

Technical Bulletin 3



**MULTIPLE CROPPING IN COCONUT
AND
ARECANUT GARDENS**

Editors

EV NELLIAT
K SHAMA BHAT



**CENTRAL PLANTATION CROPS RESEARCH INSTITUTE
KASARAGOD-670 124 KERALA INDIA**

TECHNICAL BULLETIN 3

MULTIPLE CROPPING IN COCONUT AND ARECANUT GARDENS

Editors

EV NELLIAT

K SHAMA BHAT



CENTRAL PLANTATION CROPS RESEARCH INSTITUTE
KASARAGOD-670 124, KERALA
INDIA

TECHNICAL BULLETIN SERIES 3 *

November, 1979

Published by:

Dr NM Nayar

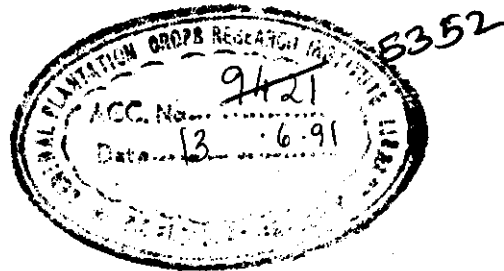
Director

**Central Plantation Crops Research Institute,
Kasaragod-670 124, Kerala, India.**

Price:

Rs. 10.00 (including postage)

US\$ 3 (by airmail)



**Earlier publications in the series*

1. Coconut diseases of uncertain etiology, 1976
2. Nematodes, fungi, insects, and mites associated with the coconut palm, 1979

Printed at Sharada Press, Mangalore-575 001, India.

CONTENTS

	PAGE
Preface ..	V
1. Why intercropping ..	1
2. Prospects of multiple cropping ..	3
3. Intercropping in coconut ..	6
4. Intercropping in arecanut gardens ..	24
5. Mixed cropping in coconut ..	28
6. Mixed cropping in arecanut ..	35
7. Multistoreyed cropping ..	39
8. Mixed farming in coconut gardens ..	42
9. Mixed farming in coconut gardens—root (wilt) affected tract ..	47
10. Farm plan models ..	50
11. Next phase in research ..	54

PREFACE

Multiple cropping with a view to enhancing agricultural production in field crops had received much attention in recent years. Growing miscellaneous crops in coconut-arecanut stands is an age old practice. It continues to be popular with farmers although the compatibility and the long term effect on the productivity of the land are not well understood.

The work done in the past has brought out valuable information on various aspects in inter/mixed cropping programmes in plantation crops. The research efforts on this aspect received special attention during the last decade and sizable amount of information is available at present.

A group of scientists involved in multiple cropping projects met in May, 1979 to assess the work so far done and suggest the line of studies to be taken up in the second generation experiments to be initiated in the eighties. In this context, it was felt that a technical bulletin containing the available information from experiments conducted on multiple cropping may be brought out. This bulletin, though not very comprehensive, is the outcome of our hurried attempt at it.

The editors record their sincere gratitude to Dr. N. M. Nayar, Director of the Institute for his constant advice and guidance in the preparation of this bulletin. The efforts put in by S/Sri P. Gopalasundaram and K. Sivaraman, Scientists (Agronomy) and Sri N. P. Sreenivasan, Stenographer, are gratefully acknowledged. We also appreciate the cooperation extended by M/s Sharada Press in getting the bulletin printed in short notice.

Kasaragod,
27-11-1979 }

EDITORS

I. WHY INTERCROPPING

N. M. NAYAR

*Central Plantation Crops Research Institute,
Kasaragod-670 124, Kerala, India.*

In recent years, two sets of definitions have been given for the various cropping patterns involving the planting of two or more crops in various combinations and sequences in the same plot of land (Papendick et al., 1976; Nelliath and Iyer, 1977). In this note, 'intercropping' is being used in the broadest sense to include all these cropping patterns.

In recent years, there has been considerable interest in intercropping because of the imperative need to increase production and productivity from a unit area of land consequent upon the increasing demands for food, clothing and shelter for the increasing population because of the increasing difficulty to get more areas under the plough. Though, it could then appear that intercropping is of recent origin, a general survey of the agricultural systems and agricultural origins would indicate that intercropping was the first agricultural system to be practised since the beginning of agriculture.

A study of agricultural origins show that the early man took to farming when it became increasingly difficult for him to obtain all his requirements for food, shelter and clothing by just gathering them from the nature. He then forsook his itinerant habits and took first to protecting plants which yield him food, fuel and his other needs and when this no longer met his requirements, to cultivating them in his backyard, possibly in homesteads established near a source of water. Thus, the early man would have

planted a number of species of plants required to meet his needs of food, fuel, clothing, medicines, poisons of plant origin to meet his hunting habits, and so on. Gradually, as his needs for the number of items and the quantity of each item increased, he would have experienced increasing difficulty to grow all his requirements. Thus, farming steadily became an increasingly specialized job, and as a consequence, different farmers took to the cultivation of different crops in pure stands. Gradually, the cultivation of crops in pure stands was developed to high levels of perfection and productivity, especially with the mechanisation of agriculture. Even then, in much of Asia and Africa, particularly in the tropics and subtropics, farmers have been generally practising intercropping to various degrees and extents. While this is less evident in situations receiving high rainfall and control of water is difficult, intercropping is the standard farming system practised by all the farmers in their homesteads. Particularly in the tropics, it is a common sight to see mixed stands of annual and perennial crops, erect and twining plants, comprising of even 20-50 species, in a homestead of 0.5-1.0 ha area.

However, since the last two or three decades particularly agronomists and plant physiologists have been trying to develop ideal compatible combinations of crops consisting of 3-5 species with a view to maximising productivity in this farming system. As a consequence, considerable

work is underway today all over the world to study the mechanics of productivity of the various cropping patterns and also to develop ideal cropping combinations or sequences of crops which could maximise the production and productivity. These are achieved in a variety of ways by maximising 'the harvesting of the sun', by ensuring optimal canopy development of different crops, by growing crops having different kinds of rooting systems so that each crop could draw nutrition from different depths of the soil, by growing together crops which show symbiotic relationships with each other, by growing mixtures that take into account the varying levels of water in a field according to the progress of the monsoon (specifically, when mixtures of rice varieties are sown and transplanted), and also by preventing an undue development of pests, diseases, and weeds by either restricting the availability of food supply to them, or by ensuring their natural biological control.

The growing of annual crops in mixtures and sequences have made it possible to increase the cropping density from 1.0 up to about 4.0 under the most optimal conditions, in situations where sunlight, nutrients, and moisture are not limiting factors and where the application of these inputs can be regulated. However, this kind of a modelling will be difficult in intercropping systems involving combinations of perennial crops, and perennial and annual crops in various

combinations. Also, often in such systems, not every component of the cropping system is used, primarily for food purposes and also that more than one part of the same plant would be utilised and for widely different purposes. The coconut is a good example, in which the nut is used as a source of oil or as a food, the husk is used for extracting fibre or as a fuel, the leaves for thatching purposes or as a fuel, and the stem again for building purposes or as a fuel. Should we then give a score of 1.00 only when a pure crop of coconut is raised? In a mixed cropping system involving coconut, cacao, black pepper, and pineapple, the cacao and black pepper are used as flavour, and pineapple as a food.

It is only since the last 3-4 decades, that the various beneficial effects of cropping systems involving the growing of annual and perennial crops in mixtures or in rotations have been increasingly appreciated. Today, as has been stated already, intercropping systems are considered as one of the most productive and profitable ways of cropping.

REFERENCES

- NELLIAT, E. V. and IYER, R. D. 1977. Quoted in Nelliatt, E. V. 1977. Diamond jubilee celebrations of coconut research in India: A report. *J. Plant. Crops* 5: 39-46.
- PAPENDICK, R. I., SANCHEZ, P. A., and TRIPLETT, G. B. (eds.) 1976. *Multiple Cropping*. ASA special publication number 27. American Society of Agronomy, Madison, Wisconsin, USA.

II. PROSPECTS OF MULTIPLE CROPPING

E.V. NELLIAT

*Central Plantation Crops Research Institute,
Kasaragod-670 124, Kerala, India.*

Coconut, in India, is essentially a crop of small and marginal farmers. It is grown in about 5 million holdings in the country. The average size of a coconut holding is as low as 0.22 ha and 98% of the holdings are below 2 ha (Thampan, 1976). Consequently, the income derived from most of the coconut holdings is insufficient to sustain the dependent families. In addition, the sole crop of coconut does not provide an adequate on-farm employment even for family labour.

To achieve increased production of coconut, the emphasis in the past was on adoption of appropriate management practices like fertiliser application, tillage, and plant protection measures. These recommendations did not receive ready acceptance of the small and marginal farmers as it did not provide an immediate increased net return, nor did it generate adequate employment opportunities. One of the feasible ways of increasing the farm level income and employment opportunities on such small holdings is to adopt good management practices for coconut in combination with growing compatible annual or perennial crops in the interspaces (Anonymous, 1977).

The crown shape and the growth habits of coconut necessitate its planting at a distance of about 7.5 m apart or allocating 50-52 m² of land area per palm. This would accommodate nearly 175-200 palms per ha, although in cultivators' garden, the density may range between 200-250 palms or more.

The studies conducted at CPCRI, Kasaragod and elsewhere have shown that the natural resources of crop production, viz., solar energy and soil are not fully utilised by a sole crop of coconut.

Kushwah et al. (1973) studied the rooting pattern of coconut palms growing in three situations, viz., regular tillage and manuring, regular tillage alone, and under neglect. The palms receiving regular cultivation and manuring produced the highest number of roots. About 74% of the roots produced did not have a lateral spread beyond 2 m from the bole. Regular tillage-reduced root proliferation to the top 30 cm of soil and vertical distribution of roots was confined mostly to 30-120 cm depth. They found that over 75% of the soil mass in a coconut stand was not being fully utilised by the roots of coconut and that there were possibilities for developing suitable cropping systems for more efficient utilisation of the soil resources in the interspaces of coconut.

Bavappa and Murthy (1961) while describing the morphology of arecanut palm reported that its roots were concentrated within 60-90 cm around the base of the palm. Bhat and Leela (1969) reported that 61-67% of the roots of arecanut palm were found within 50 cm radius of the palm, and only few roots extended beyond 100 cm.

An important requirement for intensive cropping systems is water. The water requirements of crops depend on the evaporative demand of the climate of the area.

Hence the quantity of water required to facilitate growth and yield of a single crop or a number of crops growing in a given area would remain almost the same irrespective of the number of crops grown in that area.

The venetian structure and orientation of coconut and arecanut leaves permit sizable amount of solar radiation incident on the crown to penetrate to lower levels. The extent of this transmission varies with the age of palm, the number of functional leaves on the crown, distance between palms, and system of planting. In a juvenile stand, considerable amount of sunlight reaches the ground. The light incident on the interspaces in coconut stands decreases with the increase in the age of the plantation, and very little light reaches the ground when the palms are about 8 to 10 years old. This intense shaded situation lasts up to the age of 20 years. Thereafter, increasing amount of slant light and filtered light reaches the lower profile of the coconut canopy and at

about 30 years of age about 30% of the total light incident in the area reaches the ground (Nair and Balakrishnan, 1976). The amount of light penetrating the canopy, thereafter, increases with the age of the palms (Figure 1). After attaining maturity there is little change in the spread of the coconut crown although a slight reduction in the size of the fronds may occur. The canopy coverage of the ground progressively decreases with the increase in the height of palm and the resulting increase in the amount of sunlight from the slant rays.

The analysis of the above characteristic features of coconut and arecanut palms suggest the scope for taking up intensive cropping in the interspaces of these palms with compatible crops.

REFERENCES

- ANONYMOUS, 1977. *Sixth five year plan proposals for coconut development*. Directorate of Coconut Development, Cochin-11 (Mimeo.).

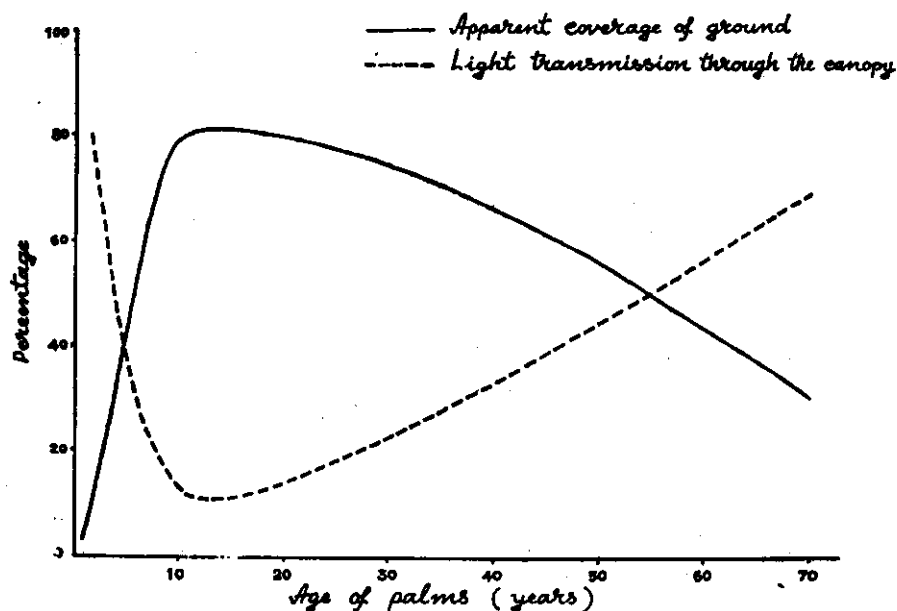


Figure 1. Apparent coverage of ground by coconut canopies of various age groups
Source: Nelli et al., 1974

- BAVAPPA, K. V. A., and MURTHY, K. N.** 1961. Morphology of arecanut palm—The root. *Arecanut J.* 12: 65-71.
- BHAT, K. S., and LEELA, M.** 1969. The effect of density of planting on the distribution of arecanut roots. *Trop. Agri.* 46: 55-61.
- KUSHWAH, B. L., NELLIAT, E. V., MARKOSE, V. T., and SUNNY, A. F.** 1973. Rooting pattern of coconut (*Cocos nucifera* L.). *Indian J. Agron.* 18:71-72.
- NAIR, P.K.R., and BALAKRISHNAN, T. K.** 1976. Pattern of light interception by canopies in a coconut cacao crop combination. *Indian J. agric. Sci.* 46: 453-462.
- THAMPAN, P. K.** 1976. *The coconut profile of India* Directorate of Coconut Development, Cochin-11, India (Mimeo).

III. INTERCROPPING IN COCONUT

P. GOPALASUNDARAM AND E.V. NELLIAT

*Central Plantation Crops Research Institute,
Kasaragod-670 124, Kerala, India.*

Growing one or more annuals in the interspace of coconut is an age-old practice in the coconut growing tracts in India. Krishna Marar (1964) estimated the extent of inter/mixed cropping in coconut gardens in Kerala at 78% and that tapioca was grown in 20% of the stands. In Andhra Pradesh 34.7% of the gardens had inter/mixed crops, viz., banana, mango, citrus, and turmeric. The area under intercrops or mixed crops in Tamil Nadu was 65% and the popular intercrops were rice, sugarcane, sorghum, tapioca and vegetables. He also added that in Philippines ginger, groundnut, colocasia and pineapple were widely grown.

The small size of the holdings makes it uneconomical to the owners to invest large

amounts on irrigation and land development. As a result most of the coconut holdings are rainfed. Krishnaji et al. (1976) have stated that in the major coconut growing state of Kerala, except in the Alleppey District, where 27.8% of the area under coconut was irrigated, only a very small percentage of the area under coconut got summer irrigation. Kerala receives an annual precipitation ranging from 2500-3600 mm. The data on the mean rainfall received in different centres of CPCRI is presented in Table 1.

The rainfall pattern clearly shows that in northern parts of Kerala (Kasaragod), there is a prolonged dry period from December to April. As many of the small and marginal farmers cannot afford to set up

Table 1. Rainfall received at different Research Centres of CPCRI in Kerala

Month	Mean rainfall received (mm)			
	Kasaragod (1957-76)	Kannara (1972-76)	Kayamkulam (1971-76)	Palode (1972-75)
January	0.8	—	15.7	8.0
February	—	1.6	25.8	25.4
March	3.8	4.9	34.9	46.8
April	42.6	100.7	182.2	297.8
May	266.1	299.8	308.5	239.3
June	976.1	1861.8	464.0	289.9
July	1098.2	701.4	427.6	351.0
August	663.8	513.8	273.6	262.6
September	324.0	239.6	289.4	196.8
October	187.5	206.0	325.0	523.8
November	77.6	91.0	89.2	309.6
December	19.3	64.7	59.9	77.1
Total	3659.8	2385.3	2495.8	2628.1

Source: Central Plantation Crops Research Institute 1977. Annual Report for the year 1976, pp. 273-283

Table 2. Management practices for intercrops

Intercrops grown	Scientific name	Variety	Population per ha gross area	Method of planting and spacing	Fertiliser dose (kg/ha) N: P ₂ O ₅ : K ₂ O	F.Y.M. t/ha	Time of planting
Elephant foot yam	<i>Amorphophallus</i> <i>complanatus</i>	Local	1295	Pits 1×1m	52: 26:52	6.5	March-April
Tapioca	<i>Manihot utilissima</i>	M4	2590	Mounds 0.9×0.9m	26: 20:43	2.6	April-May
Yam	<i>Dioscorea</i> spp.	Local	1295	Pits 1×1m	52: 26:52	6.5	March-April
Sweet potato	<i>Ipomoea batatas</i>	Local	10360	Ridges 50 cm apart	15: 10:15	2.0	May
Banana	<i>Musa</i> spp.	Poovan	666	5.4×2.7m	160:160:320	6.6	Sept.-Oct.
Pineapple	<i>Ananas sativa</i>	Kew	2590	Trenches 0.9×0.9m	26: 13:52	7.5	May-June
Ginger	<i>Zingiber officinale</i>	Maran		Beds 25 cm apart	60: 60:150	6.5	April-May

irrigation facilities, the possibility of successfully growing crops round the year is very much restricted. The only choice is growing annuals, taking advantage of the monsoon rains, in the interspace of coconut for enhancing the income from the land and employment. Hence, intercropping in coconut stands is of paramount importance to the small and marginal farmers, who form the largest group among the coconut growers.

Studies on intercropping in coconut stands were initiated in the thirties at the Coconut Research Stations (CRS), Kasaragod and Pilicode. Work on this aspect was, however, intensified during the past two decades. Field trials were conducted with different species and varieties of pulses, oilseeds, and tubers with the main objective of identifying compatible and remunerative crops and their varieties for intercropping, and to find out the optimum time of sowing/planting. The salient points of the work done and results obtained from the various field experiments are presented in the following paragraphs.

Willey (1979) had identified three different situations under intercropping. They are: 1. intercropping must give the full yield of the main crop and some yield of the second crop, 2. combined yield of intercrops must exceed the higher sole crop yield,

and 3. combined intercrop yield must exceed the combined sole crop yield.

In all the intercropping studies with coconut, only the first situation was considered. The emphasis was that the yield of the main crop of coconut should not decrease due to the growing of intercrops.

Intercrops were sown/planted taking advantage of the summer showers in April-May or in the first week of June when the south-west monsoon commenced on the west coast of India. Crops like pulses, which cannot withstand heavy rains, were sown after the heavy rains were over in August-September. All these crops are planted/sown leaving a circular area of 2 m radius around the base of the palm (effective root zone of the coconut) to facilitate the application of inputs like fertilisers for coconut. The package of practices adopted for these crops is described in Table 2.

Input requirements

Varghese et al. (1978) reported the results of a field experiment conducted at CPCRI, Kasaragod, during 1967-70 in which tapioca and elephant foot yam were raised as intercrops in coconut stands with the following treatments: t_1 —no intercrop—coconut manured, t_2 —intercrops grown—only intercrop manured, and t_3 —intercrops grown—coconut and intercrops manured.

Table 3. *Effect of raising intercrop in coconut gardens (Yield data for main crop and intercrop) (Varghese et al., 1978)*

Intercrop	Treatment	Mean annual yield of coconut		Response per palm	Mean yield of intercrop (1967-70) t/ha
		Pre-treatment 1964-67 per palm	Treatment 1968-70 per palm		
Elephant yam	T ₁ —No intercrop—coconut manured	47.0	38.4	- 8.6	—
	T ₂ —Intercrop alone manured	49.2	33.1	-16.1	8.41
	T ₃ —Both crops manured	31.9	36.2	4.3	9.18
Tapioca	T ₁ —No intercrop—coconut manured	46.5	35.8	-10.7	—
	T ₂ —Intercrop alone manured	50.1	34.0	-16.1	2.85
	T ₃ —Both crops manured	33.0	33.4	0.4	5.08

The effect of the treatments on the performance of coconut and intercrops is presented in Table 3.

There was a general reduction in the yield of coconut, which had passed the prime bearing age. But there was no such reduction when both the intercrop and coconut were manured as per the recommended package of practices. The greater reduction in the yield of coconuts (16 nuts/palm/year) when the intercrop alone was manured (t_2) compared to that of 9.7 nuts in the plots where there was no intercrop but coconut was manured (t_1) was due to the competition for nutrients between the main crop and intercrop. This was overcome by fertilising both the crops as evidenced by the yield of coconut in t_3 .

Besides, the yield of tubers was also poor when the intercrop alone was manured compared to that in the plots where both the intercrop and the main crop received fertilisers.

This study revealed that when intercrops are grown, both the main and subsidiary crops should be given the recommended management practices, as if they were grown as sole crops so as to ensure satisfactory yields and profitability of the practice.

Tubers as intercrop

Among the intercrops, tropical tubers like tapioca and elephant yam are the most popular ones. One of the main reasons for their popularity is that while the coconut gives the farmer cash income, the tubers grown as intercrops partially meet the food requirements of the farmer's family. Experiments at CPCRI, Kasaragod and Coconut Research Station (CRS), Pilicode have shown that tapioca and elephant yam are the most profitable among the intercrops.

Kannan and Nambiar (1976) reported the result of experiments on intercropping conducted at the CRS, Pilicode in coconut stands aged about 50 years during 1967-75, with tapioca, colocasia, rice, ragi and groundnut. They observed increased production of nuts and enhanced overall returns from the coconut garden due to intercropping. The increase in nut yield ranged from 2.7% in groundnut intercropped plot to 30.3% in colocasia intercropped plots. The results of their experiments are presented in Table 4.

Among the various intercrops tried tapioca gave the highest net return of Rs 1503/ha. The coconut-colocasia/ragi

Table 4. Yield and returns from different intercropping systems (Kannan and Nambiar, 1976)

Intercrop	Yield of coconuts nuts/palm/year		Yield of intercrop (kg/ha)	Addl. returns from coconut (Rs/ha)	Profit from intercrop (Rs/ha)	Total additional net profit Rs/ha
	Pre- treatment 1960-66	Treatmen- tal period 1968-74				
Rice	59.9	70.8	850	1164	885	2019
Tapioca	55.9	61.0	15452	544	1503	2047
Colocasia	45.1	58.8	6250	1463	715	2178
Groundnut	58.9	60.5	965	150	455	605

Table 5. Yield of coconut palm during pre-experimental and experimental periods under different treatments (Varghese et al., 1978)

S.No.	Treatment	Mean yield of nuts/palm/year		Response nuts/palm	Percentage increase (+) or decrease(-)
		Pre-Expt.*	Expt.**		
1.	Control (no intercrop)	48.2	45.2	-3.0	-6.2
2.	Tapioca (every year-no rotation)	54.8	51.2	-3.6	-6.6
3.	Elephant yam (every year-no rotation)	68.3	59.3	-9.0	-13.2
4.	Tapioca and elephant yam in alternate years	73.0	68.2	-4.8	-6.6
5.	Elephant yam and tapioca in alternate years	66.6	62.4	-4.2	-6.3
6.	Mean of items 4 and 5	69.8	65.3	-4.5	-6.5
7.	Tapioca, elephant yam, sweet potato, ginger, and turmeric in 5 year rotation	49.7	52.1	2.4	+4.8
8.	Yam, lesser yam, colocasia and coleus in rotation	60.8	69.8	9.0	+14.8

*For items 1 to 6 mean yield of years from 1970 to 1972 and for items 7 and 8 from 1971-73

**For items 1 to 6 mean yield of years from 1974 to 1977 and for items 7 and 8 from 1975-77.

combination also resulted in substantial increase in net additional returns.

Need for intercrop rotation

A field trial was conducted at CPCRI, Kasaragod from 1972 to '77 to study the effect of growing tapioca and elephant yam in the same plots year after year and growing these by rotation.

Another experiment was also in progress from 1973 to '78 in which five tuber crops, viz., tapioca, sweet potato, ginger, elephant yam and turmeric were grown as intercrops in coconut in different five yearly rotations. The results of these experiments were reported by Varghese et al (1978).

The data on the effect of growing tuber crops on the yield of the main crop of coconut are presented in Table 5. In the first experiment, the palms were more than 65 years old. The reduction in the yield of coconut in the plot, where no intercrop was grown, was 3 nuts/palm/year (6.2%). The

yield reduction in other treatments, except the one in which elephant yam was grown continuously was of the same magnitude. But, where elephant yam was grown every year, the coconut yield was lowered by 13.2% (9.0 nuts/palm/year). This showed that it is preferable not to grow the same tuber as an intercrop in the same coconut stand year after year, as it affects the yield of coconut.

In the second experiment, where five year-five crop rotations were tried, the coconut palms showed an increased yield of 2.4 nuts/palm over the pre-experimental yield. It is, therefore, evident that the main crop of coconut was not adversely affected when intercropping was taken up with tubers, provided rotation of intercrops and proper management practices were adopted.

Yield of intercrops

The yield of intercrops in the above two experiments is presented in Table 6.

Table 6. Yield of tubers as intercrops in coconut garden (Varghese et al., 1978)

Intercrops grown	Yield in t/gross ha of coconut plantation				
	1973-74	1974-75	1975-76	1976-77	Mean
Tapioca (every year-no rotation)	5.8	2.6	6.2	3.2	4.5
Tapioca alternated with elephant yam	7.1	6.7	8.3	3.2	6.3
Elephant yam (every year no rotation)	5.6	7.6	9.5	3.0	6.4
Elephant yam alternated with tapioca	16.2	8.9	13.8	8.1	11.8
Rotation experiment					
(a) Tapioca	7.7	7.4	14.2	8.3	7.6**
(b) Elephant yam	12.9	9.2	15.2	11.6	12.2
(c) Sweet potato	9.5	6.5	7.2	5.2	7.1
(d) Ginger	11.6	3.9	NA*	NA*	7.8
(e) Turmeric	10.9	NA	8.2	5.2	8.1
Greater yam	12.7	5.4	12.8	10.3	10.3
Lesser yam	9.0	8.5	7.4	5.3	7.5
Colocasia	NA	NA	11.8	6.6	9.2
Chinese potato	6.0	6.6	6.7	3.0	5.6

*Ginger crop was destroyed by soft-rot disease

**Mean yield for 1973-74 and 1974-75 only.

NA: Not available

Table 7. Net returns and additional employment generated per year from one hectare of coconut garden intercropped with tuber crops
(Varghese et al., 1978)

Intercrop	Yield of intercrop (t/ha)	Value of intercrop (Rs/ha)	Cost of cultivation (Rs/ha)	Net returns from intercrop alone (Rs/ha)	Input: output ratio for intercrop	Total net income including coconut	Additional employment	
							Man days	Woman days
Coconut alone	—	—	2900	8400	—	5500	—	—
Tapioca	11.2	4480	2122	2358	2.11	7858	93	12
Elephant yam	12.2	9760	3246	6514	3.01	12014	123	8
Sweet potato	7.1	2840	2055	785	1.38	6285	56	26
Ginger	7.8	9750	4730	5020	2.06	10520	108	24
Turmeric	8.1	3248	4568	1808	0.71	3692	108	24
Chinese potato	5.6	4480	2035	2445	2.20	7945	92	23
Greater yam	10.3	5150	2827	2323	1.82	7823	64	12
Lesser yam	7.5	4500	2827	1673	1.59	7173	64	12

Value of intercrops in Rs/t: Tapioca-400, Elephant yam-800, Sweet potato-350, Ginger-1250, Turmeric-400, Coleus-800, Greater yam-500, Lesser yam-500, Coconut Re 0.80/nut.

When tapioca was grown every year, it gave a mean yield of 4.5 t/ha (range 2.6-6.2 t/ha). But when rotated with elephant yam, its mean yield was 6.3 t/ha (range 3.2-8.3 t/ha). Elephant yam also showed a similar trend. Rotation with tapioca on alternate years, increased the yield of elephant yam to 11.8 t/ha from 6.4 t/ha when it was grown every year in the same field. In the second trial where five year rotation was adopted, these tubers gave still higher yields. Tapioca variety M4 yielded 7.6 t/ha in 5 year rotation, whereas variety H 165 gave the highest yield of 11.3 t/ha. Similarly elephant yam in 5 year rotation yielded 12.2 t/ha.

These results further emphasise the need to adopt intercrop rotations rather than growing the same intercrop year after year.

Feasibility studies were also conducted with tubers like greater yam (*Dioscorea alata*), lesser yam (*Dioscorea esculenta*), Chinese potato (*Coleus parviflorus*), and Colocasia (*Xanthosoma sagittifolium*). These crops gave yields ranging from 5.6 to 10.3 t/ha and were also found compatible with coconut.

Profitability and additional employment

The additional income and employment

opportunities that can be generated by tropical tuber crops as intercrops in coconut garden is presented in Table 7.

Even under rainfed conditions, a net income of Rs 7,000-8,000 per ha could be obtained by growing tuber crops in coconut gardens. Elephant yam followed by ginger gave the highest total net return per hectare. However, ginger is highly susceptible to *soft rot* disease, which can completely wipe out the crop. Hence, adequate precautions should be taken against this disease. Besides the additional returns, these crops provide additional employment for the agricultural labour. Crops like elephant yam and ginger are more labour intensive than tapioca and sweet potato. Elephant yam doubles the employment potential per unit area of land compared to sole crop of coconut.

An intercropping experiment with six tubers was carried out in the laterite gravelly soil at CRS, Pilicode. Maximum profit was realised from elephant yam (Anonymous, 1979 b). The mean yield of intercrops were: ginger 5.2 t, turmeric 7.2 t, sweet potato 1.0 t, elephant yam, 1.0 t, colocasia 0.7 t and tapioca 7.0 t/ha.

Table 8. Effect of intercropping on the yield of coconut palms in a root (wilt) affected garden (Menon and Nayar, 1978)

Treatment	Yield of nuts/palm/year		Percentage increase/decrease	Estimated net response %
	Pre-exptl. period	Exptl. period		
Control (no intercrop)	41.0	38.6	-5.8	—
Tapioca	49.8	48.9	-1.8	4.96
Elephant yam	52.5	58.7	11.8	17.57
Yam	57.0	58.3	2.3	2.04

Root (wilt) affected area

Experiments conducted at CPCRI Regional Station, Kayangulam—an area where coconut is affected by root (wilt) disease—have revealed that tuber crops like tapioca, elephant yam and yam can be grown profitably as intercrops under disease affected conditions (Menon and Nayar, 1978). This experiment was conducted in a 16 year old coconut garden spaced 7.5×7.5m apart. They were raised for three years from 1975. The yield of the coconut palms during the pre-experimental period and experimental period are presented in Table 8.

Considering the overall response of palms, there was no reduction in yield due to intercropping. A slight increase in the mean yield of palms was noticed in the plot where elephant yam was cultivated (11.8%) followed by the plot where yam was cultivated (2.2%).

The effect of intercropping on the number of palms in different disease intensity groups was also studied (Table 9). In the control plot, during the course of three years, all the apparently healthy palms had developed disease symptoms. But in the intercropped plots, some of the palms continued to be free from disease symptoms. The mean disease index for the control plot increased from 34.2 to

36.1, indicating advancement of the disease. Palms intercropped with tapioca also exhibited a similar trend, but slightly larger increase in disease intensity (32.1 to 37.3). However, palms intercropped with elephant yam showed a marginal reduction in disease intensity from 37.0 to 33.3.

Yield and net profit

Tapioca variety H 165 gave the highest tuber yield of 15.93 t/ha/year (Table 10). Raising all the three intercrops was profitable. Tapioca gave the highest net profit. From the cost benefit analysis, it was found that coconut+tapioca combination gave the highest net return per rupee invested (1:1.47).

All these experimental results establish that tubercrops, especially, tapioca and elephant yam can be profitably grown as intercrops in coconut gardens.

Rice

Rice being the staple food of the local population, efforts were made from time to time to find out the possibility of growing upland rice varieties as an intercrop in coconut gardens. One of the earliest reports on raising rice as an intercrop in coconut gardens from Nileshwar (Anonymous, 1934) was not very encouraging as the grain yield

Table 9. Effect of intercropping on number of palms under different disease intensity groups (Menon and Nayar, 1978)

Group	(% of total)							
	Control		Tapioca		Elephant yam		Yam	
	1975	1977	1975	1977	1975	1977	1975	1977
Apparently healthy	13.33	—	18.36	10.22	12.00	13.00	5.26	16.66
Diseased early	26.67	26.66	20.40	18.36	20.80	22.00	21.05	22.23
Diseased middle	40.00	40.82	40.82	51.02	42.38	33.00	60.52	41.66
Diseased advanced	20.00	33.33	20.40	20.40	23.82	35.00	13.17	19.45

Table 10. Yield and cost benefit analysis of intercropping
(Menon and Nayar, 1978)

Crop(s)	Yield of intercroppings (t/ha)	Value of intercroppings (Rs/ha)	Value of* coconut (Rs/ha)	Gross returns (Rs/ha)	Cost of cultivation (Rs/ha)	Net return (Rs/ha)	Net return per rupee invested (Rs)
Control (coconut)	—	—	5320	5320	2800	2520	0.90
Coconut+tapioca H. 165	15.93	5575	6860	12435	5020	7415	1.47
Coconut+elephant yam	5.36	2680	8260	10940	5050	5890	1.16
Coconut+yam	5.45	2725	8120	10845	5105	5650	1.08

*The values were calculated @ Rs 800/1,000 coconuts, Rs 350/t of tapioca and Rs 550/t of elephant yam and yam.

was only 160 kg/ha. However, upland rice variety Kattamodan was successfully grown as an intercrop in coconut garden at CRS, Pilicode and among the various grain crops tried, rice sown in June was found to be the best (Anonymous, 1942). It gave a grain yield ranging from 423 to 749 kg/ha under coconut compared with 755 to 1208 kg/ha in the open.

Although these trials showed that upland varieties can be grown successfully as intercrops in coconut gardens, the unsatisfactory early growth due to inadequate summer showers resulted in low yields of rice varieties PTB 29 and PTB 30 (Anonymous, 1960). Experiments were conducted at CPCRI, Kasaragod from 1976 to '78 to spot out suitable variety or varieties of upland rice for intercropping in coconut gardens. Three varieties of rice of about 110 days duration, viz., Rohini, Chennellu and Culture 12814 were tried. The yield data are given in Table 11.

Table 11. Yield of three upland rice varieties as intercrops in coconut garden

Variety	Yield (kg/ha)			Mean
	1976	1977	1978	
Rohini	1926	1586	1427	1646
Chennellu	1840	1005	849	1231
Culture 12814	1703	1036	1170	1303

Variety Rohini which gave the highest mean yield of 1646 kg/ha of coconut plantation was found to be the most suitable and remunerative. The sowing was done immediately after the onset of the monsoon rains.

Banana

Krishna Marar (1964) reported that banana was popular as an intercrop in

Andhra Pradesh, Tamil Nadu and Kerala. In Andhra Pradesh, banana was the most common intercrop in areas where irrigation facilities were adequate. It gave an yield of 1200 to 1300 bunches per ha/with an average net profit of Rs 500-750/ha (Anonymous, 1964). Narayanan and Louis (1965) found that in parts of Tamil Nadu, banana was always grown as a mixed crop in young coconut plantations. Kuttappan (1971) conducted a small survey among the coconut growers having less than one hectare and growing banana as an intercrop, and concluded that up to 1000 banana plants could be raised in one ha of coconut garden, if the density of coconut was restricted to 125 palms/ha. Banana gave a net additional income of Rs 1,000 on an average at the 1971 rates.

Experiments were conducted at CPCRI, Kasaragod to screen and find out the banana varieties best suited for intercropping. Four varieties, viz., Dwarf Cavendish, GrosMichel, Peda Pacha and Nendran were tried. The yield data are presented in Table 12.

The data showed that GrosMichel and Peda Pacha were the highest yielders during 1976, whereas Dwarf Cavendish gave higher yield during 1977. But all the varieties gave very poor yields during the third year, indicating that to get satisfactory yields,

Table 12. Yield of banana raised as intercrop in coconut garden

Variety	Weight of fruits per bunch (kg)		
	Plant crop 1976	Ratoon 1977	1978
Dwarf Cavendish	5.5	7.1	2.
GrosMichel	10.0	4.7	2.5
Peda Pacha	7.5	6.8	2.0
Nendran	5.2	4.7	—

banana should be replanted after the first ratoon crop.

At Veppankulam, Tamil Nadu, banana varieties Kanchi and Karpooravalli performed well in coconut garden, giving an yield of 11.4 kg of fruits/bunch. But the variety Dwarf Cavendish failed to establish (Anonymous, 1978b). Krishnaji et al. (1976) have reported that banana grown as an intercrop in coconut gave a net profit of Rs 2905 per ha and provided an additional employment of 132 man days and 6 woman days per ha per year.

At CRS, Pilicode, banana varieties Robusta, Nendran, Njalipoovan and Palayankodan were grown as a rainfed crop on the laterite gravelly soil (Anonymous, 1979b). A randomised block design with five replications was adopted. The yield data are given in Table 13.

Table 13. Yield of banana varieties as rainfed intercrop

Banana variety	Mean weight per bunch (kg)	No. of hands per bunch	No. of fingers per bunch
Robusta	6.57	6.9	78.2
Nendran	5.77	5.1	50.0
Njalipoovan	5.31	6.7	90.1
Palayankodan	6.50	9.2	118.7

Source: Kerala Agricultural University, 1979. Research Report for 1977, Vellanikkara, Trichur, India

The yield was low because of the moisture stress experienced during the flowering and fruit maturing stages. It appears that banana as a rainfed intercrop in laterite gravelly soil may not be successful.

Millets

A lot of interest was evinced on the possibilities of raising millets as intercrop

in coconut gardens during the thirties. However, in subsequent years, with more and more emphasis on tuber crops and perennials like cacao, nutmeg, pepper, and cinnamon, the interest in millets diminished.

The initial studies at Kasaragod during 1930-31 and 1931-32 showed that ragi was not a profitable intercrop. It gave an yield of only 292 and 236 kg grain per ha respectively, during the above years (Anonymous, 1932).

Elaborate experiments were conducted at the CRS, Pilicode, on the intercropping of millets in coconut gardens. During 1939-40 to 1941-42, intercropping trials were carried out with various millets like *tenai*, *samai*, *ragi*, *cholam*, *kudiravali*, *panivaragu*, *cumbu*, and *varagu* (Anonymous, 1941, 1942 and 1943). These millets were also grown in the open to study their comparative performances. Different dates of sowings were also tried. However, one lacuna in the above studies was that no published information is available regarding the yield of coconut under the different intercrops. The yield data of these crops are summarised in Table 14.

The data presented in the table show that sowing of the various millets at the beginning of the monsoon was more advantageous than sowing late. During 1941-42, sowing in early May and at the beginning of south-west monsoon (last week of May) were successful, but sowing in August first week was a complete failure. Among the millets *varagu* (*Paspalum scrobiculatum*) seemed to be the best suited for the west coast of India. However, due to the poor market demand from the local population which did not relish this millet, there was little scope for popularising this millet. One interesting point to be noted is that most of these millets gave equal or better yields under coconut compared to their yields in the open. Besides, in most of the cases, the yield of straw was very high

Table 14. Yield of millets as intercrops in coconut garden and in the open—Pilicorde 1939-40, 1940-41 and 1941-42

S.No.	Common name	Scientific name	Cultivar	Time of sowing	Yield of grain kg/ha		Yield of straw kg/ha	
					Under coconut	Open	Under coconut	Open
1.	Ragi	<i>Eleusine coracana</i>	EC 593	June 39	750	1275	—	—
				June 40	352	738	1566	2494
				Aug. 40	207	154	557	454
				2 May 41	755	484		
				28 May 41	483	815		
2.	Cumbu	<i>Pennisetum typhoides</i>	PT 17	June 39	1148	1102	4727	4909
				June 40	1010	352	5721	4039
				Aug. 40	137	23	1593	1171
				2 May 41	831	161	5724	6025
				28 May 41	438	106	4529	3495
3.	Varagu	<i>Paspalum scrobiculatum</i>	PS 1	June 39	1364	2250	3455	5090
				June 40	874	1352	2654	1976
				Aug. 40	716	465	2048	2687
				2 May 41	2220	1389	5121	3309
				28 May 41	906	2094	3204	3615
4.	Samai	<i>Panicum miliare</i>	PM 2	June 39	63	800	6727	6909
				June 40	57	148	8122	6852
				Aug. 40	250	397	2184	1957
				2 May 41	412	720	4579	5893
				28 May 41	45	513	3374	5000
5.	Kudiravali	<i>Echinochloa frumentacea</i>	PC 29 PC 49	June 39	108	57	—	—
				June 40	102	31	408	77
				Aug. 40	20	20	—	—

indicating excessive vegetative growth due to the continuous rains received during the monsoon.

Recently efforts were made to grow ragi as an intercrop in coconut at Thanjavur (Tamil Nadu). However, the two varieties tried EC 4847 and EC 4849 gave very poor yields of 175 and 570 kg of grains/ha (Anonymous, 1978b).

Pulses

Since growing pulses have the added advantage of fixing atmospheric nitrogen, trials were conducted from earlier days to grow pulses as intercrops in coconut stands. Experiments carried out at Kasaragod during 1930-31 showed that horse gram, grown as a grain crop, gave a poor yield of 85 kg/ha (Anonymous, 1932). During 1932-33 red gram gave a green matter yield of 1480 kg/ha and was found to be the better green manure crop among the various intercrops tried, viz., red gram, soybean, sunflower and *Crotalaria paniculata* (Anonymous, 1934).

Trials were conducted at CRS, Pilicode with seven pulse crops, viz., black gram, dew gram, green gram, red gram, pillipesara, horse gram and cowpea during 1939-40. Among these, except red gram, all others failed completely. Red gram gave an yield ranging from 133-454 kg/ha (Anonymous, 1941). Its yield in 1940-41 was very poor, i.e. 19-57 kg/ha (Anonymous, 1942).

During 1976-77, experiments were conducted at Regional Coconut Research Station, Arsikere with different pulses, viz., cowpea, horse gram, red gram and green gram. Among these cowpea (Var. C 152 and C 448) and red gram (Hybrid 3C) gave satisfactory yields (Anonymous, 1978a). At Veppankulam also the performance of cowpea var. C 152 was encouraging, whereas the other pulses like cowpea var. PLS 370, red gram, black gram, green gram, and soybean (EC 39821) gave very poor yields (Anonymous, 1978a).

Experiments were conducted at CPCRI, Kasaragod during the last few years to screen the different pulses and their varieties as intercrops. During 1974 horse gram gave an encouraging yield of 355 kg grain/ha whereas the yield of black gram was poor (72 kg/ha) (Anonymous, 1975).

During 1975 a trial was conducted to find out the proper time of sowing and to evaluate the varieties for intercropping. The results showed that cowpea, var. 779 could be sown during the last week of September as a rainfed crop under normal conditions of rainfall. Soybean var. Davis sown in September second week alone came to harvest. The subsequent sowings dried up before harvest (Anonymous, 1976).

Similar studies were conducted during 1976 also. Trials were conducted with three varieties of cowpea, two varieties of black gram and three varieties of green gram, sown at fortnightly intervals from mid-August. The yield of these crops is presented in Table 15 (Anonymous, 1977).

Another trial was also conducted with seven varieties of red gram sown at fort-

Table 15. Grain yield of pulses grown as intercrops during 1976

Crop/variety	Yield at different dates of sowing (kg/ha)	
	16-8-1976	1-9-1976
Cowpea		
779	75	83
New Era	300	267
Kunnankulam	500	467
Green gram		
Philippines	—	—
PS 7	117	67
PS 16	300	250
Black gram		
S1	58	58
T9	317	233

nightly intervals at CPCRI, Kasaragod during 1976. Late August or early September sowing appeared to be the best.

The results of the various experiments presented so far indicated that pulse crops were best sown immediately after the heavy rains i.e. second fortnight of August. Some of the pulses like cowpea appear to be promising intercrops. However, further trials are required before any final conclusion is drawn and valid recommendations are made. Though the legumes are known to enrich the soil by fixing atmospheric nitrogen, information on the influence of intercropping with pulses on soil fertility status is scanty.

Oilseeds

Though India has achieved a spectacular increase in the production and productivity of cereals, the production of oilseed crops is unable to keep pace with the increasing demand for vegetable oil. Intercropping with oilseed crops like groundnut in coconut gardens offer excellent possibilities in this regard.

Trials were conducted at Kasaragod and Pilicode during the thirties and early forties for finding out the suitable oilseed crops and their varieties for intercropping in coconut plantations. These trials were confined to three popular annual oilseed crops, viz., groundnut, gingelly and castor.

Among these, efforts to grow castor proved unsuccessful both at Kasaragod and Pilicode probably because the crop varieties were not tolerant to shade (Anonymous, 1934; and 1941).

Gingelly proved only partially successful. The crop grew fairly well and gave moderate yields. It yielded 97 kg/ha in August sowing and 278 kg/ha in June sowing during 1940-41.

Successful growing of groundnut as an intercrop in coconut gardens was reported by Sahasranaman (1964) and Kannan and

Nambiar (1976). The studies carried out on intercropping with groundnut in coconut garden reveal some interesting information.

During 1930-31 groundnut, raised as an intercrop in coconut at Kasaragod grew up well. However, it was ploughed in during October, because it was thought that the crop will deplete the soil moisture and will have an adverse effect on coconut palms if kept longer (Anonymous, 1932). Groundnut was raised as intercrop at Pilicode during 1939-42 and gave yields ranging from very low yields to very good yield of 1364 kg/ha. These results established that groundnut can be successfully grown, if sown during the first fortnight of May and then adequately managed.

Sahasranaman (1964) reported that groundnut var. TMV 2 when grown as an intercrop in coconut garden at CPCRI Regional Station, Kayangulam yielded 600 kg/ha and gave an additional net profit of Rs 183/ha (at 1964 prices). Besides it helped to suppress the weed growth and kept the soil in good tilth for a major part of the year.

Kannan and Nambiar (1976) reported that groundnut, grown as an intercrop increased the yield of main crop of coconut from 59 nuts/palm/year in the pre-treatment period to 60.5 nuts/palm/year during the treatment period. It gave an yield of 96 kg pods/ha resulting in an additional net profit of Rs 455/ha. Besides, it provided employment to the tune of 75 man days or 90 woman days per season.

Leela and Bhaskaran (1978) reported the results of intercropping studies with groundnut in coconut gardens. Groundnut variety TMV 2 was grown in a garden with middle aged palms in the red sandy loam soil of CRS, Nileshwar during May-September for two years, viz., 1972 and 1973. The recommended package of practices was followed.

Groundnut gave an yield of 1326 kg of pods and 1448 kg of haulms per ha

coconut garden. Projecting this yield on the basis of effective land occupation of 72%, the sole crop yield worked out to 1842 kg/ha. This was as good as the yield of a good sole crop of groundnut in the open under rainfed condition.

Besides, intercropping with groundnut helped to skip certain operations for the main crop of coconut like two ploughings during May and September, and liming. When the cost of these operations are added to the returns from groundnut, the net additional returns work out to Rs 2773 per ha.

In addition, weed growth was suppressed by 61% in the intercropped area. It was more pronounced on monocot weeds (85.2%) than on dicot weeds (33.0%).

Leela and Bhaskaran (1978) have also carried out studies on the nutritional status of the soil in plots with and without intercrop (Table 16).

Table 16. *Post-treatment nutritional status of soil and weed growth in plots with and without intercropping (Leela and Bhaskaran, 1978)*

Nutrient element	With intercrop (ppm)	Without intercrop (ppm)
N	815	645
P	571	419
K	378	318
Ca	601	518
Type of weed	Weed growth Dry matter (kg/ha)	
Dicot	485	724
Monocot	125	845
Total	610	1569

The data clearly showed that intercropping with groundnut resulted in the higher availability of the nutrients in soil. This could be attributed to the fixation of atmospheric nitrogen by groundnut and addition of organic matter to the soil which facilitate greater microbial activity.

Thus, growing groundnut as an intercrop in coconut stand was not only highly remunerative but also had beneficial effects on the productivity of coconut and fertility of soil.

During 1973 sunflower was grown as intercrop in coconut at CPCRI, Kasaragod. Though the early growth was satisfactory, rain water dripping from coconut leaves affected their performance (Anonymous, 1974).

Other crops

In an observational trial to find out the comparative performance of pineapple (Kew) as an intercrop with and without summer irrigation at CPCRI, Kasaragod, the number of fruits harvested per unit area and the weight of fruits was considerably higher in the irrigated crop. In the irrigated plot, 33% of the plants gave fruits, with a mean weight of 1.54 kg. The fruiting was less than 1% and the mean fruit weight was 0.71 kg in the rainfed crop (Anonymous, 1979a).

In experiments conducted at Regional Coconut Research Station, Arsikere, raising potato (Chandramuki) during the monsoon season, followed by chilli gave the highest net income of Rs 5,300/ha even though the yield of potato was lower than the normal yield. Hybrid maize followed by bengal gram gave a net income of Rs 3,855/ha. In another experiment at the same place, soybean+wheat and groundnut+wheat sequences gave high net incomes of Rs 2,600 and Rs 2,450 per ha, respectively (Anonymous, 1978b).

Sahasranaman (1961) reported that chilli was a profitable intercrop in coconut gardens.

A net income of Rs 100 per ha at the then prevailing price was obtained.

Sethi (1963) suggested that Andrews variety of sea island cotton could be grown as an intercrop in coconut gardens.

Sen (1956) reported that arrow root often grew wild in coconut gardens of West Bengal. He opined that with little more care, it could be made a source of profit to coconut growers.

REFERENCES

- ANONYMOUS, 1932. Madras Agricultural Stations report for 1930-31. Dept. of Agriculture, Madras, India. pp. 248-266.
- ANONYMOUS, 1934. Madras Agricultural Stations report for 1932-33. Dept. of Agriculture, Madras, India. pp. 267-308.
- ANONYMOUS, 1941. Madras Agricultural Stations report for 1939-40. Dept. of Agriculture, Madras, India. pp. 367-376.
- ANONYMOUS, 1942. Madras Agricultural Stations Report for 1940-41. Dept. of Agriculture, Madras, India. pp. 375-384.
- ANONYMOUS, 1943. Madras Agricultural Stations report for 1941-42. Dept. of Agriculture, Madras, India. pp. 323-334.
- ANONYMOUS, 1960. Central Coconut Research Station, Kasaragod, Annual report for 1958-59. India's Central Coconut Committee, Ernakulam, India.
- ANONYMOUS, 1964. Intercropping in coconut gardens in Andhra Pradesh. *Cocon. Bull.* 18: 343-345.
- ANONYMOUS, 1974. Central Plantation Crops Research Institute, Annual Report for 1973. Kasaragod, India. pp. 24-28.
- ANONYMOUS, 1975. Central Plantation Crops Research Institute, Annual Report for 1974. Kasaragod, India. pp. 24-27.
- ANONYMOUS, 1976. Central Plantation Crops Research Institute, Annual Report for 1975. Kasaragod, India. pp. 25-28.
- ANONYMOUS, 1977. Central Plantation Crops Research Institute, Annual Report for 1976. Kasaragod, India. pp. 31-34.
- ANONYMOUS, 1978a. All India Coordinated Coconut and Arecanut Improvement Project, Progress report for 1976-77. CPCRI, Kasaragod, India (Mimeo).
- ANONYMOUS, 1978b. All India Coordinated Coconut and Arecanut Improvement Project, Progress report for 1977-78. CPCRI, Kasaragod, India (Mimeo).
- ANONYMOUS, 1979a. Central Plantation Crops Research Institute, Annual report for 1977. Kasaragod, India. pp. 32-34.
- ANONYMOUS, 1979b. Kerala Agricultural University, Research Report for 1977-78. Vellankara, Trichur, India. pp. 90-98.
- KANNAN, K., AND NAMBIAR, K.P.P. 1976. Studies on intercropping coconut garden with annual crops. *Cocon. Bull.* 5(9): 1-3.
- KRISHNAJI, N., CHANDHAN MUKERJI, NELLIAT, E. V., NAIR, P. K. R., JACOB MATHEW, AND VARGHESE, P. T. 1976. Economics of inter and mixed cropping in the coconut gardens of Kerala: Some preliminary findings. Working paper No. 41. Centre for Development Studies, Trivandrum, India (Mimeo).
- KRISHNA MARAR, M.M. 1964. Intercropping in coconut plantations in India—Problems and prospects. Proc. 2nd session. F.A.O. Tech. Wkg. Pty. Cocon. Prod. Proceng. Colombo. pp. 393-398.
- KUTTAPPAN, M. 1971. Banana—a beneficial intercrop in coconut gardens. *Cocon. Bull.* 1 (12): 2-4.
- LEELA, K., AND BHASKARAN, U. P. 1978. Effect of intercropping coconut stands with groundnut on soil fertility and plantation management. In Proc. PLACROSYM I, Placrosym Standing Committee, Kasaragod, India. pp. 393-398.
- MENON, K. S., AND NAYAR, T.V.R. 1978. Effect of intercropping with tuber crops in root (wilt) affected coconut garden. In Proc. PLACROSYM I. Placrosym Standing Committee, Kasaragod, India. pp. 416-424.
- NARAYANAN, K. M., AND LOUIS, H. 1965. It pays to raise intercrops in coconut gardens. *Cocon. Bull.* 19(1): 3-7.
- SAHASRANAMAN, K. N. 1961. Chillies—an intercrop for coconut plantation. *Cocon. Bull.* 15(2): 49-52.



Tapioca intercropped in coconut garden



Elephant yam intercropped in coconut garden



Colocasia raised as intercrop in coconut garden



Sweet potato raised as intercrop in coconut garden



Chinese potato intercropped in coconut garden



Turmeric intercropped in coconut garden



Ginger intercrop raised in coconut garden



Banana intercropped in young areca garden

- SAHASRANAMAN, K. N. 1964. It pays to grow groundnut in coconut gardens. *Cocon. Bull.* 18(4): 123-130.
- SEN, B. C. 1956. Intercropping in coconut gardens in West Bengal. *Bull. Indian Central Coconut Committee* 10(1): 43-45.
- SETHI, B. L. 1963. Intercropping sea-island cotton in coconut garden. *Cocon. Bull.* 17(5): 129-131.
- VARGHESE, P. T., NAIR, P.K.R., NELLIAT, E. V., RAMA VARMA, AND GOPALASUNDARAM, P. 1978. Intercropping with tuber crops in coconut gardens. In Proc. PLACROSYM I, Placrosym Standing Committee, Kasaragod, India. pp. 399-415.
- WILLEY, R. W. 1979. Intercropping—Its importance and research needs. I. Competition and yield advantages. *Field Crop Abstr.* 32: 1-10.

IV. INTERCROPPING IN ARECANUT GARDENS

A. MURALIDHARAN AND T. V. RAMAKRISHNAN NAYAR

CPCRI Regional Station, Vittal-574 243,
Karnataka, India.

Raising other crops in the interspace of arecanut stands has been a common practice. The diversity of the inter and associated crops in arecanut gardens was reported by Bavappa (1951). The long pre-bearing age, low returns during the initial bearing stage, unexpected loss due to pests and diseases and natural calamities, remoteness from markets and lack of transport facilities were reported to be some of the reasons that might have induced the farmers to grow intercrops in arecanut gardens (Abraham, 1956; Bhat, 1974; Khader and Antony, 1968; Nagaraj, 1974; Naidu, 1959). According to Bhat (1974), the main objective of intercropping in arecanut gardens in the earlier days was not intensive land use, but compelling social and economic situations. The selection of the intercrops and the management practices adopted were not based on sound agronomic principles. Reduction in the productivity of the main-crop of arecanut as well as that of the intercrop, resulting from the inadequate management practices and incompatibility of the crops chosen were to a great extent overlooked. Hence, a number of field experiments were initiated in early sixties at the CPCRI Regional Station, Vittal, and the Research Centres to assess the adverse effect, if any, on the productivity of the main crop of arecanut due to intercropping with commonly cultivated tuber crops, fruit crops like banana and pineapple, and spice crops like ginger and turmeric, and to find out the productivity of these crops

grown as intercrops and to determine the profitability of the practice.

Tubers

Among the tropical tubers, elephant yam (*Amorphophallus companulatus*) and tapioca (*Manihot utilissima*) are more popular, as these edible tubers partially meet the food requirements, especially in years of scarcity for the staple cereal—rice. Further, some of the tubers like elephant yam, yams and colocasia are capable of giving satisfactory yields under the partially shaded condition prevailing in arecanut gardens and can tolerate the dripping of rain water from arecanut leaves. The other tuber crops tried were sweet potato (*Ipomoea batatas*) and arrow root (*Maranta arundinacea*).

Reporting the results of the experiment on intercropping with tapioca, elephant yam, yam and sweet potato, in a rainfed adult bearing arecanut garden at Palode, Abraham (1974) stated that no perceptible deleterious effect on the yield and condition of arecanut palms could be noticed. Sadanandan (1974), on the basis of an intercropping experiment in a bearing irrigated arecanut garden, observed that there was no adverse effect on the yield of arecanut palms due to intercropping with elephant yam. The results of an intercropping experiment at Hirehalli, which was continued for nine years, showed that tapioca had no adverse effect on the yield of arecanut palm (Anonymous, 1977).

Table 17. Productivity and profit of intercropping with tubers in areca garden

Intercrop	Location	Yield (kg/ha)	Net profit (Rs/ha)	Source of information
Elephant yam	Vittal	12,000	1,550	Bhat (1974)
Elephant yam	Palode	6,496	1,700	Abraham (1974)
Elephant yam	Kannara	4,245	1,398	Sadanandan (1974)
Tapioca	Palode	10,246	1,851	Anonymous (1977)
Dioscorea	Palode	6,744	1,824	Abraham (1974)
Sweet potato	Palode	712	61	Abraham (1974)
Arrow root	Vittal	4,000	1100	Bhat (1974)

The yield in terms of quantity of harvested produce and the net income were reported for some of the tuber crops tried at various places. The available information in this regard is summarised in Table 17.

Due to the variations in the agroclimatic conditions under which these studies were undertaken, the yield and profitability of individual crop showed wide differences from place to place. However, elephant yam had shown consistently good performance in all the three places i.e., Vittal, Palode and Kannara.

Fruit crops

Among the fruit crops grown in association with arecanut, banana is the most popular. The practice of growing banana as an intercrop in arecanut has been reported by Bavappa (1951), Bhat (1974), Brahma (1973) and Sundaramurthy (1950).

Roy (1974) reported that the yield of arecanut grown in the alluvial soils of north eastern India was not significantly influenced by intercropping with banana. Similar results were observed by Nagaraj (1974) and Bhandary (1974) in *Maidan* area of Karnataka and coastal Karnataka.

An experiment to study the long term effect of intercropping with banana in arecanut garden is in progress since 1963 at the CPCRI Regional Station, Vittal. The spacing adopted for arecanut was 2.7×2.7 m. The following were the treatments: (1) no banana throughout the period of experiment (i.e. sole crop of arecanut), (2) banana intercrop throughout the period of experiment at full level, (3) banana at full level for three years and no banana thereafter, (4) banana at full level for three years and at reduced level for the rest of the period, (5) banana at full level for three years and at reduced level for next three years, (6) banana at full level for six years and no banana thereafter, (7) banana at full level for six years and at reduced level for the rest of the period, and (8) banana at full level for six years, reduced level for next four years and no banana thereafter.

The cumulative yield data of arecanut for six years after the fifth year of plantation life showed no significant difference between treatments. Bhat (1978) based on the results obtained thus far found that growing banana as intercrop had no adverse effect on the performance of areca palms.

The yield of banana from one hectare of arecanut garden and the net profit obtained from the same at different places are provided in Table 18. The per hectare yield of banana and the profitability showed considerable variation due to the difference in the variety tried and the management practices adopted at the different locations.

Table 18. *Yield of banana and profitability*

Location	Yield (kg/ha)	Net profit (Rs/ha)	Source of information
Vittal	4,000	1,650	Bhat (1974)
Kahikuchi	12,200	728	Roy (1974)
Hirehalli	—	1,000	Nagaraj (1974)
Mohitnagar	—	850	Brahma(1973)

Pineapple

The production and consumption of fruits, which are considered protective foods, is very low in this country, when compared to the developed nations. Further, crops like pineapple can generate additional employment opportunities in the post harvest operations, viz., canning and marketing. The practice of raising pineapple as an intercrop was reported by Bavappa (1951). No adverse effect on the yield of arecanut was observed due to intercropping with pineapple in arecanut gardens (Abraham, 1974; Sadanandan, 1974). The yield of pineapple and the net profit obtained at different locations are given in Table 19.

The wide variation in yield recorded at different places, is probably due to the variation in management practices and the difference in the agroclimatic conditions.

Spice crops

Ginger (*Zingiber officinale*) and turmeric (*Curcuma longa*) are some of the spice crops

Table 19. *Yield of pineapple and profitability*

Location	Yield (kg/ha)	Net profit (Rs/ha)	Source of information
Vittal	8000	850	Bhat (1974)
Kannara	1953	703	Sadanandan (1974)
Palode	3942	847	Abraham (1974)
Hirehalli	—	500	Nagaraj (1974)
Kahikuchi	15,700	2379	Roy (1974)

commonly intercropped in arecanut gardens. Satisfactory yield in the partially shaded condition existing in the areca gardens, fair market demand, easy processing, and long storage life after processing are some of the factors that favour growing these intercrops.

An experiment on intercropping carried out at CPCRI Research Centre, Kannara, in an adult arecanut garden receiving summer irrigation, showed that the yield of arecanut palms were not affected by raising ginger in the interspace (Sadanandan, 1974). Similar results were reported from Kahikuchi (Assam) also (Roy, 1974).

The yield of ginger in the above places and the net profit from one hectare by intercropping with ginger are provided in Table 20.

Studies on intercropping with turmeric in arecanut garden are in progress at CPCRI Research Centre, Hirehalli.

Table 20. *Yield and net profit by intercropping with ginger*

Location	Yield (kg/ha)	Net profit (Rs/ha)	Source of information
Kannara	2650	905	Sadanandan (1974)
Kahikuchi	9800	998	Roy (1974)

REFERENCES

- ABRAHAM, K. J. 1974. Intercropping in arecanut helps to build up farmer's economy. *Arecanut and Spices Bull.* 5(3): 73-75.
- ABRAHAM, P. 1956. Spices as intercrops in coconut and arecanut gardens. *Arecanut J.* 7(3): 56-78.
- ANONYMOUS, 1977. Central Plantation Crops Research Institute, Annual Report for 1976, Kasaragod, India. pp. 89-101.
- BAVAPPA, K.V.A. 1951. Some common intercrops in arecanut gardens. *Monthly Bulletin of the Indian Central Arecanut Committee*, 2(2): 16-17.
- BHANDARY, K. D. 1974. Study of inter and associated crops in areca gardens of the Malnad tract of Karnataka. *Arecanut and Spices Bull.* 5(3): 76-77.
- BHAT, K. S. 1974. Intensified inter/mixed cropping in areca garden—the need of the day. *Arecanut and Spices Bull.* 5(3): 67-69.
- BHAT, K. S. 1978. Agronomic research in arecanut—A review. *J. Plant. Crops* 6: 67-80.
- BRAHMA, R. N. 1973. In North Bengal banana is a paying intercrop in areca gardens. *Arecanut and Spices Bull.* 5: 80-81.
- KHADER, K.B.A., AND ANTONY, K. J. 1968. Intercropping: a paying proposition for areca growers—What crops to grow. *Indian Fmg.* 18(4): 14-15.
- NAGARAJ, B. 1974. Intercropping in arecanut gardens of Maidan areas of Karnataka. *Arecanut and Spices Bull.* 5(3): 78-79.
- NAIDU, G.V.B. 1959. Betelvine cultivation in areca gardens and its benefits. *Arecanut J.* 9(4): 128-130.
- ROY, A. R. 1974. Intercropping in arecanut gardens of north eastern regions of India. A brief review of work done. *Arecanut and Spices Bull.* 5(3): 82-85.
- SADANANDAN, A. K. 1974. Raise intercrops in arecanut plantations for higher returns. *Arecanut and Spices Bull.* 5(3): 70-72.
- SUNDARAMURTHY, S. 1950. Arecanut plantation in Ceylon. *Monthly Bulletin of Indian Central Arecanut Committee*, Calicut, 1(6): 1-6.

V. MIXED CROPPING IN COCONUT

E. V. NELLIAT, P. GOPALASUNDARAM,
P. THOMAS VARGHESE, AND K. SIVARAMAN
*Central Plantation Crops Research Institute,
Kasaragod-670 124, Kerala.*

Mixed cropping as applied to plantation crops is the practice of growing perennials in the interspaces of the main crop of coconut, arecanut, etc. Coconut is rarely grown as a sole crop and is often grown together with many other perennials like jack (*Artocarpus integrifolius*), arecanut (*Areca catechu*), breadfruit (*Artocarpus incisa*), mango (*Mangifera indica*) and other tropical fruit trees and tree spices. But in all these cases, the suitability/compatibility of the crops in the crop mix is not considered. The requirement of each crop in respect of various crop production factors/inputs is practically ignored, and hence the gross productivity of the system is lower than that of sole crops.

The coconut growing tracts are characterised by a period of high intensity of rainfall followed by a long spell of dry weather lasting 5-6 months during the year (Table 1). The crop(s) selected for mixed cropping with coconut naturally would compete with coconut for soil moisture during the stress period. Most soils where coconut is grown, are also highly porous and light textured, and hence the stored soil moisture is limited. One of the limiting factors, therefore, for introducing perennials in the interspaces of coconut is the lack of perennial source of irrigation water during the dry months in such areas. However, this may not assume importance in areas receiving well distributed rainfall round the year.

Incidence of sunlight sufficient to meet the requirements of individual crops through the vertical depth of the crop combination is another important criterion. As stated earlier, when the palms are aged above 20 years, it is possible to take up mixed cropping successfully.

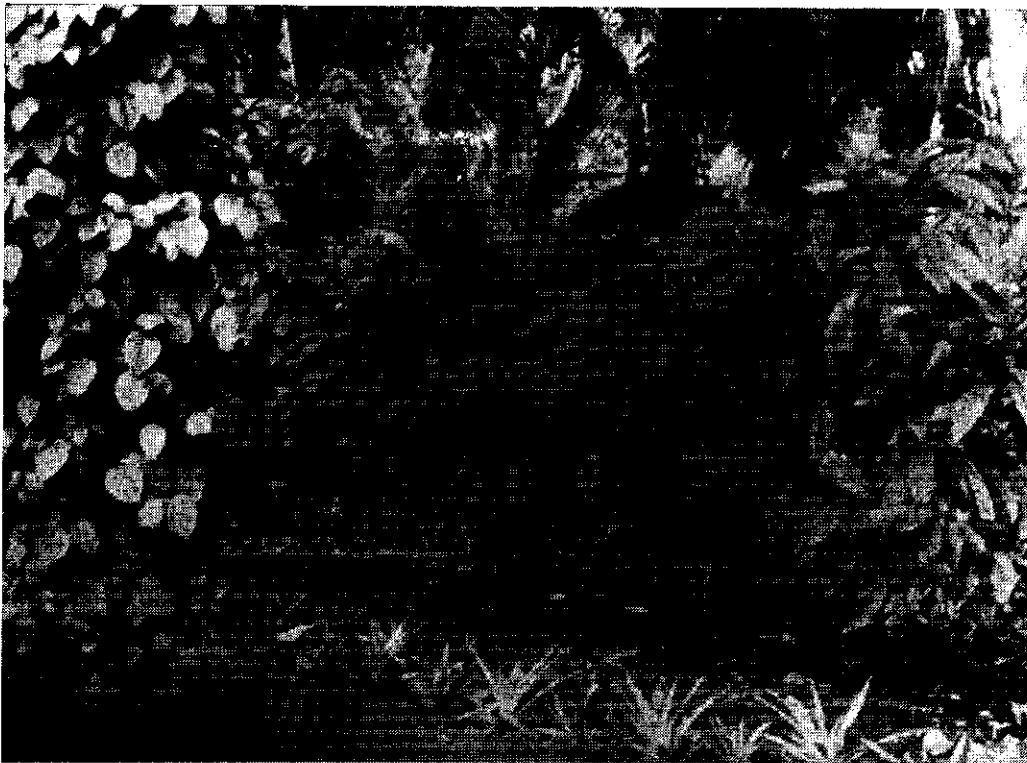
It is also desirable that the crop selected for mixed cropping with coconut should preferably be shade loving or tolerant, since the maximum solar energy received below the coconut canopy does not exceed 80 per cent at any period of growth of coconut.

In order to minimise the mutual competition between the crops for plant nutrients, the effective root zone of each of the crops introduced shall not overlap that of any other crop; although stray roots of individual crops may be found foraging in the root region of other crops. The objective is to ensure that the roots of individual crops are mutually exclusive, but together forage the entire soil mass in the system.

The most important factor to be considered in mixed cropping is the productivity of the soil and the overall production from unit area of land. In multiple cropping the accepted principle is that although the individual crop yield may be lowered, the overall production per unit area should be enhanced. In mixed cropping, since a number of crops are grown over a given area of land, a greater depletion of the plant nutrients may occur in the soil. It is necessary that



Banana grown as intercrop in areca garden



Multistoreyed cropping in coconut garden

adequate inputs like fertilisers are applied to replenish and maintain the soil fertility. The system or combination of crops selected should be such that it is conducive to the multiplication and activity of beneficial microorganisms. The individual crop in the system should contribute towards the overall success of the combination of crops and should have a mutually beneficial effect.

Another important aspect for consideration in adopting mixed cropping is the profitability of the whole cropping programme. It should be ensured that each of the crops grown in the combination should have a ready market and the quality of the produce is comparable and acceptable to the consumer.

Cacao

Growing cacao as a mixed crop in coconut stand was first attempted in 1963. Seedlings of the Criollo variety were planted in a middle aged coconut garden in sandy loam soil at CPCRI, Kasaragod. There were three shade levels in this feasibility trial, viz., (1) coconut palms well spaced and good amount of sunlight reaching the ground (2) coconut palms spaced closer and limited amount of sunlight reaching the ground and (3) coconut palms planted very close and very little sunlight reaching the ground. Cacao plants alone were watered during the dry months and the recommended dose of fertilisers were applied to cacao as well as coconut.

Cacao plants in plot receiving good amount of sunlight made satisfactory growth and flowered in 1968 (Anonymous, 1969). The plants in the fully shaded plot were least vigorous in their vegetative growth. However, the fruiting was very poor even in the plot receiving good amount of light.

In July 1970, another field experiment was initiated by planting cacao seedlings of

the variety Forastero in loamy soil. The coconut palms in this plot were planted in 1956-57, adopting a spacing of 7.6m under the square system of planting. The treatments were: (1) control (no mixed crop of cacao), (2) single row of cacao in between two rows of coconut in the north-south direction (single hedge), and (3) two rows of cacao in between two rows of coconut (double hedge). Randomised block design with seven replications was adopted. The spacing along the row was 3m in both systems of planting. About 350 plants under single hedge could be accommodated per ha of coconut stand. In double hedge, the rows were spaced 2.5m apart and the planting was staggered between the two rows, and about 600 plants/ha could be accommodated. Seedlings of 5-6 leaf stage were utilised for planting.

The cacao plants received 20 g N, 16 g P_2O_5 and 30 g K_2O / plant in the first year, which was gradually raised to 100 g N, 40 g P_2O_5 and 140 g K_2O /plant/year. The fertilisers were applied in two equal splits. The coconut palms received 1000 g N, 640 g P_2O_5 and 2400 g K_2O /plant/year applied in four equal splits. The entire experimental area was given irrigation with sprinklers during the dry months at weekly intervals, the depth of irrigation water being 28 mm.

The first flowering in cacao was observed in April 1971 i.e. after 10 months of field planting. However, the fruit set was poor and the first harvest was made in 1972.

The single hedge plants showed better vigour of growth and yield per plant than those under double hedge. Because of the larger number of plants, the yield per unit area under double hedge of cacao was greater. The mean yield of wet bean per ha per year was 652 kg and 801 kg respectively, from single hedge and double hedge plots for the four years 1974-78 (Anonymous, 1979).

There was considerable yield increase in

Table 21. *Mean yield of coconut in the coconut-cacao mixed cropping experiment (nuts per palm/year)*

Treatment	Pre-experimental period	1977-78	Increase %
Control—No cacao	68	145	113
Single hedge of cacao	57	129	126
Double hedge of cacao	39	103	164

coconut also in this experiment (Table 21). The pattern of yield response of 3 yield groups of coconut, viz., <30, 30-60 and >60 nuts/palm/year indicated that the quantum of response in terms of number of nuts increased with the increasing level of pre-treatment yield (Anonymous, 1976).

Effect on soil fertility

Investigations on the fertility status of the soil under coconut-cacao mixed cropping have shown marked improvement compared with that of the sole crop stand of coconut. The improvement noticed in soil fertility has been, to a large extent, attributed to the addition of organic matter by the periodic shedding of cacao leaves and the consequent intense microbial activity in the rhizosphere region of the crop mix.

Varghese et al. (1978) reported that under Kasaragod conditions, the main flushes in cacao occurred in April-May and August-September and maximum leaf fall was observed during April-May, synchronising with the intense flushing time. The amount of organic matter added to the soil through shed leaves and prunings of cacao under single and double hedge systems of planting of cacao was found to be 818 and 1985 kg/ha/year, respectively (oven dry weight). Nutrient concentration of cacao leaves was reported to be 2.84% N, 0.26% P and 1.73% K, on dry weight basis (Eernstman,

1968). Based on these figures, it could be assumed that about 50 kg N, 11 kg P₂O₅ and 35 kg K₂O were returned to the soil every year through leaf fall of cacao under double hedge system of mixed cropping.

Because of the addition of large amounts of biomass, the organic carbon content of soils under mixed cropping with cacao was also found to be higher than that under pure palm stands. Varghese et al. (1978) reported that the organic carbon content of soil in the coconut-cacao mixed cropped plots was markedly higher than that of pure coconut stands, especially in the top 15 cm depth, where it was 9 to 25% higher than that of the irrigated sole coconut plots (Table 22).

Available phosphorus content in the coconut rhizosphere wherein cacao was grown (double hedge) was reported to be 65 ppm compared to 41 ppm in single hedge plots, 20 ppm in control, and 10 ppm in non-rhizosphere soil (Nair and Rao, 1977b).

Effect on microbial activity

Another reason for the sustained increase in the yield of coconut under mixed cropping with cacao, in addition to the improvement in soil fertility is the production of growth promoting substances, resulting from more intense activity of beneficial microbes in the rhizosphere of the coconut, mixed cropped with cacao. Nair and Rao (1977a)

Table 22. Organic carbon content of soil as influenced by mixed cropping (Varghese et al., 1978)

Treatment	Organic carbon (%)		
	Pre-experimental period 0-30 cm	Experimental period 0-15 cm 15-30 cm	
1. Unirrigated coconut	0.2 - 0.3	0.36	0.27
2. Irrigated coconut	0.2 - 0.3	0.56	0.56
3. Coconut+cacao in single hedge + pineapple+pepper	0.2 - 0.3	0.61	0.56
4. Coconut+cacao in single hedge + pineapple+pepper	0.2 - 0.3	0.70	0.58

investigated in detail the number, nature and specific biological attributes of microorganisms in the rhizosphere of sole crop of coconut and coconut-cacao crop mix.

They observed that microbial activity in the rhizosphere of coconut under double hedge cultivation of cacao was intense as revealed by the population of bacteria and fungi. This enhanced microbial activity in the rhizosphere under mixed cropping was facilitated by the increase in organic matter content of the soil through the shedding of cacao leaves. *Beijerinckia* was observed as the dominant nitrogen fixing bacterium in the rhizosphere of coconut and cacao.

Twenty one isolates of bacteria, actinomycetes, and fungi from the rhizosphere of coconut and cacao were found capable of solubilising tricalcium phosphate to varying extent. Among these, one isolate of *Pseudomonas* sp. and one of *Aspergillus niger* were found to solubilise respectively 49.0% and 49.7% of the total $\text{Ca}_3(\text{PO}_4)_2$ incorporated in their media. A direct relationship was also noticed between the phosphate solubilising microorganisms and the amount of available phosphorus in different soils (Nair and Rao, 1977b). The available phosphorus content was observed to be the highest in coconut rhizosphere under double hedge of cacao. This

increased available phosphorus status may be due to the solubilisation of rock phosphate applied to the coconut palms.

Some of the bacteria and fungi isolated from the rhizosphere of coconut and cacao produced growth promoting substances. One isolate of *Escherichia* sp. was observed to produce IAA. Two isolates, one of *Aspergillus flavus* and other of *A. fumigatus* produced GLS (Gibberelin-like substances) in the culture media (Nair and Rao, 1977a). These investigations clearly showed the favourable influence of mixed cropping on microbial activity.

Effect on microclimate

Mixed cropping with cacao has been observed to cause marked changes in the microclimate of a coconut plantation. Daily variations in the air temperature, vapour pressure, relative humidity, evaporation, and soil temperature during the dry months of November-May were studied in pure stand of coconut, coconut-cacao crop mix, and in the open.

Air temperature

Nair and Balakrishnan (1977) reported that, as expected, the maximum day temperature was always highest in the open area and lowest inside the crop mix. However,

the minimum temperature was almost the same in all the sites. The mean differences between the maximum and minimum temperature in the ecoclimates of unirrigated coconut, irrigated coconut, and the crop combination were 2.6, 4.0 and 5.2°C less than that of the open area, respectively. They also observed that the air temperature in the open area and under unirrigated sole crop stand of coconut, at 1.0 and 2.0 m heights above the ground level in the afternoon was about 2–3°C less than that at ground surface; whereas there was no such variation in the crop combination. On the other hand, in the mornings when temperature in general was low, the air temperature in the crop mix at 1 and 2 m heights was slightly higher than that at its floor. Thus the crop mix had a buffering effect against drastic fluctuations in air temperature.

Vapour pressure

Both at 0800 hr and at 1430 hr there was practically no difference in vapour

pressure in open, unirrigated coconut, irrigated coconut and coconut-cacao crop mix.

Evaporation

The most striking difference among the microclimatic parameters was noticed in the evaporation from different ecoclimates (Figure 2). The evaporation from the ecoclimate of the crop combination was only about 30% of that from the open area, whereas it was about 60% under irrigated coconut.

Relative humidity

Diurnal variations in the relative humidity were also much less in the ecoclimate of the crop mix compared with that of pure palm stand (unirrigated) or open area. In the afternoons, particularly during November-January, when the relative humidity of the open area was low, the ecoclimate of the crop mix was much more humid.

Soil temperature

Varghese et al. (1978) studied the soil temperature in the open unirrigated coconut

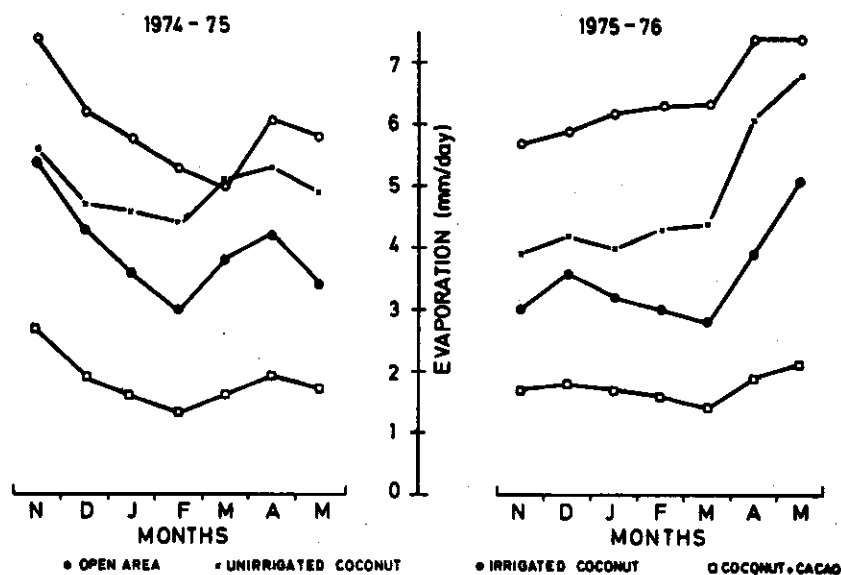


Figure 2. Evaporation from the ecoclimates of different cropping systems. (Nair and Balakrishnan, 1977)

irrigated coconut and irrigated coconut-cacao crop mix at 30 and 60 cm depths. Irrespective of the season, the soil temperature was the lowest and the variation in the mean monthly soil temperature was the least in the coconut-cacao crop mix. In the pure stand of coconut, 3–6°C fluctuation in soil temperature was observed during summer months; whereas no such variation was seen in the crop mix. Lower range of soil temperature fluctuation in the crop mix might be due to the mulch provided by the periodic shedding of leaves.

Utilisation of sunlight

More efficient utilization of the available resources such as solar energy and soil has been recognised as one of the advantages of crop-mixes, in addition to increased productivity. Nair and Balakrishnan (1976) observed that on an average, only 44% of the available sunlight was intercepted by the pure palm stand of coconut during the peak hours of sunshine (10.00-14.00 hr). Of the 56% sunlight available for cacao, the crop was able to intercept 63% when it was planted in single hedge only, and at least 76% when planted in double hedge as a mixed crop with coconut, thereby increasing the interception and utilisation of the available light. But, the light available for a single plant of cacao was less in the double hedge system than in single hedge and this could be one of the reasons for the lower yield per plant in the double hedge system.

Mixed cropping with tree spices

Spices like clove, nutmeg, and cinnamon which are expensive, thrive well under partial shade. Hence growing these crops in coconut stands was taken up in 1970. Nutmeg and clove develop large canopy, and these were planted in the centre of four coconut palms; while cinnamon which is constantly pruned

for extracting the bark was planted in rows between two rows of coconut, giving a spacing of 3 m along the row.

Clove and nutmeg were slow growing in the early stage and required constant attention. These plants have flowered for the first time in 1978–79 and it is too early to assess their suitability and profitability.

Cinnamon bark could be extracted from the second year onwards. The per plant yield of 30–35 g quills and 15–20 g chips in 1974, increased to 82 g quills and 30 g chips in 1978 (Anonymous, 1975; Anonymous, 1979).

Mixed cropping with pepper

Since pepper is usually trailed on live or dead standards, the possibility of utilising the coconut palm trunk as a standard for trailing pepper was tested. The rooted pepper cuttings were planted 1.0–1.2m away from the coconut base. When the vines attained sufficient length, they were trailed along the ground and wound round the base of the coconut trunk. The vines climbed up the trunk; but the pepper canopy was restricted to grow only up to 4–5m height from ground so that climbing on the palm may not be hindered.

The establishment, growth, and yield under irrigated condition were very good. Even under rainfed conditions at Coconut Research Station, Pilicode, there are vines grown on coconut which are over 25 years old and yielding satisfactorily. At CPCRI, Kasaragod, pepper vines of the hybrid Panniyur 1 planted in 1971–72 and trailed on palms aged over 60 years in a one ha plot, gave a mean yield of 2 kg dried berries per vine. The highest per vine yield was 5.5 kg dried berries (Anonymous, 1977).

Other crops

Coffee var. robusta was introduced as a mixed crop in coconut garden in 1974. The

performance is quite encouraging. Tea was introduced in 1979 and its performance is being watched. In the Central Karnataka, at Regional Coconut Research Station, Arsikere, mulberry was found to come up satisfactorily. It has a large potential for generating employment as silk worm rearing could be taken up.

REFERENCES

- ANONYMOUS, 1969. Central Coconut Research Station, Kasaragod. Annual Report for 1968, Kasaragod, India (Mimeo).
- ANONYMOUS, 1975. Central Plantation Crops Research Institute, Annual Report for 1974, Kasaragod, India. pp. 24-27.
- ANONYMOUS, 1976. Central Plantation Crops Research Institute, Annual Report for 1975, Kasaragod, India. pp. 25-28.
- ANONYMOUS, 1977. Central Plantation Crops Research Institute, Annual Report for 1976, Kasaragod, India, pp. 31-34.
- ANONYMOUS, 1979. Central Plantation Crops Research Institute, Annual Report for 1978, Kasaragod, India. (In press).
- EERNSTMAN, T. 1968. Chemical analysis of leaves and other organs of *Theobromo cacao* L. as a means of diagnosing fertiliser requirements. Pub. No. 54, PUDOC Wageningen, p. 55.
- NAIR, P.K.R., AND BALAKRISHNAN, T. K. 1976. Pattern of light interception by canopies in coconut-cacao crop combination. *Indian J. agric. Sci.* 46: 453-462.
- NAIR, P.K.R., AND BALAKRISHNAN, T. K. 1977. Ecoclimate of a coconut plus cacao crop combination on the West Coast of India. *Agric. Meteor.* 12: 455-462.
- NAIR, S. K., AND RAO, N.S.S. 1976a. Microbiology of the root region of coconut and cacao under mixed cropping. *Plant and Soil* 46: 511-519.
- NAIR, S. K., AND RAO, N.S.S. 1976b. Distribution and activity of phosphate solubilising microorganisms in the rhizosphere of coconut and cacao under mixed cropping. *J. Plant. Crops* 5: 67-70.
- VARGHESE, P. T., NELLIAT, E. V., AND BALAKRISHNAN, T. K. 1978. Beneficial interactions of coconut-cacao, crop combination. In Nelliatt, E. V., Ranganathan, V., Vishveswara, S., Potti, S. N., and Zachariah, P. K. (eds) *Proc. PLACROSYM I*. Placrosym Standing Committee, Kasaragod, India. pp. 383-392.

VI. MIXED CROPPING IN ARECANUT

K. SHAMA BHAT

CPCRI Regional Station, Vittal-574 243,
Karnataka, India.

Mixed cropping in arecanut gardens had been in vogue even in early times. Watt (1893) reported that in Mysore (Karnataka), coconut, citrus, jack, and other trees were interplanted with areca. He further reported that in Kolaba, arecanut was planted in coconut plantations. Nambiar (1969) stated that the practice of growing other crops in arecanut gardens was fairly universal. However, scientific efforts in this area received adequate attention only recently.

With a view to spotting out compatible perennial crops for growing as mixed crops with arecanut, a number of field experiments were initiated at the CPCRI, Regional Station, Vittal and Research Centres, Palode and Kannara. An exploratory trial garden was planted at Vittal in 1964 with arecanut seedlings (18 months old) and cacao (variety Criollo) seedlings (9 months old) under three systems: (i) arecanut and cacao at 50:50; (ii) arecanut as pure crop; and (iii) cacao

Table 23. Flowering and yield—Arecan and cacao mixed garden during the first five years (Bhat, 1978a)

Year	Treatment	Cacao		Areca	
		No. of pods/tree.	Palms flowered %	No. of nuts/palm	Weight (kg) of nuts/palm
1965-66	1	..	..	..	..
	2	..	..	..	..
	3	..	..	..	..
1966-67	1	10.6	..	..	..
	2	..	..	..	..
	3	..	..	..	..
1967-68	1	21.8	52.8	..	..
	2	..	44.6	..	..
	3	4.6	37.6	..	..
1968-69	1	23.2	88.9	..	..
	2	..	82.1	..	..
	3	4.9	75.0	..	..
1969-70	1	81.7	100.0	95.5	3.4
	2	..	100.0	42.7	1.6
	3	30.9	100.0	28.7	1.2

Treatment 1—Arecan and cacao (50:50)
2—Pure plantation of areca
3—Cacao as a border crop in areca garden.

Table 24. *Yield of areca and cacao mixed garden during the second five years (Bhat, 1978a)*

Year	Treatment	Cacao		Areca	
		No. of pods/tree	No. of nuts/palm	No. of nuts/palm	Weight (kg) of nuts/palm
1970-71	1	63.5	225.2		7.7
	2	..	169.5		6.8
	3	35.6	125.4		4.4
1971-72	1	49.9	321.8		12.2
	2	..	169.3		6.8
	3	17.0	232.9		8.0
1972-73	1	76.8	391.1		13.3
	2	..	210.0		7.5
	3	21.7	242.1		8.3
1973-74	1	107.0	230.0		8.4
	2	..	130.0		8.4
	3	40.0	124.0		4.3
1974-75	1	95.0	313.5		11.4
	2	..	269.9		10.0
	3	40.8	267.2		9.3

Treatment: 1—Areca and cacao (50:50)
2—Pure plantation of areca
3—Cacao as a border crop in areca garden.

along the borders of the arecanut garden. They were planted in quincunx method adopting a spacing of 4×4m. In the first system, the cacao seedlings occupied the centre of the square (4×4m). Both the arecanut palms and the cacao trees were manured with 100 g N, 40 g P₂O₅ and 140 g K₂O/plant. They were also irrigated during the dry months from December—May every year. Based on the observations made during the initial four year period, Bhat and Leela (1968) reported that cacao was likely to go well with areca as a mixed crop considering the early bearing of cacao under the conditions prevailing in arecanut gardens. After a period of another four years, Bhat and Bavappa (1972) observed that the cacao trees commenced flowering 14 months after

planting, and the first crop of mature fruits was harvested 13 months later. Bhat (1978b) summarised the performance of both cacao and areca at the end of 10 year plantation life. He stated that the arecanut palms commenced flowering three years after planting and that they had attained the normal bearing stage in the sixth year after planting, whereas the cacao trees attained the normal bearing age in five years after planting (Table 23 and 24). The mean yield per palm of areca in the mixed cropped plots (arecanut and cacao 50:50) was higher than that in the monocrop of areca. The cacao planted as border crop suffered from sun scorch. Based on the market prices between 1973-1975, the gross income from the arecacacao mixed cropping was 18,949

per ha compared to Rs. 13,083/ha per annum from the pure plantation of areca (Table 25).

Another mixed cropping experiment is in progress since 1969 at CPCRI Research Centre, Kannara under irrigated condition and at Palode under rainfed condition using a $2 \times 2 \times 6 \times 2$ split plot design to compare two methods of alignment, two levels of manuring and six hybrid progeny of cacao. At Kannara during the first six years of observation, the quincunx method of planting (4×4 m) cacao with arecanut was found to be better than alternate rows of cacao with arecanut. Similarly the number of pods per tree was significantly higher at higher level (200 g N, 80 g P_2O_5 and 280 g K_2O /tree/year) of manuring with a mean of 20 pods per tree as against 16 pods per tree at lower level (100 g N, 40 g P_2O_5 and 140 g K_2O /tree/year) of manuring (Anonymous, 1976). At Palode, under rainfed conditions the performance of cacao was poor, probably

because of the high exposure and lack of adequate moisture in the soil during the hot weather period.

A spacing *cum* manurial experiment, laid out in a $6 \times 2 \times 4$ confounded asymmetrical factorial design, is running at Vittal since 1970. It has six spacing combinations for the two crops and two levels of manuring under comparison (Anonymous, 1971; Bhat, 1978a). The spacing combinations are: (1) both areca and cacao spaced at 2.7×2.7 m; (2) areca spaced at 2.7×2.7 m and cacao at 2.7×5.4 m; (3) areca spaced at 2.7×2.7 m and cacao at 5.4×5.4 m; (4) areca and cacao spaced at 3.9×3.9 m in the quincunx method; (5) areca and cacao spaced at 3.3×3.3 m in the quincunx method and (6) areca at 1.8×5.4 m and cacao at 3.6×5.4 m. The manurial treatments are, (1) both areca and cacao fertilised at 100g N, 40g P_2O_5 , and 140g K_2O per tree per year and (2) areca at 100g N, 40g P_2O_5 and

Table 25. Yield and gross income from the mixed garden (areca and cacao)/pure garden (Areca)—(Based on mean yields during the five year period, 1970-'75).

Particulars	Yield in the mixed garden (Treatment 1)		Yield in the pure plantation (Treatment 2)
	Cacao	Areca	Areca
No. of fruits per tree	78	296	187
No. of trees per ha (4×4 m)	625	625	1250
Estimated no. of fruits ('000)/ha/year	49	185	134
Estimated dry weight (kg) of cacao beans or arecanut kernel/ha/year	1225	1482	1869
Estimated value of produce/ha/year (Rs)	8575*	10,374**	—
Gross income (Rs)	18,949		13,083

*Cacao at Rs 7.00/kg.

**Areca at Rs 7.00/kg.

140g K₂O and cacao at 200g N, 80g P₂O₅ and 280g K₂O per tree. Both the areca palms and the cacao trees have not reached the stabilised bearing stage. During the sixth year after planting, the yield of cacao pods per tree was the highest in 5.4 × 5.4m spacing and the lowest in 2.7 × 2.7m spacing. The yield per unit area was the highest in 3.3 × 3.3m spacing, with 5600 kg wet beans per ha, the population of cacao plants being 918/ha (Bhat, 1978; Anonymous, 1979).

The performance of cacao, so far as a mixed crop in the arecanut plantation, show that it is a highly compatible and remunerative mixed crop with arecanut.

REFERENCES

- ANONYMOUS, 1971. Central Plantation Crops Research Institute, Annual Report for 1969-70, Kasaragod, India. pp. 132-143.
- ANONYMOUS, 1976. Central Plantation Crops Research Institute, Annual report for 1975, Kasaragod, India. pp. 76-89.
- ANONYMOUS, 1979. Central Plantation Crops Research Institute, Kasaragod, Annual report for 1978, Kasaragod, India (In press).
- BHAT, K. S. 1978a. Agronomic research in arecanut—a review. *J. Plant Crops* 6: 67-80.
- BHAT, K. S. 1978b. Performance of cacao as mixed crop with arecanut. In: Nelliath, E. V., Ranganathan, V., Potti, S. N., Vishveshwara, S., and Krishna Murthy Rao, W., Zachariah, P.K., (eds.) 1978. *Proc. PLACROSYM I Placrosym Standing Committee, Kasaragod, India*: pp. 377-382.
- BHAT, K. S. AND BAVAPPA, K.V.A. 1972. Cacao under palms. pp. 116-121. In Wastie, R. L. and Earp, D. A. ed., *Cacao and Coconuts in Malaysia. Proc. of the Conference held in Kuala Lumpur, 1971. The Incorporated Society of Planters, Kuala Lumpur, Malaysia.*
- BHAT, K. S., AND LEELA, M. 1968. Cacao and arecanut are good companions. *Indian Fmg.* 18(4): 19-20.
- NAMBIAR, K. K. 1949. *A survey of arecanut crop in Indian Union.* Indian Central Arecanut Committee, Calicut, India.
- WATT, G. 1893. *A Dictionary of the Economic Products of India.* Vol. 6. Periodical Export, Delhi, India.

VII. MULTISTOREYED CROPPING

E. V. NELLIAT

*Central Plantation Crops Research Institute,
Kasaragod-670 124, Kerala, India.*

In the light of the successful growing of a number of annuals and perennials in coconut stands, a high intensity cropping system was conceived and put to practice in 1970-71 with the main objective of greater utilisation of solar energy and soil resources. In this cropping system a new dimension in crop production—air space—was identified. Crops having different stature and rooting pattern were selected to form compatible combinations.

Nelliat (1973) enumerated the differences in multiple cropping practices in field and plantation crops, and presented the details of the strategy adopted in multi-storied cropping in coconut stand. The performance of this high intensity cropping system in the early years was reported by Nelliat et al (1974).

The four crop combinations included coconut, pepper, cacao/cinnamon (single or double hedge), and pineapple. The coconut palms were about 20 years old, planted 7.6m apart under the square system and attained a height of over 10m. Pepper was trailed on the coconut trunk and allowed to develop its canopy to a height of 8m. The number of cacao/cinnamon plants planted were 350 or 600, depending on whether single hedge or double hedge planting was adopted. About 3500 pineapple suckers were planted in the alleys not occupied by cacao/cinnamon.

The entire block was given irrigation during the dry months with perfo-spray.

Pepper was fertilised at 15g N, 10g P₂O₅ and 10g K₂O/vine/year. Pineapple received 50 kg N, 20 kg P₂O₅, and 60 kg K₂O/ha/year. Cacao and coconut were fertilised as in the mixed cropping experiment.

In this four crop architecture, the feasibility and success depends on the top floor crop, unlike a masonry building where the shape and size of the super-structure is determined by the ground floor. The crown habit of coconut, as stated earlier, is ideally suited for this, when the palms are over 20 years old. The pepper vine having its canopy from 2-8m on the coconut trunk, forms the second floor crop. The spread of the above ground parts of cacao and cinnamon, which are pruned periodically, are confined to heights less than 3.5m from ground level. This constitutes the first floor. Pineapple forms the ground floor in this system. The solar energy incident on the area is intercepted at vertical intervals and utilised to a high efficiency level by the foliage of these crops (Nelliat et al., 1974).

A study of the distribution of the roots of these crops showed that they were mutually exclusive and did not overlap to any appreciable extent (Figures 3 and 4). The rooting habits of cacao and cinnamon were such that their roots had relatively less lateral spread. A three and half year old cacao plant had most of its roots within a radius of 80-100 cm and the maximum concentration was between 20-60 cm laterally (Anonymous, 1974). The fibrous roots of

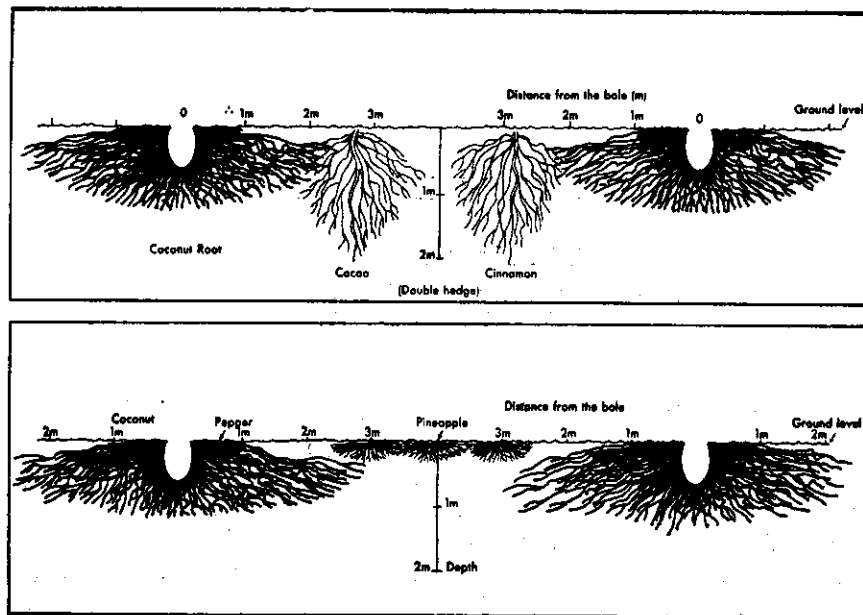


Figure 3. Schematic representation of pattern of vertical root distribution of the multi-storeyed crop combination (Nelli et al., 1974)

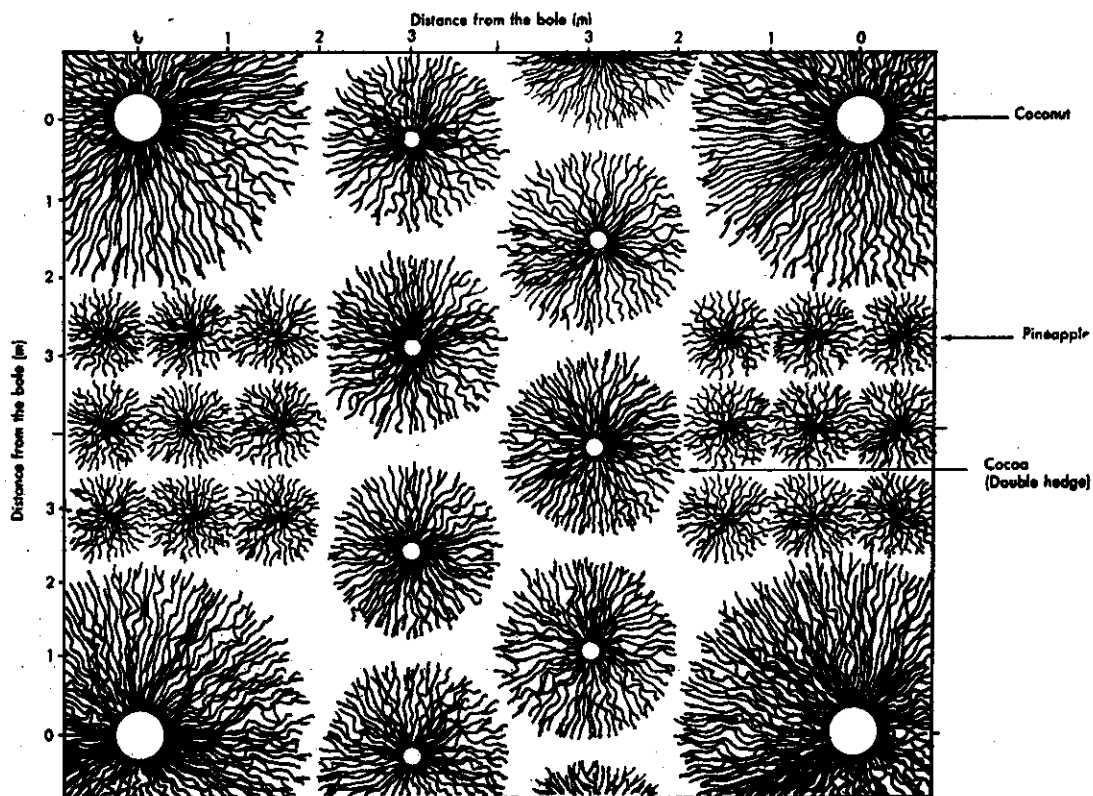


Figure 4. Schematic representation of pattern of horizontal root distribution of the multi-storeyed crop combination (Nelli et al., 1974)



Multistoreyed cropping of coconut, cacao, pepper, and pineapple



Mixed farming in coconut garden

Table 26. Mean yield of coconut in the multistoreyed cropping experiment—1978

S.No.	Treatment	Pre-treatment yield (nuts/palm)	Yield during 1978	Percentage increase over pretreat- ment yield	
				1978	Mean for 1975-78
1.	Cacao single hedge+pepper+ pineapple	45.3	107.8	138	141
2.	Cacao double hedge+pepper+ pineapple	48.1	94.0	96	90
3.	Cinnamon single hedge+pepper+ pineapple	41.5	73.6	77	147
4.	Cinnamon double hedge+pepper+ pineapple	40.1	87.8	119	94
5.	Cinnamon double hedge	40.8	89.4	119	114

pineapple rarely extended beyond 50 cm laterally or vertically.

Yield

In the feasibility trial, initiated in 1970, the mean yield of coconut increased by 33% (80 nuts/palm) in 1978 over the pre-treatment mean yield of 60 nuts/palm (Anonymous, 1979). The mean yield of coconut in the experiment, started in 1972, is presented in Table 26.

The cinnamon plants gave a maximum yield of 77g quills and 40g quillings per plant in 1977. Yield during 1978 was slightly higher.

The per plant yield of cacao was higher in single hedge and the yield continued to improve with age. During 1978, the mean yield of pods per plant was 14 and 9, respectively, in single and double hedge systems of planting.

Pepper variety Panniyur-1 was found to be shy in flowering and berry setting under excessive shade. A mean yield of 269g and 335g dried berries per standard was obtained in 1976 and 1977, respectively.

Pineapple was replanted every three years. The fruiting was good and the mean weight of fruit was 1.24 kg.

Thus, the output from the four crop multistoreyed cropping would be 17,000 coconuts, 300 kg cacao (dried beans), 60 kg dried pepper, and 4000 kg pineapple/ha/year. The cultivation expenses were around Rs 7,200 and at the prevailing market rates the net annual income would be over Rs 20,000/ha.

REFERENCES

- ANONYMOUS, 1974. Central Plantation Crops Research Institute, Annual Report for 1973. Kasaragod, India, pp. 27.
- ANONYMOUS, 1979. Central Plantation Crops Research Institute, Annual Report for 1978 (in press).
- NELLIAT, E. V. 1973. Multiple cropping or multistoreyed cropping in plantation crops. *J. Plant. Crops* 1: (Suppl.): 204.
- NELLIAT, E.V., BAVAPPA, K.V.A., AND NAIR, P.K.R. 1974. Multistoreyed cropping. A new dimension in multiple cropping for coconut plantations. *World Crops* 26: 262-266.

VIII. MIXED FARMING IN COCONUT GARDENS

JACOB MATHEW AND MOHAMED SHAFFEE

*Central Plantation Crops Research Institute,
Kasaragod-670 124, Kerala, India.*

Mixed farming programme in coconut garden involves establishing of pastures or cultivation of fodder grasses in the interspace of coconut palms, maintenance of milch animals on the fodder produced and recycling the cattle manure in the coconut-fodder mixed stand. Considerable interest is now being evinced in this country and outside in developing the coconut—fodder—milch animal mixed farming system as it enhances the output from unit area and increases the employment potential substantially.

Ohler (1969) has presented an excellent review on cattle under coconut. He pointed out that grazing of cattle under coconut, without affecting the yield of palms, was possible, provided sufficient soil moisture and plant nutrients were available for both crops throughout the year. Thomas (1978) discussed the problem of integrating pastures, livestock, and tree crops, with special reference to rubber, oil palm and coconut, and concluded that the greatest potential for integration existed in mature coconut plantations, where the Tall variety of coconut was grown. In the young plantations, the low light intensity would limit pasture growth. In a juvenile stand, though sufficient amount of light reaches the ground, grazing by cattle would damage the young palms.

Though grazing under coconut had been practised for a long time in many countries, the technical and economic merits of the

practice have been doubted as much as they have been praised, probably due to the differences in ecological factors, management practices, etc. under which this system was carried out. When establishing a pasture under coconut the existing weeds are replaced by grasses and legumes, that provide forage of good quality in sizable quantities. The undergrowth, viz., fodders cannot compete with the much taller coconuts for light and air, but competition for soil moisture and nutrients can certainly be substantial. According to Santhirasegaram (1966), the reduction in yield of coconuts caused by the pasture was negligible in soils with low or high availability of moisture and nutrients. His experience in Sri Lanka was that, in the absence of additional manuring, the yield of coconut was reduced by the pasture. When both were adequately manured, the depressive effect was completely removed.

Published reports mention only about the establishing of pastures in coconut gardens and allowing cattle to graze. This may be possible because of the large size of the holdings and less pressure on land. In India, since coconut is mainly a small holder's crop, this may not be feasible. Under these circumstances, raising of fodders and legumes and cutting them and stall feeding the cattle appear to be more suited. Two field experiments were carried out at CPCRI, Kasaragod to spot out suitable fodder species and varieties and to work

out the economics and benefits of mixed farming.

Fodders

Screening trials conducted at Kasaragod showed that the fodder grasses Guatemala (*Tripsacum laxum*), hybrid napier (Pusa giant and NB 21) and guinea grass (*Panicum maximum*) gave an yield of 50-60 t of green fodder/ha/year under coconut shade; and the legumes, Brazilian lucerne (*Stylosanthes gracilis*) and cowpea (*Vigna unguiculata*), about 30 t/ha (Sahasranaman and Pillai, 1976). The cutting interval was 30-40 days. At a feeding rate of 30-40 kg of green fodder per animal per day, with grasses and legumes in the ratio of 3:1, an area of one ha could support four milch animals. All these crops, except cowpea, will normally be in the field for a period of three years, after which they require replanting.

Family farm

The mixed farming experiment was started in 1972. The project envisaged a study on the benefits and support a small holder family could get by mixed farming practice. Hybrid napier (*Pusa giant*) and *Stylosanthes gracilis* were planted in a coconut garden in an area of 1.04 ha. The coconut palms, 191 in number, were approximately aged 60 years, at the time of starting the experiment, and were under good management in rainfed condition. There were 42 underplanted young palms also. Before planting the grass slips, the interspace was given a deep ploughing after applying 10 t compost, 80 kg P_2O_5 as superphosphate and 80 kg K_2O as muriate of potash per ha. The slips were planted in rows 50 cm apart and at a spacing of 30 cm within the row, with about 60,000 slips per ha. A circular area of 2m radius around the palm was left free. Twenty-three kg N per ha as urea was applied at the time of planting and again after every cutting. In addition, 8 kg P_2O_5 and 60 kg K_2O per

ha, were given in two equal split doses, before and after the monsoon. The grass was ready for cutting 70-80 days after planting and afterwards at 30-40 days intervals. In the initial period, cattle manure was put back to the soil in areas where the fodder was cut. Summer irrigation using sprinklers, was provided to ensure steady growth of fodder throughout the year.

Along the border and field bunds intercrops like banana, tapioca and vegetables were raised. Pepper was also trailed on some of the coconut palms.

Three milch animals of Jersey Cross breed (first lactation) were handed over to a family which consisted of a man, his wife and children in September 1972. The family was staying in a semipucca house, within the experimental plot. All the operations connected with the mixed farming system, viz., growing of fodder, milking and feeding the animals, and cleaning the cowshed were done by the family. Additional labour was provided only for replanting of grass slips, fertilising and harvesting of coconuts, repairs and maintenance of structures and field bunds. Two more animals were added during July, 1973. Since November 1975, the number of milch animals was restricted to four at any time. The animals in lactation were fed every day with 4 kg of concentrates, 30g each of common salt and minerals, besides about 30 kg of grasses and legumes. The young ones were receiving graded doses of concentrates. Whenever the fodder was insufficient, they were given paddy straw. The milk was sold to the consumers at the prevailing market rates. Every effort was made to dispose off the male calves, at the earliest opportunity. The female calves were reared till the first lactation and if found good yielder, they replaced the least economic among the older generation. This ensured maintaining the dairy production at higher level and disposal of unthrifty and senile animals.

Table 27. *Mixed farming in coconut gardens at CPCRI, Kasaragod—Analysis of farm data*

A. Capital Investments on the Farm*		(Rs.)	Fertiliser and harvesting charges for coconuts ..	(Rs.)	2,168.86
Cost of cows ..	13,092.00		Other miscellaneous expenses ..	37.20	
Cost of cattle shed ..	8,935.00		Total (cash) ..	14,730.74	
Cost of utensils and other equipments ..	552.00		<hr/>		
Cost of pumpset and pipe fittings ..	12,000.00		Depreciation of animals, buildings & equipments ..	2,706.29	
Cost of gas plant ..	5,211.00		Total (cash and non-cash) ..	17,437.03	
Total investment ..	39,790.00		<hr/>		
B. Receipts**			D. Returns**		
Sale of milk ..	17,255.07		Total receipts (cash and non-cash) ..	33,148.17	
Sale of coconuts ..	11,499.71		Total operating costs (cash and non-cash) ..	17,437.03	
Sale of subsidiary crops ..	409.22		Receipts, less operating costs ..	15,711.14	
Sale of calves, heifers and cows ..	1,627.67		Interest on investment ..	3,235.89	
Total receipts (cash) ..	30,791.67		Return to farmer and family, for labour and management ..	12,475.25	
<hr/>			<hr/>		
Appreciation of calves and cows ..	2,356.50		E. Comparative Economic Analysis		
Total receipts (cash and non-cash) ..	33,148.17		Costs		
<hr/>			Coconut alone (233 palms, rainfed) ..	2,820.03	
C. Operating Expenses**			Coconut + dairy ..	20,672.92	
Cost of raising fodder ..	2,880.66		Incremental cost ..	17,852.84	
Purchase of concentrates and straw ..	9,157.27		Benefits		
Veterinary charges ..	386.75		Coconut alone (60 nuts/palm) ..	10,385.30	
Maintenance expenses (lump sum) ..	100.00		Coconut + dairy ..	33,148.17	
<hr/>			Incremental benefits ..	22,762.87	
			Cost-Benefit ratio (incremental) ..	1:1.28	
<hr/>			<hr/>		

*Totals, spread over four years

**Averages, per year, based on six years data

The cowshed constructed during September 1972 had a floor area of 72 m² with provision to house six animals, a milk room, store room, and a pen for small calves. A *gobar* gas plant of 3 m³ capacity was also built during September 1975. The dung from the animals was generating fuel sufficient to meet lighting and cooking needs of the family and lighting the cowshed, and for sterilising the utensils in the dairy.

The coconut palms received the recommended dose of fertilisers. They were also benefited by the irrigation.

Economic analysis

One of the main objectives of this experiment was to find out the economics of mixed farming in coconut gardens. Since a large majority of coconut growers are marginal farmers, the income from a sole crop of coconut is insufficient to make a satisfactory living. Success of any system will depend upon its economic viability.

Details of receipts received and costs incurred, both fixed and variable, are presented in Table 27. Only the actuals have been taken for cash receipts and payments and the normal norms were followed for calculating the non-cash receipts and payments, viz., appreciation of animals, depreciation of buildings, etc. Appreciation of female calves was calculated at 1:3:5, for the first, second and third years; and during the next three lactations, the value was assumed to be neither appreciating nor depreciating. For subsequent years, the depreciation values—the differences between present value (Rs. 3,000) and the junk value (assumed to be 10% of the present value)—was uniformly charged for the remaining productive period of eight years. For pumpset and gas plant, depreciation was calculated at 10% per year, while for cattle shed it was taken as 5%. Veterinary charges include the cost of medicines and semen only. The underplanted coconut seedlings started giving yield only

from 1976–77 and this also was brought under the sale proceeds of coconuts. Expenses towards planting of grass slips was brought under operating costs on the assumption that replanting is necessary only at the end of third year. One third of the total cost of this item was charged for each year. Interest on capital investment was taken as 10%.

Analysis of farm data showed that the returns to the farmer family for their labour and management was over Rs. 12,000 per annum, during the six year period, from a net area of little over one hectare. The minimum returns received in any year was Rs. 8,500. The differences in the returns, received during the different years, was due to the fluctuations in the price of coconuts and length of lactation/dry periods of the cows. To a lesser extent, it depended on the sex of the calves also, male ones fetching low price.

The capital investment on mixed farming was about Rs. 40,000 per ha of which one third was incurred towards the purchase of cows and another one third on irrigation installations. The balance one third was required for construction of cattle shed, gas plant, etc.

A comparative analysis with a sole crop of coconut garden of 233 palms, under good management in rainfed condition, was made on the assumption that the yield from such a garden could be 60 nuts/palm/year. During the first four years, only 191 palms were assumed to be bearing and later all the 233. Cost of cultivation for monocrop of coconut garden was obtained from the research project on cost of production. Incremental costs incurred and benefits received by superimposing a mixed farming system in coconut garden was worked out (Table 27). Overall cost-benefit ratio (incremental), for the six year period was 1:1.28 and it was above unity, in all the years, showing thereby that this type of investment is sound.

Yield of coconuts

The effect of mixed farming on the yield of coconuts has been doubted, because grasses are vigorous growing and exhaust the nutrients. The data from the experiment showed that, when the management practices for both crops were adequate, the yield of the main crop did not decline (Table 28).

Table 28. *Yield of coconuts in the mixed farming plot.*

Plot	No. of palms	Mean annual yield per palm		
		1969-72	1972-78	Increase (%)
Mixed farming	191	64.7	69.5	7.4
Control	24	60.8	51.2	-15.8

The mean annual yield obtained per palm during the pre-experimental (1969-72) and experimental (1972-78) periods were 64.7 and 69.5 nuts, respectively, showing an increase of 7.4%, which was substantial, considering the age of the plantation. Since the palms were already under good management, as reflected in the high pre-experimental yield, and age of the palms, the response obtained was significant. The palms in an adjoining plot of almost same age and good management, had shown a decline of 15.8% in yield, for the corresponding period. Hence, the net response in yield of coconuts, due to mixed farming practice was over 23%. In a younger plantation and/or when the management was average the yield response could be much higher.

Milch animals

The milk yield of cows was found to be satisfactory. The average milk yield per day was 6 to 8 kg during the first lactation, 8 kg during the second lactation and 8 to 9 kg during the third lactation. The lactation period was about 300 days, with a gap of 16 months between calving.

Employment generation

The annual labour requirement of a pure coconut plantation of one hectare was about 150 man days (Nelliath and Krishnaji, 1976), of which about 50 was for harvesting of coconuts. Under mixed farming practice, not only the farmer family (husband and wife) was getting employment round the year, but it could provide 100-150 mandays work for outside labour. Total employment in a normal year was about 800-850 man days, and in years when grass slips were to be planted/replanted, the employment potential rose to about 1000 man days.

REFERENCES

- ANONYMOUS, 1977. *Handbook of Animal Husbandry*. Indian Council of Agricultural Research, New Delhi.
- NELLIATH, E. V., AND KRISHNAJI, N. 1976. Intensive cropping in coconut gardens. *Indian Fmg.* 27(9): 9-12.
- OHLER, J. G. 1969. Cattle under coconuts. *Trop. Abstr.* 24: 639-645.
- SAHASRANAMAN, K. N., AND PILLAI, N. G. 1976. Mixed farming in coconut garden. *Intensive Agric.* 14(9): 6-10.
- SANTHIRASEGARAM, K. 1966. The effect of pasture on the yield of coconuts. *J. Agric. Soc. Trin.* 66(2): 182-193.
- THOMAS, D. 1978. Pastures and livestock under tree crops in the humid tropics. *Trop. Agric. Trin.* 55: 39-44.

IX. MIXED FARMING IN COCONUT GARDENS

ROOT (WILT) AFFECTED TRACT

T. V. RAMAKRISHNAN NAYAR AND K. N. SAHASRANAMAN

CPCRI, Regional Station,
Kayangulam-690 533, Kerala, India.

Out of the 0.74 million ha under coconut in Kerala, about 0.25 million ha is affected by root (wilt) disease—a malady of uncertain etiology. Reduction in yield of root (wilt) affected palms is proportional to the intensity of the disease and it varies from 10-80% (Anonymous, 1976a). Because of the reduced yield and added expenditure on plant protection measures, the net return from the disease affected coconut garden steadily decreases. Improving the yield of the root (wilt) affected palms is not immediately feasible as there are no effective control measures. Raising some additional crops in such coconut gardens could augment the income from the land. It could have added advantage if the system involves recycling of organic matter enriching the soil.

Considering these points, studies on mixed farming in root (wilt) affected coconut gardens were initiated in 1970 at the CPCRI Regional Station, Kayangulam. The objectives were to develop a system of mixed farming in disease affected coconut gardens, with fodder grasses and legumes for building up and maintaining soil fertility and to assess its effect, if any, on the disease affected palms.

Screening trials were conducted to identify suitable fodder grasses and legumes and to assess their capacity to yield maximum quantity of forage under the partially shaded condition in coconut stands, low suscepti-

bility to pests and diseases and palatability and quality of the forage.

The mean yield of green fodder by the various grasses under rainfed and irrigated conditions in coconut garden is shown in Table 29. Among the grasses N.B. 21 gave maximum green fodder yield under irrigated condition. Under rainfed condition, guinea grass var. *Mackuenii* gave maximum yield (Nayar and Sahasranaman, 1978). Hence, depending upon the availability of irrigation facilities, one of these graminaceous fodder crops could be selected for growing in coconut stands.

Table 29. Yield of fodder grasses (Nayar and Sahasranaman, 1978)

Fodder grasses	Yield (t/ha/yr)			Percentage increase in yield due to irrigation
	Rain-fed	Irrigated	Mean	
Pusa Giant	37.07	53.21	45.15	44.00
N. B. 21	41.61	64.43	53.02	55.00
Guinea grass (var. <i>Mackuenii</i>)	46.91	51.51	49.21	9.80

Among the legumes tried, *Stylosanthes* was found to perform better than others and it yielded 8 t of green fodder/ha/year.

Mimosa invisa was observed to be toxic to the animals, when fed alone, in large quantities (Anonymous, 1976b).

Slips of fodder crops were planted adopting a spacing of 50×30 cm leaving 2m radius around the base of the palms. *Stylosanthes* was established by dibbling the seeds in rows 30 cm apart. Fertilisers were applied at the rate of 150 kg N, 50 kg P₂O₅ and 100 kg K₂O/ha/year. The entire quantity of P and K were applied as basal dressing and the N in 4 and 8 splits, under rainfed and irrigated conditions, respectively. The farm yard manure obtained from the dairy was applied to the fodder crops. Irrigation during the dry months was given at weekly intervals, the depth of irrigation being 28 mm. The fodder crops could be cut at intervals of 40-45 days.

As the fodder component of the daily feed of a milch animal is about 40 kg of good quality green matter, the green fodder yield from one ha of irrigated hybrid napier grass was found sufficient to feed four animals. On the other hand, the yield from guinea grass under rainfed condition was sufficient to meet the requirement of only three animals.

Selection of the right breed of milch animal is very important for successful mixed farming programme. The breed of dairy cows recommended for Southern Kerala, graded Brown Swiss (F1), viz., *Sunandini* was maintained. The average milk yield of this breed maintained at Kayangulam was 2400 kg per lactation of 285 days duration. Cows yielding upto 3 kg milk/day get all the required nutrients from good quality green fodder (grass plus legume in the ratio of 75:25) fed @ 35-40 kg/day. For higher milk yielders, concentrates and mineral mixtures were fed in addition to the green fodder as per the schedule shown in Table 30.

Coconut yield

In the root (wilt) affected area, a 28%

Table 30. Feeding schedule

Milk yield/ day (kg)	Grass+legume 75:25 (kg)	Concentrates (kg.) (L & P or Hindlever)
4	40	0.5
5	38	1.0 + 30 gm mineral
6	35	1.5 mixture and 30 gm com- mon salt
7	35	2.0
8	32	2.5
9	32	2.5
10	32	3.0
11	30	3.5
12	30	4.0

Note:—From 7th month of pregnancy an additional quantity of 1 kg conc./day should be given.

increase in nut yield was obtained by adopting mixed farming practice over a period of five years (Sahasranaman et al., 1976). It was also reported that the increase in yield was the highest in palms of the disease early group (disease index 11-25) and the lowest in palms of the disease advanced group (disease index above 51). Increase in production of inflorescences as well as female flowers was also reported (Anonymous, 1976b).

The data obtained from the field experiment on mixed farming initiated in 1975 also indicated that the production of female flowers, percentage of female flower set and the yield of coconut were not adversely affected by raising fodder crops in the interspaces of coconut palms, both under rainfed and irrigated conditions.

Disease symptoms

In the mixed farming plot, amelioration of the foliar yellowing of the root (wilt)

affected palms was reported by Sahasranaman et al (1976). But progressive increase in the other symptoms of the disease, viz., flaccidity and necrosis was observed (Anonymous, 1976b) indicating that the practice had little curative effect on the disease.

Study of the root growth of the palms in the mixed farming area (with grass and irrigation), and control (without grass and no irrigation) indicated regeneration of roots in the former (Anonymous, 1976b).

Soil properties

Mixed farming had little effect on the size of soil aggregates when observed after a period of five years. But significant increases in the organic carbon, available P, exchangeable Ca and Mg contents were noticed in the soil samples drawn at depths of 0-50 and 50-100 cm (Sahasranaman et al 1976). Increase in the available K was noticed only 50-100 cm depth. No significant change in available N and pH was observed after five years of mixed farming.

Microbial activity

An evaluation of microbiological status of the soil under different fodder crops was carried out. The highest number of soil bacteria was observed in plots cultivated with *Stylosanthus gracilis*. Maximum number of nitrogen fixing organisms was found in plots under hybrid napier and *Centrocema pubescence*. Highest number of denitrifiers and cellulolytic organisms were encountered in soil samples from plots cultivated with hybrid napier, and hybrid napier and

Pueraria javanica, respectively (Anonymous, 1976b).

Economics of mixed farming

Cost accounting of the project on mixed farming at CPCRI Regional Station, Kayangulam revealed that the annual net profit per hectare increased from Rs 860 in the case of coconut alone (pre-experimental period) to Rs 2780 from coconut and dairying (Anonymous, 1976c). The cost benefit ratio of mixed farming project in the root (wilt) affected coconut stand worked out at 1:1.15. An increase in the employment generated, from 150 man days per ha to 1000 man days by mixed farming was also reported by Sahasranaman et al (1976).

REFERENCES

- ANONYMOUS, 1976a. *Coconut diseases of uncertain etiology*. Central Plantation Crops Research Institute, Technical Bulletin 1 pp. 1.
- ANONYMOUS, 1976b. Final report of the agrostology project, 1970-75, CPCRI Regional Station, Kayangulam.
- ANONYMOUS, 1976c. Central Plantation Crops Research Institute, Annual Report for 1975, Kasaragod, India. pp. 29.
- NAYAR, T. V. R., AND SAHASRANAMAN, K. N. 1978. Performance of four fodder crops in coconut garden under rainfed and irrigated conditions. In *Proc. PLACROSYM I*. Placrosym Standing committee, Kasaragod, India. pp. 425-430.
- SAHASRANAMAN, K. N., PILLAI, N. G., JAYASANKAR, N. P., POTTY, V. P., VARKEY, T., KAMALAKSHY AMMA, P. G., AND RADHA, K. 1976. Mixed farming in coconut gardens—Economics and its effect on root (wilt) disease. Paper presented in Internat. Symp. Cocon. Res. Development, Kasaragod, India, Dec. 28-31, 1976.

X. FARM PLAN MODELS

E.V. NELLIAT

*Central Plantation Crops Research Institute,
Kasaragod-670 124, Kerala, India.*

The choice of inter/mixed crop primarily depends on its acceptability to the grower. A crop that is a staple food for the family would always get preference. Tapioca, in Kerala, is a typical example. A rational cropping pattern should include a few crops rather than a single inter crop over the entire holding. The crops may be selected in such a way that the cultivation expenses and labour employment are distributed evenly through out the year. Also the time of sowing/planting could be so adjusted that a satisfactory margin between receipts and expenditure shall be maintained, even during the fertiliser application period for coconut.

The total cost of establishing a coconut plantation upto the steady bearing stage (12 years) would be about Rs 30,000 excluding cost of land and interest on capital (Nair, 1976). Although the first harvest would become available in the seventh year, steady bearing would commence in the tenth to twelfth year. Under rainfed conditions, the mean yield of nuts per palm, per year is expected to be 60 nuts; while under irrigated condition, it would be over 100 nuts.

The cost of cultivation, net returns, labour requirement and crop production of some of the profitable intercrops in coconut garden are furnished in Table 31. A few farm plan models for one hectare holding of coconut are presented in Table 31A to E (Krishnaji et al., 1976). In developing the models the feasibility and economics

including employment opportunities and the size of the holdings have been taken into account. Under rainfed conditions tuber crops, pineapple and banana are suggested. Where summer irrigation facilities exist mixed cropping with perennials like cacao, pineapple, and pepper can be adopted with advantage (Table 31B). A model for partially irrigated and partially rainfed farm is also given in Table 31C.

The tables were prepared based on the data collected for several years at CPCRI, from experimental plots of size ranging from 0.1 ha to 0.4 ha and hence should be valid for most purpose on small and marginal holdings. The projections, when made for larger holdings, should deviate only within reasonable limits, as the data collection was made on the experimental farm. In the case of holdings of 0.1 ha and less the input strategy can be adjusted to take advantage of the idle labour. The owners in this case, will be mostly agricultural labourers and as such may have quite a few partially employed and idle days which can be most profitably utilised on their farms. For such farms the stress should be on human energy and organic manures, with corresponding reduction in chemical energy and cash input. The cash input can thus be brought down considerably.

It is preferable to have a fairly large sized plot under model B where cacao is raised as a mixed crop. Rodent damage will be more severe when cacao is raised

Table 31. Net returns per annum from one hectare of garden land under optimal conditions of spacing (for plantations above 20 years in age) Rs/ha
(Krishnaji et al., 1976)

Intercrop	Cost of cultivation of inter-crops and mixed crops		Value of inter-crop output		Net returns		Additional employment		Additional output of intercrops (t)
	From mixed crops	From inter-crops or mixed crop	From inter-crops	Total including coconuts	Man days	Woman days			
1. Elephant yam	3246	6425	3179	7246	123	8	12.85		
2. Tapioca	2122	4204	2082	6149	93	12	10.51		
3. Sweet potato	2055	3335	1280	5347	56	26	9.53		
4. Ginger (Rio-de-Janeiro)	4730	14420	9690	13757	108	24	11.57		
5. Turmeric (Armoour)	4568	5162	594	4661	108	24	12.93		
6. Chinese potato (Coleus)	2035	4800	2765	6832	92	23	6.00		
7. Yam (<i>Dioscorea alata</i>)	2827	6360	3533	7600	64	12	12.72		
8. Lesser Yam (<i>Dioscorea esculenta</i>)	2827	5400	2573	6640	64	12	9.00		
9. Banana	7272	11000	3728	7795	170	—	20.00		
(A) 50% of area for tapioca and the rest for other intercrops									
1. Elephant yam	2684	5314	2630	6697	108	10	10		
2. Sweet potato	2088	3770	1682	5719	74	19	19		
3. Yam	2474	5282	2808	6875	79	12	12		
4. Banana	4696	7602	2905	6972	132	6	6		
(B) Mixed cropping with pepper, cacao, and pineapple (Suitable for irrigated holdings larger than 0.40 ha)									
3979 11800 7821 15661 142 21									
(C) Mixed cropping with pepper and pineapple only									
3695 6400 2705 6772 189 20									
(D) 50% area under Model (B) and the rest under intercrops									
1. Tapioca	3051	8002	4951	10905	118	17	17		
2. Elephant yam	3613	9112	5499	11453	132	15	15		
3. Sweet potato	3017	7568	4551	10504	99	24	24		
4. Yam	3403	9080	5677	11631	103	17	17		
(E) 50% area under Model (C) and the rest under intercrops									
1. Tapioca	2908	5302	2394	6461	141	16	16		
2. Elephant yam	3470	6412	2942	7009	156	14	14		
3. Sweet potato	2875	4868	1993	6060	122	23	23		
4. Yam	3261	6380	3119	7186	127	16	16		

**Table 32. Monthly expenditure and returns per ha of gardenland in rupees
(Nair, 1976)**

Crop/Crops	Particulars	Jan- uary	Feb- ruary	March	April	May	June	July	Aug- ust	Sept- ember	Octo- ber	Nov- ember	Dec- ember	Total
Coconut (Rainfed)	Cost of maintenance	50	50	70	40	440	30	30	345	750	450	95	50	2400
	Value of produce	420	600	702	840	672	546	516	474	420	366	348	396	6300
Coconut (Irr.)	Cost of maintenance	264	265	285	155	440	30	30	345	750	450	95	168	3268
	Value of produce	695	997	1142	1393	1159	898	855	789	723	614	568	667	10500
Coconut + Cacao	Cost of maintenance	295	805	315	593	918	70	50	895	614	470	850	325	6200
	Value of produce	1220	1800	2100	2660	3030	2320	1020	950	860	1240	2600	1900	21600
Multistorey- ed Cropping	Cost of maintenance	315	895	375	673	1158	100	300	905	694	940	860	345	7520
	Value of produce	1620	2340	3130	4190	3680	2320	1020	950	860	1240	2600	2300	26250

in isolated small pockets and marketing opportunities are better for larger quantity of produce. Also under conditions prevailing in most parts of Kerala, irrigation is a must for cacao and it may not be economical to put up irrigation installations for small plots.

Ginger is the most remunerative intercrop as seen from Table 31. However, it is highly susceptible to the disease *soft rot* which can devastate the entire crop. The incidence is more when the crop is raised consecutively in the same area. Hence, ginger is not included in the farm plan models. Sweet potato can be followed by a pulse crop like horse gram, black gram, green gram or cowpea in years when the north-east monsoon rains are favourable; this possibility is not shown in the models.

Under rainfed conditions and good management coconut is expected to give a mean annual yield of 60 nuts/palm; while it would go up to 100 nuts/palm if irrigation is provided. The prices and costs prevailing in June 1976 was utilised for working out the returns and expenses. The net return per ha under multistoreyed cropping consisting of coconut, cacao, pepper, and pineapple is around Rs 15,600 per annum which is the highest. As the most remunerative intercrop under rainfed conditions ginger gives a combined net return of nearly Rs 13,700. Tubers and banana give net returns ranging between Rs 6000 and Rs 8,000/year (including that from coconut). Thus, one-hectare of coconut garden with adult bearing palms under intensive cropping programme, can sustain a medium sized family on average standards; while under high intensity cropping programme with irrigation facilities half hectare would be sufficient for the purpose.

The monthly break-up of expenditure and income from one-hectare coconut garden under different cropping patterns is given in Table 32 (Nair, 1976). When family labour is employed, there will be proportio-

nate reduction in expenses. It may be noted that in August, September and October, the margin of net income is low or the expenses are more than receipts. This can be checked by suitably adjusting the time of sowing/planting of intercrops, so as to have the harvest of these crops during the above months and thus bridge the gap.

Rural credit

The annual outlay for good management of one hectare coconut garden of 175 adult bearing palms would be around Rs 2,233. The subsidiary crops would need another 2,055 to 7,272 rupees per year depending upon the crops grown. Therefore, the annual requirement of credit towards the inputs for intensive cropping programme ranges between Rs 5,500-9,500 per annum. Of this outlay, the investment on the intercrop alone becomes recoverable during the course of the year, as the response to inputs for coconut start accruing only from the third year. This would mean that the credit facilities, needed for the successful implementation of this intensive cropping programmes and realisation of enhanced agricultural production, should have two components, viz., short-term and medium-term loans. If irrigation system is to be developed, especially, when mixed or multistoreyed cropping is adopted, a third component namely long-term loan also may be required which may be around Rs 5,000/ha.

REFERENCES

- KRISHNAJI, N., CHANDAN MUKHERJEE, NELLIAT, E. V., NAIR, P.K.R., JACOB MATHEW, AND THOMAS VARGHESE, P. 1976. Economics of inter and mixed cropping in coconut gardens of Kerala. Some preliminary findings. Working Paper No. 41, Centre for Development Studies, Trivandrum-1 (Mimeo.)
- NAIR, P.K.R. 1976. Intensive cropping for stabilised income at enhanced rate from coconut plantations. *Financing Agric.* (3): 3-8.

XI. NEXT PHASE IN RESEARCH

The results of work done and in progress on multiple cropping in plantation crops have brought out much useful information. However, there are some gaps. Investigations on multiple cropping in plantation crops to be initiated in the next decade shall be more comprehensive and shall have wider perspective to bring in information on various aspects. The studies shall include among its objectives the following also.

1. Selection/evolving of suitable inter/mixed crop species/varieties for tolerance to shade and/or moisture stress.
2. Assessing the nutritional requirement of the system, rather than that of the individual crops in the crop mix.
3. Studying the rooting pattern and root exudates of the crops and interactions like allelopathy, symbiosis, etc.
4. Computing the energy requirement of the system.
5. Estimating the soil loss, if any, in slopy lands when multiple cropping is practised and studying the long term effect of multiple cropping in plantation crops on the soil productivity.
6. Working out mathematical models to arrive at optimal combinations and testing their credibility.
7. Evaluating the influence of multiple cropping on the quality and activity of rhizosphere microbes.
8. Estimating the employment generated by different multiple cropping practices.
9. Studying the pattern of sunlight incidence in the crop mix profile and regulating the spread of the crop canopies by appropriate pruning and training.
10. Studying the changes in the ecoclimate.
11. Assessing the influence of multiple cropping on the occurrence of pests and diseases, and estimating the losses.