V. MIXED CROPPING IN COCONUT

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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 P_2O_5 and 35 kg K_2O 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, 1977*b*).

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 (1977*a*)

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 $Ca_3(PO_4)_2$ 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, 1977*b*). 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, 1977*a*). 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 soi temperature in the open unirrigated coconut

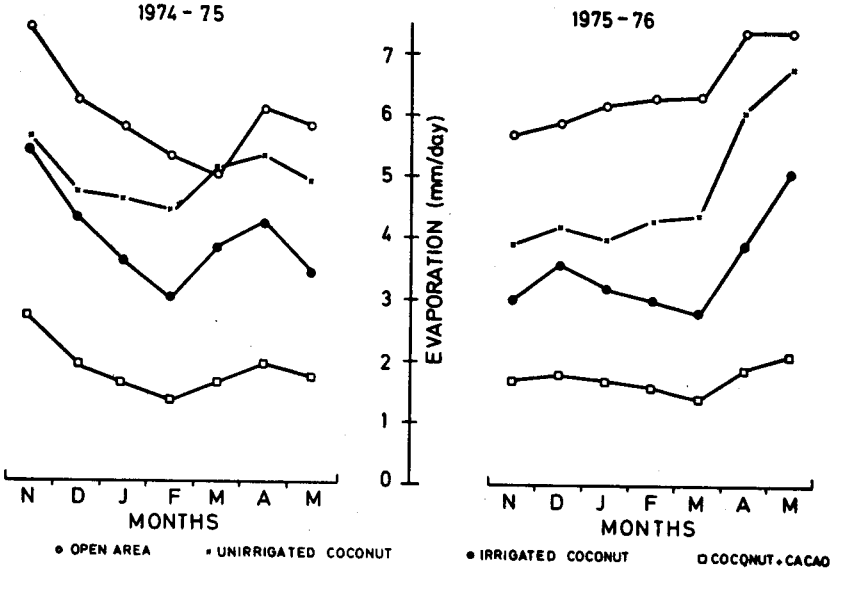

Figure 2. Evaporation from the ecoclimates of different cropping systems. *(Nair and Balakrishnan, 1977)*

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.

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