population of storage microflora in different grades of black pepper. But no difference existed in the type of microflora during different seasons in different grades of the product. The maximum population was observed in light pepper both for whole and ground samples and the minimum was in the garbled pepper for the whole sample and in the pinhead pepper for the ground sample. The garbled pepper, being more hold in size and having less moisture per cent, which is prepared after washing and drying to remove external moulds, has naturally yielded less microbial growth. But in pinhead grade, as the size is very small, the increase in surface area through grinding was less than other grades and the microbial growth was less in the ground sample.

These results also reveal that there was much fluctuation in the

microbial population over different seasons of the year. The maximum population was found during the cool moist period (July) which had the maximum moisture content and the minimum population during the warm dry period (April) which recorded the minimum moisture content. These findings on the fluctuation of the population of storage microflora in different seasons thus confirm the effect of moisture content on the growth of microflora in stored products. The studies by Moreno-Martinez (1970); Martinez and Christensen (1973) and Jose (1978) on moisture content of stored black pepper have also supported this finding.

On several occasions, the storage microflora have been reported to cause considerable changes in the stored agricultural produce namely, decrease in germination percentage, discolouration or damage to the embryos, various biochemical changes including toxin production, resulting in drastic reduction in quality or complete spoilage of the produce.

The present study clearly indicates that the dried black pepper should be stored in a cool dry place. The black pepper can absorb moisture from high humidity levels in the atmosphere, which leads to the growth of storage microflora and in turn in the reduction of the quality of black pepper.

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DISCUSSION

Q : Can you enlighten us on the significance of the findings?

Ans: The population fluctuation of microflora in different seasons of the year will help to take sufficient precautions for storing black pepper.

Q : It would have been better to relate climatic parameters with microflora?

Ans: Data on temperature and R.H. were not available in the godowns from where the samples were drawn.

SESSION III

PLANT PROTECTION 2

Chairman : K. Jayarathnam

Rapporteurs : L. Thankamma

D. Chandrahmohan

INFLUENCE OF PREY ON PRODUCTIVE POTENTIAL OF *CRYPTOLAEMUS* *MONTROUZIERI*

K. VENKATESULU

ABSTRACT

The influence of feeding on different preys (mealybug and green scale) on reproductive potential of *Cryptolaemus montrouzieri* Muls. was investigated. Observations were made on durations of pre-oviposition, oviposition and post-oviposition periods, fecundity, viability, incubation period and longevity of the predator. The present study has shown that with mealybug as prey, both in larval and adult stages, the fecundity is significantly high, irrespective of the prey of the males. On the contrary, the fecundity with green scale as prey, both in larval and adult stages is very low, irrespective of the prey of the males. The longevity is also significantly high with mealybug as prey. The influence of the prey on the reproductive potential of the predator is discussed with reference to its establishment.

INTRODUCTION

Cryptolaemus montrouzieri Muls. (Coleoptera, Coccinellidae) is used as a biological agent against mealybugs attacking economically important crops including coffee in many parts of the world (Le Pelley, 1968). In India the Coffee Board Research Department has been breeding and releasing this predator to control coffee mealybugs, *Planococcus* spp. (Homoptera, Pseudococcidae), over several years (Chacko et al., 1978). Being polyphagous, this

predator also feeds on green scale, *Coccus viridis* green and brown scale, *Saissetia coffeae* Walker (*Homoptera, Coccidae*) which occur simultaneously with mealybugs on coffee. Earlier studies have shown that *C. montrouzieri* failed to lay eggs normally when it fed on green scale alone throughout its larval and adult stages (Anonymous, 1979-80; Venkatesulu and Chacko, 1982; Kumar and Prakasan, 1984). In any biological control programme it is necessary to understand all aspects of prey-predator and host-parasite relationships. The present study was undertaken to find out the influence of feeding on different preys (mealybug and green scale) on reproductive potential of *C. montrouzieri*.

MATERIALS AND METHODS

The predator was maintained on mealybug cultured on ripe pumpkins. Ten pairs of newly emerged beetles were selected, and each pair kept in a Petri dish with mealybug as prey. The eggs laid were collected and kept in cavity blocks (5.5 by 5.5 cm), one in each and allowed to hatch. The cavity blocks were covered with glass plates and the grubs were divided into two batches after hatching. In one batch the grubs were provided with mealybug and in other bits of coffee leaves infested with green scale till the grubs pupated.

Forty adults (20 males and 20 females) of grubs which preyed on mealybug were selected and maintained in individual cavity blocks. Mealybug was given as prey. Similarly 40 adults (20 males and 20 females) of grubs which preyed on green scale were selected and supplied with green scale. From these 80 beetles four combinations were made as shown below:

Combinations of predators preying on mealybug (MB) and green scale (GS)

Combinations

I		II		III		IV		
♀	×	♂	♀	×	♂	♀	×	♂
on MB		on MB	on GS	on GS	on GS	on GS		on MB

Five replications of each of these combinations with two pairs per replication were maintained and the respective prey supplied

till their death. Each pair was allowed to mate in an individual cavity block daily between 12 noon and 4 PM from the second day of emergence. They were then separated and transferred to their respective cavity blocks. Dead males were substituted with other males maintained on the same prey.

Observations were made on the durations of pre-oviposition, oviposition and post-oviposition periods, longevity, fecundity, incubation period and viability. Laboratory temperature and relative humidity ranges during the experimental period were 21.5° to 28.5°C and 75 to 99 per cent respectively.

RESULTS AND DISCUSSION

The fecundity in combination I varied from 638 to 1097, with an average of 829.5. The pre-oviposition period varied from four to six (4.6) days; oviposition period from 83 to 132 (117.4) days and post-oviposition period from one to six (3.4) days. The eggs were bold in appearance and pale yellow. The incubation period varied from four to seven (5.67) days. The percentage of hatching was 81.39. The longevity of males ranged from 72 to 156 (128.0) days and of females from 90 to 140 (125.4) days.

The fecundity in combination II varied from 734 to 1059 with an average of 820.3. The pre-oviposition period ranged from four to seven (5.5) days; oviposition period from 85 to 140 (115.9) days and post-oviposition period from zero to five (2.3) days. The eggs were bold in appearance and pale yellow. The incubation period varied from four to seven (5.67) days. The viability was 74.2 per cent. The longevity of males ranged from 37 to 102 (65.0) days and of females from 92 to 152 (123.7) days.

On the other hand the fecundity of beetles in combination III varied from 12 to 110, with an average of 44.7. The pre-oviposition period varied from five to 21 (12.2) days; oviposition period from 28 to 66 (50.9) days and post-oviposition period from 4 to 20 (8.8) days. The eggs were supple and white. The incubation period varied from 5 to 7 (5.8) days. The viability was 85.5 per cent. The longevity of males ranged from 40 to 96 (60.5) days and of females from 38 to 105 (71.9) days.

In combination IV, the fecundity varied from 18 to 120 with an average of 46.5. The pre-oviposition period varied from five to 31 (18.8) days; oviposition period from 16 to 62 (49.2) days and post-

oviposition period from four to 20 (9.5) days. The eggs were supple and white. The incubation period varied from four to seven (5.16) days. The viability was 81.95 per cent. The longevity of males ranged from 70 to 152 (122.0) days and of females from 41 to 110 (77.5) days.

The above observations show that with mealybug as prey, both in larval and adult stages, the fecundity is significantly high, irrespective of the prey of the males. On the contrary, the fecundity with green scale as prey both in larval and adult stages is very low, irrespective of the prey of the males. The longevity is also significantly high with mealybug as prey both in larval and adult stages (Table 1).

Table 1. Influence of prey on fecundity and longevity of *Cryptolaemus montrouzieri*

Combinations of predators preying on mealybug and green scale		Fecundity (Mean)	Longevity	
			Male (Mean)	Female (Mean)
Female on mealybug	× Male on mealybug	829.50	128.00	125.40
Female on mealybug	× Male on green scale	820.30	65.00	123.70
Female on green scale	× Male on green scale	44.70	60.50	71.90
Female on green scale	× Male on mealybug	46.50	122.00	77.50
CD at 5%		97.51	19.74	18.12
1%		136.71	27.67	25.41

In this context it can be recalled that this predator was introduced into South India in 1898 by Mr. H.O. Newport in an attempt to control the coffee green scale, *C. viridis* (Puttarudriah et al., 1952; Mayne, 1953). Rao et al. (1971) reported that though this predator did not become established on green scale, it was subsequently recorded from a number of localities in South India as a common predator of mealybugs. Charanasri and Nishida (1973) reported that the population of *C. montrouzieri* was least among the three Coccinellid predators that were preying on *C. viridis* on *Plumeria robusta* in Hawaii.

The low reproductive potential of *C. montrouzieri* with green scale as prey during both larval and adult stages could be one of the reasons why it did not establish on green scale in coffee, and for its least abundance among the three Coccinellid predators that were preying on green scale on plumeria trees in Hawaii.

Studies are planned to understand the reproductive behaviour of this predator with different preys under field conditions.

ACKNOWLEDGEMENTS

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DISCUSSION

Q : Could you work out the predator-prey ratio?

Ans: The ratio of predator and prey under field conditions has not been studied.

Q : What are the other hosts on which *Cryptolaemus* preys?

Ans: It feeds on nymphs and eggs of coffee brown bug. It also feeds on other soft scales of *Coccidae* and many species of mealy bugs.

FIELD EVALUATION OF CERTAIN INSECTICIDES FOR THE CONTROL OF CARDAMOM STEM/CAPSULE BORER, *DICHOCROCIS PUNCTIFERALIS* GUEN AND THRIPS, *SCIOTHRIPS CARDAMOMI* (RAMK.)

S. VARADARASAN and DURAI KUMARESAN

ABSTRACT

Field experiments were conducted for evaluating the relative efficacy of four insecticides in three different concentrations on the percentage damage of the cardamom stem/capsule borer and thrips for two years (1982-83 and 1983-84). While the differences among the insecticides were found to be highly significant, the interaction (year versus treatment) was found to be highly or relatively significant (in the case of thrips and stem borer) or non-significant (in respect of capsule borer). Through the usage of Scheffer's S-method, it was found that all the treatments differed significantly from the control.

INTRODUCTION

Among the 54 species of insects recorded as occurring in cardamom plantations, the cardamom stem/capsule borer, *Dichocrocis punctiferalis* Guen. and the thrips *Sciothrips cardamomi* (Ramk.) are the most serious pests in Tamil Nadu causing 30 to 60 per cent and 80 to 90 per cent damage to the crop respectively under conditions of severe infestation (Nambiar et al., 1975; Kumaresan et al., 1978). While the stem borer makes an injury

in the pseudostem causing the "deadheart" symptom, thus rendering the individual tiller unproductive or underproductive, the same species bore and feed on the immature capsules, making them empty (capsule borer). Persistent feeding by a number of thrips larvae and adults around the ovary and tender capsules result in capsule shedding or the capsules developing scabes and, as a result, they become stunted, malformed and shrivelled. This affects the shape, size and appearance of the capsules, as well as it reduces the market value of the produce. The only existing method of control for these pests is by chemicals. Several field experiments were conducted to evaluate plant protection chemicals against these pests and recommendations were made for the control of thrips (Jones, 1943; Jones and Ayyar, 1948; Subbaiah, 1949; Nair, 1967; Kuttappa, 1968; Nambiar et al., 1975; Pillai and Abraham, 1978; Kumaresan, 1983 a and b) and of stem borer (Kumaresan et al., 1978; Joseph, 1981; Varadarasan and Kumaresan, 1983). No field study was conducted to evaluate insecticides, which could simultaneously reduce thrips and borer for Tamil Nadu conditions. Hence a field experiment was conducted with the object of having a combined pest control schedule for thrips and borer.

MATERIALS AND METHODS

Field experiments were conducted for two years, (1982-83 and 1983-84) at the Regional Research Station of Indian Cardamom Research Institute, Thadiyankudisai, Tamil Nadu (Lower Pulneys) to study the relative efficacy of four insecticides in three different concentrations (Table 1) on the control of stem/capsule borer and thrips. A randomised block design with three replications was used for the experiment. Based on the population dynamics of these pests, five insecticide applications with hand compression sprayer were given during January, April, June, August and October. The damage of stem borer was assessed at monthly intervals based on the number of affected tillers and the thrips, whereas capsule borer damages were assessed based on the affected capsules at each harvest. Eight harvests were made in the experimental plot for each year. The data for different observations were pooled together and analysed statistically by Scheffer's S-method.

Table 1. Treatment details

Insecticides	Concentration in % a.i.		
1. Cypermethrin 25 EC (Rhone-Polenc)	(i) 0.005	(ii) 0.01	(iii) 0.02
2. Monocrotophos (Corophos 36 EC)	(i) 0.025	(ii) 0.05	(iii) 0.075
3. Permethrin 20 EC (Rhone-Polenc)	(i) 0.005	(ii) 0.01	(iii) 0.02
4. Phasolone (Zolone 35 EC)	(i) 0.07	(ii) 0.10	(iii) 0.15

RESULTS AND DISCUSSION

All the treatments differed/significantly from the control. The differences in their efficacy among the insecticides was found to be highly significant. The interaction between periods (year) and treatments was found to be highly significant in the case of percentage damage of thrips injury on capsules, and relatively significant in the case of percentage damage of stem borer, implying that the efficacy of insecticides may not remain the same over the years for the control of stem borer and thrips. On the other hand, the interaction was non-significant in the case of percentage damage of capsule borer, revealing that the efficacy of the insecticides may not differ over the years for the control of capsule borer.

Stem borer

Cypermethrin and Permethrin at 0.02 per cent are on par when combined for two years. Comparing with organophosphorous compounds, synthetic pyrethroids at higher doses (0.02 per cent) recorded lowest percentage of damage (Table 3).

Cypermethrin and Permethrin at 0.02 per cent and 0.01 per cent and Cypermethrin at 0.005 per cent are on par for both the years. However the lowest dose of Cypermethrin at 0.005 per cent may be the economical dose for the control of stem borer. Kumaresan et al. (1978) have shown that with 11 rounds of continuous application with Monocrotophos at 0.1 per cent per year, there was 77.5 per cent reduction in the incidence of stem borer at Lower Pulneys. In the present study, with five rounds of insect-

Table 2. Comparative efficacy of the insecticides against stem borer damage

Sl. No.	Name of the insecticide	Per cent**	Per cent of damage 1982-83	Per cent of damage 1983-84
1.	Cypermethrin 25 EC*	0.005	13.1 (21.21)	15.2 (22.93)
2.	Cypermethrin	0.01	13.3 (21.37)	15.2 (22.95)
3.	Cypermethrin	0.02	11.0 (19.36)	14.7 (22.57)
4.	Permethrin 20 EC	0.005	16.3 (23.82)	16.4 (23.88)
5.	Permethrin	0.01	13.1 (21.19)	15.5 (23.22)
6.	Permethrin	0.02	12.11 (20.37)	14.7 (22.56)
7.	Monocrotophos 36 EC	0.025	15.9 (23.49)	18.3 (25.30)
8.	Monocrotophos	0.05	15.7 (23.31)	18.9 (25.79)
9.	Monocrotophos	0.075	13.6 (21.66)	19.3 (26.09)
10.	Phasolone 35 EC	0.07	19.3 (26.08)	18.5 (25.49)
11.	Phasolone	0.10	15.6 (23.28)	20.4 (26.87)
12.	Phasolone	0.15	14.1 (22.09)	18.5 (25.49)
13.	Control	—	29.7 (33.02)	30.2 (33.36)

* Figures in parentheses are angular values.

** a.i. = active ingredients.

S.E. \pm 1.0647.

Table 3. Relative efficacy of different insecticides combined for both the years (1982-83 and 1983-84) against stem borer

Name of the insecticide	Per cent	Percentage of damage
1. Cypermethrin 25 EC	0.005	48.5 (44.17)
2. Cypermethrin	0.01	48.8 (44.33)
3. Cypermethrin	0.02	44.7 (41.94)
4. Permethrin 20 EC	0.005	54.7 (47.71)
5. Permethrin	0.01	49.0 (44.41)
6. Permethrin	0.02	46.4 (42.93)
7. Monocrotophos 36 EC	0.025	56.6 (48.79)
8. Monocrotophos	0.05	57.1 (49.10)
9. Monocrotophos	0.075	54.8 (47.76)
10. Phasolone 35 EC	0.07	61.4 (51.57)
11. Phasolone	0.1	59.0 (50.15)
12. Phasolone	0.15	54.5 (47.59)
13. Control	—	86.4 (68.38)

S.E. \pm 0.7457.

ticide application using Cypermethrin at 0.005 per cent, there was 56 per cent reduction of stem borer over control. All the synthetic pyrethroids are superior to organophosphorous compounds in each of the two years (Table 2).

Capsule borer

Cypermethrin at 0.02 per cent, Permethrin at 0.01 per cent and Monocrotophos at 0.025 per cent are on par, and are significantly superior to other treatments. Considering the cost of treatment Monocrotophos at 0.025 per cent, or, Permethrin at 0.01 per cent may be the economical dose for the control of capsule borer (Table 4).

Thrips

In the first year (1982-83) Cypermethrin at 0.02 and 0.01 per cent, Monocrotophos at 0.025, 0.05 and 0.075 per cent were on par and significantly superior over other chemicals. However during the 1983-84 period, Cypermethrin at 0.02, 0.01 and 0.005 per cent and Monocrotophos at 0.075 per cent were on par and significantly superior over other treatments (Table 5).

Table 4. Relative efficacy of different insecticides against capsule borer for both the years (1982-83 and 1983-84)

Name of the insecticide	Per cent	Percentage of damage	
1. Cypermethrin 25 EC	0.005	12.5	(20.72)
2. Cypermethrin	0.01	9.7	(18.17)
3. Cypermethrin	0.02	6.7	(16.16)
4. Permethrin 20 EC	0.005	12.5	(20.70)
5. Permethrin	0.01	8.8	(17.28)
6. Permethrin	0.02	9.7	(18.17)
7. Monocrotophos 36 EC	0.025	8.0	(16.40)
8. Monocrotophos	0.05	11.5	(19.78)
9. Monocrotophos	0.075	10.0	(18.47)
10. Phasolone 35 EC	0.07	12.8	(20.92)
11. Phasolone	0.10	12.9	(21.10)
12. Phasolone	0.15	15.9	(23.47)
13. Control	—	28.8	(32.49)

S.E. \pm 0.8124.

Table 5. Relative efficacy of the insecticide for individual years against thrips

Name of the insecticide	Per cent	Percentage thrips damage 1982-83		Percentage thrips damage 1983-84	
1. Cypermethrin 25 EC	0.005	12.3	(20.57)	5.2	(13.14)
2. Cypermethrin	0.01	8.3	(16.74)	3.7	(11.10)
3. Cypermethrin	0.02	6.4	(14.68)	1.5	(7.40)
4. Permethrin 20 EC	0.005	11.6	(19.99)	13.4	(21.50)
5. Permethrin	0.01	12.3	(20.57)	9.4	(17.85)
6. Permethrin	0.02	11.7	(20.02)	9.0	(17.48)
7. Monocrotophos 36 EC	0.025	7.2	(15.52)	15.3	(23.02)
8. Monocrotophos	0.05	8.7	(17.15)	9.2	(17.64)
9. Monocrotophos	0.075	9.2	(17.69)	4.4	(12.11)
10. Phasolone 35 EC	0.07	11.1	(19.49)	29.3	(32.77)
11. Phasolone	0.10	16.6	(24.07)	31.4	(34.05)
12. Phasolone	0.15	11.1	(19.43)	29.7	(33.06)
13. Control	—	43.5	(41.28)	47.7	(43.65)

S.E. \pm 2.09.

When combined for two years, Cypermethrin at 0.02 and 0.01 per cent and Monocrotophos at 0.075 per cent recorded the lowest percentage of thrips damage. Hence Cypermethrin at 0.01 per cent or Monocrotophos at 0.075 per cent may be the economical dose for the reduction of thrips damage (Table 6). A perusal of the work done on similar lines indicates that Monocrotophos at 0.025, 0.03 and 0.05 per cent and Permethrin at 0.01 per cent considerably reduced thrips damage on capsules (Wilson et al., 1977 and 1978; Kumaresan, 1983 a, b).

Table 6. Relative efficacy of different insecticides combined for both years against thrips (1982-83 and 1983-84)

Name of the insecticide	Per cent	Percentage of damage	
1. Cypermethrin 25 EC	0.005	29.2	(33.71)
2. Cypermethrin	0.01	21.8	(27.84)
3. Cypermethrin	0.02	14.1	(22.08)
4. Permethrin 20 EC	0.005	43.9	(41.49)
5. Permethrin	0.01	38.6	(38.42)
6. Permethrin	0.02	36.3	(37.05)
7. Monocrotophos 36 EC	0.025	38.8	(38.54)
8. Monocrotophos	0.05	32.5	(34.79)
9. Monocrotophos	0.075	24.7	(29.80)
10. Phasolone 35 EC	0.07	62.5	(52.26)
11. Phasolone	0.10	72.1	(58.12)
12. Phasolone	0.15	62.9	(52.49)
13. Control	—	99.2	(84.93)

S.E. \pm 1.08.

Among the various treatments, Cypermethrin at 0.02 per cent had recorded the lowest percentage damage of stem/capsule borer and thrips and are on par with: (a) Cypermethrin at 0.01 per cent and Permethrin at 0.02 and 0.01 per cent in the case of stem borer; (b) Monocrotophos at 0.025 per cent and Permethrin at 0.01 per cent in the case of capsule borer; and (c) Monocrotophos at 0.025, 0.05 and 0.075 per cent and Cypermethrin at 0.01 per cent in the case of thrips.

Based on this result obtained in this experiment, the following tentative schedule for insecticide application may be recommended for the cardamom plantations in Lower Pulneys:

Month	Recommended insecticide based on percentage	Pests controlled
January	Cypermethrin or Permethrin at 0.1	Stem borer and Thrips
April	Monocrotophos at 0.05 or Cypermethrin at 0.01	Thrips
June	Monocrotophos at 0.05 or Permethrin at 0.01	Capsule borer, Stem borer and Thrips
August	Monocrotophos at 0.05 or Cypermethrin at 0.01	Thrips and Stem borer
October	Cypermethrin or Permethrin at 0.01	Stem borer and Thrips

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DISCUSSION

Q : Did you study the effect of these insecticides on the beneficial insect population in Cardamom plantation.

Ans: No experimental data was collected on these lines.

Q : Have you studied the residual effect of insecticides you tried?

Ans: Study is in progress on the residual effect.

Q : Could you monitor the effect of Pyrethroids on honey bee activity?

Ans: Studies have not been conducted on this aspect.

Q : The author told that the Malabar variety is resistant to thrips. If so what is the need for evaluating insecticides for the control of thrips?

Ans: Resistance of Malabar variety to thrip is a comparative statement. Comparing with Mysore variety, Malabar variety is less prone to thrips attack. We do have about 47% infestation in the harvested capsules alone. The trial is conducted to evaluate the comparative efficacy of insecticides in controlling both the thrips and the stem borer (a serious pest causing 60 to 80% damage on pseudostem and capsule).

Q : Have you taken into account the variation in climatic conditions? Does the maximum thrips population correspond to the harvesting season?

Ans: We have studied the incidence of pests as influenced by the abiotic factors. Maximum population was observed during March-May.

**BIO-ECOLOGY OF *XYLEBORUS FORNICATUS*
(EICHHOFF) (SCOLYTIDAE: COLEOPTERA),
THE SHOT-HOLE BORER OF TEA, IN THE
ANAMALLAIS (COIMBATORE DISTRICT)**

N. MURALEEDHARAN, K.G. UDAYABHANU and V. DEVADAS

ABSTRACT

The life history of *Xyleborus fornicatus* (Eichhoff) a pest of tea, was studied in an artificial rearing medium. At $25 \pm 2^\circ\text{C}$ and 75 ± 5 per cent RH, developmental period from egg to adult was 30 to 34 days, whereas under fluctuating laboratory conditions, this period ranged from 39 to 48 days. Measurements of the head width of field collected larvae showed the presence of two instars. Sex ratio was highly disproportionate, 8.8 females to one male; unfertilised eggs invariably developed into males. During the two year study, peaks in shot-hole borer populations were observed from April to July, in October and in December or January. Rainfall, to a certain extent, was favourable for the growth of *X. fornicatus* populations.

INTRODUCTION

The shot-hole borer, *Xyleborus fornicatus* (Eichhoff), is the most important perennial pest of tea in South India. The intensity of borer attack is more pronounced in the low and mid elevation (Maximum 1500 m MSL) tea districts of Anamallais, Central Travancore and Wynaad, while the high elevation (maximum 2500 m MSL) areas of the Nilgiris and the High Ranges are free from the depredations of this pest.

The female ambrosia beetles construct galleries in tea stems, leading to branch breakage and consequent crop loss. Severe infestations by this scolytid beetle result not only in crop loss but also capital loss due to the poor recovery or death of bushes after pruning (Rao, 1971; Murthy and Rao, 1979).

In general, information on the bio-ecology of *X. fornicatus* in South India is rather scanty, though several studies have been made on the biology and population dynamics of this pest in Sri Lanka (Gadd, 1941, 1949a, 1949b; Calnaido, 1964; Sivapalan, 1977). In this paper, we present the findings of laboratory and field investigations on the life history, sex ratio, gallery structure and population fluctuations of this species in the tea plantation areas of Anamallais (Coimbatore district).

MATERIALS AND METHODS

Adults of *X. fornicatus* were collected from an infested tea field in the Anamallais and were reared in the laboratory in 20 cm long test tubes, each containing 15 ml of the modified artificial diet (Sivapalan and Shivanandarajah, 1977). The dietary ingredients were chosen to provide the basic requirements of carbohydrates, proteins and fats. An extract of tea bark was also added to provide any other unknown essential component. The composition of the medium was Agar-Agar 10 g, sucrose 5 g, starch 2.5 g, casein 3 g, water 125 ml and tea bark extract 125 ml.

Water and tea bark extract were boiled together and to this, the other ingredients were added. The resulting material was autoclaved at 1.5 kg/cm² for 15 minutes and transferred to test tubes. The diet was kept unused for about seven days to obtain the required consistency. Subsequently, a pair of field collected male and female beetles was liberated into each tube and the tubes were plugged with cotton and kept in darkness. Newly emerging adult beetles were collected from these tubes and released into fresh rearing tubes to study the life history. A number of these tubes were kept in total darkness in the growth chamber at $25 \pm 2^\circ\text{C}$ and 75 ± 5 per cent RH.

Determination of larval instars was made by measuring the head capsule width of 506 field collected larvae, preserved in 70 per cent alcohol. Measurements were taken with an eye piece

micrometer. For assessing seasonal variations of shot-hole borer populations, an area consisting of 1000 tea bushes was selected and 12 infested stem cuttings, each of 25 cm long and about pencil thick size, were collected at monthly intervals. Samplings were done from June 1982 to May 1984 and data were recorded on gallery types, sex ratio and number of adults and immature stages.

RESULTS AND DISCUSSION

In the artificial medium, a very high percentage of female beetles did not excavate galleries. In successful cases, construction of galleries commenced from 45 to 60 minutes after being released into the rearing tubes, usually at the interphase of glass and diet. Though cellulose was not added, beetles reproduced in the diet. Sivapalan and Shivanandarajah (1977) observed that in the absence of cellulose *X. fornicatus* failed to make galleries and no brood developed in the diet tubes. At the beginning of tunneling, fine particles of the medium were pushed out of the entrance hole. Males, when released in the tubes, failed to make galleries. Tunnels made, were mostly vertical though circular galleries were not uncommon. Walls of galleries were lined with the ambrosia fungus *Monacrosporium ambrosium*. Under the fluctuating conditions of the laboratory, pre-oviposition period varied from seven to ten days. Creamy white eggs, measuring 0.6 to 0.7 mm long, were laid on the walls of the gallery, singly or in groups of two and 10. Often, these eggs were moved away from their original position by the movement of adult beetles and larvae, making it difficult to trace the development of any single egg in the gallery. Egg mortality, on an average, was 20.6 per cent. By the time eggs hatched into larvae, the galleries became radiated in different directions.

Larvae fed on the fungus, growing on the walls of the galleries reached a maximum length of 3 mm. Pupae could be sexed on the basis of their size, male pupae being much smaller. Full grown female pupae measured 1.5 to 2.5 mm long while male pupae were less than 1 mm long. Newly emerged, pale brown adults turned completely black in three to four days. The durations of various life stages under fluctuating and constant temperature and humidity are given in Table 1. At $25 \pm 2^\circ \text{C}$ and

75 ± 5 per cent RH, developmental period from egg to adult stage was 30 to 34 days, whereas under fluctuating temperature regimes the duration of development was 39 to 48 days. Studies conducted in Sri Lanka showed a mean developmental period of 47.2 ± 9.9 days at 24°C (Sivapalan and Shivanandarajah, 1977).

Table 1. Life history of *X. fornicatus* (Eichh.)

Developmental stage	Duration (days)			
	Under fluctuating Lab. conditions		At $25 \pm 2^{\circ}\text{C}$ and $75 \pm 5\%$ RH	
	Minimum	Maximum	Minimum	Maximum
1. Egg (incubation period)	8	10	9	9
2. Larva	21	26	16	17
3. Pupa	10	12	5	8
Total developmental period	39	48	30	34

Mated females laid a maximum of 22 eggs over a period of 40 days. Sex ratio in the laboratory progeny was 8 females to one male, and this ratio favourably compared with that obtained from field observations. Fecundity of unmated females was noted by removing the pupae into new diet tubes and rearing them into adults. Out of 20 virgin females reared, only five oviposited. The pre-oviposition period of unmated females was seven to 10 days and their fecundity rate was low. In the present study, the maximum number of eggs laid by a single virgin female was twelve. Egg mortality was around 80 per cent. Larvae and pupae developing from these unfertilised eggs were much smaller and gave rise to males only. Development of males in *X. fornicatus* is apparently by haploid *arrhenotoky*. Male haploidy has been found in several ambrosia beetles of the genus *Xyleborus* (Crowson, 1981). Haploid (male) larvae and pupae developing from the unfertilised eggs of another scolytid, *X. ferrugineus* were also significantly smaller than the diploid (female) larvae and pupae emerging from the fertilised eggs (Peleg and Norris, 1973).

The determination of larval instars was made by measuring the head capsule widths of 506 field collected larvae. Two larval instars were clearly indicated by the two high peaks of the frequency distribution histogram (Fig. 1). The smaller peak in the middle, with low frequency, represented the second larval instar of males. Apparently, the head capsule widths of the first instar male larvae came within the range of the first instar female larvae.

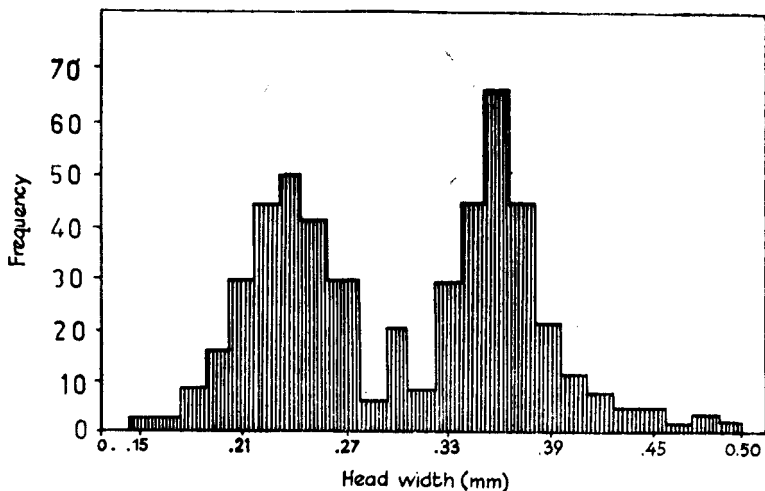


Fig. 1. Frequency distribution of larval head widths of *X. fornicatus* (n=506).

Regular field sampling of infested stems had provided data on the nature and periodicity of abundance of shot-hole borer galleries. A majority of the galleries were horizontal (83.89 per cent), whereas, vertical (4.42 per cent) and mixed (11.69 per cent) galleries were fewer in number. The tunnels when constructed on a horizontal plane, led to more serious branch breakage in comparison with vertical galleries. An assessment of the number of shot-hole borer galleries over the two year period showed that, on an average, three or more galleries per stem cutting were present in the samples collected in the months of July (1982 and 1983), October (1982), December (1983) and April (1984). It appears that the flight period of the beetle may also coincide with these or the preceding months.

Sex ratio of *X. fornicatus* varied widely throughout the period

of this investigation and did not conform to any fixed percentage of males which were always fewer in number. Monthly samplings revealed a highly fluctuating male-female ratio ranging from 1:4.9 to 1:51 in the different months. During 1982-83 the average male-female ratio was 1:11.2 and in 1983-84 this was 1:7.4. The two years data gave an average sex ratio of 8.8 females to one male. Takenouchi and Takagi (1967) noted that in species with haploid males, the sex ratio fluctuates rather widely and also could be influenced to a certain extent by various environmental factors. This offers an explanation for the highly disproportionate and widely fluctuating sex ratio in the populations of *X. fornicatus*.

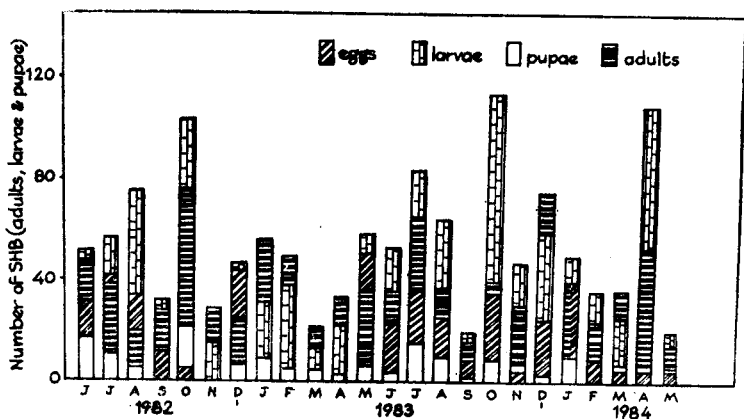


Fig. 2. Seasonal abundance of eggs, larvae, pupae and adults of shot-hole borer (SHB) at Anamallais during 1982 to 1984.

The presence of all life stages throughout the study period indicated overlapping generations. Figure 2 shows the monthly variations in the structure of shot-hole borer population. Galleries contained very few eggs in February, March and April. Larval populations gradually increased through June, July and August. suddenly declined in September and reached a very high peak in October. Although another peak in larval numbers was observed during April 1984, this was not apparent in 1983, probably due to unfavourable weather conditions. In any sample, pupae were always few. Adult beetles were more abundant during June (1982)/

July (1983), October (1982 and 1983), December (1983)/January (1983), and April (1984)/May (1983). Seasonal fluctuations in the total population including larvae, pupae and adults, also followed the above pattern (Fig. 3).

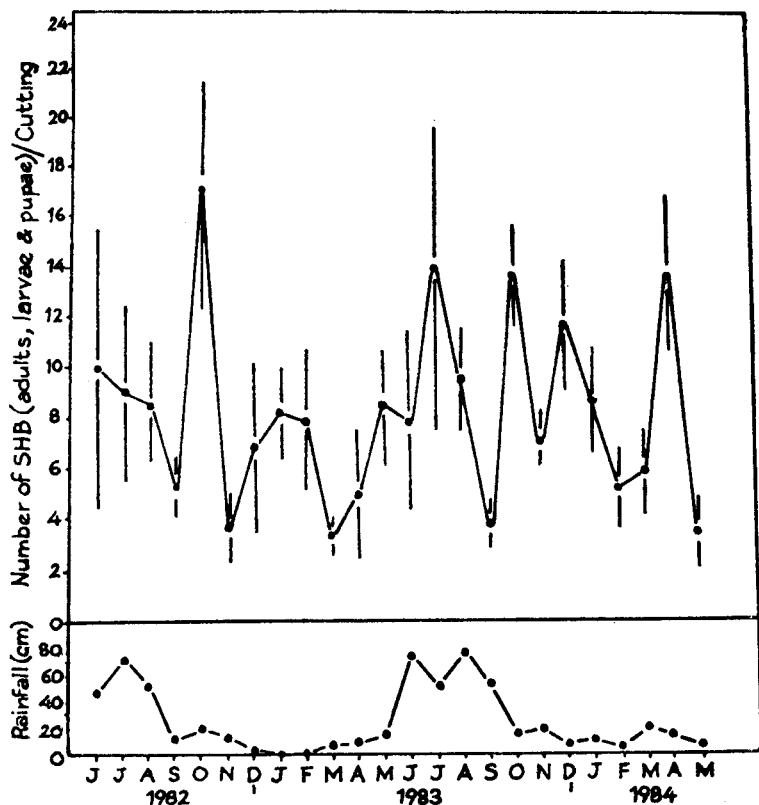


Fig. 3. Population trends of shot-hole borer (SHB) population at Anamallais compared to monthly rainfall from 1982 to 1984.

An analysis of the monthly variations of shot-hole borer populations and weather factors revealed a clear relationship only with rainfall. Figure 4 shows the effect of rainfall on shot-hole borer populations (adults, larvae and pupae) in the study area at Anamallais. The regression of total population (Y) on rainfall (X) was curvilinear. The curve, fitted to the points $Y = 68.98 + 2.796x - 0.034x^2$, $r = 0.41$ ($P = 0.05$), suggests that shot-hole borer popu-

lation increased with rainfall and gradually declined when monthly rainfall exceeded 40 cm.

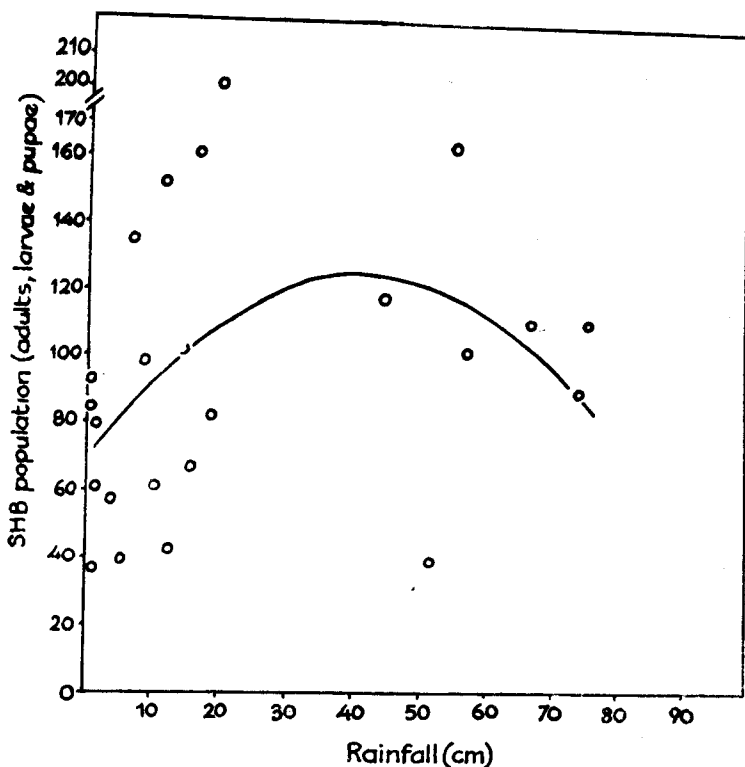


Fig. 4. Influence of rainfall on shot-hole borer populations.

No predators or parasites of shot-hole borer were obtained during this investigation. However, some galleries, mostly vacant, contained larvae and pupae of drosophilid *Phortica xyleboriphaga*. These larvae were reared in the laboratory and found to be mycetophagous.

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DISCUSSION

- Q : Since most of the galleries are horizontal, the chances of fungus infestation subsequent to pruning could be very rare?

Ans: Only when galleries are vertical or mixed chances of fungus getting inside the frame happens.

Q : Has any pathogenic fungi been isolated from the shot hole borer galleries?

Ans: No.

EVALUATION OF INSECTICIDES AGAINST BARK-FEEDING CATERPILLAR *AETHERASTIS CIRCULATA* (MEYR.) INFESTING RUBBER

C.R. NEHRU and K. JAYARATHNAM

ABSTRACT

The comparative efficacy of five insecticidal dusts namely, BHC, carbaryl, malathion, methyl parathion and phosalone was evaluated against the bark-feeding caterpillar, *Aetherastis circulata* Meyr. infesting rubber (*Hevea brasiliensis* Muell. Arg.). All the insecticidal treatments were significantly superior to control after seven and 14 days of dusting. Methyl parathion, carbaryl and phosalone proved to be most effective in relative performance.

INTRODUCTION

Of all the insect pests reported on rubber crops in India, the bark-feeding caterpillar *Aetherastis circulata* is the most serious endemic pest (Nehru et al., 1983 a, b). Around 90 per cent of the country's rubber planted area is in Kerala. In the Southern districts of Kerala and Kanyakumari district of Tamil Nadu, the attack of bark-feeding caterpillars is recorded every year and takes on serious proportions when there is a long dry spell. The bark-feeding caterpillars build galleries on the trunk and branches with chewed bark, faeces and silk, and live within. They feed on the bark and latex oozes out from certain points where they feed very deep. These points provide easy entrance

to pathogens causing diseases of the rubber bark like canker and bark rot (Jayarathnam, 1980). Severe incidence of this pest was continuously recorded on rubber since 1980, which led to the initiation of the present study on the chemical control of the bark-feeding caterpillar. Nehru et al. (1983b) published the first report of a field trial against the bark-feeding caterpillar infesting rubber in India.

MATERIALS AND METHODS

A replicated trial was conducted during 1984 in a randomized block design at the Shaliacary Estate, Punalur to evaluate the comparative effectiveness of five insecticides as dusts namely, BHC 10 per cent, carbaryl 5 per cent, malathion 5 per cent, methly parathion 2 per cent and phosalone 4 per cent at the rate of 15 kg/ha against the bark-feeding caterpillar infesting rubber. The chemicals along with a control were replicated three times. The plot size was 1250 m², and the spacing between two adjacent plots was 30 m. There were 18 plots, each with 50 trees. For evaluating the efficacy of treatments, the pest population counts were recorded on 20 randomly selected plants from each plot, a day before and seven and 14 days after the treatment. The data were statistically analysed using angular transformation.

RESULTS AND DISCUSSION

The data recorded in different treatments are presented in Table 1. All the insecticidal treatments significantly reduced the caterpillar population compared to the control. Methyl parathion and carbaryl dusts were on par and were highly effective in reducing the caterpillar population namely 99.87 per cent and 98.93 per cent respectively as against 7.6 per cent reduction in control and these two treatments were significantly superior to all other treatments in seven days. At this interval, malathion was at par with BHC but both were significantly inferior to phosalone. Data recorded 14 days after insecticidal application indicated that methyl parathion, carbaryl and phosalone were at par but, significantly superior to the untreated check in controlling the caterpillar population and proved to be significantly

Table 1. Efficacy of different insecticidal dusts against bark-feeding caterpillars

Treatments	Dosage kg/ha	Mean percentage/population reduction after	
		7 days	14 days
BHC 10% dust	15 kg/ha	76.23 (61.37)*	78.27 (62.80)*
Malathion 5% dust	..	81.50 (64.60)	88.57 (71.03)
Methyl parathion 2% dust	..	99.87 (87.93)	100.00 (88.70)
Carbaryl 5% dust	..	98.93 (84.73)	100.00 (88.70)
Phosalone 4% dust	..	94.20 (76.50)	99.40 (85.97)
Control	—	7.60 (16.00)	3.80 (11.20)
C.D at 5%		(7.33)	(9.09)

* Figures in parentheses are angular transformed values.

superior to BHC and malathion. Malathion was significantly better than BHC in minimising the population of caterpillars at 14 days after treatment. Thus, overall methyl parathion, carbaryl and phosalone significantly proved better in checking *A. circulata* Meyr. and one of these can be recommended for the control of the bark-feeding caterpillar infesting rubber. Incidence of the bark-feeding caterpillar on rubber and its control measures were reported by earlier workers (Radhakrishna Pillai, 1968; Jayaramnam, 1980; Nehru, 1983a). Nehru et al. (1983b) found methyl parathion to be most effective recording 98.52 per cent reduction in larval population and the corresponding reduction for carbaryl, BHC and malathion was 95.96 per cent, 77.14 per cent and 74.31 per cent respectively. These findings thus support the present investigation especially on the comparative efficacy of insecticides such as methyl parathion and carbaryl against this pest. It is observed that even after 30 days from the date of dusting, there was no fresh infestation of the bark-feeding caterpillar in the treated plots.

Considering the overall efficacy of different insecticides tested, it is concluded that methyl parathion, carbaryl and phosalone are effective against bark-feeding caterpillars. Since rubber is a tree crop, carbaryl is a safer insecticide for this purpose.

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DISCUSSION

- Q : Have you studied the biology and population dynamics of this insect?
- Ans: Studies on the biology has been carried out and the study of population dynamics is in progress.
- Q : Have you come across any naturally occurring parasites and predators, and if so, do dusting of these insecticides have any effect on these?
- Ans: Yes. Some chalcids have been identified as prepupal parasitoids of *A. circulata*. No predator has been observed so far. Dusting of safer insecticides may not affect them.
- Q : To what age of rubber tree is this pests a problem?
- Ans: There is no age specificity as far as infestation is concerned.

Q : Why the dusts only are tested. Could it not be economical to use insecticidal sprays rather than dusts?

Ans: Dusts are found to be more economical than sprays. One round of dusting is sufficient.

PRELIMINARY OBSERVATION ON THE EFFECT OF SOME SYSTEMIC NEMATOCIDES AND *NEEM* OIL CAKE IN A CARDAMOM FIELD INFESTED WITH ROOT-KNOT NEMATODES

S.S. ALI

ABSTRACT

A control experiment against root-knot nematodes was laid down in a cardamom field, replicated four times with nine treatments in randomised block design. Three systemic nematocides and *neem* oil cake were applied twice in a year. Aldicarb, Carbofuran, Phorate applied at the rate of 5 g and 10 g ai/plant, while *neem* oil cake at the rate of 500 g and 1000 g/plant. Maximum capsule yield was obtained from the plants applied with *neem* oil cake at the rate of 1000 g/plant followed by 500 g per plant. Statistically significant reduction in nematode population was observed in all treatments. In untreated plants heavy premature capsule drop was observed over treated plants and was statistically significant. The study has determined that *Meloidogyne incognita* reduced the yield of cardamom by 32 to 47 per cent over treated plants. By controlling the root-knot population the average yield of cardamom capsules can be enhanced by 70 per cent in the very first year.

INTRODUCTION

The total acreage under cardamom (*Elettaria cardamomum* (L.) Maton) had increased from 55,296 to 93,947 ha indicating an overall increase of 70 per cent in the last 15 years (Jos, 1982). The importance of this wide expanding plantation crops in the

agricultural economy, needs a greater knowledge of the role of plant parasitic nematodes in its production. Published studies on root-knot nematode associated with cardamom have been largely confined to reports of disease incidence (Ali and Koshy, 1982; Ali, 1982). Despite the reported decline in yield of cardamom in recent years and correspondingly losing out on the international market for this highly priced spice, no research has been carried out on yield losses incurred due to infestation of nematodes and its remedial measures in the field crop.

In cardamom, root-knot nematode disease is a problem, because of the widespread incidence of indigenous *Meloidogyne incognita* (Kofoid et white) Chitw., the continuous use of highly infested seedlings in the plantations and the absence of control measures that could curb nematode population. The disease has become a limiting factor in cardamom production in some localities. The purpose of the experiment reported here was to determine the yield losses of cardamom infested with *M. incognita* and to evaluate the efficacy of some systemic nematicides and neem oil cake to control *M. incognita* and to influence the capsule yield.

MATERIALS AND METHODS

In 1983, an infested site was selected for the present study at Central Plantation Crops Research Institute, Research Centre, Appan-gala, Karnataka. It was situated at 1000 MSL and received an average of 320 cm annual rainfall with 65 to 75 per cent humidity in a temperature range of 17 to 30°C. In 1979, after uprooting the old cardamom clumps, young plants of uniform age of a cardamom cultivar Malabar Clone 37 were planted in forest loamy soil of pH 5. The spacing adopted for the new planting was 2 × 2 m between the plants and rows. Wherever it is required, adequate drainage was provided by opening the main and subsidiary drainage channels at appropriate intervals. A mixture of ever-green forest trees like *Cedrella toona* (red cedar), *Acrocarpus fra-xinifolius* (Balangi), *Artocarpus hexaphyllum* (Jack), *Maesopsis eminii* (African shade tree), *Erythrina indica* (Dadab), were naturally grown for providing shade, totalling 81 in number and distributed in more than a half acre plot. The two-tier canopy of these trees provided moderate shade underneath the cardamom and also a good quantity of mulch throughout the year by some

trees shedding their leaves in summer, while others shedding leaves in the monsoon. Within three years the newly planted material of clone 37 exhibited symptoms of nematode infestation, like stunting, yellowing of leaf margins and tips, reduced lamina and excessive branching of roots. Probably, infestation by root-knot nematode on newly planted material might have come from the inoculum present in the soil which was constantly used for cardamom cultivation for many years, or it might have got carried from the nursery where young plants were raised.

A trial experiment against root-knot nematodes was initiated in 1983 on the present site. The experiment laid down in a randomised block design, replicated four times with nine treatments. Treatments consisted of six cardamom plants in two rows, each row with three plants. In three replications each treatment was provided with four guard rows, while the fourth replication had two guard rows as there was a deep and wide drainage channel running parallel along each treatment. Three systemic nematicides used were aldicarb, carbofuran and phorate at two rates 5 g and 10 g per plant and neem oil cake *Azadirachta indica* Juss. at 500 g and 1000 g per plant. Untreated plants served as control. All the treatments provided with regular plant protection measures and cultural practices prevailed in the cultivation of this crop. Nematicides were mixed with 500 g dry sand, applied uniformly at 2 cm depth within a radius of 30 cm, where most of the feeder roots were spread. Similarly, neem oil cake was also incorporated in the soil. Application of nematicides and neem oil cake was given twice in a year after an interval of four months.

All the plants were sampled for root and soil for nematode population assessment prior to the treatment. A composite of 250 g of soil and 5 g of roots were taken for further processing. The soil sample was processed by Cobb's sieving technique for nematode extraction. Root samples were washed thoroughly and were cut into small pieces, fixed in 4 per cent formalin, stained in boiling acid fuchsin-lactophenol for three minutes and minced in Waring Blender for 30 seconds. Three aliquotes of 5 ml examined for nematode population counts. Capsule drop was recorded in every second week. Capsule yield was collected from each plant during the picking season starting from August 1983 to January 1984 with an interval of 15 to 20 days. A fresh weight of cardamom capsules was taken after each picking.

RESULTS AND DISCUSSION

Nematicides were evaluated at two rate levels and all the nematocidal treatments significantly increased the capsule yield over control (Table 2). Results demonstrated that increase in yield was also significant between differential treatment of nematicides, where aldicarb 10 g per plant significantly out-yielded (497.33 g) followed by 5 g per plant. Capsule yield recorded from phorate treated plants gave more yield than the corresponding rate of carbofuran.

The greatest capsule yield was obtained by the plants applied with *neem* oil cake at the rate of 1000 g per plant followed by 500 g per plant. The inhibitory effect of oil cake application to soil against plant parasitic nematodes has been reported by Lear, (1959); Mankau (1963); Mankau and Minter (1962); Khan et al. (1966, 1973); Singh and Sitharamaiah (1966, 1971); Gour and Prasad (1970); Goswamy and Swarup (1971); Alam and Khan, (1974). Singh and Sitaramaiah, 1966; Khan et al., 1966 and 1973 reported that oil cakes of *neem*, castor and groundnut, when added to infested soil reduced the intensity of root-knot nematodes. Khan, 1969 demonstrated that by the incorporation of *neem* oil cake in the soil, the incidence of root-knot nematodes on tomato, egg plant, carrot and sugar beet was greatly reduced. The latter workers also showed that water extract obtained directly or from deoiled cakes, brought about marked inhibition in larval emergence of *M. incognita*. Nimbidine and thionimone, alkaloides from *neem* were reported to be highly toxic to larvae of *M. incognita*, *Pratylenchus coffeae* and *Tylenchorhynchus brassicae*. The similar trend in this study was also observed in the reduction of nematode population. *Neem* oil cake was found highly inhibitory and equally effective to those of aldicarb and phorate.

Pre-treatment distribution of infective juveniles of *M. incognita* was uniform throughout the test side (Table 1). After every subsequent application of nematicides and *neem* oil cake there was a progressive reduction in nematode population in all treatments except control. An effective and statistically significant reduction in nematode population was observed in all treatments particularly after the second application. This reduction was obviously due to nematocidal activity. There was no sharp increase in nematode population in untreated control plants, although the highest

Table 1. Effect of some systemic nematocides and neem oil cake on Meloidogyne incognita population in an infested cardamom field. Mean of four replications (per g of root and 250 g of soil)

Treatment	Pre-treatment population		Post treatment population			
	Root	Soil	After first application		After second application	
	Root	Soil	Root	Soil	Root	Soil
Aldricarb 5 g ai/plant	460	402	280	216	236	182
Aldicarb 10 g ai/plant	387	370	222	130	173	104
Carbofuran 5 g ai/plant	384	366	330	196	300	103
Carbofuran 10 g ai/plant	482	437	290	126	248	94
Phorate 5 g ai/plant	427	386	431	278	363	162
Phorate 10 g ai/plant	465	410	267	267	240	175
Neem oil cake 500 g/plant	372	371	249	186	322	112
Neem oil cake 1000 g/plant	425	397	241	280	175	192
Control	378	305	530	421	622	542
L.S.D. at 5% level	—	—	75.12	159.30	67.38	34.79

Table 2. Effect of some systemic nematicides and neem oil cake on yield, premature capsule drop number of panicles and tillers in a cardamom field infested with Meloidogyne incognita (Mean for four replications)

Treatments	Number of tillers	No. of panicles	No. of capsule drop	Capsule yield (g)	Yield increase and percentage of increase due to
Aldicarb 5 g ai/plant	192	258	164	476.33	*202.35 (74%)
Aldicarb 10 g ai/plant	151	246	106	497.33	223.35 (82%)
Carbofuran 5 g ai/plant	162	210	100	402.67	128.69 (47%)
Carbofuran 10 g ai/plant	180	222	110	422.62	148.64 (54%)
Phorate 5 g ai/plant	162	252	86	459.05	185.07 (67%)
Phorate 10 g ai/plant	150	216	103	470.17	196.19 (72%)
Neem oil cake 500 g/plant	138	204	91	492.67	218.69 (80%)
Neem oil cake 1000 g/plant	180	294	87	514.35	240.37 (88%)
Control	156	180	300	273.98	
L.S.D. at 5% level	N.S.	N.S.	29.26	25.04	(70%)
			Average % increase		

*Difference in yield between treated and untreated cardamom plants.

juveniles count was recorded after every sampling. This indicates that root-knot nematode development in untreated plants is likely to be disturbed during a heavy monsoon.

Immature capsule drop is commonly associated with stunting. Reduced lamina together with heavy infestation of root-knot nematodes on root system indicate that it is certainly due to parasitisation of nematodes. Dropping of immature capsules may result due to any impairment of normal physiology of cardamom, such as reduced translocation of water and nutrient or reduced photosynthesis, which may lead to insufficient photosynthate available to panicles and thereby affect the retention of capsules. This fact is well pronounced in untreated plants where heavy, premature fruit drop was noticed over treated plants and was statistically significant.

The data on number of tillers and panicles were not statistically significant. Cardamom being a perennial crop, attain their maturity in a period of three to four years. No marked differences in morphological characters of plants may be expected immediately after applying nematicides, which in turn also act slowly.

Comparison of yield data between treated and untreated plants show yield increase due to nematode control. The study has determined that *M. incognita* reduced the yield of cardamom by at least 32 to 47 per cent over treated plants and increases the incidence of premature capsule drop. It is clear from the foregoing that by checking the root-knot population considerably, the average yield of cardamom capsules can be enhanced by 70 per cent in the first year (Table 2). *Neem* oil cake or nematicidal treatment is a feasible means of improving cardamom performance in soil infested with *M. incognita*. More data are needed to confirm the consistent yield increase reduction in premature capsule drop, by checking the nematode infestation.

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DISCUSSION

Q : What is the difference in the degree of expression of disease symptoms in the seedling stage and in the mature plant?

Ans: No significant difference is observed.

Q : In tea nursery, application of neem cake has been found to increase the population of Eelworms which is contrary to the findings of the author. Please comment.

Ans: Increase in the saprophytic nematode population may be observed, but not the plant parasitic one.

Q : 100 g of Temik per plant will have to be applied to give 10 g a.i. Have you worked out the cost benefit ratio?

Ans: Temik treated plants gave an yield increase of 84 per cent over control and checked the fruit drop by 65 per cent. Hence Temik application will work out to be economical.

Q : Will it not be advisable to prepone the treatments to March-April?

Ans: It is not advisable to apply the nematicides during March-April since nematode multiplication/hatching is very low during dry period.

Q : Have you tried potash application for control of nematodes, as done in Brazil?

Ans: No.

Q : How have you fixed the dose of neem cake without quantifying the active ingredient?

Ans: Your suggestion on quantifying active ingredient before application will be considered for further work. Normally neem cake available in the market contains 2-3% oil.

Q : In a similar work at RRII, we could not get control of nematodes within the root system and infective juveniles in rhizosphere?

Ans: We have drawn samples 4 and 8 months after application of neem cake. Samples drawn earlier than this will not reflect the effect of neem cake since it acts slowly.

SESSION IV

AGRONOMY I

Chairman: P.K. Ramiah

Rapporteurs: Jacob Mathew

Rohini Iyer

A STUDY ON WEED CONTROL BY HERBICIDES AND MANUAL MEANS ON PLANTING STRIPS IN A YOUNG RUBBER PLANTATION

M. MATHEW, S.N. POTTY and K.I. PUNNOOSE

ABSTRACT

An experiment was conducted from 1981 to 1984 in a young rubber plantation to find the comparative effect of the herbicides Paraquat, Fernoxone and Dalapon in combinations and manual weeding on the control of weeds in contour terraces. The treatments paraquat as Gramoxone at 2.5 l/ha plus Fernoxone at 1.25 kg/ha and Dalapon at 5 kg/ha plus Paraquat at 2 l/ha were superior to manual weeding for control of weeds. The girth of the trees after three years of experimentation was higher in plots where the above herbicides were applied. On cost comparison with the treatment Paraquat plus Fernoxone was the cheapest followed by Dalapon plus Paraquat. Manual weeding was costlier to the herbicide treatments.

INTRODUCTION

The control of weeds on the planting lines or terraces of immature rubber plantations is very important to facilitate the quick growth of rubber plants. Apart from competing with young rubber plants for light, nutrients and water, weeds cause serious inconvenience to various estate operations for plant protection and manuring. The conventional method being adopted to achieve this objective is scraping with a spade. Due to favourable

moisture condition during most of the months it may require several repeated manual operations using a spade in order to get an all the year round control of weeds in the planting lines. Research work done by the various Rubber Research Institutes indicates the possibility of weed control by the application of herbicides in rubber plantations (Abdul Kalam and Punnoose, 1975; Mathew et al., 1977). Where labour is available at low cost, manual weed control may be cheaper than herbicide applications. Since in most parts of the country the labour rates show an increasing trend, chemical methods are likely to become on par with or even cheaper than manual weeding. Chemical weed control has other advantages—it does not disturb the soil surface and expose the soil to erosion, and it is less time consuming. Therefore, the present work is taken up to find the best schedule of herbicide application, and to compare its effectiveness and economy with manual methods of weed control.

MATERIALS AND METHODS

The experiment was laid out in a plantation located at Erumely in Pathanamthitta District of Kerala State. The field was a seed-at-stake planting budded with R.R.I.I. 105 in September, 1980. The treatments are listed below:

- T 1 —Gramoxone at 2.5 l/ha plus Fernoxone 1.25 kg/ha of actually sprayed area.
- T 2 —Manual weeding—scraping plant basins and slashing in between the plant basins.
- T 3 —Spraying plant basins with Treatment T 1 and slashing in between the plant basins.
- T 4 —Dalapon at 5 kg/ha and followed by Gramoxone at 2 l/ha one to ten days after Dalapon spraying—of actually sprayed area.

The above treatments were imposed only on the planting strips or terrace. The treatments were started in October, 1981 and were repeated, so as to get a continuous control of weeds. Observations on the percentage regeneration of weeds were taken periodically and the girth of trees recorded equally. The dates on which the treatments were imposed and observations recorded are given in Appendix 1. The data on rainfall during the period of experiment are presented in Appendix 2.

RESULTS AND DISCUSSION

The results of the different parameters observed are discussed:

Effect on weed regeneration: The data on percentage regeneration of weeds recorded on different dates are presented in Table I.

1) Observation on 25.2.1982: The treatment Dalapon plus Gramoxone and the treatment Gramoxone plus Fernoxone in plant basin and slashing in between were significantly superior to the treatments Gramoxone plus Fernoxone and complete manual weeding. Further the treatment Dalapon plus Gramoxone was superior to Gramoxone plus Fernoxone in plant bases and slashing in between. Treatments Gramoxone plus Fernoxone and complete manual weeding were on par with each other.

2) Observation on 23.4.1982: The results show that the treatment Dalapon plus Gramoxone was significantly better than all the other treatments. The effect of the other three treatments were on par, with each other.

3) Observation on 19.7.1982: It is seen that the treatments Gramoxone plus Fernoxone and Dalapon plus Gramoxone were superior to the other treatments and the treatment of complete manual weeding was inferior to all the others.

4) Observation on 20.9.1983: The best control was observed for the treatments Gramoxone plus Fernoxone and Dalapon plus Gramoxone. The treatment of manual weeding was inferior to all the others.

5) Observation on 29.11.1983: The treatment Gramoxone plus Fernoxone was on par with the treatment Dalapon plus Gramoxone, but was significantly better than the other two treatments.

6) Observation on 3.2.1984 and 27.6.1984: The treatments Dalapon plus Gramoxone and Gramoxone plus Fernoxone gave the best control of weeds. Manual weeding gave the lowest control.

A general evaluation of the above results indicates that the treatments Gramoxone plus Fernoxone and Dalapon plus Gramoxone are superior for efficient weed control and manual weeding is inferior. These results are in full conformity with the results obtained by different authors (Riepma, 1968; Darter, 1968; Anonymous, 1967; Peng, 1970; Lee, 1975; Mathew et al., 1977).

Effect on the girth of trees: The mean girth of plants recorded

Table 1. Mean percentage regeneration of weeds on different dates (transformed values)

Dates Treatment	25.2.1982	23.4.1982	19.7.1982	20.9.1983	29.11.1983	3.2.1984	27.6.1984
T 1	37.73 (37.50)*	53.08 (63.75)	39.23 (40.00)	12.92 (5.00)	28.14 (22.50)	15.68 (7.50)	29.89 (25.00)
T 2	37.73 (37.50)	50.77 (60.00)	45.72 (63.75)	37.44 (37.50)	45.00 (50.00)	42.82 (46.25)	45.00 (50.00)
T 3	33.17 (30.00)	52.28 (62.50)	42.13 (45.00)	24.45 (17.50)	39.11 (40.00)	23.73 (16.25)	38.45 (38.75)
T 4	26.48 (20.00)	43.56 (47.00)	39.23 (40.00)	12.92 (5.00)	33.75 (31.25)	12.92 (5.00)	29.71 (25.00)
	S.E: 1.32 C.D: 4.71	S.E: 1.49 C.D: 4.71	S.E: 0.36 C.D: 1.13	S.E: 2.69 C.D: 8.57	S.E: 2.22 C.D: 7.07	S.E: 1.21 C.D: 3.84	S.E 2.08 C.D 6.64

*Figures in parentheses indicate actual percentage.
C.D. values are at 5 per cent confidence limit.

annually is furnished in Table 2. The pre-treatment girth data (1981) did not show statistical difference among the treatments, which reveal the uniformity of experimental area. The data recorded in 1983 also did not show statistical difference, probably because a period of one year may not be enough to get the effect of weed control reflected on the growth of rubber plants.

Table 2. Mean girth of trees (CMS) on different dates

Dates Treatment	10.10.1981	15.1.1983	9.2.1984
T 1	10.08	15.62	22.73
T 2	9.98	14.61	21.07
T 3	10.24	15.26	22.82
T 4	10.36	15.60	23.20
	S.E: 0.34	S.E: 0.49	S.E: 0.47
			C.D: 1.48 (at 5%)

The girth data recorded two years after commencement of the trial (1984) showed significant difference among the treatments. Manual weeding was inferior to all the herbicide treated plots. However, there was no significant difference between the three herbicide treatments.

Cost comparison of different treatments: The treatment Gramoxone plus Fernoxone is the cheapest means of weed control followed by the treatment Dalapon plus Gramoxone (Table 3). Manual weeding is the costliest treatment.

Table 3. Cost of herbicide treatment/manual weeding per ha of rubber plantation from 10.10.1981 to 13.3.1984 involved to keep the planting lines (terraces) weed free

Treatment	Cost of herbicide Rs.	Labour charge Rs.	Total cost Rs.
T 1	324.00	160.71	484.71
T 2	—	1227.24	1227.24
T 3	137.48	886.34	1023.82
T 4	489.20	262.98	752.18

Considering the extent of weed control and growth of rubber, the treatments Gramoxone plus Fernoxone and Dalapon plus Gramoxone could be rated as the best herbicide combinations. Treatment Gramoxone plus Fernoxone is the cheapest combination of weedicides followed by the treatment Dalapon plus Gramoxone. Therefore from the point of view of benefit derived and cost involved treatment Gramoxone plus Fernoxone is the most advantageous one followed by the treatment Dalapon plus Gramoxone.

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DISCUSSION

Q : It is reported elsewhere that addition of Urea (0.5%) will reduce the quantity of weedicides. Have you tried this?

Ans: A trial on this line is in progress.

Q : A single high dose of dalapon will affect translocation of weedicides beyond the point of entry. Therefore repeated applications of lower doses might be more useful?

Ans: Doses lower than this were not effective even by repeated spraying.

Q : The girth should be retarding from the third year because herbicides affect soil microflora?

Ans: The girth increase observed could be attributed to less soil disturbance. Moreover, application of herbicides is localised.

Q : Have you given a general weeding before incorporation of treatments?

Ans: Contour terraces were cut before commencement of experiment.

Appendix 1. Dates of treatment imposition and recording observations

Dates of treatment imposition		Dates of recording weed regeneration	Dates of recording girth of trees
Weedicide spraying	Manual weeding		
10.10.1981	10.10.1981	25.2.1982	10.10.1981
11.12.1981	23. 4.1982	23.4.1982	15. 1.1983
23. 4.1982	31. 8.1982	19.7.1982	9. 2.1984
29. 7.1982	16.10.1982	20.9.1983	
9. 9.1982	10.12.1982	29.11.1983	
16.10.1982	29.11.1983	3.2.1984	
19. 7.1983	13. 3.1984		
29.11.1983			
13. 3.1984			

Appendix 2. Rainfall data from January 1981 to June 1984

Year/Month	1981		1982		1983		1984	
	Rainfall (mm)	No. of rainy days	Rainfall (mm)	No. of rainy days	Rainfall (mm)	No. of rainy days	Rainfall (mm)	No. of rainy days
January	68	4	—	—	—	—	15	2
February	44	5	—	—	39	2	181	10
March	189	14	115	8	27	1	99	13
April	208	14	193	9	22	3	278	15
May	349	15	466	16	162	13	176	10
June	1208	27	708	26	391	21	679	28
July	964	22	443	25	645	20		
August	561	24	398	18	647	24		
September	789	22	136	10	470	26		
October	549	21	236	14	241	18		
November	95	15	190	15	271	8		
December	23	2	16	1	228	7		
Total	5047	185	2901	142	3143	143		

HERBICIDES AND INTERCULTURE—THEIR EFFECT AND IMPACT ON THE YIELD OF COCONUT

T. RAMANATHAN, R. BALASUBRAMANIAN and
H. VIJAYARAGHAVAN

ABSTRACT

A trial was conducted to study the efficacy and economics of certain herbicides and ploughing practices on weed growth and nut yield. The herbicides were effective only in reducing the weed growth as indicated by the lower fresh weight of weeds in the herbicide treated plots. The suppression in the growth of weeds by weedicides did not improve the nut yield. On the other hand, ploughing the entire area enhanced the yield of nuts by as much as 21 per cent over control.

INTRODUCTION

Intercultivation is one of the most important operations in the scientific management of coconut plantations, which by itself has been found to increase the productivity substantially. It was reported that in an estate in Sri Lanka, the regularly cultivated and weeded portion gave an average yield of 55 nuts per year, whereas the neglected portion gave no yield worth monitoring (Cook, 1932). The results of long term cultural experiments carried out at the Central Plantation Crops Research Institute, Kasaragod showed that regular intercultivation alone was responsible for an increase of 32.9 nuts per palm per year (Krishnamarar and Pandalai, 1959). Application of herbicides has been found to

effectively reduce the weed population. Scientific information regarding the efficiency and economics of herbicides on one hand and cultural practices on the other is lacking (Thampan, 1975). Therefore an attempt was made to investigate the efficiency and economics of ploughing operations and herbicides on growth of weeds and yield of coconut.

The experiment was started in June, 1976 with six treatments which were replicated four times. The seventh treatment (T₇) was included in the final year of the trial—each replicate consisted of eight palms of East Coast Tall variety. The design adopted was RBD. The treatment details are as follows:

- T₁. Control—no cultivation except digging basins for fertiliser application.
- T₂. Ploughing twice a year, alternate alleys in alternate years.
- T₃. Ploughing twice a year, two metres on either side of the row of the palms.
- T₄. Ploughing twice a year, the entire area.
- T₅. Weed control by two sprays of Dalapon at the rate of 5 kg/500 l water/ha.
- T₆. Weed control by two sprays of Gramoxone at the rate of 1 l mixed with Fernoxone 0.5 kg in 500 l water/ha.
- T₇. Weed control by two sprays of Karmex at the rate of 2.5 kg/500 l water/ha.

The yield of nuts was recorded at monthly intervals. The weed growth was assessed by taking the fresh weight of weeds per unit area (g/m). This was recorded two weeks prior to the intercultivation operations in March and September.

RESULTS AND DISCUSSION

Observations on weed growth: The chemical weed killers were effective in bringing down the weed growth which was indicated by the significant reduction in all the three years studied except in the year 1983 where Dalapon spray did not give significant weed control (Table 1). The suppression of weed growth was much more pronounced during 1982. Maximum reduction in weed growth was observed in Karmex followed by Gramoxone plus Fernoxone spray.

Yield of nuts: The effect of various ploughing operations and

Table 1. Effect of various weed control treatments on the weed population in coconut
(Mean fresh weight g/m²)

Sl. No.	Treatment	1981		1982		1983		Total
		February	September	March	September	March	September	
1.	Control	185	646	188	123	136	705	841
2.	Ploughing alternate alleys	145	527	183	91	114	625	739
3.	Ploughing either side	136	559	125	96	95	643	738
4.	Ploughing entire area	79	495	150	51	59	588	647
5.	Dalapon spray	61	425	153	41	84	685	769
6.	Gramoxone + Fernoxone	19	206	110	71	44	548	592
7.	Karmex	—	—	—	—	28	140	168
SE			71.11				17.54	68.60
CD at 5 per cent			214.31				52.85	206.75

*Table 2. Effect of various weed control treatments on yield of coconut
(Mean number of nuts per palm)*

Sl. No.	Treatment	1979	1980	1981	1982	1983	Total	Percentage increase over control
1.	Control	47.2	58.0	50.7	30.7	44.4	231.0	—
2.	Ploughing alternate alleys	46.5	57.0	57.0	31.4	54.3	246.2	6.6
3.	Ploughing either side	43.7	61.0	55.6	31.0	60.9	252.2	9.2
4.	Ploughing entire area	48.6	62.0	51.9	43.0	74.4	279.9	21.2
5.	Dalapon spray	56.7	63.0	58.3	31.2	58.1	267.3	15.7
6.	Gramoxone + Fernoxone	50.6	66.0	57.9	47.1	48.1	269.7	16.8
	SE	1.50	1.94	1.00	5.36	4.97	6.15	
	CD at 5 per cent	—	—	—	—	14.96	—	

herbicides on nut yield for five years is presented in Table 2. During 1979 and 1981 Dalapon gave an increased yield of 20.1 and 15.0 per cent respectively over control and during 1980 and 1982 Gramoxone combined with Fernoxone registered an increased yield of 13.8 and 53.4 per cent respectively. Ploughing the entire area has resulted in significant yield increase of 67.6 per cent during 1983 and 21.2 per cent over control in the cumulative yield over five years. The probable reason for getting enhanced yield in ploughing the entire area treatment might be due to the loosening of top soil which helps in the infiltration of moisture and also ploughing the soil which reduces the noxious weeds (Krishnamarar et al., 1961). The other ploughing treatments did not improve the yield as much as ploughing the entire area. This might be due to the fact that some patches of weeds which were left unploughed might have produced seeds and multiplied in due course of time to compete for water and minerals with yielding palms. This increase is of a much higher order than that of herbicide treatments which show that weed suppression alone is not sufficient in coconut gardens to ensure productivity.

Economics of weedicide application: The data on cost and profit obtained in the study are presented in Table 3. The application of weedicide to reduce the weed growth is not at all economical when compared to cultural operations like ploughing. Ploughing the entire area twice a year which costs Rs. 3445 per ha per year recorded the highest net return of Rs. 6355 which is

Table 3. Economics of weedicide versus cultural operations on nut yield (Rupees/ha/year)

Sl. No.	Treatment	Cost of cultivation	Gross income	Net profit	Cost/Profit ratio
1.	Control	3265	8225	4960	0.40
2.	Ploughing alternate alleys	3445	8750	5305	0.39
3.	Ploughing either side	3445	8750	5305	0.39
4.	Ploughing entire area	3445	9800	6355	0.35
5.	Dalapon spray	3745	9450	5705	0.40
6.	Gramoxone + Fernoxone	3975	9450	5475	0.42

about Rs. 1395 of more benefit obtained than the control. Ploughing the entire area recorded a low cost/profit ratio indicating less expense and high net profit. On the other hand, weedicide application revealed the high cost/profit ratio which is due to high investment and low productivity. Ploughing the entire area not only reduces the weed growth but also increases the soil aeration, moisture infiltration and provides an environment conducive for better root growth. This enables efficient absorption of water and nutrients which ultimately is reflected in the nut yield.

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DISCUSSION

Q : Cost benefit ratio shows almost equal values for control plots, herbicide and ploughing treatments. It appears that leaving the field untreated is equally cost effective as weed control?

Ans: Though there was 15.7 and 16.8 per cent increase in yield in Dalapon spray and gramoxone + fereoxone spray treatments, ploughing the entire area resulted in 21.2% increase in yield.

Q : Can you attribute the increase in yield in ploughed plots to increased aeration?

Ans: Mainly due to supression of weed growth.

OCCURRENCE OF VESICULAR-ARBUSCULAR MYCORRHIZA (VAM) IN COCOA (*THEOBROMA CACAO*) AND ITS INFLUENCE ON THE GROWTH AND PHOSPHORUS NUTRITION

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ABSTRACT

Cocoa root samples collected from two gardens of Quilon district of Kerala State were checked for VAM fungus colonisation. Seven out of ten root samples showed mycorrhizal association (12 to 21 per cent). Response of cocoa seedlings to VAM (*Glomus fasciculatum*) inoculation with three levels of phosphorus application namely no phosphorus, 50 ppm P_2O_5 and 100 ppm P_2O_5 in a P deficient affisol was significantly ($P = 0.05$) higher. VA-mycorrhiza inoculation along with medium level of phosphorus application on plant growth was more effective than either mycorrhiza alone or higher levels of phosphorus-mycorrhiza treatments. Further, higher levels of phosphorus showed inhibitory effect on mycorrhizal development.

INTRODUCTION

It is well documented that vesicular-arbuscular mycorrhizal (VAM) association improves the nursery growth, general conditions and field establishment of transplanted crops. Improved growth and nutrient uptake due to VA-mycorrhizal association has been demonstrated in many horticultural crops (Mosse, 1957; LaRue et al., 1975; Menge et al., 1978 a, b). Nursery level inocu-

lation with VAM fungus has become an accepted practice for these crops, particularly citrus. Occurrence of VA-mycorrhizal association has been reported in transplanted crop plants like rubber (Sivaprasad et al., 1948); coffee, tea, oil palm (Hayman, 1982); and coconut (Lilly, 1975). Cocoa is also a transplanted crop and has considerable economic importance. Not much information is available about the VA-mycorrhizal association in cocoa plant. The present study reports the improved growth and phosphorus uptake of cocoa seedlings due to VA-mycorrhizal association.

MATERIALS AND METHODS

Cocoa (*Theobroma cacao*) root samples were collected from two different cocoa gardens of Quilon district, Kerala state, India. Thin feeder root samples were made into small (1 cm size) bits and subjected to trypan blue staining (Phillips and Hayman, 1970). Stained root bits were scanned under a microscope for the presence of mycorrhizal association. Fifty root bits were examined in each sample for infection, and root infection was worked out on a percentage basis.

Cocoa pods of cultivar 'forastero' were used for the response study. Seeds extracted from 'seed pods' were sown flat and shallow in sterilised soil : sand : farm yard manure mixture (1:1:2) in 46 cm × 46 cm cement pots. On germination, the seedlings were transplanted to 10 kg size pots filled with phosphorus deficient affisol (7.75 mg/kg available P by NH_4F and HCl extraction, pH 5.6, indigenous endomycorrhizal spore count of 41 per 50 ml soil).

Sand : soil (1 : 1) mixture containing extra matrical chlamydo-spores and infected root segments of guinea grass (*Panicum maximum* Jacq.) infected with VA-mycorrhizal fungus *Glomus fasciculatum* and grown for 90 days served as the inoculum. The inoculum contained 620 chlamydo-spores per 50 ml soil. In the treatments requiring mycorrhizal inoculation 50 ml of soil : sand mixture containing chlamydo-spores, infected root bits and mycelia were placed 5 cm below the soil, over which the transplanting was done. No inoculation was given while germinating the seeds in soil : sand : FYM mixture.

Three levels of phosphorus, namely no phosphorus (PO), 50

ppm P_2O_5 (P1) and 100 ppm P_2O_5 (2), with and without *Glomus fasciculatum* inoculation was included in the experiment conducted in four replications under green house conditions. One seedling was maintained in each pot. The seedlings were allowed to grow for an eight-month period and the plants were harvested, and observations were recorded on mycorrhizal infection per cent, spore count in rhizosphere soil (Gerdemann and Nicolson, 1963); dry weight of plant top and root and phosphorus content of plant top and root (Jackson, 1973).

RESULTS

All the samples collected from different locations of the Garden I (Punalur) were positive for mycorrhizal association (Table 1). In the case of Garden II, only two of the five samples were mycorrhizal. Typical vesicular-arbuscular structures were noticed in all the positive samples. However, colonisation was considerably low (10 to 21 per cent).

Table 1. Occurrence of VA-mycorrhiza in cocoa

Sample No.	Mycorrhizal association present/absent	Per cent infection
<i>Garden I</i>		
1	+	16
2	+	21
3	+	14
4	+	10
5	+	13
<i>Garden II</i>		
6	+	12
7	-	-
8	+	18
9	-	-
10	-	-

(+): Presence of mycorrhizal association.

(-): Absence of mycorrhizal association.

The intensity of mycorrhizal colonisation increased as a result of inoculation with *Glomus fasciculatum*, which was evident from the higher infection per cent and spore count recorded for inocu-

lated plants (Table 2). A decreasing trend in infection per cent and spore count was noticed when 100 mg P_2O_5 kg/soil (100 ppm) was applied. However, no such effect was noticed at 50 mg P_2O_5 kg/soil.

Mycorrhizal association, irrespective of phosphorus application, enhanced the plant top and root dry weight of cocoa seedlings (Table 3). Application of P along with *G. fasciculatum* inoculation further augmented the effect. Although the increase in plant top dry weight due to VAM fungus inoculation alone was

Table 2. Effect of inoculation with VAM fungus and phosphorus application on mycorrhizal infection in cocoa

Treatment	Infection per cent	Spore count per 50 ml soil
MoPo	13.53	73
MPo	46.1	148
MoP1	15.96	79
MP1	42.0	147
MoP2	12.3	71
MP2	35.73	121

Po—no P_2O_5 ; P1—50 mg P_2O_5 kg/soil; P2—100 mg P_2O_5 kg/soil;
Mo—No mycorrhizal inoculation; M—Mycorrhiza inoculated.

Table 3. Effect of inoculation with VAM fungus and phosphorus application on growth of cocoa

Treatment	Shoot dry wt. gm/pl.	Per cent increase over control	Root dry wt. gm/pl.	Per cent increase over control
MoPo	7.27 a	—	2.08 a	—
MPo	9.94 a b	36.72	2.88 b c	38.46
MoP1	7.96 a c	9.35	2.28 a b	9.61
MP1	12.20 b	67.81	3.28 c	57.69
MoP2	8.28 a c	13.89	2.30 a b	10.57
MP2	11.30 b c	55.43	2.93 b c	40.86
C.D. at 5%	3.43	—	0.69	—

Values not sharing a common letter differ significantly ($P=0.05$).

not significant over control, the difference that was recorded in root dry weight was significant. Surprisingly, no notable response was noticed on plant growth to the application of phosphorus alone. Inoculation of *G. fasciculatum* along with 50 ppm P_2O_5 recorded the maximum plant growth and root development. Interestingly, the response to *Glomus* + 100 ppm P_2O_5 treatment was inferior to *Glomus* + 50 ppm P_2O_5 .

Treatments did not affect the concentration of phosphorus in plant top significantly, but they do influence the root phosphorus concentration and total phosphorus content in plant top and root (Table 4). Inoculation with *G. fasciculatum*, regardless of phosphorus application increased phosphorus content in plant top and root. The highest phosphorus concentration (0.24 per cent) was in mycorrhizal plants supplied with 100 ppm of phosphorus. Total phosphorus uptake was always higher in *Glomus* inoculated plants.

Table 4. Effect of inoculation with VAM fungus and phosphorus application on P content of cocoa

Treatment	Shoot		Root	
	Per cent P	Total P (mg/pl)	Per cent P	Total P (mg/pl)
MoPo	0.178	12.94 a	0.165 a	3.43 a
MPo	0.194	19.28 a b	0.183 a b	5.27 b
MoP1	0.182	14.46 a	0.182 a	4.15 a b
MP1	0.207	25.25 b	0.209 c b	6.84 c
MoP2	0.185	15.31 a	0.220 c d	5.06 b
MP2	0.222	25.08 b	0.246 d	7.20 c
C.D. (P=0.05)	N.S.	7.05	0.027	1.4

N.S. = Not significant.

Values not sharing a common letter differ significantly (P=0.05).

DISCUSSION

Observations made on root samples collected from different gardens indicated that cocoa plants have vesicular-arbuscular mycorrhizal association. Intensity of fungal colonisation recorded in the root samples collected from the field (10 to 21 per cent) as

well as the *G. fasciculatum* inoculated plants (35 to 40 per cent) was comparatively low. Experiments conducted in the same soil with *Cajanus* has recorded more than 90 per cent root colonisation (Sivaprasad, 1983). This poor mycorrhizal colonisation observed in cocoa seedlings may be due to some factors associated with the host plant which might have restricted the fungal proliferation in the cortical region of the root.

Increased response of cocoa seedlings to VA-mycorrhizal fungus *Glomus fasciculatum* inoculation is evident from the observation made on dry weight of plant top and root. Such improved growth of seedlings due to VA-mycorrhizal association has been reported by earlier workers (Mosse, 1957; La-Rue et al., 1975; Menge et al., 1978 a and b). They have generally attributed this to improved phosphorus uptake conferred by mycorrhizal association. In the present study, the phosphorus application did not give the same effect as that of mycorrhizal inoculation. This may be due to the high fixation of applied P as Fe and Al phosphate as reported by Bowen, (1978) and hence, the nutrient was not available to the plant. However, in addition to phosphorus nutrition mycorrhiza is known to improve micronutrient uptake, photosynthetic efficiency and phytohormone production of the host plant (Mosse, 1957; Ross and Harper, 1970; Sivaprasad, 1983).

The level of response of seedlings to inoculation with *G. fasciculatum* was more when supplemented with 50 mg P_2O_5 kg/soil (50 ppm). Further, increase in P application (100 mg P_2O_5 kg/soil) did not show any stimulatory effect on plant growth. Moreover, at this level of P, there was a decreasing trend in the level of plant response and mycorrhizal colonisation. Some of the workers have pointed out that the level of P application and infection by mycorrhizal fungi are inversely related (Hayman, 1978; Asimi et al., 1980). In the present study also, an inhibitory trend was noticed on mycorrhizal infection at 100 mg P_2O_5 kg/soil. However, no such inhibition was noticed at 50 mg P_2O_5 kg/soil. This is probably because the soil P concentration was still below the critical concentration to inhibit mycorrhizal infection (Hayman and Mosse, 1971) even after addition of 50 ppm P_2O_5 , as the soil used in the study had low available P (7.7 mg/kg of soil). Hence, in phosphorus deficient soil, an addition of a small amount of phosphorus will increase the benefit of mycorrhizal

inoculation. While this study emphasises the need to inoculate cocoa with VA-mycorrhizal fungi for enhanced growth, it suggests the possibility of further improvements through intense colonisation of roots by effective isolates of VAM fungi.

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DISCUSSION

- Q : Since cocoa is grown as an intercrop in the homestead what is the practical utility of the study?
- Ans: Nursery level inoculation will be beneficial.
- Q : Optimum age for transplanting cocoa seedlings is 3-5 months. Why did you retain the seedlings up to 8 months in the pots?
- Ans: To study the effect of VAM on P nutrition of cocoa over a reasonably long period.
- Q : Did you identify the fungus?
- Ans: Yes, the fungus is *Glomus fasciculatum*.
- Q : Have you identified native VAM?
- Ans: No, an attempt has been made.
- Q : What was the pH of the medium?
- Ans: pH was 5.5.
- Q : Is pH an important factor in the VAM growth and its efficiency?
- Ans: Yes. It reflects the overall response to VAM inoculation.
- Q : In view of P \times Zn interaction can you obtain higher yields

by application of Zn?

Ans: VAM is known to enhance the Zn uptake of host plants.

Q : At what level of soil av. P inoculation with mycorrhiza will enhance the av. P in soil?

Ans: A minimum of 6 ppm of av. P is required for effective mycorrhizal symbiosis. But at very high levels of P, colonisation gets inhibited.

STUDIES ON THE OCCURRENCE OF NITROGEN-FIXING BACTERIA, *AZOSPIRILLUM* IN THE ROOT ENVIRON- MENTS OF COCOA

M. GOVINDAN and R. VIKRAMAN NAIR

ABSTRACT

An attempt has been made to study the occurrence and importance of the nitrogen-fixing bacterium, *Azospirillum* in an important cash crop, cocoa (*Theobroma cacao*). *Azospirillum* in fairly high population was observed in all the samples of rhizosphere and rhizoplane. Attempts to identify the species revealed that *A. lipoferum* rather than *A. brasilense* was predominant in the root environments of cocoa. Their nitrogen-fixing ability varied considerably. More than 35.6 per cent of them was found to fix more than 15 mg nitrogen per g malate *in vitro*. Pot experiments were conducted to study the response of selected cultures of *Azospirillum* on cocoa. The results revealed that inoculation with a broth culture of *Azospirillum* increased the number of leaves, root biomass, shoot biomass, root length and shoot length in cocoa seedlings.

INTRODUCTION

The advancing crop production technology, development of high fertiliser responsive crop varieties, and pressure for intensive farming demand huge inputs, of which nitrogenous fertilisers take a major share. Convincing evidences have pointed out that biofertilisers (a relatively simple and low cost technology, easy to execute and using largely renewable sources of energy) have

a decisive role to play in the developing and underdeveloped countries. Apart from the direct role in nitrogen fixation, most of the diazotrophs produce phytohormones whose role in crop production need not be over emphasised.

Cocoa requires a large quantity of nitrogenous fertilisers for heavy yields. *Azospirillum* has been recognised as a potential N_2 fixer in many economically important crops and grasses (Van Berkum and Bohlool, 1980). The association of *Azospirillum* in the roots of plantation crops, in general and cocoa in particular has not been investigated so far. This paper attempts to bring to light the occurrence and importance of *Azospirillum* in cocoa.

MATERIALS AND METHODS

Root samples were collected from three to four year old cocoa plants growing in the Cannanore, Trichur and Kottayam districts of Kerala. The soils are of the laterite type having pH 6.01, 5.65 and 5.40 respectively. The rhizosphere soil and the rhizoplane were separately obtained. Following the serial dilution technique, the population of total heterotrophic bacteria, total diazotrophs and *Azospirillum* population present in the samples were enumerated. The Most Probable Number (MPN) technique was used for the enumeration of *Azospirillum* (Okon et al., 1977; Hegazi et al., 1979). The tubes containing semi-solid malate medium (Baldani and Dobereiner, 1980) was employed.

Total diazotrophs were estimated following the procedures of Watanabe and Barraquio (1971). A quantity of 0.5 per cent malic acid was also added in this medium. Nutrient glucose agar medium was used for enumerating the total heterotrophic bacteria. The pH of the soil was determined following the standard procedures. The isolates of *Azospirillum* obtained in this study were purified by streaking over potato malic acid medium (Baldani and Dobereiner, 1980). Following the key for the identification of *Azospirillum* (Tarrand et al., 1978) the isolates were grouped. The nitrogen-fixing capacity of the isolates was determined by growing the isolates in 100 ml of semisolid malate medium for five days and determining the total nitrogen by Microkjeldahl method (Humphries, 1956).

In order to find out the response of cocoa to *Azospirillum*

inoculation, a pot study was undertaken using sterilised soil and sand (1 : 1 v/v) mixture. Cocoa seeds (after surface sterilisation) were inoculated with three days old broth cultures of *Azospirillum* and growth parameters were observed after 60 days of growth.

RESULTS AND DISCUSSION

Grass rhizosphere has been suggested as an ideal habitat for heterotrophic N₂ fixing bacteria (Van Barkum and Bohlool, 1980). Apart from Graminae the occurrence of *Azospirillum* has been reported from a variety of diversified plant species (Lakshmikumari et al., 1976). In this study we are reporting the occurrence of *Azospirillum* in the root environments of cocoa. The study revealed that there occurs in the rhizoplane and rhizosphere soils of cocoa a fairly large number of *Azospirillum* (Table 1). Their abundance varied from 0.034-0.07 per cent of total heterotrophic bacteria in the rhizosphere and from 0.156 to 0.387 per cent in the rhizoplane. It is of interest to note the occurrence of *Azospirillum* in a wide range pH of the soils. However, their population was found to decrease as the pH decreases. Further, their population was 11.02 times more in the rhizoplane than in the rhizosphere.

Table 1. Population of total bacteria, total nitrogen fixers and *Azospirillum* in the rhizoplane* and rhizosphere** of cocoa

Source	Total bacteria	Total nitrogen fixers	<i>Azospirillum</i>	Per cent of <i>Azospirillum</i> to total bacteria
A. Rhizosphere				
Cannanore	137.30	33.21	0.07	0.05
Trichur	120.21	28.71	0.09	0.07
Kottayam	105.21	24.12	0.04	0.03
B. Rhizoplane				
Cannanore	341.28	98.67	0.76	0.22
Trichur	238.20	69.52	0.92	0.39
Kottayam	308.10	85.28	0.48	0.16

*Population $\times 10^6$ /g of root on dry weight basis.

**Population $\times 10^6$ /g of soil on dry weight basis.

Forty-five isolates of *Azospirillum* were obtained and based on the morphological and biochemical characteristics, they were tentatively identified. Eighty per cent of the isolates belonged to *A. lipoferum* and only 20 per cent were found to be *A. brasilense*. Moreover, 64.44 per cent of the isolates were found to be nir^- . It indicates that *A. lipoferum* has preferential encouragement in the root environments of cocoa. This observation coupled with the information that rhizoplane harbours higher population stresses the need to re-examine whether rudimentary host plant symbiosis exists (Van Berkum et al., 1983).

The nitrogen-fixing efficiency of the isolates under *in vitro* conditions revealed that 35.6 per cent of the isolates fixed 15 mg N per g malate and 51.1 per cent of the isolates fixed 11-15 mg N per g malate and only 13.3 per cent of the isolates fixed nitrogen below 10 mg (Table 2). It clearly indicates the possibility of selecting superior strains of *Azospirillum* and then increasing the

Table 2. Nitrogen fixing efficiency of the isolates of *Azospirillum*

Category of isolates fixing nitrogen*	Per cent of <i>Azospirillum</i> isolates
0-10	13.3
11-15	51.3
More 15	35.6

* mg Nitrogen fixed per g malate.

colonisation of superior strains in the root environments by inoculation. With this objective a pot culture study was conducted and the effect of inoculation with *Azospirillum* on various growth parameters are presented. Fourteen promising isolates of *Azospirillum* were inoculated, and the maximum growth parameter obtained by inoculation was compared with the uninoculated control (Table 3). The results indicate that inoculation can increase the number of leaves, root biomass, root length, shoot biomass and shoot length over uninoculated control. Several workers have found positive plant growth responses in cereals after inoculation with 'associative' nitrogen-fixing bacteria (Dhanapal et al., 1978; Subba Rao, 1979). The production of plant growth

Table 3. Response of *Azospirillum* inoculation in *Theobroma cacao var. Foresteri**

Plant characteristics	(-) <i>Azospirillum</i>	(+) <i>Azospirillum</i>	% increase
1. Number of leaves	4.66	8.00	71.70
2. Root length (cm)	14.60	23.70	62.30
3. Root biomass (g)	0.12	0.26	117.60
4. Shoot length (cm)	27.50	35.60	29.40
5. Shoot biomass (g)	0.47	1.22	158.3

60-day-old plants in pots (Mean of three observations).

promoting substances (Tien et al., 1979) might have induced proliferation of root growth providing maximum surface area for the absorption of nutrients. This when coupled with the fixation of nitrogen *in vivo* might have resulted in the increased performance of the *Azospirillum* over uninoculated control.

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DISCUSSION

Q : Microbial fixation is only around 30 kg N per ha. Can this replace application of nitrogenous fertilisers?

Ans: This can at least meet a portion of nitrogen requirement.

Q : In Kayamkulam region, both Beijerinckia and Azotobacter are present. Could you isolate them?

Ans: We have restricted our study to *Azospirillum*.

POPULATION DYNAMICS OF MICRO-ORGANISMS ASSOCIATED WITH COCOA BEAN FERMENTATION

M. GOVINDAN, R.K. SASTRY and R. VIKRĀMAN NAIR

ABSTRACT

Population pattern of various micro-organisms involved in cocoa bean fermentation was studied. During the initial stages of fermentation, the yeast flora predominated reaching a peak population at the thirty-third hour. Populations of acetic and lactic acid bacteria reached their peaks at the fifty-seventh and eighty-first hour, respectively. A high percentage of yeast was found to utilise ethanol as the sole carbon source. They reached maximum population at the eighty-first hour. Their role in fermentation needs further study.

INTRODUCTION

Fermentation of cocoa beans depends entirely on the activities of the multitude of micro-organisms present. The quality and flavour of the finished chocolate depend upon the fermentation process and the acidity produced. There are indications that auxillary flavours arise due to waste metabolites of the micro-organisms growing in the pulp. Shepherd (1976) indicated that since the cotyledon acidity builds up during fermentation, investigations should be made on the fermentation phase and among the various factors requiring priorities, population dynamic studies and identification of yeasts and bacteria deserve much importance. This study was undertaken to estimate the population

build up of various micro-organisms during different stages of fermentation of cocoa beans fermented using the mini-basket method (Kumaran et al., 1980).

MATERIALS AND METHODS

Ripe pods of 'Forastero' cocoa were obtained and after breaking them, fresh beans were fermented in mini baskets made of bamboo matting closely woven and having a diameter of 20 cm and height of 25 cm. Samples of beans were drawn at regular intervals and population of different micro-organisms was determined. Bean samples of 15 to 20 g were taken and pulverised with a known quantity of sterile water in a waring blender. From this stock solution, serial dilutions were prepared and used for enumeration of the micro-organisms, namely yeast, acid-tolerant yeast, total bacteria and lactic acid bacteria using glucose yeast extract media (pH 6.8) malt extract—peptone agar (pH 5.5), nutrient agar and APT agar with 0.04 per cent sodium azide, respectively. Frateur's modified Hoyer's medium (Greenshields, 1978) was used for enumeration of acetic acid bacteria. The same medium after adding 500 ppm streptomycin sulphate was used to determine the population of ethanol-utilising yeasts.

RESULTS AND DISCUSSION

Quantitative estimates of various types of yeasts associated with the fermentation of cocoa at different stages are given in Table 1. The population is expressed as counts of colony forming units per g of beans. As the data show population of yeasts steadily increased up to 33 hours and later decreased gradually. During the initial stages, the presence of high sugar content might have induced increase in yeast population and activity. Depletion of substrates during fermentation may be considered responsible for the decrease in population of yeast after 50 hours of fermentation. The acid tolerant yeasts also showed the same pattern in their population.

Studies on acetic acid bacteria revealed that the bacterial population was initially low and increased rapidly reaching a peak at the fifty-seventh hour (Table 2). Quesnel (1969) reported that the high acidity and low oxygen content of the pulp favour the

Table 1. Population level of yeasts at various stages of fermentation of cocoa*

Time after setting (hours)	Yeast ($\times 10^6$)	Acidophilic Yeast ($\times 10^6$)	Ethanol utilising Yeast ($\times 10^6$)
0	3.986	3.62	ND
9	38.50	43.60	ND
21	62.20	59.50	4.34
33	98.70	88.20	6.67
45	40.84	40.95	8.56
48	36.50	26.22	10.47
57	22.26	23.10	12.58
69	20.15	21.75	15.21
81	20.21	18.32	17.28
93	17.61	14.21	12.81
105	15.15	17.26	7.53
117	14.90	16.23	6.23
129	12.91	15.83	3.41
141	10.35	14.82	1.20

*Population expressed as counts per g sample.

ND = Not determined.

Table 2. Changes in population level of bacteria during fermentation of cocoa*

Time after setting (hours)	Acetic acid bacteria (10^6)	Lactic acid bacteria (10^6)	Total bacteria grown in nutrient Agar (10^7)
0	1.531	1.41	1.445
9	4.93	2.31	4.36
21	33.30	15.01	30.52
33	53.10	22.42	40.13
45	98.32	30.71	15.41
48	107.77	97.61	18.45
57	120.30	110.50	11.98
69	103.40	140.20	10.01
81	92.40	148.31	8.92
93	67.04	124.68	7.51
105	71.02	108.22	9.22
117	53.28	75.52	10.15
129	40.45	24.32	9.18
141	21.87	16.87	11.26

*Population expressed in numbers per g sample.

development of yeasts only in the early stages of fermentation and that they grow rapidly increasing in number converting sugars to ethanol and degrade the pulp. The fermented pulp drains off as 'sweatings' and air becomes accessible to the mass. The aerobic acetic acid bacteria under such situation might change ethanol to acetic acid, carbondioxide and water. In this study also, the initial lower counts of acetic acid bacteria rose to a peak at the 57th hour of fermentation, by which time enough ethanol has been presumably converted from sugar by the yeasts. Exhaustion of these substrates may be the cause for decrease in the population.

A preliminary study on the occurrence of ethanol utilising yeasts revealed that they also occur in sizable number (Table 1). Their population increased reaching a peak at the eighty-first hour and then declined. When CaCO_3 was incorporated into the medium, they were able to cause a dissolution and clearing of the insoluble CaCO_3 (Fig. 1). It indicates that their metabolic by-product is acidic in nature. Under natural fermentation, their role needs to be determined. They might play a role in convert-

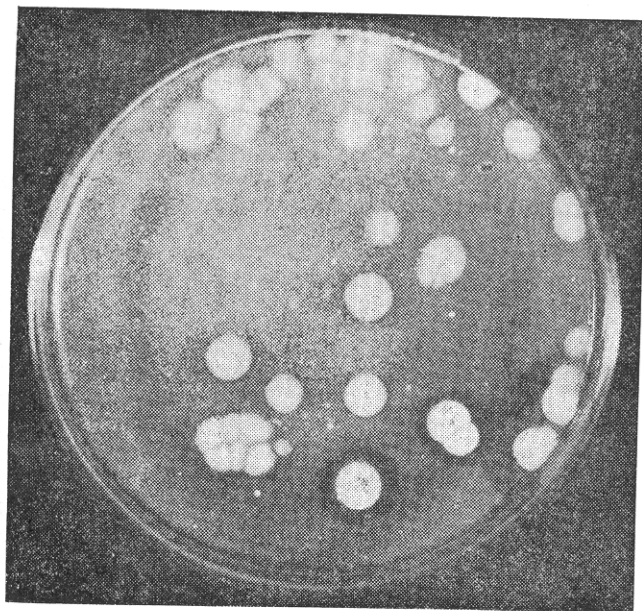


Fig. 1.

ing ethanol and thus decreasing the substrate available for acetic acid bacteria. Such an occurrence of ethanol-utilising and acid-producing yeast has not been reported earlier.

The population of lactic acid bacteria was also enumerated (Table 2). Their initial population was low and then increased reaching a peak at the eighty-first hour. Occurrence of aerobic conditions beyond this period is attributable to the noted decrease in population abundance of these anaerobic bacteria. The presence of lactic acid bacteria in substantial numbers and their persistence up to the end of the fermentation period though at reduced abundance at the latter phase are indicative of substantial production of lactic acid in the fermenting mass. Carr and Dougan (1977) on the basis of qualitative and quantitative analysis of volatile and non-volatile low-molecular weight acids have indicated that acetic and lactic acids are primarily responsible for the excessive acidity of Malaysian beans.

Observations on heterostrophic bacteria developed on nutrient agar showed high populations of various types of bacterial colonies. Fungal organisms like *Aspergillus* sp., *Penicillium* sp. and *Rhizopus* sp. were also detected as superficial mycelial growth on the fermenting mass. The role of such varied populations of fungi and bacteria in the fermentation of cocoa needs further detailed study.

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MICROBIAL POPULATION, ENZYME ACTIVITY AND VA MYCORRHIZA IN THE ROOT REGION OF COCONUT IN RELATION TO *IN SITU* GREEN MANURING

GEORGE V. THOMAS

ABSTRACT

In situ cultivation and incorporation of green manure legumes in coconut basins improved the microbial activity in the root region of coconut in a slightly acidic laterite soil. Populations of bacteria, fungi, actinomycetes, asymbiotic nitrogen fixing and phosphate solubilising bacteria were significantly increased during the maximum vegetative phase and at 30 days of incorporation of green manures. However, such a proliferation in microflora was not observed at 60 days of incorporation. Dehydrogenase activity also exhibited a similar trend, whereas the activity of urease enzyme did not increase to any significant level. The number of endomycorrhizal chlamydospores in the root region soil and the intensity of mycorrhizal infection in roots of coconut were high in green manured basins. In general, *Pueraria phaseoloides* had a better beneficial influence on microbial characteristics of coconut root region as compared to *Mimosa invisa* and *Calopogonium mucunoides*.

INTRODUCTION

The coconut palm (*Cocos nucifera* L.) is cultivated in tropical soils characterised by low organic matter content due to the fast rate of degradation of organic materials caused by heavy rainfall, optimum temperature and porous soil texture. Application of organic manures is, therefore, very vital for the maintenance

of soil fertility and productivity of coconut. Organic manuring is seldom practiced by coconut growers mainly due to the non-availability and high cost of farm yard manure. A lot of emphasis is also given for the development of suitable management practices to maintain the productivity of root (wilt) affected coconut palms due to the debilitating nature of the disease. *In situ* cultivation and subsequent incorporation of green manure legumes in coconut basins was found to be a simple and inexpensive agricultural practice to supply organic matter to coconut palms (Thomas and Shantaram, 1984). The major objective of the present study was to elucidate the changes in microbial activity in the root region of coconut during the vegetative growth and subsequent to the incorporation of green manures in the coconut basins.

MATERIALS AND METHODS

An experiment to study the performance of green manure legumes in coconut basins and the influence of green manuring on root (wilt) disease of coconut is in progress since 1982 in a cultivator's garden at Vallikunnam (Alleppey District, Kerala). The soil in the plot is laterite with a slightly acidic pH of 5.8. The garden comprises 25 to 30-year-old bearing coconut palms of the WCT cultivar. Green manure legumes were sown in the basins within the radius of 1.8 m from the bole of the palm in two concentric circles in the month of June. They were harvested and incorporated in the respective basins after five months growth. For microbial and enzymatic analyses, soil samples were collected from basins of coconut palms under the treatments of the three promising green manure crops namely, *Pueraria phascoloides*, *Mimosa invisa* and *Calopogonium mucunoides* and also from the control palms.

The selected basins received on an average 30 kg of green matter per basin. The soil samples were drawn at 0 to 30 cm depth within the basin one m away from the bole of the palm during the vegetative growth of the green manure legumes, after 30 and 60 days of their incorporation to soil. Three replications were maintained for each treatment. The microbial populations were determined following the dilution plating technique (Allen, 1957) using soil extract agar, Martins rose bengal agar, 'Kenk-

nights' agar, Waksman medium 77, Sperber's agar and acidified Sperber's agar with streptomycin and rose bengal for enumerating bacteria, fungi, actinomycetes, asymbiotic N₂ fixing bacteria, P-solubilising bacteria and P-solubilising fungi, respectively. Population estimates are based on the colony forming units derived from viable microbial propagules.

Dehydrogenase activity was assayed by the triphenyl tetrazolium chloride reduction procedure (Casida et al., 1964); urease activity was determined by the procedure of Pancholy and Rice (1973) except that the ammonia evolved due to urea hydrolysis was estimated by nesslerisation. In order to assess the mycorrhizal status of coconut palms, soil and root samples were collected 30 days after incorporation of the green manures. The percentage of mycorrhizal infection in roots was determined by clearing root segments in KOH and staining with trypan blue (Phillips and Hayman, 1970). Mycorrhizal spores in the soil were estimated by wet-sieving and decantation technique (Gerdeman and Nicolson, 1963).

RESULTS

The results revealed that there was a high level of zymogenic response by micro-organisms in the root region of coconut when green manure legumes were cultivated and incorporated in coconut basins (Fig. 1). Populations of major groups of aerobic heterostrophic micro-organisms in soil namely bacteria, fungi and actinomycetes and beneficial microbes like asymbiotic nitrogen fixers and phosphate solubilising bacteria were significantly increased as compared to those in control. The enhancement in the population of phosphate solubilising fungi was, however, not significant. The favourable influence on microbial population was highly significant during the maximum vegetative growth and at 30 days of incorporation of green manure legumes, but not at 60 days of incorporation. Fungi proliferated far more than the other microbial groups. Maximum influence on microbial population was recorded in *Pueraria* treated basins, where the populations showed two to three, five to six and two to three-fold increase for bacteria, fungi and actinomycetes, respectively. The dehydrogenase enzyme activity in the rhizosphere soil of coconut also increased as an effect of cultivation and

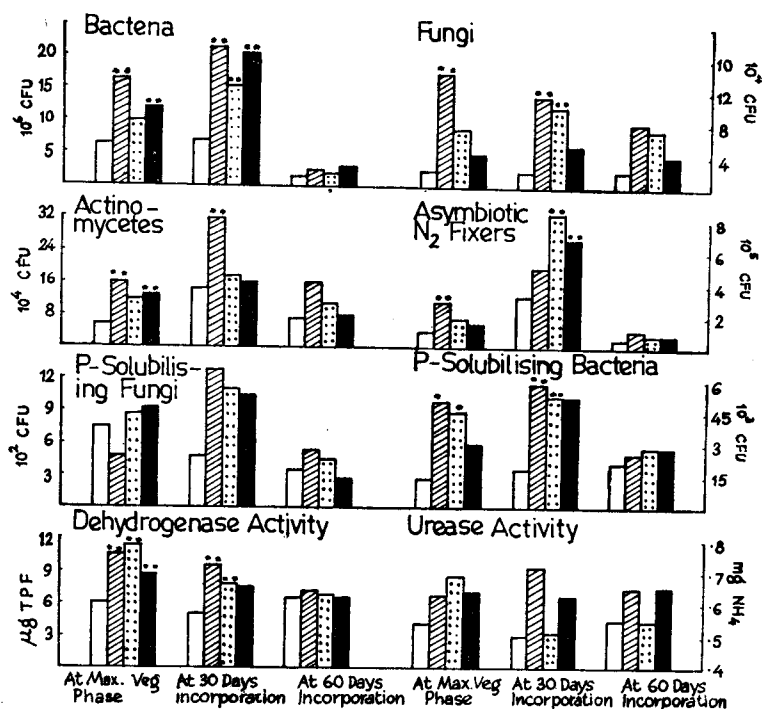


Fig. 1. Periodic microbial/enzymic activity.

incorporation of the green manure legumes. As in the case of microbial population, the increase in dehydrogenase activity was also negligible at 60 days of incorporation. Neither the cultivation nor incorporation of green manure legumes had any significant effect on the soil urease activity.

Table 1. Vesicular-arbuscular mycorrhizae of coconut as influenced by green manuring in basins

Sl. No.	Treatment	Spore count per 50 ml soil	Per cent infection in roots
1.	Control	240	62.7
2.	<i>P. phaseoloides</i>	362	79.4
3.	<i>C. mucunoides</i>	401	73.6
4.	<i>M. invisa</i>	271	69.7
	LSD at P = 0.01	76	—

It is evident from Table I that the green manuring increased both the intensity of mycorrhizal infection in coconut roots and the number of extramatrical chlamydo spores in the basin soil. The basins cropped with *Calopogonium* recorded the highest number of spores, whereas root infection was the highest in coconut palms under the treatment of *Pueraria*. The influence on vesicular-arbuscular mycorrhizae was comparatively less in *Mimosa* treatment.

DISCUSSION

The flush in microbial population in the root region of the coconut palm observed during the maximum vegetative growth of green manure legumes, can be attributed to the accumulation of root exudates, sloughed off root tissues and shed leaves of legumes in the region where the roots of the two crops are in close proximity. It is also quite possible that microflora increased as a result of enhanced root exudation from coconut when the green manure legumes were raised in basins. The influence of one crop on the rhizosphere microflora of a neighbouring crop is well known in a mixed cropping system (Shantaram and Rangaswami, 1967; Nair and Subba Rao, 1977). Potty and Jayasanker (1983) observed a favourable alteration in the rhizosphere microflora of coconut when the fodder grass, hybrid napier was grown as an intercrop in a coconut garden. The impact on the root region microflora of coconut was highly significant in the present study since the green manure crops were raised right in the coconut basins.

The proliferation of different groups of micro-organisms at 30 days of incorporation of green manures is indicative of active decomposition of the green matter applied. Plant residues serve both as a carbon and energy source for the multiplication of heterotrophic soil micro-organisms. Such high spurts in soil microflora due to the application of green manures has already been reported (Loshakov et al., 1981). An increase in microbial activity was earlier recorded in sandy soil after a week of incorporation of green manures (Thomas and Shantaram, 1984). The present study further revealed that the decomposition of most of the plant residues were over at 60 days of incorporation. The zymogenic organisms multiplied rapidly in response to

the input of fresh substrates, but they died out after a short period since their high energy requirements were not met with subsequently.

The high level of dehydrogenase activity observed in green manured basins could be the contributions of living legume roots and the activities of proliferating micro-organisms. The soil enzymatic activities could be considered as better indicators of soil biochemical activities (Burns, 1978). The increase in urease activity was not significant at all the three stages of analysis. Zantua et al. (1977) observed that increase in urease activity after the addition of organic materials was temporary and could not be detected after a few days presumably due to the inactivation of the newly formed enzyme.

The present study has also demonstrated that green manure legumes were effective in augmenting the endomycorrhizal symbiosis of vesicular-arbuscular type in coconut. Ocampo et al. (1980) found that non-mycorrhizal plants developed slight infection when mycorrhizal host plants were grown with them. Kormanik et al. (1981) observed that the cover crops like corn, millet and *sorghum* increased endomycorrhizal fungus inoculum in forest nursery soils. Vesicular-arbuscular mycorrhizae are known to improve plant growth by increasing the uptake of phosphorus and other nutrient elements. In the farming systems with perennial tree crops where mycorrhizal inoculation has limitations, the cultivation of green manure legumes can be adopted as a management practice to enhance the endomycorrhizal fungus inoculum.

Significant improvement in the microbial population, biological activity and VA mycorrhizal occurrence in the root region suggest a modification in the soil environment to the benefit of plant growth. The cultivation and incorporation of green manure legumes in coconut basins can, therefore, be considered a simple and less expensive input to build up the soil fertility under the tropical climatic conditions.

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DISCUSSION

Q : Have you studied the effect of groundnut in coconut gardens?

Ans: Groundnut is not considered as a green manure crop.

MICROBIAL SOLUBILISATION OF INSOLUBLE PHOSPHATES

JACOB MATHEW, KOCHUTHRESIAMMA JOSEPH
and R. KOTHANDARAMAN

ABSTRACT

Phosphate solubilising micro-organisms from rubber growing soils of 10 different regions were enumerated and compared with the total bacterial population. The phosphate solubilising bacteria in rubber growing soils ranges from 1 to 2.8 per cent. The population of phosphate solubilising fungi and actinomycetes are very small in rubber growing soils which are acidic in nature. The solubilisation of rock phosphate, aluminium phosphate and ferric phosphate by the soil micro-organisms as well as the effect of various carbon and nitrogen sources on the solubilisation of rock phosphate were studied. The results showed that rock phosphate is solubilised by all groups of micro-organisms. The fungi acted on rock phosphate more effectively in the presence of simple sugars and different nitrogen sources. The possibility of using *Asperigillus* spp. for phosphate solubilisation in rubber growing soils is discussed.

INTRODUCTION

Insoluble soil phosphates are rendered available either by plant roots or by soil micro-organisms through secretion of organic acids (Banik and Dey, 1983). Acid soils, in which rubber is grown, are poor in calcium and therefore phosphates are precipitated in the form of ferric or aluminium compounds which are not so easily amenable to solubilisation by plant roots or soil micro-

organisms (Subba Rao, 1977). Rock phosphate, an insoluble form of phosphate is recommended for rubber plants as a source of phosphorus (Pushpadas and Ahammed, 1980). Therefore, phosphate solubilisation is a very important aspect in the nutrition of rubber plants.

Soil bacteria, fungi and actinomycetes were reported to solubilise phosphate (Ortuno et al., 1979; Rao et al., 1982) and they differ to the extent of solubilisation (Arora and Gaur, 1979). All these phosphate solubilisers were found to be more in the rhizosphere of higher plants and solubilise native as well as applied insoluble phosphates. Besides, phosphate solubilisation, the microorganisms produce vitamins and phytohormones (Baya et al., 1981) which favour the growth of plants. Hence, soil samples from a few rubber growing areas were tested for the presence of phosphate solubilising micro-organisms and the effect of different carbon and nitrogen sources on the phosphate solubilisation by micro-organisms in broth culture were studied.

MATERIALS AND METHODS

Soil samples (0 to 5 cm) were collected from ten rubber growing areas and the microbial population were estimated by plate count method of Timonin (1940) using soil extract agar for total bacterial population and special soil extract apatite agar medium (Speeber, 1958) for phosphate solubilising micro-organisms. The population of micro-organisms in soil were expressed on oven dry soil weight basis. The pH of the soil was estimated.

Solubilisation of different phosphates

Two isolates each of bacteria and fungi and one actinomycete isolate showing more phosphate solubilising capacity were selected and studied for their ability to solubilise rock phosphate, aluminium phosphate and ferric phosphate. Two hundred and fifty mg of sterilised phosphates were added to 50 ml of sterile Pikovskaya's liquid medium. The flasks were inoculated with the test cultures and incubated for 10 days (Subba Rao, 1977). After incubation the cultures were filtered through a bacteriological filter and the cell free filterates were analysed for phosphate content following the colorimetric method (Jackson, 1962).

The effect of carbon and nitrogen sources on the solubilisation of insoluble phosphates

Glucose, fructose, xylose and mannitol equivalent to 500 mg of glucose were added to 50 ml of Pikovskaya's broth medium, so as to maintain the carbon content in the sugars at the same level. Ammonium sulphate, sodium nitrate and urea equivalent to five mg of nitrogen were added and tested for their effect on solubilisation of rock phosphate as described earlier.

RESULTS AND DISCUSSION

The results of the enumeration of total bacteria in rubber growing soils show that bacterial population is maximum in soils having pH around 5.5 (Table 1). Gray and Williams (1975) also

Table 1. Population of total bacteria and phosphate solubilising bacteria in soils of varying pH

Sl. No.	Location	pH	Bacterial population $\times 10^8$	
			Total bacteria	Phosphate solubilising bacteria
1.	Chethackal	5.2	1128.1	19.9 (1.8)
2.	Chithalvetty	5.5	1610.4	22.9 (1.4)
3.	Kaliar	5.3	982.0	23.8 (2.4)
4.	Karikatoor	5.8	452.3	12.6 (2.8)
5.	Kinalur	6.4	518.6	12.3 (2.3)
6.	Lahai	5.3	356.5	5.4 (1.5)
7.	Mundakayam	6.1	868.4	8.5 (1.0)
8.	Nagercoil	5.5	1186.1	23.3 (2.0)
9.	Thirumbadi	6.2	710.3	8.5 (1.2)
10.	Vellanikkara	6.4	413.6	6.7 (1.6)

Figures in parentheses indicate the percentage of phosphate solubilising bacteria.

reported that optimum pH level for bacteria is five. The phosphate solubilising bacteria in rubber growing soils vary from 1 to 2.8 per cent. The differences of the pH of the soil did not cause marked variation in the population of phosphate solubilising bacteria. Besides bacteria a few fungi and actinomycetes were also observed to solubilise phosphates. The results reveal that soil bacteria are major phosphate solubilisers in rubber growing acid soils. Subba Rao (1977) also reported that phosphate solubilising bacteria were more in cultivated soils.

Solubilisation of insoluble phosphates by soil micro-organisms

Table 2 shows that *Aspergillus niger* solubilised more rock phosphate when compared to other isolates of fungi, bacteria and actinomycetes. Soil micro-organism differ widely in the solubilisation of insoluble phosphates. The fungi are found to solubilise more rock phosphate and this may be due to the production of more organic acids by these micro-organisms (Banik and Dey, 1983). Among bacteria, *Bacillus* sp. II solubilised more rock phosphate than *Bacillus* sp. I. *Streptomyces* sp., was also found to be a good phosphate solubiliser as seen from the Table 2.

Table 2. Solubilisation of insoluble phosphates by micro-organisms ($\mu\text{g P}_2\text{O}_5/\text{ml}$ of culture filtrate)

Micro-organism tested	Phosphates tested		
	Rock phosphate	Aluminium phosphate	Ferric phosphate
<i>Aspergillus niger</i> Van Tieghum	21.0	19.5	4.0
<i>Aspergillus flavus</i> Link	19.0	7.0	—
<i>Bacillus</i> sp. I	4.0	4.8	4.5
<i>Bacillus</i> sp. II	19.0	—	4.0
<i>Streptomyces</i> sp.	17.0	—	1.4

Micro-organisms solubilise more rock phosphate than other types of insoluble phosphates. Similar results were reported by Banik and Dey (1983). Acid soils are not rich in *Aspergillus* population as evident in the present investigation. Hence inocula-

tion of *A. niger* in rock phosphate before its application to the soil may augment the phosphate uptake by the plants.

Among different cultures of micro-organisms tested, *A. niger* is found to solubilise more aluminium phosphate followed by *A. flavus*. *Bacillus* sp. I. A poor rock phosphate solubiliser also solubilised aluminium phosphate while *Bacillus* sp. II which was found to be a good rock phosphate solubiliser failed to solubilise aluminium phosphate. Therefore, it is clear that micro-organisms differ very much in their capacity to solubilise different forms of insoluble phosphates. All the micro-organisms except *A. flavus* had a little action on ferric phosphate. The solubilisation of ferric phosphate by *A. niger* may be due to acid production, while the solubilisation of ferric phosphate by the bacteria, which produce less acid, may be due to the production of hydrogen sulphide (Bromfield, 1953). The results show that *A. niger* is capable of solubilising more quantity of insoluble rock phosphate and bound aluminium and ferric phosphates compared to other micro-organisms.

Effect of carbon sources on the solubilisation of rock phosphate by micro-organisms

The results of the study on the effect of different carbon sources in solubilising rock phosphate reveal, that *A. niger* is capable of solubilising more phosphate when fructose is added in the medium (Table 3). Fructose was found to be a good carbon source for the phosphate solubilisation by micro-organisms, except

Table 3. Effect of different sugars on the solubilisation of rock phosphate ($\mu\text{g P}_2\text{O}_5/\text{ml}$ of culture filtrate)

Micro-organism tested	Carbon source			
	Glucose	Fructose	Mannitol	Xylose
<i>Aspergillus niger</i> Van Tieghum	21.0	34.7	24.7	2.0
<i>Aspergillus flavus</i> Link	19.0	17.7	6.2	7.5
<i>Bacillus</i> sp. I	4.0	17.7	14.0	2.0
<i>Bacillus</i> sp. II	19.0	5.4	20.0	—
<i>Streptomyces</i> sp.	17.0	22.7	2.2	26.0

Bacillus sp. II, which gave good results when glucose or mannitol was present in the medium. Mannitol was also found to favour micro-organisms in solubilising phosphates, while xylose was a poor carbon source. However, *Streptomyces* sp. solubilised more rock phosphate when xylose was used as carbon source. From the results, it is evident that simple sugars like glucose and fructose favour the micro-organisms for the effective solubilisation of rock phosphate. This may be due to more acid production with these sugars (Banik and Dey, 1983). It is also interesting to note that *A. niger* and *Bacillus* sp. I and II solubilise more rock phosphate in the presence of mannitol, which indicates sugar alcohol is also preferred by soil micro-organisms in solubilising insoluble rock phosphate.

Effect of nitrogen sources on the solubilisation of rock phosphate

Aspergillus niger and *A. flavus* solubilised comparatively more rock phosphate in all the nitrogen sources tested (Table 4). Maximum solubilisation was recorded in *A. niger* inoculated medium containing sodium nitrate. *Streptomyces* sp. solubilised more rock phosphate in the presence of ammonium sulphate followed by sodium nitrate.

Table 4. Effect of nitrogen sources on the solubilisation of rock phosphate ($\mu\text{g P}_2\text{O}_5/\text{ml}$ of culture filtrate)

Micro-organism tested	Nitrogen source		
	Ammonium sulphate	Sodium nitrate	Urea
<i>Aspergillus niger</i>			
Van Tieghum	21.0	31.2	29.5
<i>Aspergillus flavus</i> Link	19.0	26.2	22.5
<i>Bacillus</i> sp. I	4.0	11.7	4.7
<i>Bacillus</i> sp. II	19.0	17.2	9.5
<i>Streptomyces</i> sp.	17.0	6.2	—

This result shows that soil fungi like *A. niger* and *A. flavus* are capable of solubilising rock phosphate and bound phosphate like aluminium and ferric phosphates utilising simple sugars and various nitrogen sources. As the population of phosphate solubi-

lising fungi in acid soils is less, it is possible to augment the phosphate solubilisation by soil inoculation using phosphate solubilising fungi.

ACKNOWLEDGEMENT

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DISCUSSION

Q : Have you done any work on the solubilisation of rock phosphate by mycorrhiza?

Ans: The present study does not include this aspect. A separate study on mycorrhiza is in progress.

STUDIES ON GROWTH, NODULATION AND NITROGEN FIXATION BY *MUCUNA* *BRACTEATA* D.C.

R. KOTHANDARAMAN, D. PREMAKUMARI
and P.K. SIVASANKARA PANICKAR

ABSTRACT

Mucuna bracteata, a wild leguminous creeper, was collected from the forest area of Tripura State and studied its suitability for using as a cover crop in rubber plantations of Kerala State. It grows very fast, smothering noxious weeds like *Eupatorium* sp. and *Lantena* sp. and fixes atmospheric nitrogen. It also tolerates drought and shaded conditions and is mostly free from pests, diseases and cattle menace. The plants do not get fruit in the plains of Kerala and hence propagation is possible mainly by stem cuttings. The merits of *M. bracteata* as a cover crop in rubber plantations are discussed.

INTRODUCTION

Management of ground covers is an important aspect of rubber cultivation in a tropical country like India where rainfall and temperature are high. Ground covers are essential for the preservation of fertility and soil conservation (Murray, 1931; Watson, 1961). They also reduce the immaturity period of rubber and eliminate the need for nitrogenous fertiliser application during the initial period of tapping (Anonymous, 1977). In India, *Pueraria phaseoloides* is widely cultivated as cover crop for rubber. The other cover crops like *Calopogonium mucunoides*, *Centro-*

sema pubescens and *Mimosa invisa var inermis* are also grown in small scale in some localities (Potty et al., 1980). An ideal cover crop for rubber plantations should have characters like fast growth, drought resistance, shade tolerance, high nitrogen fixing capacity and be non-palatable to cattle. However, none of the cover crops presently recommended in India has the aforesaid desirable characters. Hence, detailed investigations were carried out to select a cover crop which has at least some of the above important characters. *M. bracteata*, a wild leguminous creeper, was found to have most of the desirable characters and the preliminary observations are reported in this paper.

MATERIALS AND METHODS

Mucuna bracteata was collected from Tripura State and was grown at RRII Experiment Station, Kottayam. The vegetative growth characters, rooting, nodulation, drought resistance and shade tolerance were studied under field conditions. Dry matter production and nitrogen fixation in comparison with other leguminous plants were assessed in pot culture studies under glass house conditions by planting five rooted cuttings and growing them for four months. The nitrogen content of tissues and soil was estimated by the Microkjeldahl method.

RESULTS AND DISCUSSION

Seeds and germination

The seeds were large weighing 99 to 226 mg each and black in colour with a hard seed coat. They did not germinate under normal conditions, but germinated in three days when treated with concentrated sulphuric acid for 30 minutes, or scarified mechanically using sand paper. Two weeks after germination the plants started trailing on the ground and produced roots at the nodes, when the field was wet.

Growth and spreading characters

The vines grew very fast by branching from each node. Dark green trifoliate leaves grew to a size of about 16×13 cm under favourable conditions and provided shade on the ground. Four rooted cuttings of *M. bracteata* planted between four

rubber plants grew and covered an area of about 25 m² in six months and suppressed the noxious weeds. The dead older leaves shed and formed a thick mulch over the ground. The thickness of the green vegetation on the ground ranges from 60 to 120 cm. Such a luxuriant growth of cover crops will be of much value in smothering weeds and reducing soil erosion and soil temperature. The dried leaves increase the microbial activity and enrich the nutrient status of the soil. Roots developed from the nodes of vines, touching the ground and they are fibrous. Nodules formed on such roots were small, round and pink in colour. The nodules that developed on the roots of stem cuttings and nodes of established plants were irregular in shape measuring 0.2 to 2 cm. They were pink in the initial stages and turned to black on aging. When cut open the black nodules showed only a small pink centre indicating low leghaemoglobin content which is responsible for nitrogen fixation. However, black nodules contain oxyhaemoglobin (Cloonan, 1963) which can serve the function of leghaemoglobin.

The main roots grow to a depth of one to two m. As found by Wycherley (1963) deep rooted plants may increase the fertility of surface soil by extracting nutrients from the deeper layer of soil and depositing them on the surface in the form of organic matter. The soil moisture level under this cover crop due to a deep root system was not reduced when the vines were slashed during summer (Pushpadas et al., 1976).

Flowering and fruit set

Mucuna bracteata produced flowers mainly from the older vines in racemes during the months of January and February. But fruit set did not occur even after hand pollination or trailing the vines on tall trees. However, fruit set was noticed in this plant in the high ranges of Kerala. It shows that a fairly cool climate as in the high ranges of Kerala is essential for fruit set in this plant.

Nitrogen fixation

The efficiency of nitrogen fixation and dry matter production in comparison with existing cover crops, *Pueraria phaseoloides*, *Centrosema pubescens*, *Calopogonium mucunoides* and *Calopogonium caeruleum* was studied in pot culture and the results are

given in Table 1. The results show that *P. phaseoloides* fixed 1.88 g nitrogen per pot in four months while *M. bracteata* fixed only 1.57 g nitrogen and this is comparable to *C. pubescens*. The results clearly reveal that *M. bracteata* is capable of fixing atmospheric nitrogen and enriches the soil nitrogen level. On mineralisation of organic matter, nitrogen is made available for rubber.

Table 1. Dry matter production and nitrogen fixation by different cover crops in four months

Sl. No.	Name of the cover crop	Dry matter production in g	Nitrogen gain in g/pot
1.	<i>Pueraria phaseoloides</i>	76.08	1.88
2.	<i>Centrosema pubescens</i>	56.07	1.59
3.	<i>Calopogonium mucunoides</i>	31.14	1.29
4.	<i>Calopogonium caeruleum</i>	33.80	0.85
5.	<i>Mucuna bracteata</i>	51.66	1.57

Drought resistance and shade tolerance

This plant did not dry during the summer months, even in places where the soil depth was only eight to 30 cm. Only older leaves shed during summer and new shoots come out after about 30 days. This is an important characteristic which other cover crops are lacking. Under shade also this cover crop grew, but the growth was comparatively less. Both drought resistance and shade tolerance of this cover crop will help in covering the soil surface at all stages of growth of rubber.

Pests and diseases

So far no serious pest or disease problem was noticed in this cover crop. It is also non-palatable to cattle due to the presence of high levels of phenolic compounds, and hence there is no menace from cattle.

Propagation

Propagation of *M. bracteata* is possible through seeds and stem cuttings. As seeds are not easily available, propagation by cuttings could be adopted. Stem cuttings having two nodes are

found to be suitable. However, the percentage of success in the establishment of vines was very low. An experiment to increase the success of stem cuttings was carried out and the results showed (Table 2) that the incorporation of cow dung at 50 g per kg of soil in polythene bags favour the establishment of vines.

Table 2. Effect of cow dung and chemical treatments on the establishment of stem cuttings

Treatment	Percentage of establishment
1. Cow dung 50 g/kg of soil	32
2. Calcium carborate 3 g/kg of soil	20
3. Rock phosphate 10 g/kg of soil	14
4. Seradix B2 application to stem cutting	12
5. No treatment	10

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FIELD AND NURSERY EXPERIMENTS WITH *AZOTOBACTER* IN COFFEE

MIR AZIZUDDIN and W. KRISHNAMURTHY RAO

ABSTRACT

Field and nursery experiments were conducted at the Central Coffee Research Institute to determine the effect of *Azotobacter* sp. on growth and yield of S.795 *arabica* coffee and soil nitrogen build up. Differences in yield due to different treatments were not statistically significant. Positive improvement in shoot dry weight, root spread and girth of seedlings was observed. But the data were not statistically significant.

INTRODUCTION

Supplementing nitrogen needs of the field crops through the use of wide spectrum symbiotic and non-symbiotic nitrogen fixing micro-organisms had gained popular adaptive use in an integrated concept of nutrient supply technique. Azizuddin and Awatramani, (1975) assessed commercially available cultures of *Azotobacter* sp. Marketed under the trade name 'Azo' on coffee in a nursery trial without much success. Lakshmanan and Kannan, (1982) reported that inoculation with non-symbiotic nitrogen fixing *Azotobacter* sp. increased growth in terms of height, in San Ramon genotype and increased plant vigour and yield, probably through the production of growth promoting substances, such as, IAA and GA. Confirmatory field and nursery studies to determine the benefits from the use of bacterial culture in

coffee or otherwise taken up and results obtained are reported in this paper.

MATERIALS AND METHODS

The effect of bacterial fertilisers on minimising nitrogen application was studied in a field trial conducted on the farm of the Central Coffee Research Institute between 1974 and 1979 with *S.795 arabica* coffee. Four treatments replicated six times were maintained in the experiment with Randomised Block Design lay out. 'Azo' culture (2.7 kg/ha) was applied as a pre-monsoon dose, alone and in combinations with cherry husk (5.0 t/ha) and at the rate of 2.7 kg/ha and 5.0 t/ha respectively. Soil Nitrogen status and microbial population were assessed periodically and yields obtained were collected. Nitrogen was not applied. Only P and K were applied through the soil in two split doses at 60 and 80 kg/ha, respectively.

A nursery trial was laid out with on Randomised Block Design lay out using *S.795 arabica* coffee seedlings planted in polythene bages of 15×23 cm. Sieved jungle soil, farm yard manure and sand in a 6:2:1 ratio were used for filling the bags. Commercial formulations 'Sanjeevini Azo' culture was used at 375, 750 and 1500 g/ha basis. Five treatments and three sub-treatments were replicated five times. In one sub-treatment, the soils were treated with the solution prepared by using different quantities of culture as per treatments and coffee seedlings planted later. In another sub-treatment, the seedlings were dipped for a period of 10 minutes in the respective solutions before planting.

In yet another sub-treatment, seeds were pre-treated with solutions of culture of respective concentrations. They were then sown in the primary beds under the normal nursery conditions. At the button (topee) stage the seedlings were transplanted in polythene bags.

RESULTS AND DISCUSSION

The results obtained in the field and nursery trials are discussed. The yield data as affected by varying doses of 'Azo' culture were reported in Table 1.

Table 1. Effect of 'Azo' culture and cherry husk and its combination on yield of coffee

Treatments	Ripe cherry kg/ha (mean of three seasons)
A : Control	1580
B : Cherry husk @ 5.0 t/ha	2151
C : 'Azo' culture	1768
D : 'Azo' culture + Cherry husk at 5.0 t/ha	1809
	NS

Mean yield over the past three seasons as affected by the varying doses of 'Azo' culture indicated that treatment differences were small and not significant.

The data on soil nitrogen status and bacterial population are reported in Table 2.

Table 2. Effect of 'Azo' culture with and without cherry husk on soil nitrogen status and on bacterial population

Treatments	Soil nitrogen (status percentage)		
	I Year	II Year	III Year
A : Control	0.20	0.25	0.21
B : Cherry husk	0.19	0.21	0.22
C : 'Azo' culture	0.21	0.24	0.21
D : 'Azo' culture + Cherry husk	0.21	0.25	0.20
	NS	NS	NS
	Bacterial population 10 ⁸ /g		
A : Control	2.7	46	1017
B : Cherry husk	3.2	69	1123
C : 'Azo' culture	1.7	52	1092
D : 'Azo' culture + Cherry husk	4.2	18	1154

The soil nitrogen status before and after application of bacterial fertilisers remained more or less the same indicating that higher bacterial population had contributed in the build up of soil nitrogen status probably due to unfavourable soil conditions like high initial soil N and organic matter status. The nitrogen

content in fact was found reduced in the third year though there was a marginal increase during the second year. The observation that there was a decrease in the percentage of nitrogen with time is in confirmation with the earlier findings (Azizuddin and Awatramani, 1975).

The data on dry weight of leaf, shoot and root as affected by the treatments of soil, seed and root (soil and seed inoculation and root dippings) with different concentrations of cultures are reported in Table 3.

The difference in root, shoot and leaf weights due to cultures applied differently were not statistically significant. Root dipping treatments resulted in an increased root and shoot dry weight in general when compared to the other application methods.

Soil inoculation improved dry weight of leaf and root in general. Application of 750 g/ha of culture and treating the soil before seedlings were transplanted increased the dry weight of the leaf by about 19.2 per cent over control. The increase in root weight was of the order of 18.2 per cent over control in the same treatment. Seed inoculation did not result in any general increase in the root, shoot and leaf dry weights.

The data on stem girth and root spread as affected by the different concentration of culture are presented in Table 4.

The data indicated that differences in root spread and stem girth due to different concentrations of culture applied differently were not statistically significant. Soil inoculation at 750 g/ha culture resulted in an increase of an order of 11.8 per cent in stem girth and 6.0 per cent in root spread.

Root dipping in a solution of culture (750 g/ha) resulted in a better spread. Root spread was of a higher order and better in the plants when the seeds were pre-treated with culture. There has been an evidence of a possible positive improvement in plant dry weight, root spread, stem girth from the use of cultures in the coffee nursery. Lakshmanan and Kannan (1982) also reported increased plant vigour as a result of inoculation with non-symbiotic nitrogen fixing *Azotobacter* sp. But the evidence obtained is not statistically significant.

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Table 3. Dry weight of root, shoot and leaf as affected by different treatments and methods of application of Azotobacter

Treatment	Dry weight in grammes								
	Soil inoculation		Root dipping		Seed inoculation				
	R	S	L	R	L	R	S	L	
750 g	2.08	4.94	6.03	2.08	4.43	5.94	1.59	2.33	4.82
1500 g	1.79	4.02	4.78	2.02	4.17	5.56	1.55	2.13	4.65
375 g	1.79	4.01	5.10	2.14	4.56	6.06	1.42	1.98	4.14
Control	1.76	4.15	5.06	2.15	4.40	6.06	1.63	2.32	4.70
	NS	NS	NS	NS	NS	NS	NS	NS	NS

R = Root; S = Shoot; L = Leaf.

Table 4. Effect of different treatment methods on stem girth (mm) and root spread (cm) of *S. 795* arabica coffee seedlings

Treatment	Soil inoculation		Root dipping		Seed inoculation	
	Stem girth	Root spread	Stem girth	Root spread	Stem girth	Root spread
750 g	6.24	10.63	5.96	10.70	5.23	15.20
1500 g	5.39	9.45	5.78	9.08	5.14	14.76
375 g	5.55	9.54	6.04	9.81	5.00	13.35
Control	5.58	10.02	5.82	9.73	5.15	13.75
	NS	NS	NS	NS	NS	NS

SESSION V

AGRONOMY 2

Chairman : K.K. Krishnamoorthy

Rapporteurs : V. Haridasan

K.I. Punnoose

INTEGRATED NUTRIENT MANAGEMENT IN PERENNIAL BASED HIGH DENSITY CROPPING THROUGH SYSTEM APPROACH—A THEORETICAL CONSIDERATION

C.C. BIDDAPPA, H. HAMEED KHAN, O.P. JOSHI,
P. MANIKANDAN and K.V. AHMED BAVAPPA

ABSTRACT

An effort has been made to propose theoretical models to evaluate integrated nutrient management in a mixed perennial crop stand through a system approach. Soil and crop communities are the system components of the model. Soil nutrient enrichment and nutrient depletion models are suggested. The soil nutrient pool constituting the solution, exchange and solid phases to be enriched by the enriching components are considered under the nutrient enrichment model. Various components of nutrition depletion are identified and used in the depletion model. The difference between enrichment and depletion is expected to give a nutrient balance sheet which could be used profitably in nutrient budgeting of multispace high density cropping system.

INTRODUCTION

Nutrient management in a high density multispecies cropping system is a difficult task owing to the involvement of varying nutrient requirements of different crops and crop communities, differential crop responses and crop residue additions. Inciden-

tally nutrient cycling becomes the interesting concern as it engulfs the fluxes reaching and leaving the system. Plant-soil ecosystem represents a three dimensional cut out of vegetation, cover and root zone (Nair, 1979) and a complexity of such a system is seen in the high density cropping, especially with perennials. As studies of eco-components of individual crop species can be misleading, an integrated approach taking the entire eco-processes occurring simultaneously has been attempted in the succeeding text. An effort has been made to propose theoretical models to evaluate integrated nutrient management in a mixed perennial crop stand, through a system approach. Khanna and Nair (1977) in a coconut based system and Ulrich (1971) and Ulrich et al. (1973, 1977) in a forest system outlined the system approach in studying nutrient fluxes.

SYSTEM COMPONENTS

In the proposed model the system components are mainly the soil that support the system and the aerial components, namely, the crop communities. Further, these major components are divided into various sub-components which are to be evaluated separately and integrated to the main components.

Two phases of major activity, namely nutrient enrichment and nutrient depletion of the soil, are considered. The soil nutrient pool constituting the solution phase, exchange phase and solid phase to be enriched by the enriching components that is, rain-water, fertiliser (and organic manures), organic recycling, crop residue addition and native soil nutrients are considered under the nutrient enrichment model. While the soil nutrient depletion mainly takes place through leaching, volatilisation, microbial immobilisation, fixation and plant produce utilisation, the soil matrix with its dynamic equilibrium in maintaining the labile pool of the nutrients is also the main seat of leaching. The resultant difference between enrichment and depletion tend to yield the nutrient balance in the given system which could profitably be used in nutrient budgeting.

BOUNDARY CONDITION

Despite the fact that enrichment and depletion are taking place

simultaneously in one form or the other in soil-plant continuum, the following boundary conditions are assumed in the proposed system analysis model:

1) It is an open system which is characterised by materials entering and leaving it across the boundary. However, it is necessary to adjust the system boundary, so that the relevant parts of components are included in the system. This sort of adjustment is illustrated conceptually in the figures.

2) Although nutrient cycling is done to the extent possible, the losses of nutrients from the system take place primarily by: (i) product utilisation loss wherein the nutrients present in the edible parts like nuts, tuber, fruits, berries and vegetative parts are withdrawn from the system permanently and these nutrients under no circumstances are recycled; and (ii) the uncontrolled leaching through soil profile which cannot be checked, though reasonable estimates can be made, and the process is characterised by the movement of sufficiently high quantity of nutrients out of the feeding zone or to the ground water along with the downward transmission of rain water under saturated conditions.

3) The system attains more or less a dynamic equilibrium at a given time for the purpose of studies despite the fact that equilibrium frequently changes due to continuous inflow and outflow of the nutrients in the system.

Key note on the abbreviations used in the models are as follows:

<i>Enrichment rate</i> (Er)	<i>Soil Nutrient Depletion rate</i> (Dr)
Solution phase — (epsilon) E_1	Solution phase — E_2
Exchange phase — (zeta) ζ_1	Exchange phase — ζ_2
Solid phase — (et) η_1	Solid phase — η_2
Rain water — (alpha) α	Leaching loss — κ
Fertilisers — (beta) β	Volatilisation loss — ν
Soil nutrients — (gamma) γ (native)	
Organic recycle — (lambda) λ	Microbial immobilisation loss ρ
Crop residues — (psi) ψ	Fixation loss ω
Microbial addn. — (chi) χ	Plant utilisation ϕ

SOIL NUTRIENT ENRICHMENT MODEL

Soil nutrient enrichment under a high density cropping system is a complex process to judge, as multiple crop components requiring varying input demands are involved. Thus estimation of elemental cycling requires a complete inventory of the input fluxes to the system (Ulrich et al., 1981). To consider this, soil enrichment has been classified into two categories.

- a) soil enrichment without cropping, and
- b) soil enrichment under multispecies cropping.

a) Soil enrichment without cropping

Schematic representation of processes governing soil enrichment without cropping is shown in Fig. 1. The enrichment is limited to additions through rain water and organic cycling. Rain water through the filtering process brings down soluble metabolites from the crop stand to the soil in addition to the atmospheric input. As conditioned by the interaction of nutrient

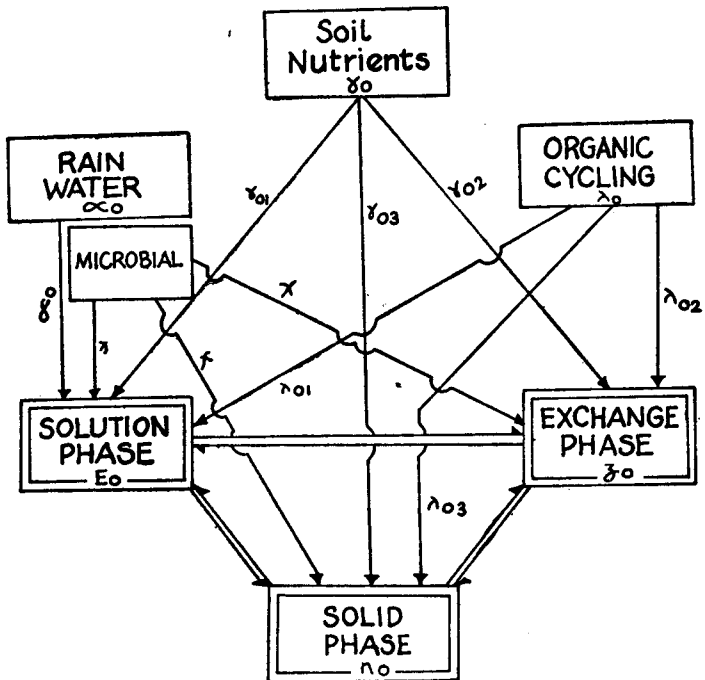
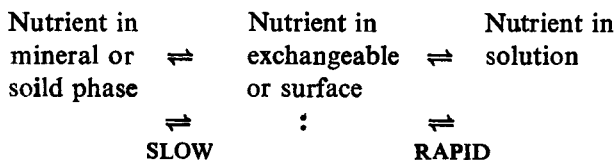


Fig. 1

addition through organic recycling and rain water, changes are brought out in the dynamic equilibrium between solution, exchange and solid phase. Weathering action on the solid phase also enriches the nutrient pool. The equilibrium changes and a static level is maintained. Methods of studying these and the difficulties experienced have been indicated by Ulrich et al. (1981).

The lower half of the diagram exhibiting interplay between the three phases in the soil holds good for all the nutrients except those that are not capable of undergoing exchange in the soil (NO_3^- and SO_4^{2-}). For phosphorus it may be modified as below since surface absorbed phosphate is used by plants (Venkateswarlu, 1976).



b) Soil enrichment under multispecies cropping

The incoming fluxes of nutrient under a multispecies cropping system is through the agencies of rain water and fertilisers inputs to the individual crop communities, and the organic addition through crop and weed growth. The addition of elements by crop growth of weeds is partly an internal turnover of the nutrients absorbed by the roots from the soil. The contribution from roots as biomass addition and through nutrient cycling will be enormous and estimations by soil monolith analysis (Karizumi, 1968) and allometric analysis (Kira and Ogawa, 1968) have been proposed. The soil enrichment is gradual along with the growth of the crop community in the system, though various stages of nutrient enrichment by the bio-elements are observed, namely initial stages, active growth stage and the equilibrium stage. The direct and indirect effects of microbial organisms also enrich the nutrient pool. The attainment of the equilibrium stage may be after four to five years of the reproductive phase of 75 per cent of the crop communities concerned. The elemental input is dependent upon the season (Ando, 1970; Pavlov, 1972) and annual variation (Rodin and Bazilevich, 1967).

A schematic diagram of nutrient enrichment phase (Fig. 2) indicates the additional enrichment components over those seen

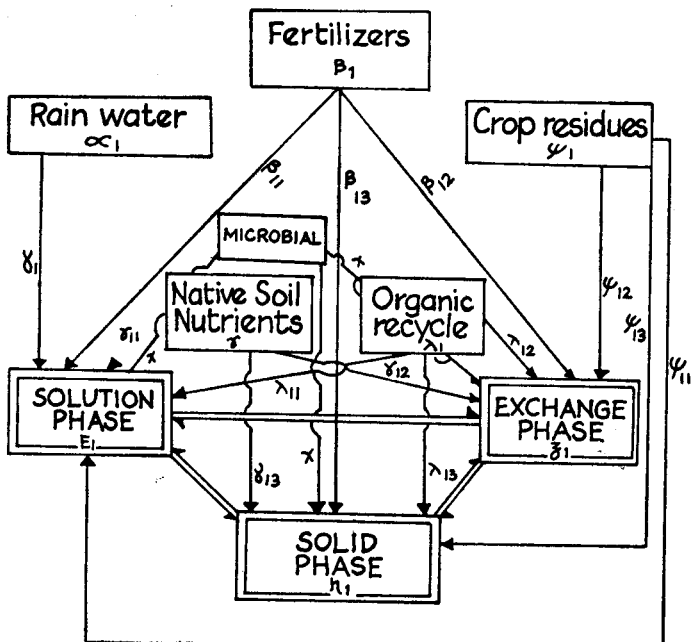


Fig. 2

in (Fig. 1) and their interrelationship on the soil matrix. Soil, more precisely the solid phase is considered as the reservoir of nutrients and is in dynamic equilibrium with the exchange and solution phase.

The reaction governing the nutrient enrichment by agencies within and between the three phases are indicated by three numerical equations (1, 2, 3)

$$\begin{aligned} \epsilon_1 - \epsilon_0 = & \int_i^f \left(\frac{\delta \epsilon}{\delta \alpha} \right) d\alpha + \int_i^f \left(\frac{\delta \epsilon}{\delta \beta} \right) d\beta + \int_i^f \left(\frac{\delta \epsilon}{\delta \gamma} \right) d\gamma \\ & + \int_i^f \left(\frac{\delta \epsilon}{\delta \lambda} \right) d\lambda + \int_i^f \left(\frac{\delta \epsilon}{\delta \Psi} \right) d\Psi + \int_i^f \left(\frac{\delta \epsilon}{\delta \kappa} \right) d\kappa \end{aligned} \quad (1)$$

$$\begin{aligned} z_1 - z_0 = & \int_i^f \left(\frac{\delta z}{\delta \beta} \right) d\beta + \int_i^f \left(\frac{\delta z}{\delta \gamma} \right) d\gamma + \int_i^f \left(\frac{\delta z}{\delta \lambda} \right) d\lambda \\ & + \int_i^f \left(\frac{\delta z}{\delta \Psi} \right) d\Psi + \int_i^f \left(\frac{\delta z}{\delta \kappa} \right) d\kappa \end{aligned} \quad (2)$$

$$\eta_1 - \eta_0 = \int_i^f \left(\frac{\delta\eta}{\delta\beta} \right) d\beta + \int_i^f \left(\frac{\delta\eta}{\delta\gamma} \right) d\gamma + \int_i^f \left(\frac{\delta\eta}{\delta\lambda} \right) d\lambda + \int_i^f \left(\frac{\delta\eta}{\delta\Psi} \right) d\Psi + \int_i^f \left(\frac{\delta\eta}{\delta\chi} \right) d\chi \quad (3)$$

The various symbols indicate (refer key) different components taking part in enrichment steps each being a rate limiting step and are in equilibrium with the other phases. The differences between the enrichment under cropping and without cropping gives the enrichment profile of the respective nutrient pool. However, the net gain or loss of the nutrient from the pool would be a resultant effect of enrichment of solution, exchange and solid phase fractions. To comprehend the individual steps in the process is rather difficult, and one usually estimates the resultant effect of interactions. Studies of sequential extraction type (Silveir and Sommers, 1977) may give information on fractionated portion of the nutrient continuum on soil matrix.

SOIL NUTRIENT DEPLETION

Under barren soil conditions nutrient depletion from the soil will mainly be through leaching, weed growth, grazing and through mechanical loss by erosion, if unchecked. In monocropping and multiple cropping systems, the integrated interaction effect of crop on soil helps in conservation and depletion of nutrients. Depletion in this context refers to the nutrient removal from the system through harvesting of crop produce both edible and non-edible. The aerial storage in lignified tissues (trunk, bark and plant parts)—a system building activity, immobilises a considerable amount of nutrient, a portion of which is activated by photosynthesis. The series of depletion parameters which would act on the soil—the ultimate reservoir of nutrients pool—are outlined in Fig. 3.

Nutrient depletion in high density cropping is a dynamic process and the nutrient pool will be unevenly tapped for resources by the companion crops. Losses due to leaching, drain of native soil nutrient contents, microbial immobilisation and nutrient fixation (especially phosphorus) are soil bound and plant utilisation is an aerial bound nutrient loss. As nutrient enrichment changes

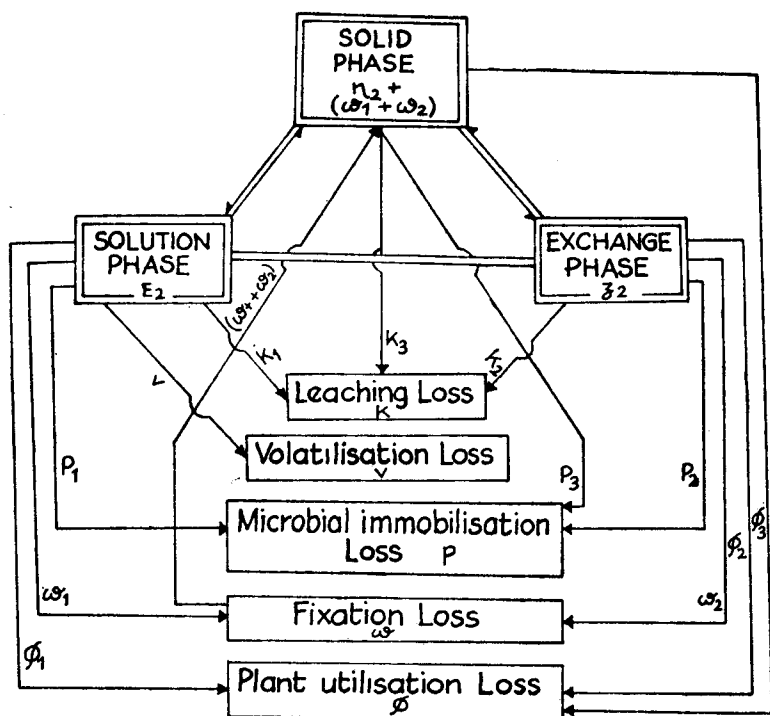


Fig. 3

the equilibrium, nutrient depletion also changes the equilibrium of soil store. The changes as influenced by different components modify the nutrient pool and are given by three numerical equations (4, 5, 6) as follows:

$$\epsilon_2 - \epsilon_0 = \int_0^1 \left(\frac{\delta \epsilon}{\delta k} \right) dk + \int_0^1 \left(\frac{\delta \epsilon}{\delta \gamma} \right) d\gamma + \int_0^1 \left(\frac{\delta \epsilon}{\delta p} \right) dp + \int_0^1 \left(\frac{\delta \epsilon}{\delta \phi} \right) d\phi \quad (4)$$

$$z_2 - z_0 = \int_0^1 \left(\frac{\delta z}{\delta k} \right) dk + \int_0^1 \left(\frac{\delta z}{\delta w} \right) dw + \int_0^1 \left(\frac{\delta z}{\delta p} \right) dp + \int_0^1 \left(\frac{\delta z}{\delta \phi} \right) d\phi \quad (5)$$

$$\eta_2 - \eta_0 = \int_0^1 \left(\frac{\delta \eta}{\delta k} \right) dk + \int_0^1 \left(\frac{\delta \eta}{\delta p} \right) dp + \int_0^1 \left(\frac{\delta \eta}{\delta \phi} \right) d\phi + \int_0^1 \left(\frac{\delta \eta}{\delta w} \right) dw \quad (6)$$

The difference between the summation of natural depletion rate under an adjacent barren land (E_0 , Z_0 , and n_0) and the summation of depletion of nutrients under a cropping system (E_2 , Z_2 , and n_2) will provide information on net nutrient depletion from the system.

NUTRIENT BUDGETING AND BALANCE

Nutrient balance in the strict sense of the term means the difference between the input and the output of nutrients in various forms. Under a high density cropping system the difference between nutrient enrichment and depletion is expected to give the nutrient balance which may be positive, negative or equal. In a perennial based system we opine that the nutrient balance (budgeting and tailoring to needs) can be studied at equilibrium: (1) after four to five years of the reproductive phase of 75 per cent of crop communities concerned; and (2) when the system is fully mature.

$$\left. \begin{array}{l} \text{Nutrient balance in} \\ \text{respective phase} \end{array} \right\} E_r^{(1,2,3)} - D_r^{(3,4,5)}$$

Such information helps to understand the nutrient profile in the system and evokes measures to regulate inputs.

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DISCUSSION

Q : The paper presented by you suggests only a theoretical model. Will this be of any practical use in nutrient management?

Ans: This theoretical model forms the basis for further work on integrated nutrient management.

Q : Is this model same as that one proposed by Ulrich?

Ans: Ulrich's outlined the system approach in a forest system and not in high density cropping systems.

Q : Could you quantify any boundary conditions in your study?

Ans: This paper gives the assumptions on boundary conditions.

AGRONOMIC PATHWAYS OF YIELD RESPONSE IN TEA TO CORRECTION OF ZINC DEFICIENCY AND CONTROL OF PESTS

V. RANGANATHAN and S. NATESAN

ABSTRACT

The agronomic pathways of yield increase due to the correction of zinc deficiency and the adoption of control measures for shot-hole borer (*Xyleborus fornicatus*) were studied using the yield model developed in tea culture in South India. The yield potential increased substantially on correction of zinc deficiency and on adoption of cultural measures; but the fraction of yield potential exploited by fertilisers decreased initially as part of the nutrients were used to restore the health of the bushes but tend to increase on continual treatments. The net response was always positive. The implications of the findings are discussed.

INTRODUCTION

In the intensive cultivation system of tea in South India, a strong interaction of manurial, cultural and managerial factors exist warranting an integrated approach for maintaining the steady growth of production and productivity. An integrated model for productivity has been developed wherein the role(s) of various components is (are) being identified and quantified (Ranganathan, 1978, 1983). Nutritional interactions among themselves combined with agronomic and cultural practices, were recogni-

sed in tea and reported time and again (de Jong, 1950; Jayaraman and de Jong, 1955; Ranganathan, 1970, 1971, 1982; Ranganathan et al., 1982; Natesan et al., 1982). The results of investigations carried out to study the agronomic pathways of response of tea to the correction of zinc deficiency and the control of shot-hole borer (*Xyleborus fornicatus*) are discussed in this paper.

MATERIALS AND METHODS

The results of two experiments, one on "Correction of zinc deficiency" carried out for two cycles (1976/1984) and the other on "The impact of shot-hole borer control measures on the efficiency of fertilisers" conducted for one cycle (1978/1982) were analysed for developing a mathematical model for studying the pathways for the increase in yield. In the experiment on correction of zinc deficiency, three levels of N, 120, 150 and 200 kg N/ha in the first cycle, and 150, 150 and 350 kg N/ha in the second cycle at two N : K₂O ratios, 2 : 1 and 4 : 3, were tested as sub-treatments with zinc sulphate application as the main treatment. Zinc sulphate was applied at the rate of 11.25 kg ZnSO₄ · 7H₂O/ha in five split applications starting from September to December combined with alternate blister sprays, once in two years. The experiment was conducted in a field planted with dark leaved Assam jat in 1923 in Central Travancore area at an elevation of 800 m MSL. The field was pruned at 65 cm in June 1976 and August 1981 and tipped at 75 cm height over ground level. In the pruned year, all the bushes received 120 kg N and 180 kg K₂O/ha uniformly and the manurial treatments were imposed only from the second year onwards.

The other experiment on the impact of shot-hole borer control measures on the efficiency of fertiliser use was carried out in a field planted in the late thirties in Central Travancore area at an elevation of 800 m MSL with Assam jat and rejuvenation pruned in late August/early September 1978. Three levels of N, 200, 250 and 300 kg N/ha each at two N : K₂O ratios, 2 : 1 and 4 : 3 were the sub-treatments while three shot-hole borer control measures: (1) spraying the prunings with Heptachlor; (2) spraying prunings with Heptachlor and mid-cycle spraying with Endosulphan and Nuvan (five rounds in the second year, 10 rounds in the third year and six rounds in the fourth year); and (3) a control, each

at two levels of K_2O in the pruned year, 150 and 300 kg K_2O/ha , were the main treatments. Heptachlor was sprayed on the prunings at the rate of 8.5 l in 675 l water/ha using a Knapsack sprayer in October 1978. Endosulfan and Nuvan at the rate of 1 l and 250 ml respectively in 350 l water/ha were together used at four to six weeks interval from the second year onwards using a motorised sprayer.

Yield model

The yield model developed for productivity analysis in tea (Ranganathan, 1976, 1978, 1983) is given below:

$$Y : M (1 - e^{-0.6932 b_1 + b_2}) \quad (1)$$

Let $(1 - e^{-0.6932 b_1 + b_2}) = P \quad (2)$

Then, $Y : MP \quad (3)$

Where Y —yield obtained; M —the yield potential or the maximum yield achievable with nutrients, all other conditions being the same; $1 - e^{-0.6932 b_1 + b_2}$ or ' P ' is defined as the yield possibility, or the fraction of the yield potential exploited by the use of an input at a given level ' b_2 ' with a soil availability at ' b_1 ', all in baule units.

The increase in yield could be achieved by enhancing the ' M ' by improving the health of the bushes by good crop husbandry practices and correction of nutritional imbalances and the ' P ' by good manurial policies and to some extent by eliminating the limiting factors.

The correction of zinc deficiency or the pest control measures improve the general health of bushes and the yield potential (M) is, therefore, increased. As zinc deficiency is limiting the growth and utilisation of nutrients, it is also possible that the correction of zinc deficiency may increase the ' P ' values. The pest control measures improve the general health of bushes and indirectly, to some extent, influence the efficiency of nutrients. Hence, any change in yield, whether an increase or decrease, due to the correction of zinc deficiency or the shot-hole borer control measures, can be due to the change in M or P or both M and P values. In order to quantify the exact partitioning of the responses obtained on the correction of zinc deficiency and on the control of pests, the following yield analytical scheme is developed.

Partitioning of the yield response

In each of the two experiments, the yields obtained (Y) at different N levels or K levels corresponding to the main treatments, namely, control and treatment (correction of zinc deficiency or shot-hole borer control measures), can be separately related to the yield potential (M) and yield possibility (P) using Eq. 3. These equations can be grouped under two series:

1) the T^- series corresponding to "control" (with respect to the main treatment) in which the yields obtained at $N_1, N_2 \dots, N_i$ are denoted as $Y_{11}, Y_{12} \dots, Y_{1i}$. As N levels change only the P values, the corresponding P values are denoted as $P_{11}, P_{12} \dots, P_{1i}$. The yield potential is M_1 .

2) The T^+ series corresponding to "treatment" (correction of zinc deficiency or control of shot-hole borer). Since the treatment can change both M and P values, the new yield potential is denoted as M_2 and the yield possibilities at $N_1, N_2 \dots, N_i$ are given in terms of P_{2i} values, viz., $P_{21}, P_{22} \dots, P_{2i}$. The yields obtained at the corresponding N levels are given in Y_{2i} values.

At N_i level of nitrogen, the equations relating the yields obtained in the control and in the treatment are:

$$\text{Control } (T^- \text{ series}) \quad Y_{1i} = M_1 P_{1i} \quad (4)$$

$$\text{Treatment } (T^+ \text{ series}) \quad Y_{2i} = M_2 P_{2i} \quad (5)$$

The yield increase or decrease from Y_{1i} to Y_{2i} is due to the change in M and P values. Let 'a' and 'b' be the percentage increase or decrease in 'M' and 'P' respectively due to treatment.

$$Y_{2i} = M_2 P_{2i} = \frac{M_1 (100+a)}{100} \times \frac{P_{1i} (100+b)}{100} \quad (6)$$

Estimation of $(a+b)$

Dividing Eq. 5 by Eq. 4.

$$\begin{aligned} \frac{Y_{2i}}{Y_{1i}} &= \frac{M_2 P_{2i}}{M_1 P_{1i}} = \frac{M_1 (100+a) \times P_{1i} (100+b)}{M_1 P_{1i} \times 100 \times 100} \\ &= \frac{(100+a) (100+b)}{100 \times 100} \\ &= 1 + \frac{a+b}{100} + \frac{ab}{100^2} \end{aligned} \quad (7)$$

Ignoring the term $\frac{ab}{100^2}$ as it is negligible, then

$$\frac{Y_{2i}}{Y_{1i}} = 1 + \frac{a+b}{100}$$

$$\text{or } \left[\frac{Y_{2i}}{Y_{1i}} - 1 \right] 100 = a+b$$

Therefore, for any input levels, the total response, $a + b$, can be calculated using Eq. 8.

The yield model equations for the "control" and the "treatment" at $N_1, N_2, \dots, N_\infty$ levels of nitrogen along with the total response are summarised below:

Nutrient level	Yield model equation for main treatment		$\left[\frac{Y_{2i}}{Y_{1i}} - 1 \right] \times 100$
	Control (T ⁻)	Treatment (T ⁺)	
N_1	$Y_{11} = M_1 P_{11}$	$Y_{21} = M_2 P_{21}$	$a + b$
N_2	$Y_{12} = M_1 P_{12}$	$Y_{22} = M_2 P_{22}$	$a + b$
:	:	:	:
N_i	$Y_{1i} = M_1 P_{1i}$	$Y_{2i} = M_2 P_{2i}$	$a + b$
:	:	:	:
N_∞	$Y_{1\infty} = M_1$	$Y_{2\infty} = M_2$	a

It should be noted that at N_∞ level of nitrogen, the $P_{1\infty}$ and $P_{2\infty}$ values become unity; hence $Y_{1\infty} = M_1$ and $Y_{2\infty} = M_2$.

Estimation of M and a

The yield potential ' M ' in a particular field could be assessed by plotting $1/N$ against $\log Y$ and extrapolating $1/N \rightarrow 0$ (Ranganathan et al., 1969) where N = fertiliser input level and Y = yield obtained, or it could be calculated using the formula for the above curve as follows:

$$\text{Log } M = \log Y_1 + \frac{(\log Y_2 - \log Y_1) 1/N_1}{1/N_2 - 1/N_1}$$

Where Y_1 and Y_2 are yields obtained at input levels N_1 and N_2 respectively.

For three levels of input usage, three combinations of yield levels are possible; the mean of ' M ' values for them, or, two of them which are close to each other eliminating the widely differing/abnormal values which are taken as ' M '. Alternatively, it is

evaluated graphically (Ranganathan et al., 1969). The ratio of M_2/M_1 refers to the increase in yield potential due to treatment and from which the percentage increase in 'a' is calculated.

RESULTS AND DISCUSSION

The impact of correction of zinc deficiency on yield parameters year-wise for two cycles are given in Table 1. The net response ($a + b$) on the correction of zinc deficiency varied between 2.6 and 7.9 per cent with a mean of 4.8 per cent. The increase in yield potential achievable with nitrogen varied between 4.2 and 7.3 per cent with a mean of 5.35 per cent and with potassium between 5.0 and 8.1 per cent with a mean of 6.15 per cent. The 'b' values for the nitrogen were negative in the initial years and progressively increased from -2.2 at the second year to -0.3 per cent at the seventh year. Only, at the eighth year the 'b' value became positive. The 'b' values for potassium were also negative, progressively decreasing from -3.0 per cent and stabilised around -1.5 per cent from the third year onwards. The visual assessment of deficiency symptoms showed that the corrective measures brought down the severity from moderate to severe to mild/very mild over the years.

Zinc deficiency is known to affect: (1) the growth of plants through the reduction in synthesis of tryptophane, a precursor of indole-acetic acid; (2) the 'N' metabolism through the reduction in RNA levels; and (3) indirectly starch formation by depressing the activity of starch synthetase. It also affects characteristically the bark of tree crops which become rough and brittle (Mengel and Kirkby, 1978). Zinc deficiency in tea is shown as (1) pale yellowing (vague chlorosis) of leaves; (2) sickle shaped leaves due to unequal growth of the two halves; and (3) shortening of internodes showing a mosaic or clustered appearance. The cumulative effect leads to debilitation of bushes and the reduction in yield. The correction of zinc deficiency in South India has been shown to increase the yield by about 14.5 per cent (Venkata Ram, 1970; Ranganathan, 1979).

The correction of zinc deficiency rectifies the metabolic and growth disorders and hence improves the general health of the bushes. This is shown by the substantial increase in 'a' values which represent the increase in yield potential achievable with

Table 1. Correction of zinc deficiency—impact on yield parameters

Stage in the pruning cycle	Mean yield kg ha ⁻¹	Per cent yield over mean						Net response (with N) (with K) %	a %	a %	
		Mean observed		'M' (with nitrogen) Zn ⁺		'M' (with potassium) Zn ⁺					a + b %
		Zn ⁻	Zn ⁺	Zn ⁻	Zn ⁺	Zn ⁻	Zn ⁺				
Pruned year	1581	96.2	103.8	—	—	—	—	7.9	—	—	
2nd year	3442	97.5	102.5	104.9	112.6	102.2	110.5	5.1	7.3	8.1	
3rd year	3089	98.7	101.3	110.3	114.9	100.2	105.2	2.6	4.2	5.0	
4th year	3104	97.7	102.3	115.8	122.6	100.2	105.2	4.7	5.9	5.0	
5th year	2940	97.4	102.5	112.6	119.3	101.2	108.0	5.2	5.9	6.7	
Pruned year	823	97.8	102.1	—	—	—	—	4.4	—	—	
2nd year	2230	98.2	101.8	104.7	108.9	99.7	104.8	3.7	4.0	5.2	
3rd year	3024	97.6	102.5	108.0	113.2	100.0	106.9	5.1	4.8	6.9	

nutrient inputs. The 'b' values are also, expected to increase on restoration of the health of the bushes; but they have shown negative values in the initial seven years with N and stabilisation at -1.5 per cent for K after the third year. One should remember that the crop harvested is only a part of the total dry matter formed and hence the reduction observed is only apparent with respect to it; the analysis of the total dry matter formed may show positive values. This means that on correction of zinc deficiency, more nutrients are utilised for forming/strengthening the frames for sustaining higher yields over the years. Such an effect of K on building frames before the response is shown in a crop harvested is frequently encountered in tea culture and is the basis of manuring young tea and pruned fields (Ferguson, 1976; Nate-san et al., 1984).

Such a phenomenon is also important and essential in a perennial crop for sustaining yield trends. It is much more important in tea where the growing parts are used for manufacture and the harvest is to be delicately balanced to the natural growth rhythm of tea shoots, nutrition and climatic conditions and also to the health of the bush and the yields. However, the increase in 'a' is substantial to give a net positive response, although more of the nutrients go in for building frames lowering the 'b' values for the crop harvested at least in the initial years of imposition of treatments.

The impact of control measures for shot-hole borer and a high dose of K applied in the pruned year on the yield response parameters are given in Table 2. The pruned year K treatments, PK₁ and PK₂, gave respectively, net responses ($a + b$) of 6.3 and 6.0 per cent for spray treatment in the pruned year only and 6.3 and 6.6 per cent for the treatment, "Spraying in the pruned year + mid-cycle sprays". The increase in 'a' values for N and K responses was more in PK₂ treatment than in PK₁ treatment. The individual mean responses which are additive in combinations are shown in Table 3.

A high rate of application of potassium in the pruned year and spraying the prunings with Heptachlor showed maximum ($a + b$) and 'a' values for 'N' and 'K' responses. The mid-cycle sprays with the chemicals tried, Endosulphan + Nuvan, did not further increase the $a + b$ and 'a' values. Also, in a recent trial on screen-

Table 2. Control of shot-hole borer—impact on yield parameters

Factor	t ha ⁻¹ cycle ⁻¹			(a + b) %			a %	
	T ⁻	T ⁺	T ⁺⁺	T ⁺	T ⁺⁺	T ⁺	T ⁺⁺	
Mean yield								
PK ₁	14.3	15.2	15.2	6.3	6.3	—	—	—
PK ₂	15.1	16.0	16.1	6.0	6.6	—	—	—
<i>N</i> response:								
M values								
PK ₁	15.4	16.7	17.3	—	—	8.4	12.3	—
PK ₂	16.2	19.5	19.2	—	—	20.3	18.5	—
<i>K</i> response:								
M values								
PK ₁	15.3	16.5	16.7	—	—	7.8	9.2	—
PK ₂	15.7	17.2	17.9	—	—	9.6	14.0	—
Response to pruned year K, %								
Mean yield	5.6	5.9	5.9					
'M' with N	5.2	16.0	11.0					
'M' with K	2.6	4.2	7.2					

PK₁, PK₂—Pruned year K₂O treatments, 150 and 300 kg K₂O/ha respectively.

T⁻, T⁺, T⁺⁺—Control, drenching with heptachlor in the pruned year only and drenching with heptachlor in the pruned year + mid-cycle sprays with Endosulphan and Nuvan, respectively.

Table 3. Mean response to individual factors

Factor	Response		
	a + b % (net yield increase)	'M' (with N) a %	'M' (with K) a %
Pruned year 'K'	5.6	11.0	4.7
Spraying in the pruned year (with Heptachlor)	6.2	14.4	8.7
Mid-cycle sprays (with Endosulphan + Nuvan)	0.3	1.0	2.9
Total increase	12.1	26.4	16.3

ing chemicals for mid-cycle sprays, Endosulphan + Nuvan combination was found to be less effective in control of shot-hole borer compared to the others tried (Muraleedharan—Personal communication).

The shot-hole borer attack in young tea stems causes branch breakage at the point of internal girdling, resulting in crop decline to the extent of loss of bearing branches by snapping. The damage is mainly mechanical (Rao, 1971). However in old stems, the attack causes chlorosis, defoliation and finally die back of branches partly arising from numerous discontinuity points in the nutrient transport vessels. It is quite possible that a high application of K and the control measures in the pruned year help to build up the health of the frames by increasing the mechanical strength of tissues and substantially controlling the pest and protecting it from new attacks in early stages respectively. The drenching sprays with Heptachlor on prunings has a residual effect up to six months in protecting the wood from a new attack (Murthy and Rao, 1979) and the use of this chemical for mid-cycle sprays has been discouraged because of undesirable side effects on other pest-predator balances. The spider mites reduced storage more than top growth and this indirect effect is important (Mistrie, 1969) and similar reduction in root growth in radish was reported to have been caused by mites (Mellers and Propts, 1983). Though such an effect on root growth by attack of pests on shoots was not reported in tea, it is quite possible that chlo-

rosis, defoliation and discontinuity in transport vessels caused by shot-hole borer might affect starch reserves and root activity leading to general debilitation. The substantial increase in 'a' values on adoption of control measures suggests the general improvement in the health of the bushes. The 'b' values were also negative showing that more of the nutrients than in control treatment were diverted to build healthy frames especially when they were protected in the initial stages of wood development in the pruned year by spraying with Heptachlor. Drenching sprays with Heptachlor was delayed by one month in this experiment and in spite of this, the net response was positive and the increase in yield potential was substantial. All these indicate the need for control measures in shot-hole borer infested fields, in the pruned year, even though the effect of these could not be correlated to the re-infestation levels with the present sampling technique. A new sampling technique is being developed to assess the infestation levels which will be better correlated to crop (Muraleedharan—Personal communication).

To sum up, the correction of zinc deficiency and the control measures for shot-hole borer increased the yield potential substantially. This involved utilisation of nutrients more for wood and supporting foliage formation which decreased the exploitation efficiency of fertilisers if the harvest alone is considered. The net response was still high. The correction of zinc deficiency showed an average net response of 4.8 per cent over eight years. Spraying the prunings with Heptachlor resulted in an increase of 6.3 per cent and the mid-cycle sprays with Endosulphan + Nuvan enhanced it only marginally by 0.3 per cent. The high rate of potassium application ($300 \text{ kg K}_2\text{O ha}^{-1}$) in the pruned year increased the yield by 5.6 per cent. The results also showed that the initial decline in exploitation efficiency of fertilisers due to increased diversion to wood formation could recover after continuing treatment over the years and the yield trends could then be sustained forever.

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DISCUSSION

Q : The 'b' values were negative during earlier years and became positive only by 8th year. Can you explain the reasons?

Ans: During earlier years more of the nutrient go in for building the frames. Consequently the 'b' values were low for young bushes.

ASSESSMENT OF SOIL ZINC AND COPPER AS REFLECTED BY THE LEAF COMPOSITION OF PEPPER (*PIPER NIGRUM* L.)

C.K. RAJAGOPAL and A.K. SADANANDAN

ABSTRACT

The youngest matured and the next matured leaves of the lower one-third, the middle one-third and the upper one-third portions of 10 year old pepper vines growing in an alfisol were analysed for zinc and copper and the values related to the zinc-copper extractable by DTPA in the soil. Zinc and copper in the youngest matured leaf of the middle one-third portion of the vine was found to have the highest correlation with the soil available zinc ($r = 0.892^{**}$) and copper ($r = 0.766^{**}$) respectively, thus showing the possibility of using the youngest matured leaf as the indicator leaf of pepper for these nutrients.

INTRODUCTION

Early detection of nutritional disorders is very essential for proper crop husbandry of pepper. It has been established that the youngest matured leaf could be used as the Indicator Leaf of pepper for major plant nutrients (Waard, 1969). The present investigation is aimed at finding out the portion of the vine and the position of the leaf thereon, which could indicate correctly the status of zinc and copper in the soil.

MATERIALS AND METHODS

Ten year old Panniyur-I pepper vines trained on *Erythrina* standard in a homogenous tract in the District Agricultural Farm at Koothali (Calicut district, Kerala) where uniform physiological condition of the vines existed, were selected at random and used in this investigation. Soil sampling to a depth of 30 cm was done using aluminium soil samples at four spots around the vine 30 cm away the base of each vine (Anonymous, 1982). One composite sample was made from the four samplings. In this way 20 composite soil samples were collected from the base of the vines. The samples were dried under shade, sieved through a 2 mm plastic sieve and used for analysis.

Leaf samples (including petioles) were collected during the forenoon, from two positions of the lateral branches (designated as the youngest-matured and 'the next matured' leaf by Waard, 1969). The whole vine was divided into three portions covering the lower one-third, the middle one-third and the upper one-third of the vine. Leaves from the two positions, referred to above, collected from all the three portions of the vine. Eight leaves were sampled representing all the four sides of the vine and taken as one composite sample. Thus there were 120 leaf samples from 20 vines.

The soil was extracted with DTPA extractant in the ratio 1 : 2 (Lindsay and Norvell, 1969) and the contents of copper and zinc in the extract were determined using the Varian techtron atomic absorption spectrophotometer.

RESULTS AND DISCUSSION

The DTPA extractable zinc in the soil ranged between 0.9 ppm and 3.5 ppm and copper between 0.9 ppm and 6.3 ppm. As per the classification of Viets and Lindsay (1973) the zinc value ranked between marginal and high category whereas all the copper values were of the high category.

The high range of values for zinc and copper in the soil could be attributed to the effect of intensive spraying with zinc and copper, containing pesticides on the vines and the continuous drip into the soil of these pesticides, which resulted in the incorporation of these compounds into the organic and inorganic

colloids of the soil. The wide heterogeneity in the status of zinc and copper in the soil could be due to the undulating nature of the terrain, where, during rains, the dissolved chemicals got transported to the depressions in the land, thereby registering higher values for soils collected from such locations, compared to the soil taken from the other (elevated) locations. Such high values have been reported by Sim (1973) in Sarawak soils.

Table 1. Mean zinc and copper contents of pepper leaves in different portions of vine (values in parentheses denote the range)

Portion of vine	Zinc ppm		Copper ppm	
	Youngest matured leaf	Next matured leaf	Youngest matured leaf	Next matured leaf
Lower 1/3rd	43 (15-69)	45 (15-84)	77 (15-164)	83 (17-156)
Middle 1/3rd	55 (23-129)	52 (22-100)	61 (17-163)	78 (19-167)
Upper 1/3rd	53 (13-111)	55 (15-125)	87 (20-206)	85 (34-163)

The content of zinc in the leaf varied from 13 to 12 ppm, and copper from 15 to 206 ppm (Table 1). The highly abnormal values obtained in certain cases could be attributed to the high amount absorbed by the leaf through pesticide sprays and also absorption from the spots in the soil having a high level of zinc and copper.

Soil-plant nutrient relationship

Correlations worked out between soil zinc and copper and the corresponding leaf zinc and copper of the three different portions of vine for the two specific leaf portions are given in Table 2. The high correlations obtained in the case of both these elements establish the fact that the leaf content of zinc and copper is a very good reflection of the status of these elements in the soil. Statistical significance of a high order has been obtained in almost all cases. The greatest degree of correlation was obtained between soil zinc and copper and the contents of these in the youngest-matured leaf of the middle one-third por-

tion of the vine. ($r = 0.892^{**}$ and 0.766^{**} for zinc and copper respectively.)

Table 2. Simple correlation coefficiently between zinc and copper in soil and those in pepper leaf

Portion of vine	'r' value leaf Zn vs soil Zn		'r' value leaf Cu vs soil Cu	
	Youngest matured leaf	Next matured leaf	Youngest matured leaf	Next matured leaf
Lower 1/3rd	0.523**	0.592**	0.720**	0.635**
Middle 1/3rd	0.892**	0.600**	0.766**	0.570**
Upper 1/3rd	0.380	0.530**	0.588**	0.578**

**1 per cent level of significance.

*5 per cent level of significance.

The leaves in the upper one-third portion of the vine registered a lower degree of correlation for these elements. This is a clear indication that leaves in different portions of the vine are not similar in reflecting the status of soil nutrients and emphasise the necessity for pin pointing the specific leaf to be considered as the Indicator Leaf. The study has also revealed that as in the case of major nutrients, in micro-nutrients also the youngest matured leaf could be chosen as the Indicator Leaf for assessing soil zinc and copper levels.

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DISCUSSION

- Q : Have you studied the correlation between Cu and Zn levels in leaves with yield?
- Ans: Not in the present study.
- Q : You have attributed high values for soil Cu and Zn to the terrain. Have you any data to show that these nutrients were more in the soil collected from the depressions.
- Ans: The explanation given by me is based on observations.
- Q : Were the bushes (sprayed with uniform dose of pesticides containing the nutrients under study.
- Ans: No. The abnormal values are attributed to high amount of these pesticides absorbed by the leaves.

EFFECT OF N, P, K, Ca AND Mg ON LEAF NUTRIENT CONTENT AND YIELD OF YOUNG COCONUT

S. ROBERT CECIL

ABSTRACT

The effect of graded doses of nitrogen, phosphorus, potassium, calcium and magnesium on the yield, yield attributes and leaf nutrient concentration of young coconut palms of West coast Tall variety is presented hereunder. Application of all the nutrients except phosphorus increased the concentration of these nutrients in the leaf. However, the effects of nitrogen and potassium were significant only in the initial years. Applied phosphorus had only marginal influences on leaf phosphorus. Higher levels of nitrogen, phosphorus and potassium had no significant influence over the lower levels on the yield and yield attributes. The main effect of magnesium was significant on the yield and yield attributes. The direct and indirect effects of soil and leaf nutrient concentrations on the yield are also discussed.

INTRODUCTION

Foliar analysis has been considered as the most useful of all diagnostic aids for assessing the nutritional status of perennial plants (Bould, 1963; Goodall and Gregory, 1947; Smith, 1962). The practicability of using specific nutrient levels in the plant as indicators of the uptake pattern of nutrients and their consequent effects on growth and yield, has been widely established and has been found highly useful for studying the fertiliser responses of perennial crops (Bould, 1963; Hardy et al., 1935;

Chapman, 1941; Prevot and Ollagnier, 1954; Reuther et al., 1958; Ziller and Prevot, 1962). The present paper deals with the effect of application of graded levels of N, P, K, Ca and Mg on leaf nutrient concentrations and the yield of young coconut palms of the West coast Tall variety.

MATERIALS AND METHODS

The study was carried out in a field fertility experiment started in 1970 with newly planted West coast Tall seedlings on the experimental farm of CPCRI, Regional Station, Kayangulam. The soil is loamy sand (Entisol) developed from marine alluvium (Sankaranarayanan and Verghese, 1961) pale brown to light yellowish brown, very deep and well drained, and the area has nearly level to flat topography.

The design of the experiment was in a split plot, where the main plot treatments were combinations of three levels of N, P and K in a 33 confounded factorial arrangement confounding NP^2K^2 , and sub-plot treatments were factorial combinations of two levels of Ca and Mg with single replication. The main plot consisted of 24 palms and the sub-plot six palms.

Three levels each of nitrogen (500, 750 and 1000 g N), phosphorus (300, 450 and 600 g P_2O_5) and potassium (1000, 1500 and 2000 g K_2O) and two levels each of calcium (Zero and lime requirement) and magnesium (0 and 500 g MgO) were applied per palm per year. The young palms were fertilised at the rate of one-third adult palm dose in the first year after planting, two-third in the second year and the full dose in the third year and onwards. The nutrients were given in the form of amorphous (16 : 20) plus urea for N and P, muriate of potash for K, slaked lime for Ca and magnesium sulphate (hydrated) for Mg. The annual dose of NPK and Mg fertilisers was applied by broadcasting in circular basins of the palms in two splits, one-third in April and May (pre-monsoon) and two-thirds in August and September (post-monsoon) every year. The lime requirement of the soil was estimated (Shoemaker et al., 1961) and the quantity of lime required to maintain the pH of 0-50 cm layer of soil around 6.5 was broadcast uniformly over the entire sub-plot area including the palm basins during June and ploughed in. A basal application of 50 kg well rotten cattle manure was

given to all the experimental palms during August every year since 1973.

Composite leaf samples representing each sub-plot were collected and prepared by standard methods (Anonymous, 1961; Prevot and Bachy, 1962) during the month of March before the application of the first dose of fertilisers. Nitrogen was estimated by the modified Kjeldahl method (Jackson, 1973). Wet oxidation of the leaf tissues by triacid mixture was employed for estimating P, K, Ca and Mg. Phosphorus was estimated by the vanadomolybdic phosphoric yellow colour method described by Jackson (1973). Potassium was estimated flame photometrically, and Ca and Mg by the versene titration method (Jackson, 1973). Sulphur was extracted by wet oxidation with 2:1 HNO₃-HClO₄ diacid mixture and was estimated by the turbidimetric method described by Jackson (1973). The yield of nuts was recorded during harvests. Female flower production was recorded by counting the number of nuts and the number of scars of shed flowers in the harvested bunches.

RESULTS AND DISCUSSION

Leaf nutrient levels

The main effects of treatments on foliar nutrient levels are presented in Tables 1 to 4.

1) *Nitrogen*: Increased rates of N application had increased the leaf N levels, but the increase was significant only up to the fifth year. Even at the first treatment level of N, the palm had been able to maintain an adequate N nutrition as evidenced by the foliar N values in comparison with the critical level of 1.8 to 2.0 per cent reported by different workers (Fremond et al., 1966; Smith, 1968; Kanapathy, 1971; Magat, 1979; Manciot et al., 1979). These results support the present recommendation of 500 g N per adult palm per year. The influence Ca (liming) was invariably positive and the effect was significant in all the years except in 1977. This might be due to the influence of Ca on pH and other soil factors for better absorption of the added nitrogen by the palm (Cecil, 1981).

2) *Phosphorus*: Increased rates of P application had increased the foliar P levels but not to a significant level. Treatment with Ca improved the P content while that with Mg showed the maxi-

Table 1. Main effects of treatments on foliar nutrient levels (in per cent dry matter) of young West coast Tall Palms

Year of sampling : 1973 (3rd year)

FronD number : 4

Nutrients level	Nutrient content in per cent					
	N	P	K	Ca	Mg	S
N1	1.94	0.162	1.68	0.373	0.146	0.149
N2	1.99*	0.163	1.70	0.373	0.140	0.146
N3	1.96	0.165	1.70	0.379	0.159	0.146
P1	1.95	0.164	1.66	0.383	0.146	0.140
P2	1.95	0.160	1.69	0.371	0.150	0.150
P3	1.99*	0.166	1.73	0.371	0.149	0.151
K1	1.97	0.165	1.64	0.383	0.154	0.158
K2	1.99*	0.166	1.67	0.381	0.149	0.146
K3	1.93	0.159	1.76	0.361	0.141	0.137
C.D (P=0.05)	0.03	NS	NS	NS	NS	NS
Cao	1.93	0.163	1.70	0.364	0.149	0.146
Ca1	2.00**	0.164	1.69	0.386**	0.148	0.148
Mgo	1.95	0.159	1.72	0.387	0.118	0.137
Mg1	1.98	0.167**	1.66**	0.362**	0.179**	0.157**
C.D (P=0.05)	0.03	0.002	0.04	0.011	0.011	0.007
General mean	1.96	0.163	1.69	0.375	0.148	0.147

* Significant at 5 per cent level.

** Significant at 1 per cent level.

NS = Not significant.

Table 2. Main effects of treatments on foliar nutrient levels (in per cent dry matter) of young West coast Tall Palms

Year of sampling : 1975 (5th year)

FronD number : 9

Nutrients level	Nutrient content in per cent					
	N	P	K	Ca	Mg	S
N1	1.95	0.192	1.90	0.389	0.185	0.142
N2	1.99	0.194	1.85	0.387	0.192	0.142
N3	2.02*	0.194	1.82	0.373*	0.191	0.141
P1	1.99	0.188	1.84	0.384	0.202	0.140
P2	2.00	0.195	1.84	0.369	0.194	0.138
P3	1.97	0.196	1.90	0.396	0.171**	0.146
K1	1.99	0.195	1.81	0.379	0.193	0.142
K2	2.01	0.191	1.87	0.384	0.193	0.137
K3	1.96	0.192	1.90*	0.386	0.182	0.145
C.D (P=0.05)	0.06	NS	0.08	0.014	0.019	NS
Cao	1.97	0.192	1.86	0.355	0.185	0.144
Ca1	2.01*	0.194	1.85	0.411**	0.194*	0.139
Mgo	1.98	0.189	1.86	0.379	0.167	0.137
Mg1	1.99	0.197**	1.86	0.387	0.212**	0.146
C.D (P=0.05)	0.04	0.006	NS	0.011	0.008	NS
General mean	1.99	0.193	1.86	0.383	0.189	0.142

* Significant at 5 per cent level.

** Significant at 1 per cent level.

NS = Not significant.

Table 3. Main effects of treatments on foliar nutrient levels (in per cent dry matter) of young West coast Tall Palms

Year of sampling : 1977 (7th year)
 Frond number : 14

Nutrients level	Nutrient content in per cent					
	N	P	K	Ca	Mg	S
N1	1.97	0.254	2.29	0.399	0.202	0.228
N2	1.97	0.251	2.21	0.400	0.194	0.226
N3	1.99	0.256	2.23	0.393	0.201	0.223
P1	1.98	0.253	2.20	0.396	0.192	0.227
P2	1.95	0.253	2.23	0.397	0.198	0.220
P3	2.00	0.253	0.230	0.400	0.208	0.231
K1	1.93	0.252	2.18	0.382	0.193	0.231
K2	1.97	0.260	2.25	0.407	0.207	0.221
K3	2.02	0.249	2.30	0.404	0.196	0.225
C.D (P=0.05)	NS	NS	NS	NS	NS	NS
Cao	1.97	0.253	2.23	0.367	0.195	0.227
Ca1	1.98	0.254	2.26	0.429**	0.203	0.223
Mgo	1.98	0.243	2.21	0.407	0.179	0.222
Mg1	1.97	0.263**	2.28	0.389	0.217**	0.230
C.D (P=0.05)	NS	0.011	NS	0.019	0.015	NS
General mean	1.97	0.253	2.24	0.398	0.199	0.226

* Significant at 5 per cent level.

** Significant at 1 per cent level.

NS = Not significant.

Table 4. Main effects of treatments on foliar nutrient levels (in per cent dry matter) of young West coast Tall Palms

Year of sampling : 1979 (9th year)

FronD number : 14

Nutrients level	Nutrient content in per cent					
	N	P	K	Ca	Mg	S
N1	1.94	0.214	2.14	0.384	0.206	0.219
N2	1.96	0.224	2.07	0.381	0.195	0.227
N3	2.00	0.222	2.06	0.373	0.202	0.213
P1	1.96	0.214	2.08	0.377	0.204	0.210
P2	1.96	0.222	2.13	0.385	0.201	0.222
P3	1.98	0.223	2.07	0.376	0.198	0.228
K1	1.97	0.217	1.99	0.390	0.195	0.219
K2	1.97	0.218	2.11	0.381	0.211	0.220
K3	1.95	0.224	2.17	0.366	0.197	0.220
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS
Ca ₀	1.91	0.216	2.09	0.350	0.194	0.219
Ca ₁	2.02**	0.224	2.09	0.408**	0.208**	0.220
Mg ₀	1.97	0.210	2.07	0.382	0.177	0.212
Mg ₁	1.96	0.230**	2.11	0.376	0.225**	0.228*
C.D. (P=0.05)	0.05	0.011	NS	0.016	0.009	0.012
General mean	1.97	0.220	2.09	0.379	0.201	0.220

* Significant at 5 per cent level.

** Significant at 1 per cent level.

NS = Not significant.

num increase throughout the period. The interaction between P and Mg was positive and the effect was pronounced at higher levels of P.

P-Mg interaction on foliar P in 1973

	P1	P2	P3	Mean
Mg ₀	0.162	0.156	0.160	0.159
Mg ₁	0.166	0.163	0.172	0.167**
Mean	0.164	0.160	0.166	0.163

*C.D (P = 0.05) for two Mg means at the same level of P = 0.004 at the same level of P = 0.004 C.D (P = 0.05) for two P means at the same or different levels of Mg = 0.007.

The foliar P levels were not significantly correlated with available soil P, but they were positively correlated (Cecil, 1981) with the exchangeable Mg in soil in 1977 ($r = 0.237^*$) and 1979 ($r = 0.269^{**}$). There was also a strong positive correlation between leaf P and Mg contents in 1973 ($r = 0.346^{**}$), 1977 ($r = 0.194^*$) and 1979 ($r = 0.363^{**}$).

Smith (1968) observed similar improvement of leaf P by Mg treatment. De Silva et al. (1973) reported that translocation of P from root to shoot was adversely effected when the supply of Mg was low. It is well known that Mg plays an important role as a 'carrier' in the transport of P in plants (Jacob, 1958).

The effect of P on yield increases in coconut, was not very common, and the effect was visible only after the continued application of P for longer periods (Menon and Pandalai, 1958; Smith, 1968; Child, 1974; Rosenquist, 1980). The results of Manciot et al., 1979 generally show that only when the foliar P levels were below 0.12 per cent response to P treatments on yield was significant. In a field fertility experiment at CPCRI, Kasaragod, on sandy loam soil, the skipping of P application continuously for a period of five years did not affect adversely the yield or leaf P status even though the available soil P was reduced from a level of 90 ppm to 62 ppm, but the foliar P levels were well above the critical level (Anonymous, 1981).

It is evident from Tables 1 to 4 that the P contents were well above the critical level in all the years even at the first treat-

Table 5. Main effects of treatments on initial yields and yield attributes of young West coast Tall Palms

Nutrient level	No. of bunches per palm						No. of female flowers/bunch						Nut set (per cent)						No. of nuts per palm						
	up to Dec. '77		in '78		in '79		up to Dec. '77		in '78		in '79		up to Dec. '77		in '78		in '79		up to Dec. '77		in '78		in '79		
	2	3	4	5	6	7	8	9	10	11	12	13	2	3	4	5	6	7	8	9	10	11	12	13	
1	3.7	7.9	9.5	10.6	21.4	23.3	24.2	23.0	22.2	13.8	41.04	48.0	4.5	8.8	10.1	10.5	19.9	24.1*	25.5	23.1	21.9	17.8	41.5	51.2	
N1	4.3	8.2	10.0	10.4	17.4	21.1	26.7	23.8	23.4	18.7	36.3	49.0	4.1	8.5	10.1	10.2	19.8	22.9	28.0	22.4	21.9	15.5	40.0	47.5	
P1	4.9	8.7	10.0	11.7	19.4	23.9	27.2	24.3	24.4	22.3	43.1	56.8	3.5	7.7	9.5	9.6	19.3	21.8	21.2*	23.2	21.3	12.4	35.6	43.9	
P2	4.0	7.9	9.7	10.1	19.2	20.1	27.9	25.3	24.2	17.6	39.8	47.2	4.4	8.9	10.5	10.8	19.5	24.7*	22.7	22.0	21.3	17.7	40.4	52.2	
P3	4.1	8.1	9.4	10.6	19.8	23.7*	25.7	22.6	22.1	14.9	38.5	48.8	K1	NS	NS	NS	NS	NS	2.8	6.8	NS	NS	NS	NS	NS
K2	3.8	8.0	9.5	9.4	19.4	21.7	26.7	22.6	22.6	14.9	36.2	46.0	K3	4.5	8.6	10.2	11.6	19.7	24.0	24.2	24.1	22.5	18.6	43.0	52.7
K3	2.5	6.6	8.9	8.9	18.3	21.7	19.4	21.8	22.5	9.5	27.8	41.7	C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Cao	3.8	8.0	9.5	9.4	19.4	21.7	26.7	22.6	22.6	14.9	36.2	46.0	Ca1	4.5	8.6	10.2	11.6	19.7	24.0	24.2	24.1	22.5	18.6	43.0	52.7
Mgo	2.5	6.6	8.9	8.9	18.3	21.7	19.4	21.8	22.5	9.5	27.8	41.7													

(Contd.)

Table 5. Continued

	1	2	3	4	5	6	7	8	9	10	11	12	13
MgI		5.8**	9.9**	10.8**	12.1*	20.8	24.0	31.5**	24.8	22.5	24.0**	51.4**	57.1**
C.D (P=0.05)	1.2	1.1	0.8	2.5	NS	NS	NS	5.8	NS	NS	6.1	8.1	7.4
General Mean	4.2	8.3	9.9	10.5	19.5	22.8	25.5	23.3	22.5	16.8	39.6	49.4	

* Significant at 5 per cent level.

** Significant at 1 per cent level.

NS = Not significant.

ment level of 300 g P₂O₅ per palm per year. There was no significant response to higher levels of P on growth and on onset of bearing (Cecil, 1981) or on initial yields (Table 6). In view of this high leaf P levels, the rate of P fertilisation to coconut needs to be regulated based on leaf P levels and growth/yield responses.

3) *Potassium*: Higher levels of K had improved the leaf K levels, but the increase was significant only in the early years of growth. Correlation analysis (Cecil, 1981) showed that there was a significant correlation between leaf K and soil K in 1973 ($r = 0.368^{***}$), but in 1977 and 1979 the correlations were not significant. The K levels observed in the present study were well above the critical level of 0.8-1.0 per cent (Manciot et al., 1979) even at the first treatment level of 1000 g K₂O per palm per year, and there was no significant response on growth (Cecil, 1981), or, initial yields to higher levels of K. Treatment with K fertilisers, particularly on soils poor in K, had increased the leaf K levels and there was a spectacular increase in yield of nuts as well as copra per nut (Menon and Pandalai, 1958; Kanapathy, 1971; Child, 1974; Magat, 1976; Manciot et al., 1979). The present results show that the continued use of K fertilisers for the first few years had built up a sufficient leaf content even at the first treatment level. Prolonged use of K fertilisers, particularly at high rates, had been reported to induce Mg deficiency conditions in the palm (Child, 1974; Manciot et al., 1979; Cecil, 1981). As in the case of P, the K fertilisation also needs to be regulated based on foliar K levels and growth yield responses as suggested by Magat (1979).

4) *Calcium*: An addition of Ca increased leaf Ca at a significant level in all the years while Mg had a depressive effect. Even in the absence of Ca treatment, the Ca levels in frond nine and 14 were comparable to the critical level of 0.3 to 0.4 per cent as suggested by Manciot et al. (1979) while Magat (1979) suggested 0.3 per cent Ca as critical for the tall variety. The mean leaf Ca in the absence of Ca treatment ranged from 0.35 to 0.367 per cent. Values as high as 0.43 were observed with Ca treatment. Even though the Ca treatment increased foliar Ca and improved some of the growth factors of these young palms (Cecil, 1981), they were not correlated with growth and the onset of varying or initial yield. This suggests that the increased

Table 6. Main effects of treatments on yield of newly planted West coast Tall Palms
(Date of planting : October, 1970)

Nutrient level	Number of nuts per palm harvested							
	up to Dec. '77	in 1978 (8th yr)	in 1979 (9th yr)	in 1980 (10th yr)	in 1981 (11th yr)	in 1982 (12th yr)	Total up to Dec. '82	
1	2	3	4	5	6	7	8	
N1	13.8	41.0	48.0	44.5	61.9	53.1	262.3	
N2	17.8	41.5	51.2	46.5	68.7	53.0	278.7	
N3	18.7	36.3	49.0	43.6	58.0	50.3	255.9	
P1	15.5	40.0	47.5	42.8	61.2	52.8	259.8	
P1	22.3	43.1	56.8	48.6	70.8	56.3	297.6	
P3	12.4	35.6	43.9	43.2	56.7	47.3	238.8	
K1	17.6	39.8	47.2	42.5	59.1	53.0	259.3	
K2	17.7	40.4	52.2	44.5	65.1	52.4	272.3	
K3	14.9	38.5	48.8	47.6	54.5	51.0	265.3	
C.D (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Cao	14.9	36.2	46.0	41.2	59.9	50.3	248.5	
CaI	18.6	43.0	52.7	48.5*	65.9	54.0	282.7	
Mgo	9.5	27.8	41.7	38.2	56.6	46.6	220.4	(Contd.)

EFFECT OF N, P, K, Ca AND Mg

	1	2	3	4	5	6	7	8
MgI		24.0**	51.4**	57.1**	51.5**	69.2**	57.6**	310.8
C.D (P=0.05)		6.1	8.1	7.4	6.7	8.2	8.0	—
General mean		16.8	39.6	49.4	44.8	62.9	52.1	265.6
Percentage response of MgI over Mgo		152.6	84.9	36.9	34.8	22.4	23.6	41.0

* Significant at 5 per cent level.

** Significant at 1 per cent level.

NS=Not significant.

leaf Ca contents had not been a function of growth or initial yields. The good effects obtained by Ca treatment appear to be indirect and not of its own improvement in the foliar status.

Instances of Ca deficiency in coconut were rarely reported. Manciot et al. (1979) reported an instance in Malayan yellow Dwarfs in the Ivory Coast when the leaf Ca levels were below 0.10 per cent. They suggested that no improvement on growth or yield could be expected from calcic fertiliser application when the leaf Ca levels were sufficient. The present data agree with the critical level of 0.30 per cent in frond 14 suggested by Magat (1979) and this may be followed under West coast conditions for tall variety. The data also suggest that heavy liming, as had been done in the present trial, is not necessary for the management of the palm. Nevertheless, regulated addition of Ca through Ca bearing fertilisers like rock phosphate/superphosphate, or light additions of liming materials may be followed for supplying the Ca requirement of the palm.

5) *Magnesium*: Levels of N, P and K had no consistent influence on leaf Mg content. Addition of Ca had increased, but the effect of Mg was highly significant in all the years. The Ca Mg interaction was also positive and this had been very much reflected on growth, onset of bearing and initial yields of these young palms (Cecil, 1981).

Ca-Mg interaction on foliar Mg in 1975

	Ca ₀	Ca ₁	Mean
Mg ₀	0.167	0.167	0.167
Mg ₁	0.203	0.221	0.212**
Mean	0.185	0.194*	0.189

C.D. (P=0.05) for Ca Mg = 0.012.

The results of Nair Achuthan and Sreedharan (1983) show that in a similar trial with oil palm, the main effect of Ca was more than that of Mg in improving the leaf Mg content. It appears that the positive responses obtained by Ca treatment might be due to its indirect effect by improving foliar Mg levels.

Correlation analysis showed that among the major nutrients, only leaf Mg contents were significantly correlated with initial

yields and yield attributes (Table 7). Leaf Mg contents were highly correlated with all the growth characters of these young palms in 1973, 1977 and 1979 (Cecil, 1981). The number of palms flowered at 74 months (Dec. 1976) was significantly correlated ($r=0.238^*$) with only foliar Mg levels. The foliar Mg levels were positively correlated with soil Mg in 1973 ($r=0.213^*$), 1977 ($r=0.373^{***}$) and 1979 ($r=0.544^{***}$) and the correlation was strengthened by continued treatment (Cecil, 1981).

The leaf Mg levels in the absence of Mg treatment were less than 0.20 per cent and the palms showed characteristic Mg deficiency symptoms with reduction in growth, and these values could be considered to be in the deficiency level, particularly when K was present at a higher level. Treatment with Mg had brought about highly significant increases in leaf Mg contents and simultaneous improvements in all growth factors which ultimately resulted in a significant reduction in the pre-bearing age (Cecil, 1981) and a highly significant increase in initial yields and yield attributes (Tables 5 and 6). Further the leaf Mg levels in frond nine and 14 were above 0.20 per cent which is considered as the critical level of Mg for tall variety (Magat, 1979).

The data show that, among the major nutrients, Mg was found to be limiting in the experimental area. Judicious manuring with Mg salts like magnesium sulphate from the time of planting in the main field was found to be highly beneficial for the successful growth and higher productivity of the palm. A level of 500 g Mg (3.0 kg magnesium sulphate) per adult palm per year is found to be a satisfactory dose for areas with agroclimatic conditions comparable to those of the experimental area. However, the dose may be regulated based on the extent of limitation in the availability of Mg in the soil. The foliar concentration of 0.20 per cent Mg in frond 14 may be considered as critical for regulating the Mg status of the palm.

6) *Sulphur*: Sulphur did not form a treatment in the present trial, but when P and Mg were supplied in the form of Factamfos (15 per cent) and magnesium sulphate (13 per cent S) respectively, sulphur was added incidentally to the palm. Higher levels of P showed some improvement while Mg treatment increased the S content significantly. Manciot et al. (1980) reported similar improvement of sulphur due to Mg additions in the form of *kieserite*. Sulphur was not found to be limiting in the present trail as it

Table 7. Correlation of leaf nutrient contents with yield and yield attributes in 1979

Nutrients level	No. of bunches per palm	No. of female flowers per bunch	No. of nuts per bunch	Nut set (per cent)	Weight of copra per nut	No. of nuts per palm
N	0.142	-0.088	-	0.024	-0.030	0.001
P	0.030	0.062	0.127	0.044	-0.020	0.123
K	-0.019	-0.022	0.084	0.064	0.023	0.097
Ca	-0.048	0.057	0.121	0.093	0.080	0.071
Mg	0.230*	0.276**	0.247**	-0.094	0.055	0.282**

(d.f = 107).

* Significant at 5 per cent level.

** Significant at 1 per cent level.

was not correlated with growth (Cecil, 1981) or initial yield and yield attributes (Table 7). According to Cecil and Pillai (1976) sulphur deficiency does not seem to be an immediate problem for coconuts in the west coast of Kerala, and they suggest the inclusion of any one of the S-bearing fertilisers in the fertiliser schedule for coconut as a preventive measure. The present data show that, even without magnesium sulphate treatment, the S content in frond 14 had reached to a level of 0.22 per cent by the continued application of a S-bearing phosphatic source which is more than the critical level of 0.15 to 0.20 per cent S (Manciot et al., 1980). These data show that the sulphur nutrition of the palm can be incidentally taken care of if any of the S-bearing fertiliser is used for fertilising the palm.

Yield and yield attributes

The main effects of treatments on yield and yield attributes recorded up to December 1979 are given in Table 5 and those on the yield of nuts up to December 1982 are given in Table 6. The correlation of leaf nutrients with yield and yield attributes is given in Table 7. The results show that higher levels of N, P and K had no significant response over the first on yield and yield attributes. Reviewing the mineral nutrition and fertilisation of coconut around the world, Manciot et al. (1979, 1980) reported highly significant increases in the yield of nuts/tree, copra/nut and copra/tree due to N, P and K fertilisation when the availability of these nutrients was not sufficient for optimum production.

Addition of Ca had been giving positive responses on yield and yield attributes, but the effects were not significant except the yield of nuts in 1980. Among the treatments, only the main effect of Mg showed significant and consistent influence on initial yields and yield attributes. The increased yield was mainly due to the production of a higher number of bunches per palm. Since Mg treatment favoured early growth and early flowering (Cecil, 1981) of these young palms, the response on nut yield in the early period was more compared to subsequent years. Similar yield response by Mg was reported by Manciot et al. (1979). The cumulative yield of nuts up to 1982 (Table 6) shows that the initial yield of nuts was increased by about 40 per cent by systematic treatment with magnesium sulphate right

from the time of planting in the main field.

Correlation analysis showed that only soil and leaf Mg contents were significantly correlated with yield in 1979. Path analysis was carried out (Cecil, 1981) with nutrient content as independent characters (causes) and yield as the dependent characters (effect). It was found that the path coefficient of exchangeable Mg content of soil on yield was 0.274 when the correlation coefficient (r) between exchangeable Mg and yield was 0.240**. Similarly the path coefficient of foliar Mg content on yield was 0.265 when the correlation coefficient was 0.282***. The magnitude of the path coefficients and correlation coefficients between soil and foliar Mg levels on the one hand and yield on the other were found to be nearly equal. This observation further emphasises the direct contribution of Mg in enhancing the nut yield.

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DISCUSSION

Q : You found that there is no response for N, P and K. Based on this can we conclude that application of these nutrients is not needed for coconut palms?

Ans: Increasing of doses of these nutrients beyond the lowest dose tried may not be beneficial.

Q : Can you attribute the response to Mg to that nutrient alone since sulphur was also added along with Mg?

Ans: In this study, the effects of sulphur and Mg are confounded.

OPTIMUM N AND K LEVELS AND THEIR RATIOS FOR ACHIEVING HIGH PRODUCTIVITY IN YOUNG TEA

S. NATESAN, N. PALANI and V. RANGANATHAN

ABSTRACT

Results of the investigation carried out with three N levels (N_1 , $N_{1.5}$ and N_2) and three N : K_2O ratios (4 : 3, 4 : 4, 4 : 6) on young tea up to first (formative) prune for optimising N level and N : K_2O ratio in order to develop healthy bushes with sound frames and to achieve maximum productivity showed significant response to N and K. The interaction of N level and N : K_2O ratio on tea yield was significant at 5 per cent probability level. At all the three N levels, the highest productivity was observed only at 4 : 6 N : K_2O ratio. About 2 to 2.5 more tea per ha was harvested over the cycle at 4 : 6 N : K_2O ratio than at 4.3 N : K_2O . Not only the highest productivity was achieved at 4 : 6 N : K_2O ratio but also the overall health and vigour of the young tea, as assessed from collar diameter and dry matter content of prunings, improved significantly. An overall analysis of the yield data and the growth parameters showed that N level at or around 120 to 300/Kg N/ha/year (increasing with age from planting) and N : K_2O ratio of 4 : 6 (2 : 3) at least up to the fourth year from planting, and 1 : 1 thereafter appeared to be optimum for young tea for achieving high productivity as well as for better frame development.

INTRODUCTION

Tea, *Camellia sinensis* (L) O. Kuntze, being a perennial crop, its establishment and development in the initial years is vital for

yield exploitation in the subsequent years. Presently, tea is propagated vegetatively and grown in a nursery for 12 to 15 months before transplanting. After planting in the field, attempts are made to develop a rapid spread and early cover. The young plants in the field up to first prune (formative pruning), which take about five years (first cycle), are called young tea. The crop that could be harvested during the first and the subsequent cycles is greatly dependent on the health and vigour of the young tea. Though attaining high yield alone is not the main criterion for young tea, the development of a healthy young bush with sound frames is a prerequisite for achieving high yields in the subsequent cycles. Hence, all agronomic and cultural practices including manuring of young tea are aimed at developing healthy bushes with good frames and to bring the plants to bearing by the earliest.

Manuring with major nutrients, especially N and K fertilisers plays a major role in achieving the above objective. Earlier, NPK mixtures of N:P₂O₅:K₂O ratios 1:2:2 or 1:2:3 (de Jong, 1957) or 4:3:3 (Ranganathan, 1973 a; 1976 a) with N levels varying between 96 and 192 kg/ha/year have been recommended for young tea. The rates were decided on consideration other than yield and immediate cost/benefit ratio (Ranganathan, 1976b). However, recently, the accent is not only on achieving the above objective of developing healthy young bushes with good frames but also on attaining high productivity in young tea by optimising the applied nutrient levels and their ratios. Studies made in this direction for finding optimum N and K levels and their ratios for achieving high productivity in young tea are discussed in this paper.

MATERIALS AND METHODS

The experiment was carried out during 1977 to 1982 in a young clonal tea, UPASI-3 (R/5/63), planted (double hedge triangular planting: 1.50 × 0.75 × 0.75 m) in July 1977 in the UPASI Tea Research Institute experimental farm at Cinchona, Anamallais. The experiment was conducted in four randomised blocks with a plot size of 35 bushes with three main treatments of nitrogen levels (N₁, N_{1.5} and N₂) and three sub-treatments of N:K₂O ratios

(4 : 3, 4 : 4 and 4 : 6). The above N : K₂O ratios to sub-treatments were adopted only up to the fourth year from planting, and at the fifth year, only one N : K₂O ratio of 1 : 1 (or 4 : 4) was adopted to all the sub-treatments at all the three levels of N, in order to determine the effect of different N : K₂O ratios adopted up to the fourth year on the fifth year's crop.

The treatments were imposed two months after planting and continued up to the first prune (called formative pruning) in August 1982. N and K fertilisers, as per the treatments, were applied together by broadcasting and dibbling in method in as many splits as possible; three to four splits during post-monsoon and winter seasons (end August to early December) and two to three applications during the pre-monsoon season (April to June). Details on the levels of N applied during the various years, number of splits of NK applications and of pluckings, and average yield are given in Table 1. During the first three years, ammonium sulphate was the source of N for all the splits, and later on ammonium sulphate, urea and calcium ammonium nitrate were used as sources of N for pre-monsoon, post-monsoon and winter applications respectively.

Phosphorus fertiliser as rock phosphate was applied at the rate of 80 kg P₂O₅/ha once a year by placement method at a depth of 15 to 25 cm using a crowbar, (Ranganathan and Natesan, 1983). All other cultural and plant protection operations were carried out as per the recommendations of the department.

The field was brought under plucking only from the second year of planting. Observations on yield at every harvest, and the collar diameter at the base of the plant were recorded once a year. The data were analysed statistically. At the time of formative pruning, the bushes were pruned hard at 35 cm from ground level and the prunings of four bushes in each plot were collected, separated into foliage, branchlets and twigs (less than pencil thick) and wood (more than pencil thick). The dry matter content of each fraction was determined.

RESULTS AND DISCUSSION

The statistical analysis of the yield data showed that the levels of N, N : K₂O ratios (that is, K levels) and their interaction are significant. The individual and interaction effects as discussed for

Table 1. Levels of N applied to young tea during the first cycle (kg N/ha)

Clone : UPASI-3 (B/5/63) Soil : Latosol
 Planted : July 1977 pF : 4.8 - 5.0
 Location : Anamallais Organic matter : 3.4%
 Altitude : 1165 m above MSL

N level	1st year		2nd year		3rd year		4th year		5th year*		Total for the cycle 1977/1982
	Aug 77- July 78	Aug 78- July 79	Aug 78- July 79	Aug 79- July 80	Aug 79- July 80	Aug 80- July 81	Aug 80- July 81	Aug 81- Aug 82	Aug 81- Aug 82		
N _{1.0}	80	150	150	175.0	175.0	200	200	125.0	125.0	730	
N _{1.5}	120	225	225	262.5	262.5	300	300	187.5	187.5	1095	
N _{2.0}	160	300	300	350.0	350.0	400	400	250.0	250.0	1460	
NK applications, no.	5	5	5	7	7	7	7	5	5	29	
Pluckings, no.	—	23	23	45	45	44	44	42	42	154	
Average yield (kg made tea ha ⁻¹)	—	259	259	1312	1312	2903	2903	3113	3113	7587	

* Field was pruned in end August 1982.

optimising the N and K levels and their ratios for achieving high productivity in young tea.

Response of young tea to N

Nitrogen is the most important nutrient for tea and is absorbed by the plant in large quantities (Ranganathan, 1973b; Venkata Ram, 1980; Willson, 1975a). The effect of different N levels on the productivity of young tea over the various years is given in Table 2. The response by way of increase in crop due to N application at $N_{1.5}$ or N_2 level over N_1 level is statistically significant in three out of four years of harvesting. Overall for the cycle, the crop increase over N_1 level is 4.7 per cent at $N_{1.5}$ level and 4.2 per cent at N_2 level, both are significant at $P = 0.05$. However, no significant difference in yield is observed between $N_{1.5}$ and N_2 level.

Table 2. Effect of N level on productivity (kg made tea/ha) of young tea

N level	2nd year	3rd year	4th year	5th year	Total for the cycle	
					kg/ha	per cent
$N_{1.0}$	246	1320	2785	3018	7369	100.0
$N_{1.5}$	265	1312	2946	3189	7712	104.7
$N_{2.0}$	263	1305	2979	3132	7679	104.2
SE	8	NS	31	9	127	1.7
CD at $P = 0.05$	17	NS	74	17	248	3.4

Response of young tea to K

Next to nitrogen, potassium is taken up by the tea plant in large quantities, and is essential for the formation of sound and healthy frames (Ranganathan, 1970, 1973b, 1982; Willson 1975b). The levels of K applied (or N : K_2O ratios adopted) and the crop harvested in different years are given in Table 3. Generally, increase in K level has resulted in increase in productivity; the increase is significant in all the years of cropping. Overall for the cycle, adoption of 4:4 and 4:6 N : K_2O ratios has increased the crop by 26.8 and 36.4 per cent over the crop obtained due to adoption of 4:3 N : K_2O ratio; which are significant at 1 per cent

Table 3. Levels of K applied and effect of K level (N : K₂O ratio) on productivity (kg made tea/ha) of young tea

K level (N : K ₂ O ratio)	1st year	2nd year	3rd year	4th year	5th year*	Total for the cycle**
<i>K₂O applied, kg ha⁻¹</i>						
K ₁ (4:3)	90	169	197.0	225	187.5	868.5
K ₂ (4:4)	120	225	262.5	300	187.5	1095.0
K ₃ (4:6)	180	338	394.0	450	187.5	1549.5
<i>Made tea kg ha⁻¹</i>						
K ₁ (4:3)	—	187	1091	2330	2659	6267 (100.0)
K ₂ (4:4)	—	287	1413	3050	3194	7944 (126.8)
K ₃ (4:6)	—	300	1433	3331	3486	8550 (136.4)
SE	—	13	40	58	13	194 (3.1)
CD at P = 0.05	—	25	79	113	26	379 (6.3)
CD at P = 0.01	—	33	103	149	33	500 (8.0)

*During this year, K level was constant (N : K₂O ratio of 1 : 1 or 4 : 4) for all the sub-treatments.

** Values in parentheses denote per cent yield.

probability level. Although, the yield increase due to K application at the N : K₂O ratio of 4 : 6 over 4 : 4 is not significant in the second and the third year, its (adoption of 4 : 6 N : K₂O ratio) impact on the subsequent year's crop as well as on the cycle yield is large and significant at 1 per cent probability level. During the fifth year, even though the levels of K applied, as well as N : K₂O ratios adopted, are constant (1 : 1 or 4 : 4), the tea yields corresponding to K₁, K₂ and K₃ treatments show significant difference among themselves. This reveals that the effect of adoption of higher N : K₂O ratios in the previous years persist on the fifth year's crop also, thus stressing the importance of high K (or more precisely the N : K₂O ratio) application in the early years of young tea establishment.

Interaction of N level and N : K₂O ratio on tea yield

In all the four years of cropping, the young tea has shown significant interaction of N level and N : K₂O ratio on tea yield (Table 4). In the second year, increasing nitrogen beyond N₁ level (150 kg N/ha) has not resulted in any significant increase in crop in the three N : K₂O ratios adopted. However, increasing the N : K₂O ratio from 4 : 3 to 4 : 4 significantly increased the crop which ranges between 50.8 per cent at N₁ level and 68.5 per cent at N₂ level. Further increase in the N : K₂O ratio from 4 : 4 to 4 : 6 increased the crop marginally; however, the increase is not statistically significant. During the third year, at low N : K₂O ratio, increasing N increased the crop significantly, whereas at higher N : K₂O ratio (4 : 6) it decreased the crop. The plots receiving nitrogen at N₁ level (175 kg N/ha) and at N : K₂O ratio of 4 : 6 produced the highest yield during the third year. In the fourth year increasing N significantly increases the crop at 4 : 3 and 4 : 4 N : K₂O ratios, whereas there is no significant difference in yield at 4 : 6 N : K₂O ratio. It is also shown that at 4 : 3 N : K₂O ratio, the maximum response is observed at N₂ level (400 kg N/ha), whereas at 4 : 4 and 4 : 6 N : K₂O ratios the maximum responses to N are observed at N_{1.5} (300 kg N/ha) and N₁ (200 kg N/ha) levels respectively. This indicates that the applied N is efficiently utilised by the young tea at high K levels as in the case of mature tea, especially in the pruned year (Ranganathan, 1973b; Natesan et al., 1982). During the fifth year, even though the N : K₂O ratios adopted is constant (1 : 1) to all the sub-treatments there is significant difference in yield

Table 4. Interaction of N level and N : K₂O ratio on young tea yield (kg made tea/ha) for different years

N level	2nd year		3rd year		4th year		5th year*													
	N : K ₂ O ratio	Yield (kg)	N : K ₂ O ratio	Yield (kg)	N : K ₂ O ratio	Yield (kg)	N : K ₂ O ratio	Yield (kg)												
N _{1.0}	4:3	181 (100.0)	4:4	273 (150.8)	4:6	285 (157.5)	4:3	1498 (141.9)	4:4	2831 (130.4)	4:6	3354 (154.5)	4:3	2602 (100.0)	4:4	3074 (118.1)	4:6	3378 (129.8)		
N _{1.5}	4:3	203 (112.2)	4:4	284 (156.9)	4:6	307 (169.6)	4:3	1108 (104.9)	4:4	1424 (134.8)	4:6	1403 (132.9)	4:3	2358 (108.6)	4:4	3321 (153.0)	4:6	2660 (128.6)	4:3	3561 (136.9)
N _{2.0}	4:3	178 (98.3)	4:4	305 (168.5)	4:6	307 (169.6)	4:3	1110 (105.1)	4:4	1409 (133.4)	4:6	1397 (132.3)	4:3	2460 (113.3)	4:4	3317 (145.5)	4:6	2716 (152.8)	4:3	3519 (121.5)
SE		22 (12.2)	43 (23.8)	7 (0.7)	14 (1.3)	100 (4.6)	196 (9.0)	23 (0.9)	45 (1.7)											
CD at P = 0.05																				

Values in parentheses denote per cent yield over the N₁ yield at 4 : 3 N : K₂O ratio.

*During this year, only 1 : 1 (or 4 : 4) N : K₂O ratio was adopted to all the sub-treatments in order to find out the effect of different N : K₂O ratios adopted up to the fourth year on the fifth year's yield.

among the plots corresponding to the N : K₂O ratios 4 : 3, 4 : 4 and 4 : 6. The plots which received NK fertilisers at 4 : 6 N : K₂O ratio up to the fourth year produced the highest crop in the fifth year; thus necessitating the adoption of high N : K₂O ratio (namely 4:6) at least in the early years of young tea.

It is shown from Fig. 1 that the interaction of N level and N : K₂O ratio on the overall cycle yield of young tea is also significant. It clearly indicates that the increase in response due to increasing K levels (that is, changing N : K₂O ratio from 4 : 3 to 4 : 6) is much more than that due to increasing N levels. As high as 2 to 2.5 t more crop as made tea per ha is harvested at 4 : 6 N : K₂O ratio than at 4 : 3 N : K₂O ratio. Overall for the cycle, the highest crop is obtained in N₂ plots at 4 : 6 N : K₂O ratio.

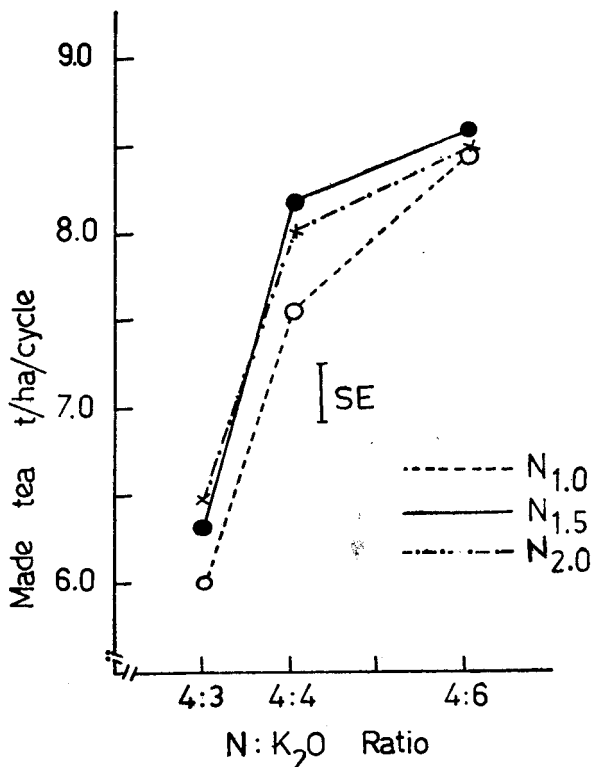


Fig. 1. Interaction of N level \times N : K₂O ratio on cycle yield.

Effect of N : K₂O ratio on certain growth characters

The statistical analyses of collar diameter at the base of the plant over the years of young tea and of the dry matter of prunings at the end of the experimental period (at the time of formative pruning) show that the level of N and the interaction, N level \times N : K₂O ratio, are not significant. Only the N : K₂O ratio (that is, K level) shows significant effect on these growth characters (Table 5). Increasing K level in the NK mixture increases the collar diameter of the plant in all the years; the highest collar diameter is observed in plants that received 4 : 6 N : K₂O ratio fertilisers. The collar diameter data also clearly show the positive effect of adoption of higher N : K₂O ratios in the early years of young tea (up to the fourth year) on the fifth year's collar diameter.

Table 5. Effect of N : K₂O ratio on certain growth characters

	N : K ₂ O ratio			SE	CD
	4 : 3	4 : 4	4 : 6		
<i>Collar Diameter (cm)</i>					
First year (April, 1978)	0.66	0.70	0.72	0.01	0.03*
Second year (April, 1979)	1.77	1.92	1.98	0.05	0.10*
Third year (October, 1980)	3.60	3.84	3.97	0.10	0.20*
Fourth year (May, 1981)	4.04	4.32	4.57	0.09	0.17*
Fifth year @ (August, 1982)	4.98	5.49	5.56	0.16	0.31*
<i>Dry Matter of Prunings (kg/bush)</i>					
Foliage	0.24	0.22	0.27	NS	NS
Branchlet and Twigs	0.36	0.30	0.49	0.09	0.15**
Wood	0.22	0.32	0.36	0.06	0.10**
Total	0.82	0.84	1.12	0.15	0.26**

@ During this year, the N : K₂O ratio adopted was only 1 : 1 (or 4 : 4) for all the three sub-treatments.

* at P = 0.05; ** at P = 0.10; NS: Not significant.

The effect of different N : K₂O ratios on the overall growth and health of the young tea plant could be judged from the dry matter content of the prunings and its fractions (Table 5). The statistical analyses of the different fractions of the prunings show that

the N : K₂O ratio (or K level) does not show any significant effect on the foliage, that is, the amount of foliage formed is not significantly affected by the three N : K₂O ratios tried in this experiment. However, the dry matter contents of the branchlets and twigs, the wood and the total prunings show significance at 10 per cent probability level. Increasing N : K₂O ratio (or K level) from 4 : 3 to 4 : 6 significantly increases the dry matter content of the branchlets and twigs and the wood; which indicates that K is important for the formation of sound and healthy frames and wood, which is one of the prime objectives in the development of young tea. The data, hence, clearly show the necessity of adoption of higher N : K₂O ratio (namely 4 : 6) for the formation of healthy bushes with sound frames.

Optimum N level, K level and N : K₂O ratio for young tea

In tea culture at two stages namely the young tea and the mature tea in the pruned year, the fertiliser application rates are decided on considerations other than yield and immediate cost/benefit ratio (Ranganathan, 1976b). The manuring of young tea in general and the levels and ratios of N and K in particular are primarily aimed at producing sound and healthy frames in addition to maximising the young tea yield. Hence, the optimum levels and ratios of N and K should be based on the growth characters and the productivity trend.

As the levels of N tried in this experiment do not show any significant effect on the growth parameters studied, the optimum N level may be decided from the yield trend alone. The overall cycle yield (Fig. 1) shows: (1) no significant difference in yield among N₁, N_{1.5}, and N₂ at 4 : 6 N : K₂O ratio (which resulted in high productivity at all N levels); and, (2) the highest productivity at N_{1.5} level, which varies from 120 to 300 kg N/ha/year (Table 1).

The data on yield (Tables 2, 3 and 4; Fig. 1) and growth characters (Table 5) show that irrespective of N levels tried in the experiment not only the highest productivity is achieved at 4 : 6 N : K₂O ratio but also the overall health and vigour of the young tea as assessed from the collar diameter and dry matter of prunings, improved significantly. As in the case of mature tea in the pruned year (Ranganathan, 1973b; Natesan et al., 1982), the

young tea is also shown to require high K level more precisely high N : K₂O ratio of 4 : 6 or 2 : 3) for better frame development and wood formation. The increase in made tea of about two to two and a half tonnes over the cycle due to the adoption of 4 : 6 N : K₂O ratio more than offset the cost involved in increasing the K level. Also, such an increase in crop, will significantly reduce the gestation period of young tea as well as the break-even point. Additionally, from the yield trend and based on the better collar and frame development at 4 : 6 N : K₂O ratio it is expected that the subsequent cycle's yield will also be substantially high in these plants which received 4 : 6 N : K₂O fertilisers up to the fourth year and 4 : 4 or 1 : 1 N : K₂O in the fifth year.

Optimising N level and N : K₂O ratio automatically decides the level of K for young tea. This investigation shows that N level at or around N_{1.5} level (120 to 300 kg N/ha/year; increasing the level from first year of planting) and N : K₂O ratio of 4 : 6 or 2 : 3, at least up to the fourth year and 1 : 1 thereafter, are optimum for young tea for achieving high productivity as well as for better frame development.

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DISCUSSION

- Q : Will the optimum N:K ratio change with age of the bushes?
- Ans: The present study is restricted to first prime stage. The ratio may change from one stage to the other.

EFFECT OF RAISING COCOA AS A MIXED CROP IN ADULT COCONUT PLANTATIONS

ABDUL KHADER, L. RAJAMONY and P.C. BALAKRISHNAN

ABSTRACT

In a mixed cropping trial with cocoa in a coconut garden under un-irrigated conditions, observations were made on the yield of coconut and cocoa from 1965 to 1983. Cocoa, as a mixed crop in a coconut garden, had not influenced the yield and the bearing habit of coconut. The double hedge system of cultivation of cocoa in the interspaces of coconut was found to be superior to the single hedge with respect to the yield and economic return obtained per ha. Even in the double hedge system of raising cocoa under coconut, no crop or plant competition was observed.

INTRODUCTION

Cocoa (*Theobroma cacao* L.) needs partial shade for healthy establishment and economic yield. Therefore, cocoa can rightly be fitted into the polyculture system of cultivation existing in Kerala. It can be cultivated as a mixed crop in plantations like coconut, arecanut or even rubber.

Here the association of taller trees with cocoa has the practical advantage of providing sufficient shade to cocoa plants as well as increasing the return from unit area.

Occasional interplanting of cocoa with other crops like banana, hevea rubber, oil palm or coconut was reported by Purseglove (1974). Successful coconut-cocoa crop mix has been reported from Lower Perak Districts of Malaysia (Leach, 1971) and from

India (Nelliath et al., 1974). Nair et al. (1975) reported cocoa as the most promising mixed crop with coconut when compared to cinnamon, nutmeg, clove and black pepper. Coconut-Cocoa mix is often practiced in Philippines also. Promising results were obtained from the mixed cropping of arecanut with cocoa at the Central plantation Crops Research Institute, Vittal (Bhat and Leela, 1968). Wood (1978) reported that partial shade was necessary for successful cocoa cultivation. At the same time, he pointed out that many of the shady trees compete with cocoa and reduce yield. The present trial was aimed to find the possible influence of cocoa raised as a mixed crop on coconut yield and the performance of cocoa in different systems of planting in a coconut garden under rainfed conditions.

MATERIALS AND METHODS

The planting materials of cocoa used for the study were obtained from Landas Jerangau Estate in Malaysia. The seedlings were raised at the Central Plantation Crops Research Institute, Vittal and supplied by the Institute. The genetic origin of these materials was not clearly known and it is assumed that these are natural hybrids of Forestro and Criollo.

The trial was started in 1970 at the Regional Agricultural Research Station, Pilicode. The soil type of the area is gravelly laterite. The cocoa seedlings were planted in the interspaces of a 50 year old coconut plantation (Variety, West coast Tall, spacing 9×9 m) in July 1970 in a Randomised Block Design with the following three treatments replicated eight times. In the control plot the interspaces of coconut were left vacant. Treatment No. 1 consisted of three single rows of eight seedlings each, planted in the centre of two coconut palm rows at a spacing of 3.65 m (24 seedlings per plot). In treatment No. 2 there were three double rows of eight seedlings each spaced at 3.65 m in the triangular system of planting (48 seedlings per plot).

The coconut and cocoa plants were separately given manure and fertilisers. Each coconut palm was provided with 25 kg organic manure per year. Fertilisers were applied at the rate of 0.5 kg N, 0.32 kg P_2O_5 and 1.2 kg K_2O per palm per year in two splits. The cocoa plants were given fertilisers at the rate of 100 g N, 40 g P_2O_5 and 140 g K_2O per annum in two equal splits

after the third year onwards. Dolomite (100 g) was applied per plant per year after the third year. During the first and second years one-third and two-third of full dose of fertilisers were given respectively. Cultural operations like pruning of cocoa, cleaning the basins and crown of coconut and digging the interspaces were carried out regularly.

The experiment was conducted under unirrigated conditions. However, cocoa plants were given weekly irrigation during the summer months for the first two years. Observations on pre-treatment yield of coconut from 1965 to 1970, post-treatment yield of coconut from 1971 to 1983 and the yield of cocoa in different systems of planting from 1976 to 1983 were recorded.

RESULTS AND DISCUSSION

The mean yield of coconut per ha for six pre-treatment years and 13 post-treatment years is given in Table 1.

Table 1. Pre-treatment and post-treatment yield of coconut

Years	Coconut yield (No./ha)		
	Single hedge cocoa	Double hedge cocoa	No cocoa
1	2	3	4
<i>Pre-treatment</i>			
1965	7397	6856	6544
1966	8922	9409	9453
1967	8455	8698	9072
1968	7006	6595	6689
1969	7261	8088	7645
1970	4206	5258	5292
Mean	7208	7484	7449
<i>Post-treatment</i>			
1971	7800	7781	6817
1972	9081	8922	8523
1973	8344	9481	8423

(Contd.)

1	2	3	4
1974	7350	7408	8292
1975	8439	8911	8273
1976	7088	7386	6839
1977	12128	9628	9373
1978	8641	8261	10005
1979	6820	7236	7019
1980	6491	5769	8081
1981	8614	9446	9441
1982	6173	4475	6247
1983	8203	6610	8076
Mean	8090	7800	8108

Coconut yield did not differ significantly in any of the pre-treatment or post-treatment years. This indicated that cocoa cultivated (in single hedge or double hedge) in the interspaces of coconut palms had no influence on the yield of coconut. This was in agreement with the results obtained by Khan (1962), Celino (1963), and Leach (1971).

The beneficial effect of cocoa on coconut has been reported by Rodrigo and Mangabat (1964), and Kannan and Sudhakara, (1977). Similar results were reported from the Central Plantation Crops Research Institute, Kasaragod (Anonymous, 1973, 1974). In a mixed cropping experiment with coconut and cocoa at the Institute, Nair and Varghese (1976), found an increase up to 55 per cent in coconut yield as compared to pure crop. This increase in yield was explained by the authors to be due to the beneficial effect of a compatible crop combination. However, in the present study, there was no substantial yield increase in coconut due to the influence of cocoa raised as a mixed crop under rainfed conditions.

The mean values of the number of pods per plant of cocoa under two systems of planting are furnished in Table 2.

Table 2. Mean yield of cocoa for eight years from 1976 to 1983

Years	No. of pods/plant		Dry beans (kg/ha)		
	Single hedge	Double hedge	Single hedge	Double hedge	CD
1976	17.1	19.4	146.86	334.11	140.79**
1977	35.9	35.7	305.88	614.06	228.39**
1978	21.9	21.2	186.81	363.97	150.77**
1979	11.9	14.4	93.96	248.58	125.34*
1980	18.2	20.4	163.82	435.39	201.92**
1981	17.3	22.2	146.97	381.32	195.63*
1982	15.9	18.9	135.12	323.46	147.15*
1983	16.9	18.7	143.47	319.95	154.69*
Mean	19.3	21.4	165.36	377.6	

There was no significant difference in the number of pods/plants of cocoa under the two systems of planting. This revealed that there was no crop competition between plants even in the double hedge system of planting. The present trial was conducted under rainfed conditions and plants were at a wider spacing (coconut, 9 × 9 m and cocoa, 3.65 m in single hedge and 3.65 m in triangular system in double hedge.) These could be some of the reasons for lack of competition between plants. However, results obtained by Nair et al. (1975), indicated a significant decrease in per plant yield in cocoa when resorted to double hedge planting as compared to the single hedge system in mixed cropping with coconut at CPCRI, Kasaragod.

The double hedge system of planting was far superior to the single hedge system with respect to the per ha yield of cocoa (Table 2). This might be attributed to: (1) high plant density; (2) lack of plant competition; (3) mutual shade effect; and (4) more quantity of leaf litter available in the double hedge system when compared to the single hedge planting.

Table 3 gives annual per ha expenditure, receipt and profit of cocoa cultivated as mixed crop in a coconut garden from 1976 to 1983 that is, after the cocoa plants started yielding.)

Table 3. Average per ha expenditure, receipt and profit of cocoa cultivated as a mixed crop in a coconut garden under different systems of planting

Year & Treatment	Expenditure on cocoa (Rs/ha)	Receipt			Profit Rs/ha
		Beans Rs/ha	Rate Rs/ha/kg	Return Rs/ha	
1976 T1	780	147	34	4995	4215
T2	1560	334	34	11359	9799
1977 T1	1000	306	30	9177	8177
T2	2000	614	30	18423	16423
1978 T1	1050	187	30	5604	4554
T2	2100	364	30	10920	8820
1979 T1	1200	94	25	2350	1150
T2	2400	249	25	6215	3815
1980 T1	1275	164	15	2457	1182
T2	2550	435	15	6531	3981
1981 T1	1300	147	12	1764	464
T2	2600	381	12	4575	1976
1982 T1	1350	135	12	1621	271
T2	2700	324	12	3882	1182
1983 T1	1400	144	12	1722	322
T2	2800	320	12	3840	1040
Mean T1	1169	165	21	3711	2542
T2	2339	378	21	8218	5880

T1 : Cocoa planted in single hedge.

T2 : Cocoa planted in double hedge.

The mean annual profit from cocoa alone worked out to Rs. 2,542 and Rs. 5,880 under single hedge and double hedge systems respectively. Hence, cocoa under the double hedge system gave 131 per cent increase over the profit obtained from single hedge cocoa in mixed cropping with coconut. Double hedge has been reported to be 20 per cent more efficient in utilising the available sunlight (Nair and Balakrishnan, 1976) as compared to cocoa planted in single hedge. The population of beneficial micro-organisms like free nitrogen fixers (*Beijereikia* sp.) phosphate solubilisers (*Pseudomonas* sp. and *Aspergillus* sp.), and Indole Acetic Acid synthesisers (*Escherichia* sp. *Aspergillus flavus* and *Aspergillus fumigatus*) in the rhizosphere of coconut and

cocoa has also been reported to be more under high density planting (Nair, 1974).

The results indicate that the double hedge system of cultivation of cocoa in a coconut garden is more efficient in utilising the available interspace profitably and augmenting return from unit area per unit time when compared to the single hedge system. Again, cocoa cultivated as a mixed crop in a coconut garden in no way interfered with the yield and bearing habit of coconut.

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DISCUSSION

Q : The net return from coconut cocoa mixed cropping has come down as could be seen from Table 3. Does it reflect any adverse effect of cocoa?

Ans: No. The reduction in net profit is due to low price for cocoa.

MOISTURE CONSERVATION THROUGH MULCHES IN COCONUT

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H. VIJAYARAGHAVAN

ABSTRACT

Different mulching materials which are locally available such as coconut husks, fodder trash, coconut leaves and palmyrah leaves were tried in the rainfed adult bearing coconut garden in order to find a suitable mulching material. Mulching coconut husks in a 2 m radius around the base of the palms increased the yield by 49.6 per cent followed by burying coconut husks and leaves in trenches between the rows of palms which increased the yield by 44.6 per cent over control. The coconut husks leaves conserved the moisture very effectively as evidenced by the highest moisture per cent recorded in the soil.

INTRODUCTION

Coconut is mostly grown as a rainfed crop. Hence moisture is a great limiting factor for successful cultivation of coconut palm. Proper supply of moisture, either through well distributed rainfall or irrigation is essential for proper growth of coconut (John, 1952). Copeland (1931) reported that a coconut palm can absorb 24 l of water per day. He investigated the water relationship of the palms during drought conditions. After a prolonged drought, it took years for the palms to recover. Crop-weather studies on coconut have revealed a close correlation

between the nut yield and rainfall. Soil moisture conservation through certain agronomic practices have been found to improve the yield of coconut. Mulching the area round the base of the palm before the onset of dry weather will keep the soil moist and prevent the ground from becoming hard. Also it may reduce the bad effects of drought conditions and promote better growth of the palms. However, definite mulching material for use in a particular soil and agro-climatic condition has to be investigated so as to enable the conservation of moisture with a particular type of mulch. Therefore, in order to find suitable mulching material for use in the standing east coast Tall Plantations, an investigation was carried out with several mulching materials available locally.

MATERIALS AND METHODS

The experiment was started in June, 1976 with six treatments replicated four times. Each replicate consisted of four trees. The design of experiment was RBD. The various treatments are: (1) control; (2) mulching the area for 2 m radius around the base of the palms with dry coconut leaves; (3) burying coconut husks and leaves in trenches 40 cm deep and 150 cm broad in between rows of coconut at the rate of 1000 husks per palm; (4) mulching the area for 2 m radius around the base of the palm with NB 21 fodder trash; (5) mulching the area for 2 m radius around the base of the palms with coconut husks; and (6) mulching the area for 2 m radius around the base of the palms with palmyrah leaves. Recording of nut yield and estimation of soil moisture were carried out at monthly intervals.

RESULTS AND DISCUSSION

Effect of different mulches on soil moisture

Soil moisture was estimated in all the treatments for a period of four years and the results are presented in Table 1. The conservation of moisture in the soil was significantly higher in all the treated plots than in the control plots from 1981 to 1983. During 1980, high moisture percentage was recorded in the treatment of mulching the palms with dry coconut leaves followed by burying coconut husks and leaves, and mulching the

palms with NB 21 fodder trash. During 1982, the highest moisture was observed in the treatment burying coconut husks and leaves followed by mulching the palms with coconut husks, palmyrah leaves and with dry coconut leaves. This trend continued in 1982 and 1983.

Table 1. Effect of different mulching treatments on soil moisture (mean percentage)

Treatment	1980	1981	1982	1983
1. Control	24.2	24.5	45.3	26.3
2. Mulching with coconut leaves	30.2	28.5	51.8	29.8
3. Burying coconut husks and leaves	29.2	30.5	58.0	33.8
4. Mulching with NB 21 fodder trash	27.7	26.0	50.0	28.8
5. Mulching with coconut husks	25.7	29.0	54.8	33.5
6. Mulching with palmyrah leaves	26.5	26.5	52.3	30.8
7. SE	1.14	0.65	1.08	0.58
CD (P : 0.01)	—	2.71	4.54	2.42

Effect of different mulches on nut yield

The mean nut yield per palm is given in Table 2. The yield of nuts is significant during 1979 and the cumulative yield from 1979 to 1983 is also significant. The per cent increase in yield due to treatments ranged from 6.2 to 49.6. Mulching with coconut husks for 2 m around the palm improved the yield by 49.6 per cent followed by burying coconut husks and leaves in the trenches between rows of the palms by 44.6 per cent over control. Similar results were obtained by Bhaskaran and Leela (1977). They emphasised that coconut husk can store nearly three times of water by its weight and contains about 15 per cent K_2O . The increased yield recorded in this treatment may also be attributed to the potash content of the husk because potassium plays a very important role in the nutrition of the coconut palm. In Sri Lanka, it was found that the potash content of the husks was correlated to the potash status of soil from where husks have been obtained (Salgado, 1941). It was estimated that 1,000 husks gave rise to 7 to 8 kg of potash. Moreover the potash content in the husk is readily soluble and available to the palms. It has been reported in arecanut gardens that

Table 2. Effect of different mulching treatments on coconut yield (Mean yield of nuts per palm)

Treatment	1979	1980	1981	1982	1983*	Cumulative yield	Per cent increase over control
1. Control	26	60	30	31	30	177	
2. Mulching with coconut leaves	15	89	43	48	40	235	32.8
3. Burying coconut husk and leaves	28	85	47	53	43	256	44.6
4. Mulching with NB 21 fodder trash	19	82	45	41	47	234	32.2
5. Mulching with coconut husks	36	84	47	52	46	265	49.6
6. Mulching with palmyrah leaves	17	66	37	33	35	188	6.2
SE	1.05	2.89	1.40	8.20	5.20	17.	
CD (P : 0.05)	3.16	—	—	—	—	52.	

* Yield data relate to January-October 1983 period.

mulching increases the humus content of soil, its water holding capacity and aeration besides preventing the loss due to evaporation. Also, due to mulching, erosion and run off losses are minimised, weed growth can be controlled and plant nutrient elements are added to soil (Anonymous, 1983). All these factors might have contributed to the increased nut yield in the present study.

Economics of the use of mulching materials in coconut gardens

Data on the cost of application of mulching materials, profit and cost/profit ratio are presented in Table 3. The highest net profit was obtained in the treatment of mulching the area for two metres radius around the base of the palms with coconut husks. The application of mulching materials namely coconut leaves, NB 21 fodder trash and palmyrah leaves are not beneficial in terms of net profit.

Table 3. Economics of use of mulching materials on yield of coconut (Rupees/ha/year)

Treatment	Cost of treatment	Gross profit	Net profit	Cost/profit ratio
1. Control		4375	2625	0.40
2. Mulching with coconut leaves	2800	5250	2450	0.53
3. Burying coconut husks and leaves	4550	8750	4200	0.52
4. Mulching with NB 21 fodder trash	2900	5075	2175	0.57
5. Mulching with coconut husks	3500	9275	5775	0.38
6. Mulching with palmyrah leaves	2800	4550	1750	0.62

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INFLUENCE OF WEATHER ON COCONUT YIELD

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ABSTRACT

The data on different weather parameters, monthly as well as annual coconut yields of West coast Tall and button shedding of coconut were collected at the Regional Agricultural Research Station, Pili-code to study the influence of weather on Coconut yield and button shedding under the rainfed conditions. The results indicate that the absence of post- and pre-monsoon showers (October to April) and the high rainfall during the rainy season (June to August) adversely affected the subsequent year's nut yield of coconut. The mean cumulative bright sunshine hours from the primordium of inflorescence to the initiation of spikes (44 to 28 months before harvest) favourably influenced the nut yield of coconut. The percentage of button shedding was more if the minimum temperature, the intensity and the amount of rainfall were high.

INTRODUCTION

Coconut is mainly grown as a rainfed crop in Kerala. Much of the seasonal variations in coconut yield are attributable to the vagaries of weather under the rainfed conditions. Among the different weather parameters water and solar radiation are the most essential which govern the growth and yield of coconut under good management and cultural practices. Prasad Rao (1982), found that the absence of post- and pre-monsoon showers

as well as high water surplus during the south-west monsoon season adversely affected the coconut yield of the subsequent year. According to Wickramasuriya (1968) rainfall has no effect on the induction of spadix primordia or the number of spadix produced. However, spadix initiation and production were found to be greater during March to September, when the average day length is at a maximum, than during the rest of the year. Gadd (1922), reported that shedding of buttons—a phenomenon related to yield—was high in the rainy season. On the other hand, Patel (1938), based on studies conducted at Nileshwar concluded that there existed no relationship between shedding of buttons and rainfall or drought. In order to elucidate more information on the relationship between weather factors and yield, three experiments were conducted at the Regional Agricultural Research Station, Pilicode. The results of which are presented in this paper.

MATERIALS AND METHODS

Experiment 1: In this experiment, the relationship between the seasonal rainfall and the yield of coconut for the subsequent three years was studied. The nut yields of 168 WCT palms raised under rainfed conditions in block D of Pilicode farm were gathered from 1942 to 1982 and correlations between seasonal rainfall and the yield of three successive years were worked out.

Experiment 2: The effect of bright sunshine hours prior to maturity of nuts on the productivity of coconut palms was studied using the monthly yield data gathered from WCT palms in block D of the Pilicode farm during the years 1968 and 1969. The mean cumulative bright sunshine hours were worked out for four different periods such as Primordium of the inflorescence to initiation of spikes (44 to 28 months before harvest), initiation of spikes to female flower initiation (27 to 24 months before harvest), female flower initiation to opening of spathe (23 to 12 months before harvest) and the opening of spathe to harvest. Correlations were worked out between the yield and the mean cumulative bright sunshine hours of the four different stages before the harvest.

Experiment 3: The effect of weather factors on the phenomenon of button shedding was investigated in this. Ten WCT

palms of uniform growth were selected for the study and button shedding was recorded at weekly intervals starting from the first week after the opening of spathe for a period of one year (March 1983 to February 1984). Data on various weather parameters were collected from the Agrometeorological station at Pilicode and correlations were worked out between the different weather parameters and the percentage of button shedding.

RESULTS AND DISCUSSION

Seasonal rainfall and coconut yield

The data on seasonal rainfall (October to April and June to August) and nut yield of three successive years from 1942 to 1982 are presented in Table 1, and the physical relationships between yield and rainfall are given in Table 2. It can be seen that the second year yield was positively correlated with the October to August rainfall while that with June to August rainfall was negatively correlated. Both the relationships were statistically significant at 10 per cent level. This indicates that the absence of rains and consequently moisture stress during the post- and pre-monsoon seasons and high rainfall during the rainy period adversely effect the second year's yield of coconut. In Kerala, the bulk of the rainfall is received during the south-west monsoon and there is a prolonged dry spell from December through to May which might lead to low productivity in coconut.

Sunshine hours during different stages and monthly coconut yield

The correlations between mean cumulative bright sunshine hours of the four different stages before the harvest and the monthly coconut yield are given in Table 3. It is seen that positive (significant at 0.05 level) correlation existed between the mean cumulative sunshine hours of the primordium of inflorescence to initiation of spike (44 to 28 months before the harvest) and the monthly coconut yield, thus indicating that if the number of bright sunshine hours before the initiation of spikes are more, the yield might be high. There was no significant relationship between the yield and the hours of sunshine hours at the other three phases before the harvest.

Table 1. Seasonal rainfall and annual coconut yield (WCT)

Year	Rainfall (mm)		Yield (nuts/palm)		
	October-April	June-August	1st year	2nd year	3rd year
1942-43	353	2668	43	34	55
1943-44	614	2071	34	55	34
1944-45	334	2693	55	34	49
1945-46	396	3341	34	49	70
1946-47	790	2480	49	70	30
1947-48	327	2917	70	30	33
1948-49	723	2975	30	33	15
1949-50	198	2715	33	15	40
1950-51	262	2176	15	40	31
1951-52	378	2345	40	31	44
1952-53	566	2317	31	44	47
1953-54	594	3345	44	47	55
1954-55	264	2064	47	55	45
1955-56	453	1989	55	45	38
1956-57	331	3730	45	38	52
1957-58	419	2415	38	52	55
1958-59	297	3125	52	55	53
1959-60	178	2736	55	53	33
1960-61	387	4929	53	33	54
1961-62	666	2651	33	54	61
1962-63	675	2337	54	61	45
1963-64	344	1945	61	45	64
1964-65	210	2209	45	64	64
1965-66	454	1865	64	64	44
1966-67	689	2921	64	44	44
1967-68	223	3601	44	44	23
1968-69	101	1913	44	23	49
1969-70	291	3163	23	49	56
1970-71	301	2766	49	56	57
1971-72	173	2341	56	57	48
1972-73	262	2437	57	48	41
1973-74	278	2830	48	41	39
1974-75	220	3349	41	39	47
1975-76	380	2199	39	47	42
1976-77	529	3183	47	42	32
1977-78	313	3693	42	32	28
1978-79	423	3403	32	28	37
1979-80	373	2318	28	37	37

Table 2. Simple correlation coefficient between seasonal rainfall and annual coconut yield

Season	Coconut yield		
	First year	Second year	Third year
October-April	-0.035	0.288*	-0.160
June-August	-0.034	-0.314*	-0.011

* Significant at $P = 0.10$.

Table 3. The mean cumulative sunshine hours and monthly coconut yield

	Mean Sunshine Hours/Day				Yield
	1	2	3	4	5
Primordium of the inflorescence to initiation of spikes (44 to 28 months before the harvest)		Initiation of spikes to female flower initiation (27 to 24 months before the harvest)	Initiation of female flower to opening of spathe (23 to 12 months before the harvest)	Opening of spathe to the harvest (11 months before the harvest)	
	6.52	8.43	6.85	7.25	2.91
	6.49	8.75	6.87	7.19	2.97
	6.74	8.98	6.88	7.25	3.73
	6.99	9.50	6.86	7.25	6.61
	7.32	9.43	6.78	7.35	8.38
	7.64	7.98	6.87	7.69	5.30
	7.81	6.23	6.83	7.89	5.00
	7.92	5.13	6.67	7.78	5.34
	7.93	4.25	6.81	7.79	5.00
	7.61	4.63	6.97	7.64	5.05
	7.16	5.85	7.14	7.51	4.02
	6.92	5.85	7.43	7.51	4.39
	6.69	6.88	7.44	7.51	3.02
	6.73	8.00	7.43	7.45	4.03
	6.94	8.55	7.42	7.51	6.69
	7.01	9.60	7.39	7.55	8.19
	7.26	9.20	7.49	7.55	8.65
	7.42	7.98	7.39	7.92	4.86

(Contd.)

	1	2	3	4	5
	7.46	6.10	7.39	8.15	4.95
	7.51	4.55	7.73	7.85	5.46
	7.54	4.35	7.63	7.89	4.01
	7.31	4.93	7.66	7.69	5.38
	6.84	6.78	7.60	7.58	3.33
	6.47	8.15	7.68	7.42	2.23
Correlation coefficient (r) between the mean cumulative sunshine hours and yield	0.40*	0.17	0.09	0.10	

* Significant at $P = 0.05$.

Table 4 gives the monthly button shedding and the mean monthly coconut yields of WCT. It can be seen that the average button shedding was estimated as 68.66 per cent. Button shedding had reached the maximum (92.15 per cent in July and the minimum (38.49 per cent) in January. The data on season-wise button shedding and yield are summarised in Table 5. It shows that the button shedding was high (83.02 per cent) in the south-west monsoon and less (39.12 per cent) in winter. It also indicates that if the yield was more, the button shedding was high. This is possibly due to the greater number of female flowers as the cause for the greater button shedding. The correlation between the monthly button shedding and the different weather parameters during 1983-84 are presented in Table 6. It is seen that the percentage of button shedding showed positive significant correlation with the minimum temperature, total amount of rainfall and the average intensity of rainfall. It may be noted that the high amount of rainfall during the rainy season might cause water logging in coconut gardens leading to physiological drought. Gadd (1923), explained that the root of the coconut, which when arrested in growth due to dry or waterlogged conditions, brought about physiological drought due to the formation of hypodermal thickening up to the root cap reducing the

Table 4. Monthly yields (WCT) and button shedding

Month	Mean yield nuts/palm (1968-1982)	Button shedding (1983-1984) per cent
March	4.95	74.96
April	6.09	82.31
May	6.51	77.88
June	5.51	82.35
July	5.39	92.15
August	5.25	80.20
September	5.40	77.36
October	5.07	67.13
November	4.09	72.27
December	3.54	38.68
January	3.30	38.49
February	4.00	40.19
Total/Mean	59.10	68.66

Table 5. Seasonal yield and button shedding

Season	Mean yield nuts/palm	Button shedding per cent
Summer (March-May)	5.85	78.38
South-west Monsoon (June-September)	5.39	83.02
Post-monsoon (October-November)	4.58	69.70
Winter (December-February)	3.61	39.12

area of absorption of nutrients from soil. In addition to this the high intensity of rainfall might also wash out the pollen causing mechanical damage to the buttons.

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INFLUENCE OF CLIMATIC FACTORS ON THE DRY MATTER CONTENT OF CROP SHOOTS IN TEA (*CAMELLIA* spp.)

N. SATYANARAYANA

ABSTRACT

The ratios between the dry and fresh weights of crop shoots of three tea clones were determined during different seasons of a year. Seasonal variations in the ratios showed strong correlations with the climatic parameters, clones and age of the bushed from pruning. Appropriate conversion factor for estimating the out-turn (made tea) of green leaf for a mixed population has been suggested; the wide variation of the conversion factor from season to season, between the clones and the influence of age on it were highlighted.

INTRODUCTION

Significant correlation between climatic factors and the rate of production of crop shoots in tea were established in earlier investigations (Carr, 1972). Seasonal variations, in addition to the genetic, physiological and agronomic factors, influence the biometric characters of flush shoots (Eden, 1976). In view of this the practice of using an average conversion factor of 23 per cent (Haridas, 1978), or some such figure for converting the green leaf into made tea irrespective of the season or variety, would only give a rough estimate of the yield since the seasonal differences from the average conversion factor could be wide. A need,

hence exists to determine the ratio between dry and fresh weights of the harvested shoots, so that appropriate conversion factors for different seasons of the year are available. In this paper, results obtained from a study on three tea clones broadly representative of different commercial populations, over a year are discussed.

MATERIALS AND METHODS

Bushes of the clones UPASI-3, UPASI-9 and UPASI-10 in their second, third and fourth year from pruning were chosen for the study. Sampling of harvested shoots from the bushes, which were under weekly plucking, was done at monthly intervals, from July 1981 to June 1982. At each sampling, 100 crop shoots comprising three leaves and a bud were collected from the plots under each clone and brought to the laboratory in sealed polythene bags. The surface moisture on the shoots was removed using blotting paper and fresh weights recorded. The shoots were then dried at 100°C for 16 hours and the dry weights recorded. The ratios between dry and fresh weights are given in Table 1. The

Table 1. Dry weight/fresh weight ratios of crop shoots in tea

Clone	Year from pruning	Dry and fresh weight ratios				
		July and Aug. 1981	Sept. to Dec. 1981	Jan. to Mar. 1982	Apr. to June 1982	July 1981 to June 1982
UPASI-3	II	0.16	0.19	0.24	0.26	0.21
	III	0.17	0.20	0.27	0.25	0.22
	IV	0.18	0.22	0.25	0.24	0.22
UPASI-9	II	0.19	0.22	0.25	0.25	0.23
	III	0.20	0.22	0.26	0.25	0.23
	IV	0.20	0.22	0.26	0.25	0.23
UPASI-10	II	0.18	0.21	0.24	0.25	0.22
	III	0.19	0.22	0.26	0.24	0.23
	IV	0.19	0.22	0.24	0.23	0.22
Average for the three clones	II	0.18	0.21	0.24	0.25	0.22
	III	0.19	0.21	0.26	0.25	0.23
	IV	0.19	0.22	0.25	0.24	0.22

Note: Conversion factor = $\frac{\text{Dry weight}}{\text{Fresh weight}} \times 100$.

conversion factor for estimating made tea from green leaf could be obtained by multiplying the ratio between dry and fresh weight by 100.

The year was divided into two high cropping (September to December and April to June), rainy (July to August) and dry (January to March) seasons; the meteorological data, except the rainfall, were pooled, averaged per day for different seasons and given in Table 2. The rainfall is given as total precipitation for different periods.

Table 2. Meteorological data during the period of study

Climatic parameters	July to Aug. 1981	Sept. to Dec. 1981	Jan. to Mar. 1982	Apr. to June 1982
Total rainfall (mm)	1905	1296	6	864
Mean no. of hours of sunshine in a day	1.7	4.0	9.5	4.5
Mean min. ambient temp. (°C)	18	15	11	17
Mean max. ambient temp. (°C)	21	23	27	24
Mean min. relative humidity (%)	78	64	36	62
Mean max. relative humidity (%)	92	94	91	87

RESULTS AND DISCUSSION

Clonal variation in the ratios between dry and fresh weights was noticed; these ratios were influenced by seasonal change and also the age of the bush from pruning (Table 1). Dry weight to fresh weight ratios at the highest range were noticed during the dry period of January to March, while they were on the lowest scale during the very wet period of July and August; the ratios were in an intermediate range in the two high cropping seasons. The pattern was the same in all the three clones and also at different stages from pruning. The highest ratios were associated with least rainfall, longer sunshine hours, wider diurnal variation in ambient temperatures accompanied with low mean minimum

relative humidity (Tables 1 and 2). Higher dry matter content in the shoots during this period may be due to a higher moisture loss consequent upon a greater rate of transpiration resulting in the increased cell sap concentration. The lowest ratio of dry to fresh weights of shoots recorded during the July and August months were associated with the highest rainfall, low ambient temperatures accompanied with high mean minimum relative humidity, all of which contribute to maximum succulence as a result of a high level of leaf-water content. The higher levels of dry matter accumulation in the shoots during the growing periods is due to the favourable weather conditions inducing a faster rate of growth and accumulation assimilates.

Generally, the dry matter content of shoots either increased with the age of the bush from pruning or the level obtained in the third year was maintained; in UPASI-9, the dry matter component was the same in all the three years during certain seasons (Table 1). Deviation from this general pattern in a few instances is inexplicable.

It is evident from the data that the conversion factor for estimating the made tea yield from green leaf varies widely, ranging from 16 to 27 per cent; as expected, it is a clonal factor and is influenced by the seasonal changes as also the age from pruning. While precise conversion factors for each season, clone and age should be used for the conversion, a conversion factor of 22 to 22.5 per cent is more appropriate to be used in determining the made tea out-turn from green leaf, in a mixed population.

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DISCUSSION

Q : What is the practical utility of this study?

Ans: Conversion factor of 22.0-22.5 can be used for mixed population of tea.

SESSION VI

**ECONOMICS, MARKETING, EXTENSION
AND TECHNOLOGY**

Chairman : Prafulla K. Das

Rapporteurs : G. Subbarayalu

S.J.K. Annamalai

THE ECONOMICS OF COCOA MIXED CROPPING WITH COCONUTS IN INDIA

PRAFULLA K. DAS

ABSTRACT

Cocoa was introduced for commercial cultivation in India after experiencing success in field experiments as a mixed crop with coconuts and arecanuts at CPCRI during the early seventies. After a brief period of accelerated growth the momentum of cocoa expansion was not only checked, but also the newly introduced crop was exposed to gross neglect owing to unremunerative prices and marketing constraints. A protective price policy for cocoa has now been executed as a remedial measure to cocoa crisis, and this study aims to find out whether this protection could motivate the farmers to adopt cocoa as a mixed crop with coconuts. The analysis reveals that the net return from cocoa grown in the interspaces of coconuts amounts to Rs. 2900/ha/year. The coconut-cocoa system as a whole promises a net return of Rs. 16,500/ha/year as against Rs. 7300/ha/year in the case of rainfed coconut monoculture. In view of this, the interplanting of cocoa with coconuts is found to be a very attractive proposition.

INTRODUCTION

In the year 1963, the Central Plantation Crops Research Institute (CPCRI), Kasaragod first attempted raising the Criollo variety of cocoa as a mixed crop in coconut gardens. In the following year, a similar exploratory trial was carried out in arecanut gardens at CPCRI Regional Station, Vittal. However, these trials did not show much promise as the variety was found to be unsuitable

for a given environment. In the year 1970, another attempt was made for raising the Forestero variety of cocoa as a mixed crop in coconut/arecanut gardens in loamy soils at CPCRI, Kasaragod/Vittal. Having observed the encouraging performance of this variety, the farmers of Kerala, Karnataka and Tamil Nadu adopted this crop in their garden lands and presently cocoa is grown in some 29,000 ha mainly as a mixed crop in coconut and arecanut gardens.

In India, cocoa gained real momentum only in 1977 when its prices became very attractive and this accelerated phase continued only up to 1979. From the year 1980 the cocoa prices in India started declining on account of adverse fluctuations in the international markets, and this led to apprehension in certain quarters, particularly among growers, that with the accelerated rate of expansion of the cocoa area, the prices could further decline due to insufficient capacity for absorption by industry. By 1983, the area of expansion had not only come to a halt, but the crop was very neglected caused by unremunerative prices and marketing bottlenecks. In the recent past however, some corrective measures have been taken to remove the bottlenecks and condition the market to accept an upward revision of prices, so as to rehabilitate the cocoa sector in India, which holds a great promise for the future.

The objective of this study is to examine whether cocoa as a mixed crop with coconuts is economically viable under the present factor-product market situations in Kerala which alone accounts for about 83 per cent of cocoa area in India.

RESULTS AND DISCUSSION

Table 1-A shows the operation-wise and year-wise requirements of labour for coconuts as a monocrop as well as coconut with cocoa as a mixed crop. Similarly, Table 1-B shows the labour requirements for cocoa under the coconut based cropping system.

The requirements of material inputs for coconut as a monocrop and coconut with cocoa as a mixed crop operation-wise and year-wise are shown in Table 2-A, while Table 2-B deals with the material inputs for cocoa as a mixed crop in coconut gardens.

Table 1-A. Estimated labour requirements for coconut as monocrop and as mixed crop with cocoa (Mandays/ha/year)

Operations	Establishment period				Adult stage (per year)	
	1	2	3	4-7 per year		
					As mono-crop	As inter-crop with cocoa
Fencing and repairs	70	8	8	8	8	4
Land levelling and peg marking	55	—	—	—	—	—
Taking pits (175 Nos.)	35	—	—	—	—	—
Planting and gap filling	8	2	1	—	—	—
Shading and mulching	15	11	6	—	—	—
Manuring	16	18	20	22	24	16
Weeding/forking	10	20	25	30	36	12
Watering in summer	42	52	60	20	—	25
Spraying and other plant protection	3	4	6	7	12	12
Total	254	115	126	87	80	69

Table 1-B. Estimated labour requirements of cocoa under coconuts (Mandays/ha)

Operations	Age of cocoa in year						
	1	2	3	4	5	6	7 onwards
Peg marking and taking pits (400 Nos.)	37	—	—	—	—	—	—
Planting seedlings and gap filling	8	2	—	—	—	—	—
Manuring	10	12	14	16	16	16	16
Weeding and after-care	20	20	20	10	—	—	—
Irrigation	25	25	25	25	25	25	25
Plant protection	4	6	8	10	12	15	20
Pruning	—	—	—	2	4	6	10
Harvesting and carrying pods	—	—	3	7	13	20	24
Repair of fence	5	5	5	5	5	5	5
Total	109	70	75	75	75	87	100

Table 2-A. Material input requirements in coconut cultivation as monocrop and mixed crop with cocoa

Item	Unit	Establishment period			Adult stage (per year)		
		Age of plantation					
		1	2	3	4-5 per year	6-7 per year	as mono- crop with cocoa
Seedlings	No.	175	18	7	—	—	—
Farmyard manure	Tonnes	4.5	4.5	4.5	4.5	4.5	4.5
<i>Fertilisers*</i>							
Urea	Kg	63.5	127	190	190	190	190
Super phosphate	Kg	117.0	234	350	350	350	350
Muriate of potash	Kg	117.0	234	350	350	350	350
<i>Plant protection chemicals</i>							
BHC 5 per cent	Kg	3.5	7	14	14	28	44
Copper sulphate	Kg	3.5	7	9	9	14	17.5
Lime	Kg	3.5	7	9	9	14	17.5
Contingency	Rs.	200	200	200	200	200	600

Table 2-B. Estimated material input requirements of cocoa under coconuts

Description	Unit	Age of cocoa in year						
		1	2	3	4	5	6	7 onwards
Seedlings	Nos.	400	40	—	—	—	—	—
Fertilisers**								
Urea	Kg	29	58	87	87	87	87	87
Superphosphate	Kg	33	67	100	100	100	100	100
Muriate of potash	Kg	31	62	93	93	93	93	93
Plant protection chemicals	Rs.	75	100	160	200	250	300	325
Contingency	Rs.	500	500	500	500	500	500	500

* at 500 gN, 320 g P₂O₅ and 1200 g K₂O/palm/yr from the third year onwards for coconut.

** at 100 gN, 40 g P₂O₅ and 140 g K₂O/tree/yr for cocoa with coconut as mixed crop.

Note: First year one-third of full dose of fertilisers.

Second year two-third of full dose of fertilisers.

Investment

In the case of coconut, the first seven years from planting are considered as the establishment period and all the expenditure in this connection including contingencies have been added up to derive the investment which comes to Rs. 35,300/ha (Table 3-A). However, at the stage of introducing cocoa as a mixed crop a further investment to provide assured irrigation was needed and 50 per cent of the investment on this account was charged to the coconut crop and the remaining 50 per cent was charged to cocoa. In this situation, the investment on coconut works out to Rs. 42,300/ha (Rs. 35,300 plus 50 per cent of the cost of irrigation infrastructure: Rs. 7,000). Since the pre-bearing years in the case of cocoa have been observed to be not more than three years, the investment or the cost of bringing cocoa up to the bearing stage was assessed by computing the expenditure on all inputs for the first three years from its planting. According to this study, the investment on cocoa comes to Rs. 15, 200/ha (Table 3-B).

Maintenance cost

Like any other perennial crops with a long economic life, the input requirements for coconut and cocoa remain constant over several years during their adult stages. According to this study the apportioned inputs for coconuts and cocoa remained stable from the fourteenth year and the seventh year respectively from their planting, and in monetary terms the annual maintenance cost for coconut as a monocrop comes to Rs. 4,930/ha and as a mixed crop Rs. 4,660/ha, while for cocoa it comes to Rs. 3,250/ha (Tables 3-A and 3-B).

Average yield

The average yield of 58 nuts/palm/year was assumed under Kerala conditions for the rainfed coconut monocrop and 80 nuts/palm/year for irrigated coconut with cocoa as mixed crop. In the case of cocoa, the average yield was assumed to be 35 pods/plant/year. With the plant population of 400/ha, the total number of pods/ha/year thus comes to 14,000. On weight basis this yield comes to 4,200 kg of pods or 420 kg of dry beans/ha.

Production cost

For estimating the cost of production of coconut and cocoa,

Table 3-A. Costs of investment and maintenance in coconut cultivation (Rs./ha)

Item	Rate/unit	Investment cost (initial seven yrs. expd.)	Maintenance cost at adult stage (with perfo Irrig.) Annual Expenditure/year	
			as rainfed mono-crop	as irrigated mixed crop with cocoa
Labour	20.00/manday	16,860	1600	1,380
Materials for fencing, shading and mulching	—	3,800	—	—
Seedlings	6.00/seedling	1,200	—	—
Farm yard manure	100.00/tonne	3,080	450	—
Fertilisers		7,550	1258	1,258
Plant protection chemicals		1,410	372	372
Harvesting	1.00/palm/harvest	—	1050	1,050
Contingencies	200.00/yr.	1,400	200	600
Total		35,300	4930	4,660

the investment, overheads and maintenance costs were taken into account. For coconut the total investment, namely the initial seven years expenditure in the establishment of the crop and the compound interest thereon were reduced to an annuity bearing 10 per cent interest and 60 years of economic life. The annuity value in this case comes to Rs. 6,600/ha. Since the perfo-spray irrigation was introduced at the time of cocoa interplanting, and the life period for the motor is 10 years and of perfo-pipes 20 years, the proportionate annuity value of Rs. 940 was further charged to the coconut crop. Thus the total annuity value in the case of irrigated coconut came to Rs. 7,540/ha in the presence of cocoa as a mixed crop.

Similarly, the initial three years expenditure in establishing cocoa in the coconut garden including the apportioned outlay on

Table 3-B. Cost of investment and maintenance of cocoa under coconuts (Rs./ha)

Item	Rate/unit	Investment cost (one to three yrs.)	Annual maintenance cost
Labour	20.00/manday	5,080	2000
Seedlings	1.00/No.	440	—
Fertilisers		845	825
Plant protection chemicals		335	325
Contingencies		1,500	500
Proportionate investment on perfo-spray irrigation		7,000	—
		15,200	3,250

the perfo-spray irrigation system and the compound interest thereon were reduced to an annuity, bearing 10 per cent interest and 30 years of economic life of this crop. The annuity value in this instance was found to be Rs. 2,250/ha (Rs. 1,310 plus Rs. 940 for the irrigation infrastructure).

As the annuity values are the annual shares of total investment to be adjusted over their life span, in order to arrive at the total annual cost, these values have been added to the annual maintenance costs, and in the process the total annual costs per ha for rainfed coconuts come to Rs. 11,530 for irrigated and mixed cropped coconuts Rs. 12,200 and for cocoa Rs. 5500. For the coconut-cocoa cropping system as a whole the figure thus comes to Rs. 17,700/ha.

Considering the production levels of 14,000 nuts and 4,200 kg of pods per ha per annum, in this system the cost of production thus works out to Rs. 0.83/coconut and Rs. 1.31/kg of cocoa pods. However, in the case of coconut monoculture the cost of production per nut comes to Rs. 1.08 (Table 4).

Net returns

Even though the ruling prices for coconuts were in the range

of Rs. 2.50 and Rs. 3.50/nut, due to unprecedented drought of the previous year, for this study Rs. 1.80 was considered based on the normal trend. With the given farmgate prices of Rs. 1.80/nut and Rs. 2.00/kg of pods and the corresponding production cost of Rs. 0.83/nut and Rs. 1.31/kg of pods, the net returns per ha per year for rainfed coconut, irrigated coconut and cocoa come to Rs. 7,300, Rs. 13,600 and Rs. 2,900 respectively, and for the cropping system under reference, the net return works out to Rs. 16,500/ha/annum (Table 4).

This study reveals that cocoa with the present price structure is a profitable mixed crop and there is no reason to neglect this crop under any apprehension. As one could see it is a common practice in Kerala to grow several crop species, particularly annuals, such as cassava (tapioca), yams, sweet potato and ginger in the interspaces of coconut palms without proper care and management. Indiscriminate practices of mixed/intercropping systems in coconut gardens without due regard to compatibility and nutritional needs have often resulted in inefficiency in the land use pattern by reducing the productivity of main crop (coconuts) and adding very little as intercrop(s) to the system as a whole (Das, 1983). On the other hand, cocoa with its inherent nature is a compatible crop with coconuts and yields relatively higher income compared to most of the commonly practised intercrops. The investigation has also indicated that there was no adverse effect on coconuts by cocoa under single hedge system. This was also evident in earlier studies elsewhere (Bhat and Bavappa, 1972).

Apart from monetary benefits, the coconut-cocoa system provides long-term benefits to most scarce resource land, as fertility status and conservation of soil improve as compared to other systems in coconut gardens because of the microbial action of the rhizosphere region and the ideal canopy architect of cocoa. In other words, the land use efficiency increases with the coconut-cocoa cropping system.

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Table 4. Estimated cost and returns in coconut-cocoa cropping system (Rs./ha)

Particulars	Cost of production & returns			Coconut and cocoa system
	Coconut monocrop	Coconut with cocoa	Cocoa as a mixed crop with coconut	
1. Investment during establishment up to bearing	35,300	35,300	8,200	43,500
2. Compound interest on investment (10 per cent)	20,510	20,510	4,160	24,670
3. Total investment (Col. 1 + 2)	55,810	55,810	12,360	68,170
4. Annuity value	6,600	6,600	1,310	7,910
5. Investment on perfo-irrigation system	—	7,000	7,000	14,000
6. Annuity value for investment on perfo system	—	940	940	1,880
7. Annual maintenance cost	4,930	4,660	3,250	7,910
8. Total cost/yr (Sl. No. 4 + 6 + 7)	11,530	12,200	5,500	17,700
9. Income from dry leaves, petioles etc/yr	560	560	—	560
10. Net cost of production/yr. (Sl. No. 8-9)	10,970	11,640	5,500	17,140
11. Average production/yr	10,150 nuts	14,000 nuts	4,200 kg pods	—
12. Cost of production/unit (Sl. No. 10 ÷ 11)	Rs. 1.80/nut	Rs. 0.83/nut	Rs. 1.31/kg. pods	—
13. Farmgate price/unit	Rs. 1.80/nut	Rs. 1.80/nut	Rs. 2.00/kg. pods	—
14. Net return/yr.	7,308 or 7,300	13,580 or 13,600	2,890 or 2,900	16,500

Dr. K. Shama Bhat, Joint Director, CPCRI Regional Station, Vittal for providing information on the introduction of cocoa into India and to Dr. Snoeck, Agronomist, Coffee and Cocoa Research Institute (IRCC), France for his valuable suggestions.

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DISCUSSION

- Q : In recent years, there has been a fall in price of cocoa. Do you feel that cultivation of cocoa is still economical?
- Ans: The net returns are worked out adopting a farm gate price of Rs. 2 per kg of pods. Even at that price level, the net return works out to be Rs. 16,500 per hectare per annum for the coconut cocoa system.
- Q : It appears that the estimates regarding the returns are much lower than the actuals.
- Ans: The ruling price of coconut is very high due to unprecedented drought of the previous year. This cannot be taken as a normal price realisable. The price of Rs. 1.80 per nut is based on the normal trend.
- Q : Is it worthwhile to take up a similar study for arecanut cocoa system?
- Ans: A large number of farmers are raising cocoa as a mixed crop in arecanut gardens also. Therefore a similar study is being done on that mixed cropping system.
- Q : In view of the fall in the price of cocoa, why other crops can not be recommended?
- Ans: We have to take into consideration, the compatibility and nutritional needs of the inter/mixed crop. Cocoa has been found to be one of the compatible crops with coconut.

TRENDS IN THE PRODUCTION AND TRADE OF PEPPER IN INDIA

PRAFULLA K. DAS

ABSTRACT

India's position in the world production and trade of pepper has slipped from the first rank during the period 1950 to 1955 to the fourth rank during the period 1976 to 1980. Although this country accounted for nearly 52 per cent of the world area under pepper it constituted about 15 per cent of the world production of this spice during the period 1976 to 1980. The compound growth rates of pepper production in India were 2.49 per cent in the fifties, (-) 0.82 per cent in the sixties and 0.16 per cent in the seventies. The average productivity of India's pepper was estimated as 254 kg/ha/year as against 4574 kg in the case of Malaysia, 2887 kg in Brazil, 2287 kg in Sri Lanka, 1158 kg in Indonesia and 508 kg in Madagascar in the late seventies. The compound growth rates of exports of pepper from India for the fifties, sixties and the seventies were 5.2 per cent, (-) 0.7 per cent and (-) 0.5 per cent respectively. For this country 1973-74 was the year of the highest attainment in the volume of export (31,648 tonnes) and 1977-78 was the year of the highest attainment in export earnings (Rs. 498 million) as well as unit value realisation (Rs. 20/kg). The Rupee-Trade Zone is now the biggest overseas buyer of Indian pepper. Considering the overall potential, a massive rejuvenation-cum-replanting programme in pepper for the traditional pepper growing areas and cultivation of this spice crop in the non-traditional south-eastern and north-eastern regions in India have been suggested.

INTRODUCTION

Pepper, a tropical spice crop originated in the Malabar region of Kerala in India and is an important item of trade in the world since time immemorial. Rosengarten (1969) in his work "The Book of Spices" has revealed that the kings sent expeditions, merchants risked lives, wars were fought and the globe was explored in search of oriental spices in general and pepper in particular. While in Europe, pepper was often used for the payment of custom duties, rents, taxes and even court fines, in China, a part of the salary of all civil and military officials was paid in the form of this commodity (T'ien, 1982). By the early part of the seventeenth century pepper had ceased to be a valuable spice available only to the wealthy, and with the growth of the world market there was a rise in its production and trade, and commerce in this article flourished. The recent trends in the production and trade of pepper in India in comparison with her competitors in these fields have been studied in this paper.

MATERIALS AND METHODS

The data used for the analysis in respect of area, production and yield of pepper in India are the estimates of the Directorate of Economics and Statistics (DE & S), Ministry of Agriculture and Co-operation, Government of India, and the corresponding figures for the other major pepper growing countries are the estimates of the respective countries available in the FAO Production Yearbooks and computer printout.

For constructing the index numbers for area, production and yield of pepper in India, the triennium ending 1969-70 has been used as the base period. This is in accordance with the selection of the base period by the DE & S and also the FAO.

The figures relating to India's exports, export earnings and unit values of pepper are the estimates of the Directorate General of Commercial Intelligence and Statistics (DG, CI & S), Government of India. The corresponding figures in respect of the other exporters are the estimates of the respective nations available in the FAO Trade Yearbooks and computer printout.

The statistics on the imports of pepper by major importing countries are the estimates of the respective nations available in

the "Spices—a survey of the world markets", published by the International Trade Centre (ITC), UNCTAD/GATT; and in the title "Spices trends in world market" published by the FAO.

RESULTS AND DISCUSSION

Pepper area

As far as the area under pepper is concerned India occupies the first place accounting for around half of the total pepper area in the world. Indonesia, Malaysia, Sri Lanka, Brazil and Madagascar accounted for 23.2 per cent, 5.5 per cent, 4.5 per cent, 10.4 per cent and 2.8 per cent of the world pepper area, respectively during the period 1976 to 1980. While India's pepper area expansion between 1961 and 1980 was 2.5 per cent, the world area under this spice expanded by 22 per cent during the same period largely due to the expansion programmes of Brazil, Indonesia and Malaysia. Table 1 shows the country-wise quinquennium average area of pepper during the period 1961 to 1980.

Pepper production

While India's pepper production during the period 1961 to 1980 came down by 6.9 per cent, the world production increased by 52.4 per cent. Barring India, in all other major pepper growing countries the rise in production was substantial. Under these circumstances, India lost her prime position as pepper producer during the sixties, the second position during the early seventies and the third position during the late seventies. Brazil which made a beginning in the pepper production during the twenties, now stands as the largest producer of pepper in the world followed by Indonesia and Malaysia (Table 1).

Production estimates by trade circle

On the basis of the market arrivals of pepper, the concerned trade circle of India estimates yearly production of this commodity and those estimated figures are always higher than the official estimates. According to the Trade Circle estimates, the average production of pepper in India for the seventies was 37,000 t/annum as against 28,000 t/annum estimated by the DE & S. If such is the case, India's position among the pepper producers

Table 1. Trends in area, production and exports of pepper (Average per annum)

Country	Area ('000 ha)				Production ('000 t)				Export ('000 t)			
	1961-65	1966-70	1971-75	1976-80	1961-65	1966-70	1971-75	1976-80	1961-65	1966-70	1971-75	1976-80
India	102.6 (61.7)	117.2 (63.6)	107.6 (58.8)	105.2 (51.9)	26.0 (24.1)	25.4 (23.8)	24.6 (19.6)	24.2 (14.8)	19.2 (33.6)	22.9 (28.7)	23.0 (24.8)	21.2 (18.0)
Indonesia	29.0 (17.5)	32.8 (17.8)	38.9 (21.3)	48.6 (24.0)	36.9 (34.3)	26.8 (25.1)	27.3 (21.8)	39.0 (23.7)	18.0 (31.5)	20.5 (25.7)	21.5 (23.2)	31.4 (31.4)
Malaysia	5.5 (3.3)	5.8 (3.2)	7.5 (4.1)	11.6 (5.7)	25.3 (23.5)	25.6 (24.0)	32.1 (25.6)	34.9 (21.3)	14.5 (25.4)	23.5 (29.5)	28.7 (30.9)	35.6 (30.4)
Brazil	3.6 (2.2)	5.1 (2.8)	7.7 (4.2)	16.5 (8.1)	6.1 (5.7)	12.5 (11.7)	22.4 (17.8)	45.4 (27.7)	3.9 (6.8)	9.9 (12.4)	15.8 (17.0)	25.0 (21.4)
Sri Lanka	5.6 (3.4)	5.4 (2.9)	5.9 (3.2)	7.6 (3.8)	9.8 (9.0)	12.1 (11.3)	13.6 (10.9)	15.5 (9.5)	0.3 (0.5)	0.6 (0.8)	0.5 (0.5)	0.8 (0.7)
Madagascar	10.2 (6.1)	10.6 (5.8)	8.3 (4.5)	6.0 (3.0)	1.9 (1.8)	2.6 (2.4)	3.4 (2.7)	3.1 (1.8)	1.3 (2.2)	2.3 (2.9)	3.3 (3.6)	3.1 (2.7)
Other Countries	9.7 (5.8)	7.4 (3.9)	7.1 (3.9)	7.2 (3.6)	1.7 (1.6)	1.9 (1.7)	2.0 (1.6)	2.0 (1.2)	—	—	—	—
World	166.2 (100)	184.3 (100)	183.0 (100)	202.7 (100)	107.7 (100)	106.9 (100)	125.4 (100)	164.1 (100)	57.2 (100)	79.7 (100)	92.8 (100)	117.1 (100)

Figures in the parentheses express the percentage of the world figures.

would become third instead of fourth.

Pepper yield

The average productivity of pepper for the period 1976 to 1980 was worked out as 254 kg/ha/year in the case of India, while the corresponding figures for Indonesia, Malaysia, Sri Lanka, Brazil and Madagascar were 1,158 kg, 4,574 kg, 2,287 kg, 2,887 kg and 508 kg, respectively. Productivity-wise, India's position is miserable.

Index numbers

The index numbers of area, production and yield of pepper in India for the period 1960-61 to 1980-81 have been presented in Table 2.

Compound growth rates

The estimated compound growth rates of India's pepper area, production, yield, export and export value for different periods are shown in Table 3.

Pepper exports

India's Malabar—the home of pepper was the only supplier of this spice to the world market till the turn of the nineteenth century. Since then slowly she lost her grip to the region representing present Indonesia and Malaysia. During the post second world war period this country regained her monopoly in pepper production as well as trade, consequent to the war effect in the south-east Asia region, but that situation was short-lived. India's share in the world exports of pepper continues to decline since the fifties. On the other hand, the shares of the competing countries continue to rise at the cost of this country as evident in Table 1.

Export earnings

Table 2 indicates the yearly export earnings and unit value realisation in respect of Indian pepper for the period 1950-51 to 1982-83. While 1973-74 was the year of the highest attainment in the volume of exports (31,648 tonnes), 1977-78 was the year of the highest attainment in the export earnings as well as the unit value realisation for India.

Table 2-A. Index numbers of area, production and yield of Black pepper in India (Base: Triennium ending 1969-70=100)
B. Trends in export earnings of unit value realisation from Black pepper in India

Year	A. Index Numbers			B. Trends in	
	Area	Production	Yield	Export value (Rs. million)	Unit value (Rs./kg.)
1960-61	101.6	132.3	130.3	85	5.00
61-62	101.6	132.3	130.2	81	3.72
62-63	101.1	121.3	120.1	66	3.16
63-64	101.1	111.6	110.4	59	3.56
64-65	101.6	112.5	110.7	68	3.92
65-66	101.2	107.3	106.1	111	4.22
66-67	101.3	106.8	105.5	118	5.22
67-68	100.8	102.2	101.4	130	5.23
68-69	100.0	99.3	99.3	97	5.14
69-70	99.2	98.5	99.3	161	7.26
70-71	99.0	101.3	102.3	153	8.49
71-72	97.8	101.3	103.5	148	7.70
72-73	98.8	101.3	102.5	143	7.17
73-74	100.4	111.0	110.6	295	9.33
74-75	100.6	109.0	108.4	345	13.09
75-76	99.9	110.6	110.7	339	13.99
76-77	102.1	136.5	133.7	382	18.63
77-78	100.0	110.6	110.6	495	20.06
78-79	75.6	92.9	122.9	281	18.39
79-80	75.8	95.0	125.3	335	16.04

Direction of exports

The main destination for Indian pepper in the forties and the fifties was the U.S.A. followed by West European countries (Purseglove et al., 1981). From the sixties the volume of exports to these countries tended to decline due to a major change in the export policy of India in favour of the Rupee-Trade with the U.S.S.R and the other centrally administered East European countries. As could be seen from Table 4, the East European Zone constituted 69.8 per cent of the total exports from India, while the American Zone and West European Zone constituted

PRODUCTION AND TRADE OF PEPPER

Table 3. Compound growth rates of area, production, yield, exports, export earnings and unit value of pepper in India

Period	Area	Production	Yield	Export	Export earnings	Unit value
1951-52 to 1960-61	2.30**	2.49**	(-) 0.36	5.20*	(-) 14.16	(-) 18.50*
1961-62 to 1970-71	1.48*	(-) 0.82	(-) 2.23**	(-) 0.75	10.04**	10.97**
1971-72 to 1980-81	(-) 1.10**	0.16	1.27	(-) 0.80	9.55*	10.09**
1951-52 to 1980-81	1.24**	0.31	(-) 0.92**	1.96**	6.80	4.73**

*Significant at 0.05 level. **Significant at 0.01 level.

14.2 per cent and 6.3 per cent, respectively during the period 1976 to 1980.

India's share in the total imports of pepper from her by the individual importing countries is shown in Table 4. The table reveals that during the period 1976 to 1980 nearly 91 per cent of the import demand from the U.S.S.R was met by this country while India supplied only 8 per cent of the total imports into the U.S.A., 2 per cent each to West Germany and the U.K and 3.6 per cent to Japan. This country's supplies to the major as well as traditional pepper buyers namely the U.S.A., West Germany and the U.K have been minimised partly due to lack of exportable surplus left over after meeting the obligatory trade demand from the U.S.S.R and the other East-European countries, and partly due to the stiff competition from Brazil, Indonesia and Malaysia in the international markets (Das, 1980).

OUTLOOK

India's pepper industry stands at the cross-road point facing stiff competition from the major producers each trying to raise its export market share and an economic recession faced by the major pepper buying markets, where each country is attempting to regulate its imports. Frequent and violent fluctuations in the unit value realisation are the offshoot of this crisis. The economic compulsions coupled with political equations must have prompted the Indian policy makers to choose the soft option of expanding the Rupee-Trade with the U.S.S.R. and East European Countries. Despite recession in the capitalist markets the demand for pepper is not going to be effected considerably as long as the food industry in those countries are expanding. The International Trade Centre has estimated a growth rate of the world demand for pepper as 4 per cent per annum. In view of this there is an obvious need for India to increase her pepper production and exports.

The strategy for increasing the production of pepper in India calls for a massive replanting/rejuvenation programme as a significant portion of pepper plantations in Kerala, (which accounts for 96 per cent of pepper production in this country) is either senile or severely affected by wilt diseases. Genetically poor yielders need to be replanted by the high yielding types such as

Table 4-A. Exports of pepper from India to major importing countries and zones
 B. India's share in total imports of pepper by major importing countries

Country/Zone	(A) Export as percentage to India's Total		(B) Total import Countrywise t/year		India's share in per cent	
	1961-65	1976-80	1961-65	1976-80	1961-65	1976-80
United Kingdom	0.4	0.4	3157.0	3816.0	2.4	2.3
Italy	8.5	4.9	2243.6	3387.8	79.8	31.3
West Germany	0.8	0.9	4374.4	10345.2	3.9	2.0
U.S.S.R.	23.2	46.3	5365.2	11060.4	91.0	90.5
U.S.A.	24.6	10.6	19191.6	28342.0	26.9	8.1
Canada	5.6	3.7	1627.0	2318.6	72.4	34.0
Japan	0.1	0.7	1019.2	4508.4	0.9	3.6
European Zone	10.2	6.3				
East European Countries	43.4	69.8				
Other European Countries	1.7	0.3				
American Zone	30.5	14.2				
Middle East Zone	6.2	5.5				
East Asia Zone	5.2	1.9				
Africa Zone	2.3	1.3				
Australia & Oceanic Zone	0.1	0.3				
Total	100.0	100.0				

Panniyur I. There is evidence that the farmers by adopting the recommended package of practices in Panniyur I variety with proper manuring and plant protection measures have realised on an average 1 kg yield/vine as against 0.25 kg average yield of pepper in India. Thus, the rejuvenation programme should be given top priority to put this historically important export oriented crop in its old honoured place. In addition to revamping the pepper production sector in Kerala, Tamil Nadu and Karnataka, serious efforts ought to be made to introduce this crop on a commercial basis in non-traditional areas, such as, Andhra Pradesh; Orissa; West Bengal; the North-Eastern regions, and, Andaman and Nicobar Islands, in order to meet the domestic and the overseas demand of this spice.

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DISCUSSION

- Q : The production of pepper in India declined gradually from the sixties. What is the reason?
- Ans: Competition from other pepper-producing countries like Brazil, Indonesia and Malaysia resulted in a fall in price. Naturally, the production of pepper in India declined.
- Q : Cultivation of the crop in non-traditional areas like the southeastern and northeastern regions in India has been suggested. Do we have any data on the performance of this crop in these regions?
- Ans: Yes, the performance of pepper in these regions is encouraging.

MARKETING AND PRICE SPREAD OF ARECANUT IN KERALA STATE

R.K. SIKKA, M.S. LAKSHMANACHAR and C.K. GEORGE

ABSTRACT

The study reveals that 72 per cent of the cultivators preferred sales through traders and curers in the village or nearby primary market, 6 per cent of them sold the produce through the commission agents in the assembling markets, 5 per cent through the regulated market, and the remaining 17 per cent through the cooperative (CAMPCO). The study further reveals that the cultivators get on an average 57.70 per cent of the consumers price in the marketing of boiled types of arecanut, 54.85 per cent for *chali* and 62.28 per cent for *Iylan*. However, the disposal through the CAMPCO gave higher share of 58.51 per cent for boiled types and 60.56 per cent for *chali*.

INTRODUCTION

Kerala has the largest area under arecanut in India. During 1982-83 it had 58,100 ha accounting for about 32 per cent of total area of 1,80,200 ha for the country as a whole. Since the average per ha yield was as low as 700 kg against the all India average of 1024 kg, the production was only 40,700 tonnes. Therefore, Kerala could occupy only the third place in the production field among arecanut growing States.

More than 70 per cent of arecanut production is sold in the processed form. According to the method of processing the varieties marketed can be classified into two categories namely boiled

types, called *Kaliadakka* and unboiled types, called *Kottadakka*. Boiled types of arecanut for example, *choor*, *edachoor*, *Madurai choor*, *Mukkal choor*, *Chalakkudi*, *Erazil*, *Ottavettu* and *Naluvettu*, are obtained from tender and semi-ripe fruits while unboiled types like *chali* and *fadcha* are prepared from ripe nuts 10 to 11 month old and those like *Iylan* and *Nayampak* from tender and semi-ripe nuts.

Semi-ripe and ripe arecanuts are marketed at the village level. However, in the processed form, they are sold in the primary as well as assembling markets. Much of the produce arriving into the markets is cornered by a few big wholesalers who command and manipulate prices. However, the establishment of procuring and processing centres by the Central Arecanut Marketing and Processing Cooperative Ltd. (CAMPCO) at various marketing centres in the State, in the recent years, has attracted a part of the arrivals. Marketing of arecanut in Kerala with the involvement of many intermediaries is yet to be organised under well established regulated markets to enable the producers to realise higher percentage of the price paid by the ultimate consumer. A study on the marketing and price spread of arecanut was, therefore, undertaken during the year 1982-83 with the following objectives:

- 1) To study the marketing practices in arecanut.
- 2) To locate, identify and analyse the nature and magnitude of the marketing costs and their implications.
- 3) To determine the price spread and the share received by the producer in the consumers price.
- 4) To suggest measures to improve the marketing of arecanut.

Methodology

A multistage random sampling technique was adopted in selecting sampling units. Six districts, namely, Cannanore, Trichur, Ernakulam, Malappuram, Kozhikode and Wynad were included in the study. From each of these selected districts, one assembling market, two primary markets and four villages were selected at random. Mangalore (where a considerable proportion of the produce from various areas in Cannanore district is brought for sale) and Delhi, Nagpur, Madras, Panrutti and Madurai representing important consuming centres were included for the investigation. The CAMPCO was selected as a purposive sample.

In all 72 cultivators 24 village merchants and traders, 12 curers, 20 wholesalers, 30 secondary wholesalers and 30 retailers were selected at random. The data were collected in specially designed schedules by personal interview.

RESULTS AND DISCUSSION

Channels of marketing arecanut

The cultivator has four options to sell namely, trader/curer at the village level, commission agent in the assembling market, regulated market and the cooperative (CAMPCO).

About 72 per cent of the cultivators contacted preferred sale through the traders and curers in the village or nearby primary markets where sales were generally effected by auction. Semi-ripe, ripe and dried whole arecanuts were transacted. Semi-ripe and dried arecanuts were sold in the husked form, while ripe nuts were sold in the unhusked form. In order to have uniformity in the trade, the sale of unhusked whole arecanut was restricted to be by weight only with effect from 1st April 1982 in Kerala. Six per cent of the cultivators contacted sold dried whole husked arecanuts in the assembling markets through commission agents.

At present, there are only four regulated markets in Kerala namely at Perambra, Kanhangad, Changaramkulam and Vattankulam. Ripe and peeled semi-ripe nuts are transacted in these markets. The cultivators and traders from adjoining areas bring their produce to the places and sell it by open auction. The amount due to the cultivators is given by the buyer through the market officials. There is no commission charged for the sale. Many cultivators prefer a regulated market as they can anticipate better prices for their produce. However, due to lack of sufficient regulated markets in the State, only about 5 per cent of the cultivators contacted sold the produce through these markets.

The CAMPCO has established 10 procuring centres with three sub-centres in Kerala. Mainly peeled semi-ripe and husked dried nuts were procured. Sale through cooperatives was preferred by 17 per cent of the cultivators contacted. The factors which motivated them to select this agency were, the better price offered for their produce according to quality, absence of intermediaries,

and absence of levy of charges like commission, brokerage and weighing charges.

Boiled types

Boiled types of arecanut are produced mainly at Pazhanji, Trichur, Chalakudi, Thalakadathur and to some extent at Palghat and Calicut. They are despatched mainly to Bangalore and Bangarpet in Karnataka and Madras and Madurai in Tamil Nadu.

Marketing costs of curers of boiled types of arecanut is presented in Table 1. The average marketing cost of curers worked out to Rs. 2042.50 per quintal including the cost of raw materials. The secondary wholesaler in the consumer centres stored the cured product, and sold to the retailers when the prices were up to their expectation. The CAMPCO disposed of the product through sales depots at Madras and Madurai and through selling representatives to the secondary wholesalers and to the retailers.

Unboiled types

Chali and *Fadcha*: The wholesalers purchased the produce either directly from the cultivators and traders in the primary markets or through the commission agents to the assembling markets. After bringing the produce to their godowns it was dried, sorted, graded and sulphur fumigated. Grading was done according to size using rectangular sieves. Although there are 12 grades, the general practice was to separate the husked produce into *Moti*, *Vacharas*, *Jani* and *Jeeni*. The inferior grades like *Fatori* and *Karigotu* were hand picked. In the case of *Fadcha*, the grading was done after cutting into halves and the produce marketed as 'Best', 'Medium' and *Chilta*.

It is estimated that more than 90 per cent of *Chali* and *Fadcha* stored by the wholesalers in areas under this study were despatched to the markets in North India mainly to Bombay, Nagpur, Kanpur, Delhi, Cuttack, Rajkot, Jaipur etc. Each of these markets have their own preferences. As for instance, in Bombay the big size was preferred, whereas, in Nagpur and Delhi small and medium sizes were preferred. In industrial areas inferior grades were favoured. However, in all the markets uniformity of size appeared to fetch a premium price. The wholesalers sold their

Table 1. Marketing cost of the curers of boiled types of arecanut

Items	(Rs. per quintal of cured produce)				
	Madurai Choor/ Mukkal Choor/ Eda Choor	Chalakudi	Erazil	Ottavettu	Average
1. Cost of 3 quintals of raw tender nuts to make 1 quintal of cured produce	1600.00	1700.00	1520.00	1600.00	1605.00
2. Transport charges to the processing unit	8.50	7.50	7.50	6.50	7.50
3. Cost of firewood	40.00	40.00	40.00	40.00	40.00
4. Expenses on sorting, cutting, boiling, Kali coating and drying	104.00	95.00	77.00	67.00	86.00
5. Packing and transport to assembling market	12.70	13.30	14.10	12.10	13.00
6. Purchase tax	178.12	211.87	165.00	172.50	181.87
7. Commission (3 to 4%)	95.00	84.75	88.00	69.00	84.19
8. Rent and interest on loan	11.88	42.38	11.00	34.50	24.94
Total	2050.20	2194.80	1922.60	2001.60	2042.50
Average sale price	2375	2825	2200	2300	2425.00

products to the secondary wholesalers of northern States through commission agents mostly on consignment basis. The details of the marketing cost of the wholesalers of *chali* and *fadcha* are given in Table 2.

Iylan: The important centres of production of *Iylan* are Perambra, Mananthody and Thalakkadathur. In the study area the processing method adopted was that the peeled semi-ripe nuts were cut breadth-wise into four to eight slices and dried without boiling. The dried product was sulphur fumigated and despatched to Calicut for sale through commission agents. On market

Table 2. Marketing cost of wholesalers of *Chali* and *Fadcha*

Item	(Rs. per quintal)	
	For goods distributed through commission agent I	For goods transferred to Head Office/ Branch office II
Price at which purchased	1222.80	1344.00
Handling and/transport charges to godown	1.84	—
Commission	6.12	—
Brokerage	1.14	—
Sorting, sizing, garbling, fumigation, packing etc.	20.70	22.99
Shortage, storage	42.22	33.06
Interest	—	16.30
Purchase tax and market cess	97.08	115.50
Packing and forwarding	2.50	—
Cost of packages (including polythene)	13.89	11.87
Insurance on transport	2.63	2.32
Commission	41.50	42.00
Transport consuming centre	—	35.00
Bank charges	—	7.00
Octroi	—	2.90
Brokerage and Discount	—	16.80
Total	1452.42	1649.74
Average sale price	1582.60	1775.00

days samples were displayed from each consignment and sales were made by direct negotiation with the secondary wholesalers mostly from Panrutti. The factors considered for price settlement were moisture content, percentage of broken pieces and presence of matured nuts. The average marketing cost of the curers of *Iylan* at Perambra market is given in Table 3.

Table 3. Marketing cost of the curers of Iylan

(Rs. per quintal of cured products)

S. No.	Items	Cost
I	Cost of semi-ripe nuts	1,572.72
II	Transport charges to processing unit	8.70
III	Expenses on sorting, cutting, drying, fumigation and packing etc.	77.40
IV	Transport to Calicut	10.00
V	Cooly expenses	3.00
VI	Commission	59.40
VII	Brokerage	4.00
	Total	1,735.22
	Average sale price	1,880.00

The expenses born by the secondary wholesalers were the purchase tax, market cess, brokerage, and packing and transport charges. They transported the produce to their respective destinations and sold it, after grading, in the off season when the prices were generally higher. Grading was done on the basis of size by means of sieves and hand picking. The grades prepared were *Sithanam*, *Pottu*, *Nadappu*, *Ammankasu*, *Iylan*, *Sannam No. 1* and *Sannam No. 2*, *Nosumbar* and *Vettai*. *Sithanam* which is a superior grade was in good demand. The produce was sold to the retailers directly or through brokers.

Marketing channels

Boiled types

Channel I: Producer-curer-commission agent-secondary wholesalers-retailer-consumer.

Channel II: Producer-Co-operative (CAMPCO)-Retailer-Consumer.

Unboiled types

Chali/Fadcha

Channel I: Producer-Village merchant-Commission agent-Wholesaler-Secondary wholesaler-Retailer-Consumer.

Channel II: Producer-Co-operative (CAMPCO)-Retailer-Consumer.

Iylan Producer-Curer-Commission agent-Secondary wholesaler-Retailer-Consumer.

Price spread

Boiled types

In the marketing of boiled types of arecanut, the producer received a higher share of 58.51 per cent in Channel II, when he sold the produce to the co-operative. His share was lower at 56.89 per cent in Channel I, when he disposed it off to the traders. The price spread was also lower in Channel II (41.49 per cent) and higher (43.11 per cent) in Channel I. Thus sales through the CAMPCO ensured a higher share of consumer's price to the areca growers. The combined margins of intermediaries namely the cooperative, retailer and commission agents in Channel II came to 19.18 per cent, while in the case of intermediaries in Channel I, where the secondary wholesaler was the additional intermediary the margin came to 24.00 per cent. The commission received by the commission agents was much higher at 6.41 per cent in Channel I against 1.04 per cent in Channel II. The major costs of marketing are purchase/sales tax and expenses on processing, transport and merchandising. The latter included expenses incurred on cost of packages and packing, handling, storage, rent, interest and shortage, etc. The share of purchase/sales tax in the consumer's price was 9.80 per cent in Channel I and 9.45 per cent in Channel II. A single point purchase tax at 6 per cent plus additional tax of 15 per cent plus surcharge of 10 per cent was being levied by the Government of Kerala on the last purchase of the produce within the State. General sales tax was

levied on sales within the country at the rate of 7 per cent in Delhi, 2 per cent in Maharashtra and 5 per cent in Tamil Nadu.

Unboiled types

Chali/Fadcha: The producer's share in the consumers price in the marketing of *chali* and *fadcha* was 49.14 per cent in Channel I against 60.56 per cent in Channel II. This difference was mainly due to the large number of intermediaries, such as, the village merchant, commission agent, wholesaler, secondary wholesaler and retailer involved in Channel I. Their combined share came to 24.54 per cent of consumers' price. A total of 20.53 per cent was shared between the CAMPCO, retailer and commission agent in Channel II. The maximum margin was, however, shared by the retailer in both the channels. It varied from 11.19 to 12.84 per cent. The price spread was 50.86 per cent of the consumers' price in Channel I, and much lower at 39.44 per cent in Channel II. Thus with the entry of the co-operative in the marketing of arecanut the areca growers received a higher share in the consumers price. The share of marketing costs on processing and grading, purchase/and sales tax, transport and merchandising was 26.32 per cent in Channel I as against 18.91 per cent in Channel II.

Iylan: In the marketing of *Iylan* only one Channel is considered since cooperative (CAMPCO) had not yet started its own production of this variety of arecanut. The cultivators sold semi-ripe nuts to the curers in the village, or in the nearby primary markets. The cultivator's share in the consumers price was 62.28 per cent. The price spread was 37.72 per cent. The combined margins of intermediaries namely curer, commission agent, secondary wholesaler and retailer came to 19.60 per cent and the remaining 18.12 per cent covered the costs of marketing, that is purchase/sales tax (9.62 per cent), processing (3.10 per cent) and transport and merchandising (5.40 per cent).

Conclusions

Seventy-two per cent of the cultivators preferred sales through the traders and curers in the village or nearby primary market, and 6 per cent of them sold their produce through commission agents in the assembling markets. Only 5 per cent of them preferred sales through the regulated markets, and 17 per cent

through the cooperative (CAMPCO). The traders after purchasing the produce from the cultivators processed it and sold it to the wholesalers at a reasonable profit through commission agents. Therefore, the process of negotiation for the cultivators was weak. The cultivators can gain by processing the produce themselves, or, selling it to the cooperative, or, selling it in the assembling markets, instead of disposing it off in the village.

The study revealed that the cultivator received on an average 57.70 per cent of the consumers price in the marketing of boiled types of arecanut, 54.85 per cent for *chali* and *fadcha* and 62.28 per cent for *Iylan*. He received a higher share of 58.51 per cent for boiled types and 60.56 for *chali* and *fadcha* when he sold these commodities through the cooperative (CAMPCO). This was due to the existence of a smaller number of intermediaries when the commodity passed through this cooperative. It was also observed that the margin appropriated by the retailer was considerably high. Moreover, commission to commission agents at the rate of 3 to 4 per cent *ad valorem* at Trichur was higher. Greater marketing efficiency has been achieved through the entry of CAMPCO in the marketing of arecanut, although generally the malpractices have not yet been routed out in the trade. Only a small percentage of the total arrivals of arecanut was marketed through this cooperative. The cooperative is yet to enter the market with their own production of *Iylan*. Small cultivators because of their small produce and poor bargaining power disposed off the produce in the villages or nearby primary markets. Efforts should be made by the cooperative for the collection of ripe, semi-ripe and dried arecanuts through cooperative societies in the primary markets, and for production of all commercial varieties.

The Regulated Market Act is now in force in the Malabar region of Kerala and there are only four regulated markets. Only ripe and peeled, semi-ripe arecanuts are sold in these markets. There is a need for extending the Act to the whole of Kerala and to include all the commercial arecanuts as notified commodities. Regulated markets should be established in all the primary and assembling markets. All these steps will help the CAMPCO to procure arecanut directly from the growers through the cooperative societies, or its agents, and the grower would get higher prices according to quality.

UNIFORMITY TRIAL : SIZE, SHAPE AND DIRECTION OF EXPERIMENTAL PLOTS FOR TURMERIC

M.V. GEORGE and M. SANMARAPPA

ABSTRACT

The Fairfield Smith equation with standard notations $Y = ax^{-s}$ and its generalisation in the form $Y = ar^{-s_1}c^{-s_2}$ was fitted to the uniformity trial data on turmeric collected from Hirehalli for two different directions with 24 beds of size 1 m \times 12 m each. The directions were north-south and east-west. However, the fertility gradient was in the north-south direction. In both cases the plot sizes consisting of 3 beds of size 1m \times 1m along the fertility gradient was found to be optimum.

INTRODUCTION

The importance of optimum size and shape of plots and blocks in agricultural field experimentation is well recognised. Fairfield Smith (1938), worked out an empirical relationship between plot size and the C.V. of yield. Many attempts have been made in evaluating the optimum size and shape of plots for various crops including plantation crops (Agarwal et al., 1968; George et al., 1979, 1983 and 1984).

India ranks first in the world on production of turmeric, producing about 1.2 lakh tonnes from an area of 0.67 lakh ha. Turmeric is generally cultivated in raised beds of varying sizes and shapes. Though the length of the bed varies according to the local practices and conveniences, the breadth is usually maintain-

ed around 1 m. It was a matter of curiosity whether the direction of forming the bed has any influence on the size and shape of plots. In this paper an attempt has been made to evaluate and compare the optimum size and shape of plots under different price situations with beds being formed in two different directions.

MATERIALS AND METHODS

Uniformity trials were laid out at the CPCRI Research Centre, Hirehalli on turmeric during the year 1981-82 with 24 beds of size 1 m \times 12 m in the north-south direction and another in the east-west direction. The ultimate unit was taken as the total of the produce from 1m \times 1 m area of the bed. This resulted in 24 rows of units for both the directions of beds. Plots of varying sizes and shapes were formed, combining the adjacent units column-wise and row-wise and the corresponding C.V. was worked out.

Fairfield Smith's law $Y = ax^{-g}$ was fitted to find the relationship between plot size (X) and C.V. (Y) where g is the heterogeneity coefficient. Generalisation of this law in the form $Y = ar^{-g_1}c^{-g_2}$ was also tried to compare the heterogeneity of rows (r) and columns (c) where g 's denote the heterogeneity coefficients. The plot size and shape giving the required information at a minimum cost was taken as the optimum. The cost of experimentation per treatment to estimate the means at 5 per cent C.V. was worked out for three different price situations K_1 , K_2 and K_3 when the plots are arranged in blocks of 4, 6, 8, and 12 treatments, using the relationship $C_{ki} = C_1r + C_2E$ where C_{ki} is the cost for the i th price situation, C_1 is the cost of maintaining experimental plot, C_2 is the cost of maintaining experimental plants. The arbitrary cost ratios $C_1 : C_2$ for the price situations are 1 : 2; 1 : 3 and 1 : 4 respectively.

RESULTS AND DISCUSSION

The C.V. values determined for various sizes of plots followed closely the relationship $y = ax^{-g}$ (Fairfield Smith's law). The equations and their generalised form along with their R^2 values for both directions are presented in Table 1. The equations were found to be a satisfactory fit in all cases as seen from the R^2

values. The C.V. decreased with the increase in plot size in both directions. When the beds were formed in the north-south direction, column-wise heterogeneity was significantly more than row-wise heterogeneity, indicating that the fertility gradient was in the north-south direction. But in the case of beds formed in east-west direction as seen from Table 1, row-wise heterogeneity was more than column-wise, showing that the fertility gradient was again in the north-south direction. Hence, it is advantageous to form the blocks across the fertility gradient and the plots along it.

Table 1. Fairfield Smith's Law $Y = a X^{-s}$ and its generalisation
 $Y = a r^{-s_1} c^{-s_2}$

Direction	$Y = a x^{-s}$	$Y = a r^{-s_1} c^{-s_2}$
	—0.10	—0.09-0.10
North-south	41.33 × ($R^2 = 0.94$)	40.58 r c ($R^2 = 0.82$)
	—0.08	—0.08-0.07
East-west	59.96 × ($R^2 = 0.96$)	58.50 r c ($R^2 = 0.82$)

Table 2 gives the C.V. percentage, minimum number of replications (r) required and the relative cost of experimentation per treatment under three different price situations K_1 , K_2 and K_3 . Here the plots are arranged in blocks of four and 12 for different sizes and shapes of plots on the observed C.V. for the beds formed in the east-west direction. A close study of the cost of experimentation revealed that relatively a plot size of three units of one column gave the minimum cost in almost all the price situations.

A similar trend was also observed in the case of beds formed in the north-south direction, except that the rows and columns were interchanged (Table 3). The plot size obtained by graphical method also confirmed these results. The optimum size obtained for turmeric is almost the same as the one worked out earlier for ginger (George et al., 1984) another *Zingiberaceae* family, for which the cultivation practices are almost the same. Hence a plot 1 m × 1 m along the fertility gradient was found to be optimum.

Table 2. C.V. per cent, number of replications required and cost of experimentation per treatment for three price situations k1, k2, and k3 in 4 and 12 plot blocks—(Beds formed in east-west direction)

Size and shape of plot	4 plot block				12 plot block					
	CV%	r	k1	k2	k3	CV%	r	k1	k2	k3
1 × 1	32.30	42	504	672	840	42.07	71	2556	3408	4260
1 × 2	29.15	34	408	544	680	48.45	94	3484	4512	5640
1 × 3	36.43	53	636	848	1060	—	—	—	—	—
2 × 1	28.04	32	384	512	640	45.97	85	3010	4080	5100
3 × 1	24.44	24	288	384	480	35.92	52	1872	2496	3120
4 × 1	25.70	27	324	432	540	35.05	55	1980	2640	3300
3 × 2	26.41	28	336	448	560	46.67	88	3168	4224	5280
6 × 1	23.46	22	264	352	440	34.68	49	1764	2354	2940
12 × 1	19.48	16	192	256	320	32.07	42	1512	2016	2520
6 × 2	25.10	26	312	416	520	45.01	81	2916	3888	4860

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Table 3. C.V. per cent, number of replications required and cost of experimentation per treatment for three price situations k1, k2 and k3 in 4 and 12 plot blocks—(Beds formed in north-south direction)

Size and shape of plot	4 plot Block					12 plot Block				
	CV%	r	k1	k2	k3	CV%	r	k1	k2	k3
1 × 1	23.68	23	276	368	460	29.31	35	1260	1680	2100
2 × 1	27.11	30	360	480	600	33.21	45	1620	2160	2700
3 × 1	24.83	25	300	400	500	—	—	—	—	—
1 × 2	19.40	15	180	240	300	25.80	27	972	1296	1620
1 × 3	17.03	12	144	192	240	24.48	24	864	1152	1440
1 × 4	16.98	12	144	192	240	23.69	23	828	1104	1380
2 × 3	24.11	24	288	382	480	30.22	37	1332	1776	2220
1 × 6	14.54	9	108	144	180	21.75	19	684	912	1140
1 × 12	12.94	7	84	112	140	19.46	16	576	768	960
2 × 6	12.28	20	240	300	400	28.33	33	1188	1584	1980

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DISCUSSION

Q : Is it not necessary to study the interaction between the cultivars used and plot size?

Ans: The interaction between cultivars and plot size is worth studying. Different plot sizes for different groups of cultivars may have to be adopted, if interaction is found to exist.

IMPACT OF THE FARM RADIO SCHOOL ON THE SMALL TEA GARDENS IN THE NILGIRIS

P. SWAMINATHAN and G. BORIAH

ABSTRACT

In collaboration with All India Radio, Coimbatore, a Farm School on AIR was organised between 1st January and 31st March 1984 and 13 lessons on tea culture were broadcast. The programme was encouraged with an enrolment of 3,016 growers.

A majority of the farmers included in this study were either young or middle aged; educated up to secondary level; owned land below 2 ha; engaged as full time tea growers; had farm experience of less than 10 years and had an annual income between Rs. 5,000 and Rs. 15,000. Ninety-two per cent of the registered farmers owned radios, which goes to show that a considerable number of growers depend on farm radio programme for information and the potentiality of this mass media may profitably be exploited for popularising farm innovations among the farmers, in future.

INTRODUCTION

In the Nilgiris, tea is grown in about 27,000 ha and is the major crop of economic importance occupying approximately 48 per cent of the net cultivated area of the district. It is a remarkable and revealing feature that nearly 60 per cent of the registered small tea gardens in India are located in the Nilgiris. It is estimated that the actual number of small tea gardens in the Nilgiris could be between 15,000 and 20,000.

Due to the unorganised nature of the small holdings and adoption of outmoded, traditional cultivation, the average yield of the small gardens is about 900 kg/ha compared to more than 2,500 kg/ha of made tea, in the organised corporate sector estates. To bridge this wide gap in yield, several small growers development schemes namely training, demonstration, supply of planting material and crop diversification, have been undertaken by the UPASI Tea Scientific Department with financial assistance from the Tea Board. Though these schemes have brought about a marked impact on the development of the small tea gardens (Swaminathan and Boriah, 1982), there is yet a great deal of ground to cover, in view of the larger number of gardens involved.

In order to cover a large number of growers in a short span of time, a Farm School on AIR was organised in collaboration with all India Radio, Coimbatore. Thirteen lessons covering the entire gamut of tea culture were broadcast, every Sunday evenings during the Farmers' Programme commencing from 1st January to 31st March 1984. The lessons were rebroadcast to serve revision on the afternoon of the following Sundays, prior to the subsequent lesson on that evening, which also provided continuity. The programme was encouraged with an enrolment of 3,016 growers. At the end of the programme, a test was conducted and attractive prizes for the first five participants who had secured the highest marks were distributed. In order to find the impact of the Farm School on AIR on a scientific basis, a study was undertaken.

The results of evaluation of Farm Radio School and its impact on small tea gardens in the Nilgiris are discussed in this paper.

METHODOLOGY

The study was confined to a random sample of 100 out of 3,016 respondents scattered over all parts of the Nilgiris. A structured interview schedule was used to collect the necessary data from the selected respondents. Hence, it is only a qualitative study based on the views expressed by the farmers for a set pattern of questions.

FINDINGS AND DISCUSSION

The radio broadcast programme is meant for all small tea growers, but not all had registered for this programme. In this context, the characteristics of those registered tea growers, if analysed, will be useful for better interpretation of the knowledge acquired as well as their adoption behaviour of the practices broadcast.

Characteristics of participants of Farm School on AIR

The basic information about the participants like age, education farm size, occupation, experience in tea cultivation and income level are furnished in Table 1.

1) *Age*: Among the listeners 44 per cent were in the young age group, 43 per cent were middle aged and only 13 per cent were older people.

2) *Education*: The study revealed that 47 per cent of the listeners had high school education, followed by 34 per cent with college education and the rest 19 per cent had middle and primary school level education.

3) *Farm size*: Among the participants, only 12 per cent were landless and 86 per cent owned either small or medium size tea gardens, and the remaining 2 per cent were agriculturists without any area under tea.

4) *Occupation*: The remarkable finding of the study was that 82 per cent of the listeners were full time tea growers out of which nearly 72 per cent of them were from traditional tea areas (Coonoor and Kotagiri taluks) of Nilgiri district and their main income is from tea.

5) *Experience in tea cultivation*: It was found that only 5 per cent of the listeners were new to tea, 34 per cent had one to five years, 27 per cent between five and ten years and the rest had more than ten years experience in tea cultivation.

6) *Income level*: The survey revealed that 61 per cent of the farmers were in the middle and high income group. Ninety-two per cent of the listeners possessed radios.

The majority of the farmers included in this study were either young or middle-aged, were educated up to secondary level; owned lands below two ha; were engaged as full time tea growers; had farm experience of less than 10 years and had a family in-

Table 1. Characteristics of participants of Farm School on AIR

Sl. No.	Particulars	Per cent
I Age		
i)	Young < 30 years	44
ii)	Middle 30-50 years	43
iii)	Old > 50 years	13
II Education		
i)	Illiterate	—
ii)	Primary	2
iii)	Middle	17
iv)	Secondary	47
v)	Collegiate	34
III Farm size		
i)	Landless	12
ii)	Small < 2ha	74
iii)	Medium 2-8 ha.	12
iv)	Large > 8 ha.	—
IV Occupation		
i)	Full time tea grower	82
ii)	Part time tea grower	7
iii)	General agriculturist	5
iv)	In service personnel from tea estates	6
V Experience in tea cultivation		
i)	Nil	5
ii)	1-5 years	34
iii)	5-10 years	27
iv)	10 years	34
VI Income level		
i)	Low < Rs. 5000/	39
ii)	Medium Rs. 5000-15,000	44
iii)	High > Rs. 15,000	17

come between Rs. 5,000 and 15,000 per annum.

Source of information

To 85 per cent of farmers the various training activities of UPASI happened to be the source of information in gaining first hand knowledge on tea cultivation. Specifically, one-third obtained the information through the Farm Radio School. Among various mass media, the radio is easily accessible and is

within the reach of all farmers, especially in the hilly tea tracts of the Nilgiris with the scattered nature of small holdings. In the study sample 92 per cent owned radios and others might have listened through other radio sets available in their neighbourhood. The fact remains that a considerable percentage of small tea growers continue to depend on the Farm Radio School programme for information and the potentiality of this medium may profitably be exploited in popularising farm innovations, in future among the farmers particularly small tea growers (Table 2).

Table 2. Source of information in gaining first hand knowledge on tea cultivation

Source of information	Per cent
i) Through Farm Radio School for the first time	33
ii) By attending the two week training at UPASI	43
iii) Through UPASI trained farmers	9
iv) Through UPASI Advisory Service	6
v) Through Training and Visit Scheme	9

Motives of the tea growers in joining the Farm School on AIR

Eighty-seven per cent of farmers viewed that their primary objectives of listening to the farm broadcast was to learn new technology and then to adopt the same in their garden to raise their economic conditions.

This shows that radio listening is more purposeful and intentional. Six per cent had listened to the programme with the specific purpose of sharing their ideas with others. This percentage though it is small, supports the fact that farm practices spread from farmer to farmer through inter-personal communication, which becomes significant in the technology transfer system. Such information giving farmers may otherwise be treated as immediate contact farmers in multiplying extension educational efforts. UPASI or any extension agency may not be in a position to maintain personal contact with all the farmers due to its limited extension worker-farmer ratio; and one way to overcome these limitations is to work through information sharing farmers.

Impact of the Farm School on AIR programme in respect of

1) Knowledge level of listeners

To assess the knowledge level of listeners, 25 questions relating to specific techniques of tea cultivation were asked. The different levels of knowledge gained by the listeners, based on their answers are given in Table 3. It is gratifying to note that nearly 86 per cent of the listeners had a medium to very high level of knowledge.

Table 3. Knowledge level of the listeners

Knowledge score range in percentage	Per cent
Low 0-20	14
Medium 20-40	32
High 40-60	34
Very high above 60	20

2) Symbolic adoption of scientific/improved practices

Tea being a perennial crop most of the operations are highly seasonal, it is very difficult to assess the extent of adoption of the recommended practices by the listeners during the period of survey, which was conducted just three months after the completion of the broadcast of lessons. However, in order to assess the impact of the lessons broadcast on the listeners, they were asked to list out important cultural aspects, which they had considered for adoption in the near future (symbolic adoption), the particulars of which are given in Table 4.

Of the ten cultural practices listed in Table 4, chemical weed control has emerged as the important practice for use by more than one-third of the farmers among the listeners of the broadcast. More than one-fifth of them had shown interest on three other practices like split application of fertiliser, use of v.p. clones for new planting and plant protection. The two practices—correction of zinc deficiency and soil conservation have registered relatively less percentage of symbolic adoption (about 6 per cent).

Symbolic adoption in a sense is a parameter of future actual usage. The study implies that farmers are more concerned with

Table 4. Symbolic adoption of recommended practices

N = 87

Sl. No.	Practices	Per cent	Rank
1.	Chemical weed control	34.48	1
2.	Split application of fertiliser	27.59	2
3.	Use of v.p. clones for new planting and infilling	24.14	3
4.	Plant protection	20.70	4
5.	Step up plucking	19.54	5
6.	Maintenance of pruning cycle	18.41	6
7.	Adoption of double hedge system for planting	17.24	7
8.	Shade management	13.79	8
9.	Correction of zinc deficiency	6.88	9
10.	Soil conservation	5.75	10

areas like chemical weed control, fertiliser application, plant protection and use of v.p. clones and hence there is a need to intensify extension efforts in all these practices. The reasons for the low percentage of symbolic adoption with regard to correction of zinc deficiency and soil conservation is that they have become the routine established cultural practices in many of the small tea gardens.

Opinion of listeners

The opinion of listeners with regard to the level of understanding, speed of speech, adequacy of information, usefulness of lessons etc., are furnished in Table 5. The survey results were highly encouraging to note that nearly 87 per cent of the participants had listened to more than 50 per cent of 13 lessons and more than one-third to all the lessons.

About 75 per cent farmers uniformly opined the lessons to be highly understood; the speech to be with optimum speed in consistency with the normal receiving speed, the information to be sufficiently adequate enough and above all the content to be more useful. These opinions also add to the quality of the broadcast. The farmers were asked to state whether or not they need contact programmes as part of Farm School on AIR. Almost all

Table 5. Opinion of listeners about the lessons

Sl. No.	Particulars	Per cent
<i>I Lessons listened frequency</i>		
	i) < 6 lessons	13
	ii) 6-12 lessons	59
	iii) All the 13 lessons	28
<i>II Lessons understood</i>		
	i) High	74
	ii) Moderate	26
<i>III Speed of speech</i>		
	i) Optimum	90
	ii) Fast	10
<i>IV Sufficiency of information</i>		
	i) Sufficient	78
	ii) Insufficient	22
<i>V Usefulness of lessons</i>		
	i) Most useful	75
	ii) Moderately useful	21
	iii) Low	4
<i>VI Contact programme after broadcast</i>		
	i) Necessity of contact class	91
	ii) Duration of the contact class	
	1 to 2 days	13
	3 to 4 days	13
	5 and above	74

but a few had fully realised the need for contact programmes to immediately follow the broadcast. Again about three-fourths of farmers were of the view that the duration of contact programmes should be for five or more days.

The interest with which farmers had been attentive to radio broadcast was also reflected through the farmers' immediate response to listening. Nearly two-thirds of farmers had noted the important points of the message for future reference and use. Eight per cent of the farmers had even taped the broadcast programmes. The study revealed that through the registered listeners there is involvement of the non-registered listeners also, who got the message from the registered participants. Fourteen per cent of the farmers used to listen to the programme along with their friends. Regarding sharing the message with others, 50 per

cent of listeners had communicated the message to their friends, and another 38 per cent to their neighbours and relatives.

Implications

One-third of the registered small tea growers had acquired first hand knowledge on tea culture through the Farm School on AIR. More than 90 per cent of the participants had listened to the programme with the purpose of using the message. Nearly 86 per cent of the listeners had gained a medium to high level of knowledge on the practices disseminated through the Farm Radio School. About one-third listeners had mentally decided to use one or more of the practices, at the appropriate time.

Not only had the programme influenced the registered listeners but through the listeners the message had disseminated to a considerable number of other farmers. This impact strongly supports the need for the continuance of the Farm School on AIR as an appropriate tool in the transfer of technology to the small tea growers.

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DIFFUSION OF INFORMATION ON RUBBER THROUGH DAILY NEWSPAPERS—A STUDY OF ITS EFFECTIVENESS

**V. HARIDASAN, K.K. RAMACHANDRAN PILLAI and
K.G. SREENIVASAN**

ABSTRACT

The paper deals with the result of a study conducted by taking 60 rubber growers from the Changanacherry Co-operative Marketing Society by applying a random sampling technique. The study attempted to find the extent of adoption of scientific information through the medium of Malayalam newspapers. All the rubber growers interviewed were found to be literates. There were 10 graduates and four post-graduates among them. The study reveals that 59 growers were reading some newspapers every day. The Malayalam dailies patronised by the growers according to importance are: Malayala Manorama, Deepika, Mathrubhumi, Kerala Kaumudi and Deshabhimani. Twelve growers also read English dailies. The growers have assimilated scientific information on the cultivation of rubber through the medium of the agricultural page appearing in the dailies during the last 10 years. However, some deficiency has been noted in the area of diffusion of knowledge namely, in the sphere of processing soil and leaf analysis and tapping. By and large the growers are happy with the role of the Malayalam dailies in the dissemination of scientific information.

INTRODUCTION

About 80 per cent of Keralites are literate and hence efforts are going on to disseminate information on modern techniques of

rubber cultivation through the written medium. A large number of popular scientific articles on rubber cultivation have been published during the last 10 years in the Malayalam dailies. All important newspapers in the State carry a one page feature exclusively on agriculture every week. On a regular basis articles on rubber cultivation and processing have been appearing in that feature. Articles have appeared on such subjects as planting materials, and the method of planting; cover crops, inter-crops, fertiliser application, soil and leaf analysis, diseases and pests, tapping, stimulation, rainguarding and processing. Therefore a study was undertaken to assess the effectiveness of the agricultural page with special reference on rubber.

MATERIALS AND METHODS

The study covered 60 small rubber growers selected from among 1,500 members of the Changanacherry Rubber Marketing Society, Karukachal in Kottayam district, applying the random sampling technique. The study was restricted to the members of the Co-operative Society since 65 per cent of small rubber growers in Kerala are members of co-operative societies and the societies provide a homogeneous group for such a study.

The small growers were interviewed by investigators using a standard questionnaire prepared to elicit information on the area under rubber and other crops, the level of education, the newspaper reading habits of growers, their preferences in reading news, their awareness of the subjects read, the extent of application of the knowledge acquired through newspapers, their views on the agricultural page and the importance given by the newspapers to agriculture.

FINDINGS OF THE STUDY

Age of interviewed growers

The age distribution of the sample growers is given in Table 1.

Level of education

All the growers interviewed were literates. The most important group consisted of growers who had studied up to SSLC (Table 2).

Table 1. Age distribution of growers

Age group	No. of rubber growers	%
30 years and below	3	5.00
31 to 40 years	12	20.00
41 to 50 years	10	16.67
51 to 60 years	20	33.33
61 to 70 years	11	18.33
71 and above	4	6.67
Total	60	100.00

Table 2. Level of education of the growers

Level of education	No. of growers	per cent
Can read and write	3	5.00
Primary and below	4	6.67
Secondary and below	33	55.00
Above Secondary but below Degree	6	10.00
Degree	10	16.67
Post-graduate degree	4	6.66
Total	60	100.00

All the rubber growers excepting one person was reading newspapers every day. The lone grower discontinued reading newspapers only because of the increase in the monthly subscription rate.

Reading habits

Fifty persons were subscribing to the dailies. There were 22 growers who read two Malayalam dailies, seven growers who read three dailies and one grower who read four Malayalam dailies regularly. In addition, 12 growers read English newspapers as well.

Subjects read

Information was collected on the priorities given by growers to reading various subjects. The subjects were grouped into poli-

tics, cinema, sports and agriculture. Twenty three growers gave first priority to agriculture and 13 growers gave first priority to politics. Eleven growers replied that they were not specific on any particular news and the rest had no comments to offer. The agricultural page has been in print for the last ten years, and 16 growers were aware of it. Fifteen growers knew of it for a period of five to 10 years, and the remaining 28 persons knew of the page for a period of five years. Five growers were keeping important articles for permanent record.

To a specific question whether they were reading articles and reports on rubber on the agricultural page, 53 growers replied positively. Out of the 53 growers, 35 read the page regularly and the remaining 18 read occasionally. There were six persons who did not read the agricultural page. There were 41 growers with other agricultural crops as well. Of the 41 growers, 29 had made use of the information from the newspapers related to these crops. Twenty-eight persons had occasion to discuss the subject they read with their friends and five persons had corresponded with the Rubber Board officials/Editors and sought clarification from them.

In addition to the articles and reports, the agricultural page carried advertisements on fertilisers, plant protection chemicals, implements etc. and a question was included in the questionnaire whether the grower also read the advertisements. Twenty-seven persons replied that they looked into the advertisements regularly and another 25 occasionally.

Agricultural page and rubber cultivation

The most important aspect of the study related to the testing of the growers' awareness of the various pieces of scientific information on rubber published in the agricultural page during the last 10 years. The growers were, therefore, asked whether they could recall having read articles or reports on specific subjects on rubber. A question was also included whether they made use of the pieces of information thus collected for their rubber cultivation. The details of replies received from the growers are given in Table 3.

From Table 3 it can be seen that there are some deficiencies in the diffusion of knowledge. Information on processing appears to have reached a few growers only. Similar is the case with leaf

Table 3. Awareness and adoption of scientific information on rubber

Topics	Awareness persons	%	Adopting persons	%
1. Planting materials	43	73	39	66
2. Planting	39	66	25	42
3. Polythene bag plants	38	64	21	36
4. Cover crops	40	68	32	54
5. Inter-crops	39	66	24	41
6. Fertiliser and its application	37	63	34	58
7. Soil and leaf analysis	26	44	6	10
8. Diseases, pests and the treatment	41	69	32	54
9. Tapping	27	46	6	10
10. Stimulants and rainguarding	34	48	4	7
11. Processing	13	22	2	3

and soil analysis and tapping. Tapping and processing, it may be mentioned are areas more often left to the tapper in the small holdings. During the interviews it has been brought out that the tappers are less receptive to new ideas even with the growers' best efforts to infuse the knowledge. This partly explains the deficiency in the adoption of knowledge on tapping and processing. A stimulant is applied to old trees at the end of their economic life. Therefore, there is less scope for applying this piece of information in the plantations. Rainguarding has not been popular with the small growers. This may be due to the additional cost involved in fixing rainguards and also due to the habit of growers to resort to tapping in the afternoon, when the rain is over. Further in the majority of small holdings, the tapper is paid piece rate wages and is not a permanent employee and therefore there is no fixed cost on him necessitating daily employment.

Regularity of publication of agricultural page

A number of growers have replied that they had encouraged their friends to read the agricultural page. There was a direct question whether the regularity of publication of the agricultural page should be increased. Twenty-seven growers replied that the present arrangement of publishing one day in a week would

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be sufficient, while 10 growers wanted the page to appear two days a week and the remaining 22 growers expressed no opinion on the subject. Twelve persons wanted the space allotted for articles and news in the agricultural page to be increased, while 32 persons replied that there was no need for increasing the space and 15 had no opinion on the subject. Forty-two growers would like to have photographs published along with articles and reports, while four did not feel that was necessary and 13 did not make any comments. Forty-three growers wanted the newspapers to publish the success stories of growers, while 11 did not give any opinion, and five did not say that it was necessary.

Role of cooperative societies

A majority of growers were of the opinion that the co-operative societies could render much help to promote the dissemination of knowledge by organising study circles, taking copies of relevant pages of articles and circulating them, and also displaying the articles on the notice boards of the societies. One enlightened grower suggested that in future, video tapes on rubber cultivation should be made available to the rubber growers with the advent of the television age. He was of the opinion that a number of prosperous growers and co-operative societies could afford VCRs.

Conclusion

As to the question whether the Malayalam dailies were giving adequate coverage on agricultural news and views and more particularly on rubber, 23 growers replied in the positive and 21 growers replied in the negative, while 15 growers did not make any comments. By and large, the growers were grateful to the Malayalam newspapers for their role in disseminating scientific information on rubber cultivation.

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DISCUSSION

Q : Your study was restricted to members of cooperative societies. Can you extend this study to rubber growers who are not members of cooperative societies?

Ans: Yes, this study can be extended to such growers also.

Q : Since only the growers in Kerala State were interviewed, the results are applicable to that State only. Will it be possible to cover other rubber-growing states?

Ans: Yes, the study will be extended to other states and new areas of rubber plantation.

STUDIES ON PROTECTIVE SYSTEMS FOR NATURAL RUBBER VULCANISATES AGAINST OZONE ATTACK

M. SUNNY SEBASTIAN, K.T. MANI, ROSAMMA ALEX
and E.V. THOMAS

ABSTRACT

Comparative evaluation of three commonly used antiozonants in protecting NR against ozone cracking was made. The efficiency of the antiozonants was in the order DBPPD IPPD DPPD. It was observed that ozone resistance can be enhanced by blending with CR in appropriate ratios in which the polymers are compatible.

INTRODUCTION

Ozone attack on natural rubber vulcanisates held under strain and the resulting deterioration of the products are widely studied (Fogg, 1962; Thornley, 1964; Lake and Lindeey, 1965; Andries et al., 1979). Ozone resistance of rubber vulcanisates is influenced by several factors like the nature of the polymer, nature of cross linking system, type and quantity of the protective agent added and service conditions of the finished material. The extent of chemical unsaturation of the polymer primarily determines whether or not it is prone to ozone attack. The stereoregularity of the polymer has little to do with its ozone resistance. Natural rubber (NR) in both raw and vulcanised forms, is attacked by ozone and the severity of attack increases when the material is

under strained condition. Braden and Gent (1963) developed the concept of critical stress on ozone cracking. Above a critical stress, cracking becomes very sensitive to strain and in this region the rate of crack growth increases exponentially. Above a certain critical strain, the increase in crack growth rate ceases.

Braden and Gent (1962) suggested that ozone degradation of polymers in general can be minimised either by reducing the rate of crack growth or by increasing the critical condition. The reduced rate of crack growth can be achieved by several methods of which one is the addition of chemicals known as antiozonants. Other than chemical methods of protection from ozone, physical methods, like coating the rubber surface with an unreactive protection layer by addition of wax or by blending with an ozone resistant polymer, are also available. Andrews (1966) studied the ozone resistance of NR when blended with the ozone resistant rubber EPR. The inclusion of an ozone inert phase in an elastomer blend imparts some protection to the material by raising the critical energy necessary to initiate macroscopic cracking. The inert phase hinders the development of macroscopic cracks from microscopic ones by providing physical barriers to crack propagation.

The present study is taken up with the following objectives:

- 1) Evaluation of the effect of different curing systems on ozone cracking of NR.
- 2) Comparison of the performance of three indigenously available disubstituted-p-phenylene diamine antiozonants namely, N,N'-diphenyl-p-phenylene diamine (DPPD), N-isopropyl, N'-phenyl-p-phenylene diamine (IPPD) and N-(1,3 dimethyl butyl) N'-phenyl-p-phenylene diamine (DBPPD).
- 3) Evaluation of the synergistic action of these antiozonants.
- 4) Study of the ozone resistance of Natural rubber-chloroprene rubber blends.

EXPERIMENTAL

Compounds containing various cure systems were prepared by mixing NR with other compounding ingredients in an open laboratory mill (Formulation given in Table 2). The optimum cure time of the compounds at 150°C was determined using Monsanto Rheometer R-100. Ozone resistance of the vulcanisates was

determined according to ASTM D 1171 (1968) using a Mast Ozone Test Chamber at 50 pphm ozone concentration at $38 \pm 2^\circ\text{C}$. The intensity of the cracks developed on the test pieces, were evaluated after 24, 48 and 72 h of ozone exposure and the percentage retention of property was calculated. A butyl rubber compound (Table 1) which developed no cracks even after 72 h of ozone exposure was used as a reference standard.

Table 1. Formulation of butyl compound

Butyl rubber	—	100
Stearic acid	—	3.0
ZnO	—	5.0
HAF black	—	50
Benzothiazyl sulphide	—	0.5
TMTD	—	1.0
S	—	2.0

The evaluation of antiozonants was carried out by incorporating them at different levels in NR compounds. The test pieces were exposed to ozone and percentage retention of property was estimated (Tables 3, 4 and 5). For the evaluation of the synergetic action of antiozonants, combination of two antiozonants at different concentration (Table 6) were incorporated to NR compounds (cure system 1 of Table 2) and ozone resistance determined.

To study the ozone resistance of NR-CR blends both the rubbers were blended in the mill in different proportions (Table 7). The three antiozonants were added to the blends at a level of 1 phr and ozone resistance was evaluated (Table 7).

RESULTS AND DISCUSSION

Evaluation of the cure systems

Braden and Gent (1960) observed that crack growth rate decreases with an increasing degree of crosslinking in the vulcanisates. During the evaluation of the different cure systems, surface blooming was observed to a high level in system 4 and to a lesser extent in systems 2 and 3. Hence in addition to the inherent ozone resistance of these cure systems, the surface bloom also

Table 2. Composition of NR Mixers

	Cure System					
	1	2*	3*	4**	5	6
Natural rubber	100	100	100	100	100	100
Stearic acid	2.5	2.5	2.5	2.5	2.5	—
ZnO	3.5	3.5	3.5	3.5	3.5	—
SRF black (N-55)	50	50	50	50	50	50
Aromatic oil	4	4	4	4	4	4
CBS	0.5	3.0	2.2	—	0.8	—
TMTD	—	2.0	1.0	—	—	—
MBTS	—	—	—	1.5	—	—
DPG	—	—	—	—	0.6	—
Sulphur	2.5	0.33	0.25	—	1.2	—
Sulfasan R	—	—	—	2.0	—	—
Dicumyl peroxide	—	—	—	—	—	2.0
Percentage retention of property	25	10	10	35	10	0

*Surface bloom was observed

**Intensity of bloom was higher.

Table 3. Evaluation of *N,N'* Diphenyl-*p*-Phenylene Diamine—percentage retention of property

Cure System	Concentration of Antiozonant (phr)				
	0	0.5	1.0	1.5	2.0
1	25	25	60	75	75
2	90	100	100	100	100
3	95	100	100	100	100
4	100	100	100	100	100
5	25	60	60	75	80
6	0	5	20	20	20

Table 4. Evaluation of N (Isopropyl) N' Phenyl-p-Phenelene Diamine—percentage retention of property

Cure System	Concentration of Antiozonant (phr)				
	0	0.5	1.0	1.5	2.0
1	20	20	25	60	60
2	80	80	80	95	95
3	40	40	80	80	80
4	100	100	100	100	100
5	25	25	60	35	35
6	0	0	5	5	5

Table 5. Evaluation of N (1, 3 Dimethyl Butyl) N' Phenyl-p-Phenelene Diamine—percentage retention of property

Cure System	Concentration of Antiozonant (phr)				
	0	0.5	1.0	1.5	2.0
1	25	30	75	90	90
2	80	80	95	100	100
3	40	40	90	95	95
4	100	100	100	100	100
5	25	60	65	90	90
6	0	5	5	5	5

might have contributed to the ozone resistance. Observing the intensity of cracks developed on the test specimens the following rating for ozone resistance can be made. (Crack intensity increases towards right) $4 > 1 > 2 = 3 = 5 > 6$. If the systems with the surface blooms are excluded the gradation will be $1 > 5 > 6$.

Braden and Gent (1960) have reported that crack growth rate in a dicumyl peroxide vulcanisate is less compared to that in a sulfanamide accelerated sulfur cured one. The results obtained in this study are not in agreement with this report. But this abnormal behaviour may be due to the varying stiffness of the vulcanisate, since the critical condition of a vulcanisate is related to its stiffness (Braden and Gent, 1961). From the Monsanto Rheometer cure curve it was observed that the torque value for

Table 6. Evaluation of antiozonant combinations

Concentration of Antiozonants (phr)			Percentage retention of property
IPPD	DPPD	DMPPD	
0.0	2.0	—	75
0.5	1.5	—	70
1.0	1.0	—	70
1.5	0.5	—	70
2.0	0	—	60
0	—	2.0	90
0.5	—	1.5	70
1.0	—	1.0	70
1.5	—	0.5	70
2.0	—	0	60
—	0	2.0	90
—	0.5	1.5	70
—	5.0	1.0	70
—	1.5	0.5	70
—	2.0	0	75

Table 7. Formulation of NR-CR blends

	NR-CR Ratio					
	50/50	60/40	70/30	80/20	90/10	100/0
Natural rubber	50	60	70	80	90	100
Polychloroprene	50	40	30	20	10	0
Stearic acid	1.5	1.5	1.5	1.5	1.5	1.5
ZnO	5.0	5.0	5.0	5.0	5.0	5.0
Naphthenic oil	6	6	6	6	6	6
CBS	0.30	0.35	0.40	0.45	0.50	0.55
TMT	0.20	0.16	0.12	0.08	0.04	0.04
MgO	2.0	1.6	1.2	0.8	0.4	0.0
DOTT	0.5	0.4	0.3	0.2	0.1	0.0
S	1.5	1.7	1.9	2.1	2.3	2.5
Antiozonant	1.0	1.0	1.0	1.0	1.0	1.0

the peroxide vulcanisate was less compared to sulphur cured systems. Since the chemical contribution to network chain density can be directly assessed from Rheometer torque values,

it is inferred that the network density in the peroxide vulcanisate was less and this might have contributed to its poor ozone resistance.

Evaluation of substituted para phenylene diamine antiozonants

In a rubber vulcanisate under strain, for the initiation of crack due to ozone attack, the energy of the system must be above a critical level. Once a crack is generated, the severity of cracking can be controlled if the crack growth rate can be kept low. The function of the antiozonants is to either increase the critical condition or reduce the crack growth rate. N, N'-dialkyl para phenylene diamines act in the first way (Braden and Gent, 1962, 1963) while the dialkyl or aryl alkyl para phenylene diamines act in the latter way. In all the cure systems studied the antiozonant activity, on unit weight basis is DBPPD > DPPD > IPPD. In all the sulfur/sulfur donor cure systems blooming was observed when IPPD was added at a level of 2 phr. Also it was observed that the activity of the antiozonants above a level of 1.5 phr is not very significant. The performance of the peroxide cured vulcanisate is not markedly improved even after the addition of the antiozonants. This is apparently due to the reaction between dicumyl peroxide and the amines.

Synergism of antiozonant combination

Synergism of antiozonant combinations was studied in the sulfur cure system (No. 1). The performance of the different antiozonants in combination was almost similar. During the evaluation of individual antiozonants it was observed that IPPD when added to this cure system at a level of 2 phr, a bloom appeared on the surface while in the combination of two antiozonants (total concentration 2 phr) no such blooming was observed. Also the performance of antiozonant combinations was only comparable to that of individual antiozonants when added in equivalent quantities.

Evaluation of NR-CR blends

Among the various blend ratios studied, 50/50 NR-CR blends containing 1 phr of IPPD or DBPPD were found to be free from cracks even after 72 h of exposure to ozone, while slight cracking was observed in the 50/50 blend containing DPPD,

(Table 8). The performance of 60/40 NR-CR blend was poor compared to the 50/50 blend. The performance of 70/30 blend was even poorer than 90/10 blend. This abnormal behaviour may be due to the incompatibility of the two polymers in the 70/30 ratio (Marsh et al., 1968) Walters and Keyte (1965) have reported the presence of zones in NR-CR blends by phase contrast and electron microscopy. Cracking was observed in all other blends, the crack intensity increasing with a decrease in polychloroprene content. From the NR-CR blends, if the regions of incompatibility are excluded, it can be seen that the ozone resistance of the blend increases in polychloroprene content. Similar results were reported by Andrews (1966) on NR-EPR blends.

Table 8. Evaluation of natural rubber—polychloroprene blends

NR/CR ratio	Percentage of property		
	DPPD	IPPD	DBPPD
100/0	5	10	10
90/10	25	60	25
80/20	75	70	60
70/30	15	15	15
60/40	60	90	90
50/50	90	100	100

CONCLUSIONS

1) Among the cure systems evaluated, the conventional sulfur system was found to be better than Semi E.V., E.V. or peroxide systems. (Systems which showed blooming tendency were not taken into consideration.)

2) The efficiency of antiozonants was in the order DBPPD > IPPD > DPPD. The activity of antiozonants above a level of 1.5 phr was not found to be significant.

3) Ozone resistance of NR can be enhanced by blending with CR in appropriate ratios in which the polymers are compatible.

ACKNOWLEDGEMENT

The authors express their deep gratitude to the Director, Rubber Research Institute of India for the interest he had shown in this work. The valuable suggestions and assistance rendered by our colleagues in the Chemistry/Rubber Technology Division are sincerely acknowledged.

ABBREVIATIONS

TMTD	— Tetramethyl thiuram disulphide
CBS	— N-Cyclohexyl-2 benzothiazyl sulphenamide
MBTS	— Dibenzothiazyl disulphide
DPG	— Diphenyl Guanidine
DOTT	— Di O-Tolyl thiourea
HAF	
Black	— High Abrasion Furnace Black
SRF	
Black	— Semi Reinforcing Furnace Black
FEF	
Black	— Fast Extension Furnace Black

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PLENARY SESSION

Chairman : M.R. Sethuraj

Convenor : S.N. Potty

The Plenary Session of Placrosym VI started with the introductory remarks of the General Chairman in which he emphasised the need for multidisciplinary approach in plantation crop research. A comprehensive approach to problems with the support of other related disciplines will enable the scientists to generate more useful data which can be ultimately transferred to the farmers.

The Chairmen of the various sessions presented summaries of their respective sessions with their remarks.

SESSION I: CROP BOTANY

Session I of the symposium consisted of 11 research contributions on crop botany of different plantation crops. The first paper on isolation of *Pythium* tolerant ginger by tissue culture method is very relevant to other plantation crops also. Resistance/tolerance to diseases is a high priority area and the approach followed to isolate tolerant lines could also be tried in other crops. The genetic divergence observed among the *arabica* coffee cultivars reveals that diversity exists in the cultivars and directed breeding approach could be done in the evolution of new cultivars. It is however, worth considering the enrichment of germ plasm of all plantation crops and studying its genetic divergence with each other with regard to different characters. The correlation and heritability studies done in rubber and coffee are also worthy in nature in identifying suitable characters for selection. The utilisation of heritability of characters in selection work must be used with caution. It is advisable to study the basic factors concerning the production of plantation crops rather than studying the yield alone.

The leaf area estimates may provide an indication to the yield potential of a crop, but this has to be done taking into account the environmental factors affecting growth. Foliar anatomy to locate plants with C_4 pathway may be beneficial in exploitation of photosynthetic efficiency. Research on increasing foliage in

tea with proper pruning techniques and boosting it through growth regulators may find practical applications. The light requirements of shade loving plants could be estimated with modern methodology which may help in multistoried cropping.

Physiological investigations on the biochemical changes occurring in plant subsequent to diseases may be useful in developing appropriate control measures from a new angle.

In general it is felt that there is the need to lay out broad-plan experiments through a multi-disciplinary approach as suggested by the General Chairman to achieve the common goal of higher productivity and self-sufficiency in plantation crops.

SESSION II: PLANT PROTECTION I

Ten research papers were presented in this session. The result of the investigation on integrated control of root (wilt) disease of coconut revealed that application of fungicides, nematicides and bactericides had no effect while application of Ca Mg and Zn along with recommended dose of fertilisers reduced the disease incidence. The discussion emerged of this paper emphasised the need for the layout of broad-plan experiments on this aspect. However, the findings could be adopted as an interim recommendation. Analysing the result of field trial on Tanjavur wilt of coconut, it was concluded that the physical factors like orientation of the initial symptoms of the disease, soil and atmospheric temperature and soil moisture level may be included in further studies. The yield loss in Cardamom due to 'Katte' disease was reported to be ranging from 16 to 58 per cent depending upon the infection level. It was also observed that higher transmission of virus was obtained when young growing parts are used as sources of inoculum. Based on discussions it was recommended that the effect of shade trees and environmental parameters on 'Katte' disease may be studied in detail. The result of a glass house experiment on collateral hosts of *Corynebacterium* sp. causing Chenthal disease of cardamom at low elevation on certain species of Zingiberaceae family was discussed. The desirability of repeating this study at higher elevation under shaded conditions was suggested. A report on *Eletteria cardamomum* as a new host for *Phytophthora palmivora* (Butler) was presented. It was suggested that identification of the pathogen by the

CMI may be carried out for confirmation. One per cent Bordeaux mixture was reported to be most effective in the control of leaf spot disease of Ginger.

The paper on Modulation of leaf surface pH and Blister blight disease control in Tea generated a lot of discussion. The practical difficulty to adopt this method the high cost involved and the possible adverse effects on the soil microflora and soil fertility were pointed out during the course of discussions. An evaluation of several fungicides for the control of leaf spot disease of Cocoa revealed that Bavistin and Dithane M 45 were very effective.

The last paper on the seasonal variation in microflora of stock-ed black pepper reported that several fungal species could isolated from the samples drawn during all seasons. The need for repeating this experiment supported by data on climatic parameters and storage conditions was emerged during the course discussion of this paper.

SESSION III: PLANT PROTECTION 2

In this Session, five papers were presented. Out of these, four were in Entomology and one on Nematology. Among the four papers in Entomology, one each was on biological control and bioecology and the rest two were on insect control with insecticides.

The paper on influence of prey on reproduction potential of *Cryptolaemus montrouzieri* proved that the predator survived better on mealy bugs than on green scales. This study will lead to possible mass production and release of the predator.

Field evaluation of certain insecticides for the control of stem/capsule borer *Dichocrocis punctiferalis* and Thrips, *Sciothrips cardamomi* indicated that highly significant control of these pests could be achieved with synthetic pyrethroides. Satisfactory control could be achieved with monocrotophos and phosalone also. In the discussion on this paper, emphasis was made on the effect of insecticides on honey bees responsible for pollination. It was stressed that in such studies, adequate attention should be given to time of application and residual toxicity of insecticides to reduce the harm to beneficial insects considerably.

In the paper on bioecology of *Xyleborus fornicatus*, the Shot Hole Borer of tea in the Annamallais, the successful rearing of

the pest in artificial media was explained. The biology of the pest as well as its population variation during different months of the year were also reported. The importance of artificial medium for studies on borer pests especially their biology was highlighted.

From the field evaluation of insecticides against bark-feeding caterpillar, *Aetharartis circulata* infesting rubber, it was found that good control of the pest could be achieved by applying carbaryl and methyl parathion dusts with a power duster. The reasons for using dust formulation of insecticides instead of liquid formulation was explained. Rubber trees being very tall applying liquid formulation is difficult and costly. Moreover, water based formulations could not be effectively sprayed using the available ground and aerial power spraying equipments.

In the preliminary observations on the effect of some systemic nematicides and neem oil cake in a cardamom field infested with Root-Knot nematode, it was stated that significant control of the nematode could be achieved using three nematicides viz., Aldicarb, Carbofuran and Phorate as well as neem oil cake individually. The latter is found to act as an ovicide. Nematicide and neem oil cake application also increased capsule yield and reduced capsule drop. Controversial results obtained with neem oil cake by other workers were discussed at length and it was proposed that in future studies the oil content of neem oil cake should also be evaluated. Coraborative laboratory studies on the effect of neem oil cake on nematodes was solicited. Use of large doses of highly toxic nematicides for the control of nematodes may lead to toxic residue problems in a crop like cardamom which is used for human consumption. Isolation, characterisation and mass production of active principles responsible for the control of nematodes in neem oil cake was suggested. Use of potassium compounds for the control of nematodes also was proposed.

SESSION IV: AGRONOMY 1

Nine papers were presented mainly dealing with herbicides and microbiological aspects on plantation crops and the presentation and the discussions followed were lively, interesting and useful.

First paper was on the studies on weed control by herbicides and manual means on planting strips in young rubber plantations. Comparative effects of Gramoxone, Fernoxone and Dala-

pon in combinations and manual weeding on the control of weeds in rubber plantations were tried. The results of the trial showed that Gramoxone at 2.5 l/ha plus Fernoxone at 1.25 kg/ha plus Gramoxone at 2 l/ha was superior to manual weeding. On cost comparison the treatment Gramoxone plus Fernoxone was the cheapest. It was suggested that Gramoxone may adversely affect soil microflora. It is also suggested that the more number of application using a lower dose might be more beneficial in perennial crops. Another suggestion was that addition of urea/ammonium sulphate at 1 kg/barrel (0.5 per cent) will reduce the quantity of weedicide by 50 per cent.

The second paper was on herbicide and interculture, their effect and impact on the yield of coconut. In the study conducted it was found that the suppression of weeds by weedicide did not improve the nut yield. However ploughing the entire area enhanced the net yield by as much as 21 per cent over control. A question was raised whether increase in yield due to ploughing was consequent to more aeration. Another suggestion was to grow fodder grass in coconut plantation to increase the microflora.

Paper three was on the occurrence of Vesicular-Arbuscular Mycorrhiza development. This paper generated lot of interest. To a question it was stated that above 44 ppm of P was inhibitory to VAM. It was also suggested that VAM inoculation is practicable only in cocoa nursery. pH 5.5 is ideal for the growth of the micorrhiza. It was also suggested that the importance of zinc in areas where P is a limiting factor in spite of its abundance may be taken into consideration. It was also stated that minimum of 6 ppm of available P is required for effective micorrhizal symbiosis. This may be taken as a low cost technology.

The next paper was on occurrence of nitrogen fixing bacteria, *Azospirillum* in the root environment of cocoa. In this paper *A. lipoferum* was predominant in the root region of cocoa and that 35.6 per cent was found to fix more than 15 mg of nitrogen/g malate *in vitro*. There was a suggestion that since this study was conducted in laboratory conditions it has to be conducted under field conditions also. It was also suggested that a study to evaluate the combined effect of micorrhizae and phosphobactrin should be carried out. The population dynamics of microorga-

nisms associated with cocoa beans fermentation was presented in the next paper.

The sixth paper was on microbial population, enzyme activity and VAM in the root region of coconut in relation to *in situ* green manuring. The studies reveal that *in situ* cultivation and incorporation of green manure legumes in coconut basins improved the microbial population in the root region of coconut. It was also observed that the population of fungi, actinomycetes, asymbiotic nitrogen fixing and phosphate solubilising bacteria was significantly increased. A doubt was expressed that *Mimosa* may become a weed later if allowed to grow unchecked and that actinomycetes population may affect the nodulation.

The next paper was on the studies on microbial solubilisation of insoluble phosphates. It was stated that the percentage of phosphate solubilising bacteria in rubber growing soil ranges from 1-2.8. The solubilisation of rock phosphate, aluminium phosphate and ferric phosphate by the soil microorganism as well as the effect of various carbon and nitrogen sources on the phosphate solubilisation were studied. Possibility of using *Aspergillus* sp. for PO_4 solubilisation was discussed. A suggestion was that phosphobactrin also should be tried. It was also suggested that study should be undertaken to find out the bacteria that solubilise rock phosphate at different pH levels.

The next paper was on studies on growth, nodulation and nitrogen fixation by *Mucuna bracteata* which is a leguminous creeper collected from Tripura and found grow very fast, smothering the weeds. It is drought tolerant and fixes nitrogen and it is free from pests, disease and cattle menace. The study was considered useful for the extension workers.

The last paper was on field and nursery experiment with Azotobacter in coffee. The effect of Azotobacter sq. on growth and yield of S. 795 arabica coffee and soil nitrogen build up was studied in field and nursery stage. Positive improvement in shoot dry weight and root spread and girth of seedlings were observed. But the data were not statistically significant.

SESSION V: AGRONOMY 2

Out of the nine papers presented in this session three were on

coconut, three on tea and one on pepper and another one on coconut and cocoa and one on the integrated nutrient management.

The first paper explained a theoretical model to evaluate the integrated nutrient management for the mixed perennial crop system which generated a lot of discussions. Some members felt whether such a theoretical model would be of practical use. The Chairman replied that a theory or hypothesis is the basis for any scientific investigation and as such even though it may not be of immediate use in course of time it will find practical application.

The second paper on "agronomic pathways of yield response in tea to correction of zinc deficiency and control of pests" presented results obtained for correcting zinc deficiency and control of shot-hole borer. The results clearly indicated that correction of zinc deficiency would increase yield of tea.

The paper on "Assessment of soil zinc and copper as reflected by the leaf composition of pepper" brought out that zinc and copper in the youngest matured leaf of the middle 1/3 portion of the pepper vine was found to have the highest correlation with the zinc and copper in the soil.

The next paper was on the "Effect on N,P,K, Ca and Mg on leaf nutrient content and yield of young coconut. The research finding revealed that application of magnesium significantly increased the yield and reduced the maturity period of coconut. The results also indicated that higher levels of nitrogen, phosphorus and potassium did not increase the yield attributes and yield.

The results of the investigation on optimum N and K ratios for young tea showed that the highest productivity was at 4:6 N:K₂O ratios and it also led to the overall health and vigour of the young tea plant.

The next paper dealt with the results of intercropping coconut with cocoa. It was indicated that the double row system of cocoa planting gave the highest yield and profit.

The seventh paper dealt with the use of different mulching materials in coconut gardens and its beneficial results. Mulching with coconut husk around the palm increased the yield by about 50 per cent.

Paper 8 was "Influence of weather on coconut yield". The paper examined the rainfall pattern over a long period and its

effect on yield of coconut. The results revealed that the absence of post and pre-monsoon showers and the high rainfall during the rainy season adversely affected the second years nut yield. It was significant that the production of female flowers was high during summer period and the button shedding was high during the high rainfall period.

The last paper discussed the variation with dry and fresh weight of tea as influenced by different climatic parameters. Approximate conversion factor for estimating the out-turn of made tea from green leaf for a mixed population has been suggested; the wide variation of the conversion factor from season to season, between the clones and the influence of age are highlighted.

The Chairman requested the scientists working on coconut to find out whether there is any influence of iodine on coconut and he said that in the future only the integrated system approach is the solution for breakthrough in plantation crops.

The Chairman concluded the session with an appreciation to the authors for the nice presentation of the papers and the delegates who actively participated in the discussion.

SESSION VI: ECONOMICS, MARKETING, EXTENSION AND TECHNOLOGY

Seven research contributions on crops like rubber, tea, pepper, arecanut, turmeric, cocoa and coconut were presented in this session. The paper on the economics of cocoa coconut mixed cropping system, highlighted the economic viability of cocoa. It was suggested similar study may be done for arecanut cocoa system. In the paper on Trends in Production and Trade of Pepper in India, the declining trend in the production and export of pepper was focussed and the constraints were identified. Considering the outlook that the global demand for pepper as 4 per cent per annum, it was suggested that a massive rejuvenation and replanting programme for traditional growing areas and introduction in non-traditional areas would save the situation. In the paper on Marketing and Price Spread of Arecanut in Kerala, it was focussed that the cultivators on an average received 58 per cent of consumer price in the marketing of boiled types of arecanut and 55 per cent for chali.

The results of the uniformity trail conducted in turmeric revealed that a plot size consisting three beds of 1 m × 1 m along the fertility gradient is the optimum. The usefulness of such a study on all crops was felt by the delegates.

The study on Impact of Farm Radio School on Small Tea Growers, revealed that a considerable number of small farmers depend upon Farm Radio Programmes for information on tea. The paper on diffusion of information on rubber through newspaper" highlighted that the growers have assimilated scientific information on the cultivation of rubber through the medium of agricultural page appearing in the dailies during the last ten years. However some deficiency has been noted in the sphere of processing, soil and leaf analysis and tapping. It was suggested that the study may be extended to the new areas of rubber plantation and rubber growers who are not members of cooperative societies.

In the technology paper on protective system for natural rubber vulcanizates against ozone attack, the authors have shown that blending of natural rubber with polychloroprene rubber provided better ozone resistance.

After the presentation of reports of various sessions declaration of awards instituted by the C.S. Venkata Ram Memorial Trust was made and awards were distributed.

The session came to a close with the vote of thanks by Dr. S.N. Potty, Convener.

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