# Mixed Cropping of Black Pepper in Coconut and Arecanut Gardens



केन्द्रीय रोपण फसल अनुसंधान संस्थान
(भारतीय कृषि अनुसंधान परिषद)
कासरगोड - ६७१ १२४, केरल, भारत

भाकृअनुप
ICAR

CENTRAL PLANTATION CROPS RESEARCH INSTITUTE
(Indian Council of Agricultural Research)
KASARAGOD 671 124, KERALA, INDIA

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CPCRI

Technical Bulletin No. 42

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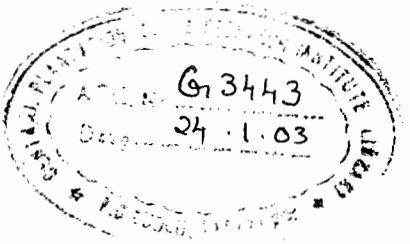



**October, 2001**

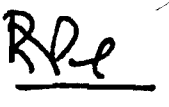
*Printed at*

Codeword Process and Printers, Mangalore - 575 001

# FOREWORD

Coconut and arecanut are traditional plantation crops grown in an area of 2.1 m ha in the country. The farming communities of these two crops are constrained with the declining prices of thier produce and inadequate income obtained from their fragmented holdings. In the research programme on these two palms, emphasis has been given on cropping system approach for the optimum utilization of natural resources and also to generate higher income from unit holdings. Cropping system experiments conducted by CPCRI have clearly demonstrated the suitability of black pepper, the king of spices as the most remunerative crop in coconut and arecanut based cropping systems not only in the traditional home of black pepper, Kerala but also in states such as Karnataka, West Bengal and Assam. CPCRI functioned as the national institute to conduct research on most of the plantation crops including spices till National Research Centres were established to cover specific crops. The research on spices was delinked from CPCRI in 1987 with the formation of National Research Centre for Spices (Presently Indian Institute of Spices Research).

From the cropping system experiments conducted during the last four decades, voluminous information has been generated on the feasibility as well as economic viability of black pepper as a component crop in cropping systems with coconut and arecanut. In order to achieve the ultimate goal of promoting the well being of small farmers, black pepper needs to be introduced as a key component to provide significant economic advantage to the farmer. In this publication, an effort has been made to take stock of available information on the performance of black pepper in coconut and arecanut based cropping systems in different regions of the country representing agroclimatic zones. There is lot of scope for extending black pepper cultivation to large unexplored areas in coconut and arecanut plantations. I appreciate the decision of Dr V. Rajagopal, Director of CPCRI for bringing out the publication at the appropriate time and compliments to Dr George V. Thomas and Dr D.V. Srinivasa Reddy for meticulously compiling the data generated over the years. I am also extremely happy that this publication is being released at the time of Silver Jubilee of Spices Research being celebrated by the Indian Institute of Spices Research, Calicut during 8-9th October, 2001.



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Date: 28.09.2001

## ACKNOWLEDGEMENTS

We take this opportunity to acknowledge all the personnel who were involved in the experiments on mixed cropping of black pepper in coconut and arecanut gardens at CPCRI and elsewhere in the country and generated excellent data, which are documented in this publication. We sincerely acknowledge the significant contributions of all the scientists, namely Dr K.V.A. Bavappa, Late Shri K. Shama Bhat, Late Dr K.B. Abdul Khader, Dr K. Venugopal, Shri N.T. Bhat, Shri N. Yadukumar, Shri M.G.K. Nair and Dr A. Muralidharan at CPCRI Regional Station, Vittal, Dr M. Sannamarappa at CPCRI RC, Hirehalli, Dr A.K. Ray at CPCRI RC, Kahikuchi and Late Shri E.V. Nelliat, Dr N.N. Potty, Dr P. Gopalasundaram, Dr M.R. Hegde, and Dr M. Yusuf at CPCRI, Kasaragod and Dr A. K. Sadanandan, at IISR, Calicut.

***- Editors***

## Introduction

Black pepper (*Piper nigrum* L.), the king of spices, is one of the major export earners among the various crops grown in India. Presently, India is exporting about 42,000 tonnes of black pepper to other countries contributing nearly 46 per cent of the total export value of spices from India. Pepper is cultivated both as a monocrop and also as a mixed crop in coconut and arecanut gardens in Kerala and Karnataka States. It is estimated that pepper is being cultivated in about 0.195 M ha area and producing about 53011 tonnes of black pepper in India. Of this, more than 90 per cent of the area and production of pepper is from Kerala State. The productivity of pepper in India is the lowest in the world even though India has the largest area under this crop. The main reason for the low productivity of pepper is that most of the production comes from the small and marginal holdings, where scientific cultivation practices are not followed. The estimated global demand for black pepper is 2.1 lakh tonnes by 2025 AD. In order to capture atleast 50 per cent of global market, India should increase its production from the present level of around 53011 tonnes to 1.25 lakh tonnes. As the scope for increase in area is limited, the other alternatives will be to cultivate pepper as mixed crop in the existing areca and coconut plantations and increase the productivity by following scientific production practices. Pepper is sufficiently shade tolerant and is ideal for mixed cropping with coconut and arecanut palms and can be conveniently trained to the palms once the stem grows to certain height. In this publication, efforts are made to explore the potentials of coconut and arecanut plantations for mixed cropping with pepper.

## Opportunities for mixed cropping in coconut and arecanut gardens

In India, plantation crops like coconut and arecanut are grown over an area of about 2.18 M hectares. These crops, which occupy the land continuously, utilize the natural resources only to a very limited extent producing less than 10 per cent of the potential dry matter production in the tropics. Studies conducted at Central Plantation Crops Research Institute (CPCRI), Kasaragod have shown that the effective root zone of an adult bearing coconut palm growing under normal management is confined laterally within a radius of 2 m around the base of the palm (Kushwah *et al.* 1973). The vertical distribution of roots have shown that the top 30 cm layer soil was practically devoid of functioning roots and that about 86 per cent of the roots were found between 30 and 120 cm depth from the surface. However, the morphological feature of the coconut palm necessitates its planting at 7.5 x 7.5 m spacing. These observations indicate that 77.7 per cent of the total available land area in a pure stand of coconut is not effectively utilized by the coconut roots. The venetian structure and orientation of coconut leaves permit sizeable amount of solar radiation incident on the crown to penetrate to the lower levels. The light intensity at ground level was always higher than 6700 lux at all the periods of the year (Nair, 1979). Of the solar radiation

received, on an average about 50 per cent alone is intercepted by the coconut canopy. Making use of the underutilized soil space and solar radiation in monocrop stands, a variety of crops having different stature, canopy shape and size and rooting habits can be mix planted to form compatible combinations. Such mixed plantations will intercept and utilize light at different vertical intervals and forage soil at different layers and columns maximizing biomass production per unit area of land, time and inputs.

Similarly, arecanut (*Areca catechu* L.) as a sole crop does not utilize fully the natural resources such as soil, space and light. The compact nature of arecanut crown, raised well above the ground (10 to 15 m), allows more sunlight to pass down to ground and maintain high humidity which, in turn, favour excellent growth of shade loving crops. Studies at CPCRI have revealed that orientation and structure of arecanut canopy permits 32.7 - 47.8 per cent of incident radiation to penetrate down depending on the time of the day (Muralidharan, 1980). Normally in an areca garden spaced at 2.7 x 2.7 m, the light energy reaches the ground and wasted. Rooting pattern revealed that arecanut palms planted at 2.7 x 2.7 m spacing could use effectively only 30 per cent of the land area (Bhat and Leela, 1968). The normal cultural operations are also confined within about 75-80 cm radius from the base. Thus, the areca palm exploits only 2.27 sq.m of (r = 0.85 m) land area out of 7.29 sq.m (2.7 x 2.7 m) land available to each palm. Arecanut plantations are mostly located in fertile soils in the coastal and Ghat regions in Kerala and Karnataka, and show good soil fertility and moisture holding in the soil throughout the year except for a few months in the summer. Thus, the arecanut plantations also are more ideal for inter/mixed cropping.

Further, coconut and arecanut being perennial crops, the land planted with these crops remains committed to it for several decades. To meet the diverse needs of farm families for cash, food, fuel, fodder, fruits, vegetables and timber, there is only little or no prospects of bringing fresh land under cultivation of these crops. Land to man ratio in our country is fast narrowing and has already reduced the per head availability of arable land to less than 0.25 ha. The great majority of small farmers, therefore, have small sized holdings and income derived from such smallholdings is invariably low. Besides, these plantations as mono crops provide employment only for a part of year and farm families have to remain unemployed or have to go elsewhere searching employment. Present day crash in prices of coconut and arecanut have further added to the sorrow of small and marginal holders of coconut and arecanut. It is, therefore, imperative that the production, productivity and profitability of these smallholdings is maximized considerably through more on - farm employment generation. Practising mixed cropping in coconut and arecanut plantations offer considerable scope for increasing production, productivity per unit area, time and inputs by more efficient utilization of resources like sunlight, soil, water and labour.

Coconut and arecanut based multiple cropping systems are practiced in India,

particularly in Kerala and Karnataka from the time immemorial. In all these traditional systems, 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. It is also desirable that the crop selected for mixed cropping with these plantation crops should be preferably shade tolerant, since the maximum solar energy received below the canopy of the crops does not exceed 50 per cent at any period of growth. Pepper is one of the most compatible mixed crops for both coconut and arecanut gardens. Pepper is raised exclusively as mixed crop in homestead gardens in Kerala and Karnataka and over 90 per cent pepper is trained on coconut and arecanut trunks. Studies carried out at CPCRI and elsewhere have also revealed that pepper is the most compatible perennial spice crop with coconut and arecanut and can be profitably grown as mixed crop.

## Climate and soil requirements for pepper

Pepper requires a warm and humid climate like in coconut and arecanut gardens. Though an annual rainfall of 2500 mm is ideal for the proper growth of the crop, it can also come up well in low rainfall areas with good distribution. Very long spells of dry weather are unfavourable for the crop growth. The plant tolerates a minimum temperature of 10°C and maximum of 40°C, the optimum being 20- 35°C. It can be grown up to an altitude of 1200 m from sea level but lower altitudes are preferable.

Pepper prefers a light porous and well-drained soil rich in organic matter. Water stagnation in the soil, even for a very short period is injurious for the plant. So, plantations established in heavy textured soils in locations where drainage facilities are inadequate should be avoided for pepper mixed cropping. Sites with slight to moderate slopes are ideal for pepper cultivation, as these promote drainage. Slopes facing south are to be avoided as far as possible. When such slopes are to be used for cultivation, the young plants are to be sufficiently protected from the scorching sun during summer months.

## Selection of pepper variety and multiplication

The improved varieties emerging from breeding programmes need to be tested as mixed crop in coconut and arecanut gardens from time to time to find out the best variety suitable for growing under coconut and arecanut shade. Potty *et al.* (1979) evaluated the performance of six varieties of pepper in the multistoreyed cropping system and suggested that Karimunda and Panniyur-I perform better under mixed cropping situations. In recent years, many new pepper varieties/hybrids have been developed in the country and CPCRI has already initiated field-screening trials of these varieties/hybrids as mixed crops in coconut and arecanut gardens at various locations. Till we get the information from these trials, cultivate only varieties which are proven to be highly productive. Select mother plants which give regularly high yields and possess other desirable attributes such as vigorous growth, maximum number of spikes per unit area, long spikes, close setting of berries, disease tolerance etc. Selected mother plants should

be in the age group of 5-12 years. Rooted cuttings from these selected mother palms are propagated vegetatively from shoot cuttings. Separate the runner shoots (even terminal shoots also can be used) from the vines in February-March. These vines are grown over the rooting medium (composed of cow dung-coir dust-sand in equal proportions) filled in a bamboo split piece. Tie each vine carefully to the bamboo using banana fibre, so that every node is in contact with the rooting medium (Bavappa and Gurusinghe, 1978). For rapid growth, add a nutrient solution consisting of urea (1 kg), super phosphate (1 kg), muriate of potash (1 kg) and $MgSO_4$ (0.75 kg) in 250 litres of water. Drench each vine once in every fifteen days with one litre of this solution. As the vines grow, the nodes get rooted, and each of these nodes is later separated and planted in individual polybags. After three months of planting in the bamboo, the rooted cuttings can be taken in polybags. Arrange the polybaged seedlings in a well-shaded area or in a shade house and give a spray of 1 per cent Bordeaux mixture. The seedlings are ready for field planting when buds start growing.

**Rapid multiplication of pepper in arecanut garden**

## Agrotechniques for pepper mixed cropping

### Coconut gardens

A spacing of 7.5 x 7.5 m in the square system is recommended for coconut (175 palms/ha) but in the homestead gardens of Kerala, the density is much higher (200-250 palms/ha), whereas in the Malnad region of Karnataka state, much wider spacings are adopted with densities as low as 120 palms/ha. For the sake of multiple cropping, the life span of coconut plantation can be divided into three phases. In the initial phase from planting to 8 years age, there will be adequate space and light for intercropping with short statured annuals. Under no circumstances, perennial crops like pepper should be planted during this period, because they may overgrow the palms and affect their growth. In the second phase, from 8 to 20 years, there will be very little penetration of light downwards and practically no cropping is possible during this period. In the third phase from 20 years onwards, pepper can be mix cropped in coconut gardens (Fig. 1). By this time, the coconut palm attains a height of about six metres, and about 55 per cent of light is available below the palm canopy.

Rooted cuttings of pepper raised in polybags may be planted in 0.5 sq.m pits at a distance of 1 m away from the bole of the palm on the Northern side. The pits have to be half filled with a mixture of farm-yard-manure or compost, 5 kg neem cake and top soil. The soil around the pit may be treated

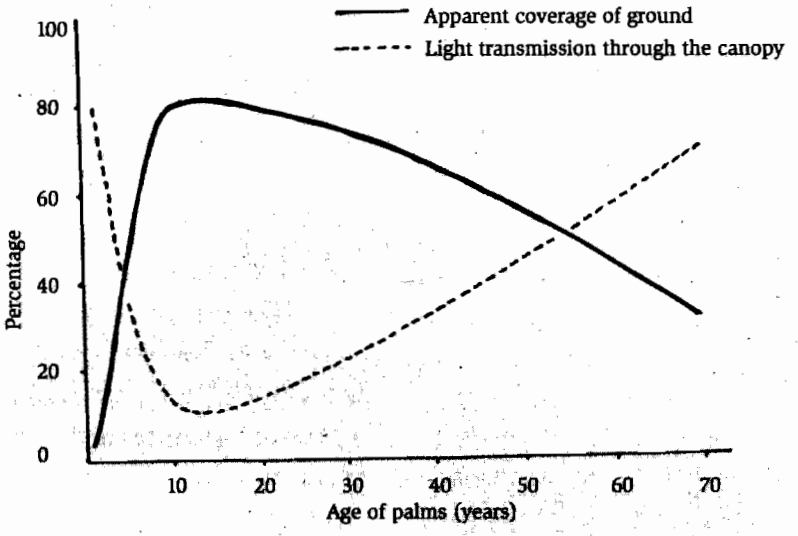


**Fig. 1: Apparent coverage of ground by coconut canopies of various age groups (Source: Nelliat *et al.*, 1974)**

with 50 g *Trichoderma* culture as a precaution against quick wilt of pepper. The vines may be trained on to the palm as and when they grow and tied to the trunk for the first two years. In the later years the aerial roots of pepper vines, itself gets attached with the coconut trunk. Both crops have to be adequately manured to prevent competition for nutrients between crops. Fertilizer at the rate of 100: 40:140 g of N, $P_2O_5$ and $K_2O$ respectively have to be applied for an adult vine every year in two equal split doses during May and September along with the recommended dose of fertilizers for coconut. The recommended fertilizer dose for adult coconut palm is 500 g N, 320 g $P_2O_5$ and 1200 g $K_2O$/palm/year applied in two split doses @ one-third in May-June and two-third in September-October. Fertilizers for pepper may be applied at a distance of 30 cm around the plant and earthed up. One-third of the full dose is to be given in the first year, two-third in the second year and full dose from the third year onwards. In the early years of planting, banana may be grown as an intercrop, which provides shade to young plants and protects them from drying up during summer months. However, it is not recommended beyond three years as it may compete with pepper and reduce the pepper yield. Mixed cropping of pepper should be practiced under assured water supply conditions throughout the year in regions where rainfall distribution is unimodel. The establishment, growth and yield under irrigated condition will be very good. Perfo-irrigation is preferable as it wets the entire surface. Perfo-irrigation at the rate of 20 mm irrigation once in a week has been found to be optimum for pepper in a coconut based high-density multispecies cropping model at Kasaragod. Even pepper can be drip irrigated along with coconut at the rate of 30-35 litres of water/day/palm depending on weather conditions. Pepper has 10-12

adventitious roots, 3-4 m long, and penetrates to a depth of 1-2 m with an extensive mat of surface feeding roots. Care should be taken not to damage the surface roots of pepper while doing cultural operations for coconut and fertilizer application.

Pepper is a climbing vine and usually it grows as tall as coconut. But the height of pepper vine is to be restricted to 4 m by pruning. This helps in harvesting of coconuts by climbing the tree up to the pepper height with the help of a ladder by the climbers without damaging pepper vines on the trunk.

Pepper begins to yield in the third year and comes to full bearing by 7th or 8th year. The yield declines after 15 years but vines have been found to yield even upto 60 years. It flowers during April-May and comes to maturity after 6-8 months. During this period, dry spells will adversely affect the pepper yield. Therefore, the vines are to be irrigated and optimum moisture maintained in the soil. The berries are harvested manually when two or three berries in a spike turns red in colour. The separated berries are to be sun dried for 7 -10 days till they turn black in colour. The recovery of black pepper from the fresh is around 33 per cent. On an average 1 kg dry pepper can be obtained from a single vine trained on coconut palms.

## Arecanut gardens

Arecanut planted at recommended spacing of 2.7 x 2.7 m does not fully utilize the natural resources like soil, space and light in a sole crop. Therefore, arecanut plantations are invariably put into some kind of intercropping. Among the many perennial crops grown with arecanut, black pepper was reported to be the most remunerative crop. Experimental evidences, in general, indicate that intercropping in arecanut was not harmful to the main crop, provided all the crops are manured separately and managed scientifically as per the recommendations.

Nayar (1982) recommended the black pepper hybrid Panniyur-I for well spaced (2.7 x 2.7 m) arecanut gardens where the infilteration of light is higher and Karimunda for more densely planted gardens. Pepper mixed cropping is possible only in areca gardens aged over 15 years. Rooted seedlings of pepper raised in polybags may be planted in 0.5 sq.m pits at a distance of 0.75 m away from the bole of the areca palm on the Northern side. The pits have to be half filled with a mixture of farm-yard-manure or compost, 5 kg neem cake and top soil. The soil around the pit may be treated with 50 g *Trichoderma* culture as a precaution against quick wilt of pepper. The vines may be trained on to the areca palm as and when they grow and tied to the trunk for the first two years. When black pepper is grown on arecanut, the manurial and fertilizer dose applied to arecanut should be doubled. Each palm should receive in addition to its normal recommended dose of 10 kg of farm yard manure or compost, 100g N, 40g $P_2O_5$ and 140g $K_2O$ for areca palm, an equal additional dose of manures and fertilizers to support the pepper crop starting from the third year of planting. These fertilizers have to be applied for an adult vine every year in two equal split doses during May and September along with the fertilizers for arecanut. During the first

and second years, one-third and two-third dose of recommended fertilizers of pepper, respectively should be applied. Application of lime at the rate of 500g/vine during April-May in alternate years is reported to be beneficial (Nayar, 1982). Mixed cropping of pepper should be practiced under assured water supply conditions throughout the year. Sprinkler or perfo-irrigation is preferable as it wets the entire surface. Irrigation at the rate of 20 mm irrigation once in a week has been found to be optimum for arecanut-pepper mixed cropping system. Care should be taken not to damage the surface roots of pepper while doing cultural operations to arecanut and fertilizer application. The pepper vine starts bearing from third year of planting and reach potential bearing by 10th year. On an average 1 kg black pepper can be obtained from a single vine trained on areca palms under optimum management conditions.

## Performance of pepper as mixed crop

A series of experiments were conducted in Central Plantation Crops Research Institute, Kasaragod and elsewhere in the country on the performance of pepper as mixed crop in coconut and arecanut gardens. Attempts were made to examine the results of various experiments on the successful cultivation of pepper as a mixed crop in coconut and arecanut gardens.

## In coconut gardens

Kerala accounts for 96 per cent of the area and production of black pepper in India. It is also cultivated in Karnataka, West Bengal and Assam to a small extent. Pepper is cultivated mainly as a mixed crop in coconut gardens. Way back in 1971-72, pepper variety Panniyur-I planted as a mixed crop in coconut garden and trailed on palms aged over 60 years in a 1 ha plot at CPCRI, Kasaragod yielded a mean of 2 kg dry black pepper/vine/year. The highest per vine yield was 5.5 kg black pepper/year (Anon. 1977). In a similar trial carried out at the Pilicode station of Kerala Agricultural University in 1970 clearly brought out the economic advantage of pepper mixed cropping in coconut holdings along with other compatible crop combinations (Table 1).

The recalculated economics for the earlier yield data from CPCRI, Kasaragod revealed that among the various mixed crop combinations, Coconut-Pepper system was found more remunerative. This system could generate a net return of Rs 45025/ha/year in a coconut garden as compared to Rs 22300/ha/year from the coconut monocrop (Table 2).

In 1970's, CPCRI has developed a multistoreyed cropping model, the most productive and remunerative combination of coconut-pepper trained on coconut palms and cocoa and pineapple as component crops in the coconut interspaces. These crops developed their canopies at varying heights, simulating the features of a multistoreyed building. The labour requirement of a sole crop coconut plantation of one hectare was 157 man days in a year.The multistoreyed cropping model requires 366-400 man days labour per year and the work is also evenly distributed round the year. The annual cost of cultivation and returns of multistoreyed cropping system

**Table 1: Economic advantage of mixed cropping in coconut garden at Pilicode, KAU.**

| Crop combination | Man days/year | Cost of cultivation* (Rs/ha/year) | Net profit* (Rs/ha/year) |
|---|---|---|---|
| Coconut mono crop | 220 | 3500 | 6050 |
| Coconut + Pepper trained on coconut + Cocoa + Pineapple | 360 | 7520 | 17430 |

* As per market prices of 1970-71.

**Table 2: Economics of coconut-pepper mixed cropping at CPCRI, Kasaragod (Rs/ha/year at 2000-01 prices)**

| | Invest. cost | Annuity value | Total annual cost | Yield of pepper* (kg/ha) | Unit value of pepper | Gross returns | Net returns |
|---|---|---|---|---|---|---|---|
| Coconut mono crop | 60,000 | 17000 | 24500 | - | - | 46800 | 22300 |
| Coconut-Pepper | 70,000 | 19600 | 28800 | 175 | 100 | 64300 | 35500 |

Yield of coconut: 18720* nuts/ha **(*Source: CPCRI Technical Bulletin No. 24)**
Unit value of coconut: Rs 2.50/nut
Unit value of pepper: Rs 100/kg black pepper

Black pepper as a mixed crop in coconut based high density multispecies cropping system

Black pepper mixed cropping in coconut garden at CPCRI, Kasaragod

consisting of coconut-pepper-cocoa-pineapple are recalculated based on the present market prices for the inputs and outputs data of 1976 and presented in Table 3.

Multistoreyed cropping initiated in 1972 to evaluate the performance of four crop combinations at Kasaragod, revealed that yield of coconut was better in plots where cocoa was grown in single hedge along with pepper and pineapple. Pepper yield was highest in plots where cinnamon was grown in single hedge (SH), followed by cinnamon double hedge, cocoa single hedge and cocoa double hedge (Table 4). The yield of pepper was affected by the reduced incidence of sunlight on the vines of cocoa plots (DH/SH) (Anon. 1984).

Mixed farming programme in coconut involved establishment of fodder grass in the interspaces of coconut palms and maintenance of milch animals and recycling of cattle manure in the coconut-fodder-pepper

**Table 3: Labour requirement, expenses and returns from multistoreyed cropping in coconut plantations (1 ha) at CPCRI, Kasaragod.**

| Crops | Labour (man days) | Yield | Annual cost* of cultivation (Rs) | Gross* returns (Rs) | Net* returns (Rs) |
|---|---|---|---|---|---|
| Coconut | 157 | 17500 nuts | 22000 | 43750 | 21750 |
| Pepper | 16 | 88 kg (dry) | 5000 | 8800 | 3800 |
| Cocoa | 163 | 500 kg beans | 5000 | 10000 | 5000 |
| Pineapple | 30 | 3710 kg | 3000 | 14840 | 11840 |
| Total | 366 | | 35000 | 79150 | 42390 |

Coconut: Rs 2.50/nut; Pepper: Rs 100/kg; Cocoa: Rs 20/kg beans; Pineapple: Rs 4/kg.
* Recalculated data based on 2001 market rates. **(Source: Nelliat *et al.* 1976)**

**Table 4: Yield of different crops in coconut based multistoreyed cropping system (1980).**

| Treatments | Coconut (nuts/palm) | Cocoa (pods/tree) | Pepper dry wt/standard (kg) | Cinnamon yield/plant | |
|---|---|---|---|---|---|
| | | | | Quills (g) | Quillings (g) |
| 1. Cocoa in SH + pepper + pineapple | 81 | 44.1 | 0.90 | - | - |
| 2. Cocoa in DH + pepper + pineapple | 59 | 36.7 | 0.63 | - | - |
| 3. Cinnamon in SH + pineapple + pepper | 55 | - | 1.3 | 146.0 | 43.4 |
| 4. Cinnamon in DH + pineapple + pepper | 62 | - | 1.17 | 44.8 | 37.9 |

**(Source: Anon. 1984)**

mixed crops stand. This model at CPCRI, Kasaragod generated additional employment to the tune of 850 man days and ensured good returns without any yield decline in coconut. The out put from the 1.04 ha model yielded 11276 coconuts, 60 kg pepper, 250 kg banana and 14495 litres of milk. The total revenue from this was Rs 67,705 and net return to the family was Rs 43654 (Anon. 1990).

**Black pepper as a component crop in the coconut based mixed farming at CPCRI, Kasaragod**

Sadanandan *et al.* (1993) have made efforts to study the performance of pepper varieties in two villages, Pannikottur and Peruvanna in Calicut district of Kerala State in 50 randomly selected gardens both under farmers practice and experimental situations. The experimental plots were manured at the rate of 5 kg FYM, 0.5 kg each of neem cake and bone meal along with recommended dose of chemical fertilizers for coconut and black pepper. The predominant black pepper varieties were Karimunda (49 per cent), Panniyur-I (28 per cent), Arakulammunda (14 per cent), Narayakodi (5 per cent) and Kuthiravally (1 per cent) and remaining were unspecified varieties. Application of inputs for four years as per recommendation to coconut and black pepper increased the soil fertility status compared to plots receiving inputs in accordance with farmers' practice. The health of pepper vines was also much improved due to systematic fertilizer application and nutrient management. Among the varieties, Panniyur-I was more efficient in extracting nutrients. The varieties Arakulammunda and Karimunda were found alike in their efficiency in nutrient extraction from soil as evident by the nutrient content of black pepper leaves. There was 53 per cent increase in yield of coconut and 172 per cent increase in yield of black pepper due to systematic and scientific cultivation (Table 5). The employment potential of farmers was increased by 15 to 20 per cent due to adoption of pepper mixed cropping in coconut gardens.

Experiments conducted in Goa conditions revealed that black pepper grows satisfactorily as a mixed crop in coconut

**Table 5: Effect of coconut-pepper cropping on pepper productivity (yield kg/vine)**

| Year | Farmers' practice | Experimental plot | Increase (%) |
|---|---|---|---|
| 1986-87 | 0.356 | 1.100 | 209 |
| 1987-88 | 0.413 | 1.178 | 185 |
| 1988-89 | 0.336 | 0.836 | 149 |
| 1989-90 | 0.498 | 1.227 | 146 |
| **Mean** | **0.401** | **1.085** | **172** |

**(Source: Sadanandan *et al.* 1993)**

gardens and the plants started yielding from the third year onwards. The average yield obtained from one-hectare coconut garden was 0.76 t/ha and 0.44 t/ha of dry pepper, respectively from Panniyur-I and Karimunda (Mathew *et al.* 1990). Thus, it may be summarized from the above experiments that mixed cropping pepper in coconut gardens is always labour intensive and economically profitable compared to monocropping of coconut.

**Black pepper as a mixed crop in coconut in farmers garden under IVLP**

←
**Black pepper mix cropped in a homestead garden**

## In arecanut gardens

Arecanut plantations in India are invariably put into some kind of intercropping. Pepper from early days was raised on areca standards in Kerala and Karnataka. It is becoming a popular mixed crop in the entire areca growing regions now. The advantages of pepper mixed cropping in areca plantations are not fully exploited by most of the farmers due to the fear that growing black pepper on arecanut may depress the yield of arecanut. Nair (1982) and Abdul Khader (1982) found pepper as a profitable cash crop, suitable for mixed cropping in areca gardens. According to Singh *et al.* (1982) pepper can be recommended as a mixed crop along with areca in North Bengal. Experimental data from mixed cropping of arecanut and black pepper for the duration of 10 years showed that there was no detrimental effect on the yield of arecanut palms due to training black pepper on them (Table 6). Further, it helped to augument the income of the farmer by about Rs 8940/ha from black pepper alone (Nayar, 1982).

A study was conducted to investigate the performance of four varieties of pepper as a mixed crop in a 19-year-old arecanut garden with six planting densities. The results revealed that, in arecanut garden with

Table 6: Long term effect of training pepper on arecanut at CPCRI, RC Vittal

| Year | Yield of arecanut per palm | | | |
|---|---|---|---|---|
| | Arecanut | | Areca + pepper | |
| | No. of nuts | Fresh wt. (kg) | No. of nuts | Fresh wt. (kg) |
| 1969-70 | 225.7 | 7.5 | 267.0 | 6.9 |
| 1970-71 | 303.0 | 10.0 | 265.3 | 8.8 |
| 1971-72 | 370.0 | 12.0 | 366.3 | 12.2 |
| 1972-73 | 267.6 | 8.9 | 256.6 | 8.4 |
| 1973-74 | 280.0 | 9.3 | 278.8 | 9.0 |
| 1974-75 | 225.9 | 7.5 | 240.7 | 8.2 |
| 1975-76 | 275.4 | 9.1 | 280.8 | 9.6 |
| 1976-77 | 418.7 | 13.6 | 413.0 | 13.0 |
| 1977-78 | 362.5 | 12.8 | 376.9 | 12.1 |
| 1978-79 | 373.0 | 12.4 | 381.9 | 12.7 |
| **Mean** | **310.2** | **10.4** | **306.6** | **10.1** |

**(Source: Muralidharan, 1980)**

recommended spacing of 2.7 x 2.7 m, 43 per cent of sunlight is available to other crops. Pepper as a mixed crop did not influence the yield of arecanut. As regards the yield of pepper, 1.8 x 2.7 m spacing had given significantly more yield per plot (7.09 kg) followed by 1.8 x 3.6 m spacing (Fig 2). Among the cultivars of pepper, Karimunda gave the highest yield (8.92 kg/plot) followed by Panniyur-I (6.68 kg/plot). The cultivars Uddakare and Malligesara had resulted in poor yield (Khader *et al.* 1993).

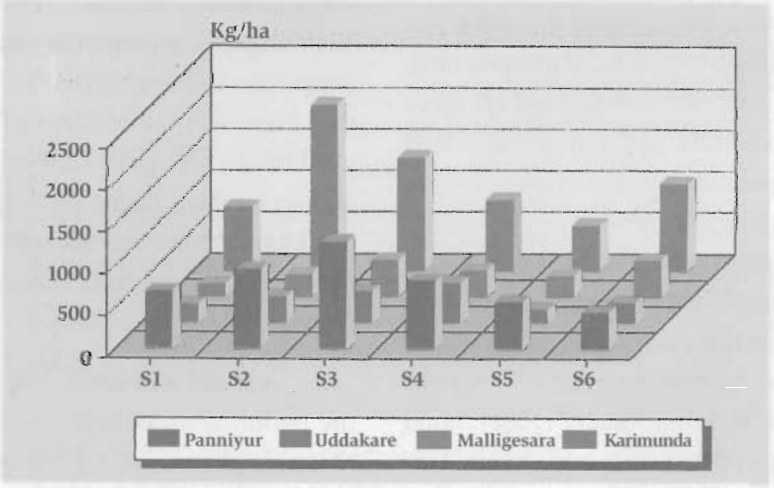


**Fig. 2: Yield of pepper for 6 years (kg/ha) 1981-82 to 1986-87**
**(Source: Khader *et al.*, 1993)**

A high-density multispecies cropping model involving six crops, viz. banana, pepper, cocoa, clove, coffee and pineapple was laid out in CPCRI Regional Station, Vittal during 1983 in an arecanut plantation aged 17 years. The yield of arecanut and other intercrops in the model from 1984 to 1988 is presented in Table 7 and total income from different crops in the system is given in Table 8. Black pepper proved to be better mixed crop by providing revenue of Rs 49630/ ha from the sale of pepper alone. The system as a whole generated a gross return of Rs 150313 from the one-hectare model (Khader and Venugopal, 1992).

A similar high-density model consisting of pepper-cocoa-coffee-mulbery-elephant foot yam was laid out in a 20-year-old arecanut plantation in the Maidan parts of Karnataka (CPCRI, Research Centre, Hirehalli). The results of the experiment indicated that arecanut yield increased by 7 to 20 per cent due to cropping system as compared to monocrop of arecanut. The increase in yield of arecanut was due to the complimentary nature of various crops in the system and recycling of organic matter contributing 50 per cent N and 50 per cent K (Bavappa *et al.*

**Table 7: Yield of different crops in the arecanut based multistoreyed cropping model at Vittal**

| Crops | Plant population/ha | 1984 | 1985 | 1986 | 1987 | 1988 |
|---|---|---|---|---|---|---|
| Arecanut (chali) | 1300 | 1582 | 2490 | 4130 | 3507 | 3832 |
| Banana (fruit) | 390 | - | 2650 | 2146 | 1422 | 391 |
| Pineapple (fruit) | 2400 | - | 1263 | 419 | 244 | 427 |
| Pepper (dry) | 1300 | - | - | 45 | 320 | 1418 |
| Cocoa (pods) | 210 | - | - | 71 | 941 | 1084 |
| Coffee (dry beans) | 780 | - | - | 10 | 31 | 68 |
| Clove (kg) | 180 | Not flowered | | | | |

**(Source: Khader and Venugopal, 1992)**

**Table 8: Total revenue (Rs/ha) from different crops in the arecanut based multistoreyed cropping model**

| Crops | 1984 | 1985 | 1986 | 1987 | 1988 |
|---|---|---|---|---|---|
| Arecanut | 39550 | 62250 | 103250 | 87675 | 95800 |
| Banana | - | 5300 | 4292 | 2843 | 781 |
| Pineapple | - | 2526 | 838 | 488 | 854 |
| Pepper | - | - | 1575 | 11183 | 49630 |
| Cocoa | - | - | 142 | 1882 | 2160 |
| Coffee | - | - | 160 | 480 | 1088 |
| Clove | - | - | - | - | - |
| Total | 39550 | 70076 | 110257 | 104551 | 150313 |

**(Source: Khader and Venugopal, 1992)**

**Black pepper mix cropped in arecanut garden**

**Black pepper as a component crop in arecanut based high density multispecies cropping system at CPCRI, RS, Vittal**

1986). The yield of component crops increased progressively, especially in pepper and cocoa. During the 8th year of experimentation, the yield of pepper (dry) and cocoa (pods) was 986 kg/ha and 4755 kg/ha respectively. The gross income from the monocrop of arecanut was Rs. 148335/ha, while it was Rs. 203700/ha in the multispecies cropping system at 8th year (Table 9). The additional income derived from other crops was Rs. 39090/ha and the major share was from pepper (Rs. 29580/ha). The net returns were Rs. 171734/ha from the mixed cropping system as a whole as compared to Rs. 135594/ha in the arecanut monocrop (Sannamarappa, 1993). Another high-density multispecies cropping model consisting of arecanut-pepper trained on areca palm-banana-turmeric-pineapple studied under three levels of

**Table 9: Economics of arecanut monocrop and arecanut based high density multispecies cropping system at CPCRI RC, Hirehalli, Karnataka.**

| Year | Arecanut monocrop | | | Arecanut based HDMSCS | | |
|---|---|---|---|---|---|---|
| | Gross income | Cost of cultivation | Net income | Gross income | Cost of cultivation | Net income |
| 1984-85 | 47394 | 3745 | 43649 | 56417 | 19048 | 37369 |
| 1985-86 | 73950 | 4149 | 69801 | 81128 | 17714 | 63614 |
| 1986-87 | 73800 | 4916 | 68884 | 79838 | 15664 | 64174 |
| 1987-88 | 76190 | 6792 | 69398 | 103999 | 18528 | 85471 |
| 1988-89 | 126900 | 11355 | 115545 | 164665 | 29048 | 135617 |
| 1989-90 | 110460 | 9115 | 101345 | 158296 | 20886 | 137410 |
| 1990-91 | 153732 | 16580 | 137152 | 201216 | 34298 | 166918 |
| 1991-92 | 148335 | 12741 | 135594 | 203700 | 31966 | 171734 |

**(Source: Sannamarappa, 1993)**

fertilizer management full, two-third and one-third dose of recommended fertilizers for productivity at CPCRI Research Centre, Kahikuchi, Assam. Nine years of mean economic yield revealed that full dose of recommended fertilizer application resulted in higher production with areca chali yield of 2405 kg/ha, dry pepper yield of 1252 kg/ha, pineapple fruit yield of 987 kg/ha and 2127 kg turmeric/ha (Table 10). The system generated a net return of Rs 185520/ha in 1995-96 under full dose of fertilizers (Ray *et al.* 2000). The major contribution towards this net returns was from the component crop pepper (48 per cent) and this was followed by main crop, arecanut (31.3 per cent). This clearly demonstrated the potential of pepper as a mixed crop in arecanut plantations.

**Black pepper mix cropped with arecanut in farmers garden**

**Table 10: Yield response of different crops under different fertilizer levels in areca based cropping system at Assam**

| Crops | Fertilizer levels | Yield (Mean of 9 years) | Net returns (Rs/ha in 1995-96) |
|---|---|---|---|
| Arecanut | Full | 2405 | 58105 |
| (kg chali/ha) | Two-third | 2388 | 58478 |
| | One-third | 1975 | 48875 |
| Pepper | Full | 1252 | 89209 |
| (kg dry/ha) | Two-third | 1128 | 80795 |
| | One-third | 884 | 58246 |
| Banana | Full | 6313 | 19696 |
| (kg bunches/ha) | Two-third | 6331 | 21751 |
| | One-third | 5165 | 16712 |
| Pineapple | Full | 987 | 4638 |
| (kg/ha) | Two-third | 733 | 3085 |
| | One-third | 543 | 1658 |
| Turmeric | Full | 2127 | 13872 |
| (kg/ha) | Two-third | 1973 | 13235 |
| | One-third | 1801 | 15030 |
| **Total** | **Full** | | **185520** |
| | **Two-third** | | **177344** |
| | **One-third** | | **140522** |

**(Source: Ray *et al.* 2000)**

## Effect of mixed cropping black pepper on soil fertility and beneficial micro-organisms

Higher productivity is achieved in cropping systems as a result of synergistic interaction among the compatible crops or crop-livestock components. The favourable impact of mixed cropping of black pepper was reflected in the increased yield of coconut and arecanut palms under mixed cropping when compared to the monocrops. The beneficial effects recorded in cropping systems include enhanced soil fertility status, microbial activity, better microclimatic conditions and utilization of natural resources for the benefit of plant growth and sustainable crop productivity.

Black pepper is trained on coconut and arecanut palms as standards in different cropping systems. Planting of pepper in the basin area of these crops results in the development of root system of black pepper in the root zone of the crops in close proximity to each other. Analysis of soil samples from the root zone region revealed proliferation of various beneficial microbial groups in the coconut-pepper and arecanut-pepper root regions when compared to monocrop of coconut. The introduction of mixed crops in the system favoured the devlopment of beneficial flora comprising of bacteria, fungi, actinomycetes, asymbiotic and associative $N_2$ fixers, phosphate solubilizers and growth promoting bacteria in the root region. The microbial biomass content which gives an

indication of total microbial load in the system was increased in coconut basins planted with pepper when compared to the monocrop of coconut. The increased level of soil enzyme activities of dehydrogenase, phosphatase and urease was also indicative of augumented biological activity in the system.

Associative $N_2$ fixing *Azospirillum* spp. was found colonizing the roots of coconut and black pepper in varying intensities under different cropping systems such as high density multispecies cropping system, multistoreyed cropping and mixed farming (Ghai and Thomas, 1989). The incidence of *Azospirillum* was determined by two methods viz. 2,3,5 triphenyl tetrazolium cholride reduction and by culturing root fragments in N-free semisolid malate medium. (Table 11). The isolates of *Azospirillum* from coconut and black pepper exhibited significant level of nitrogenase activity which indicated contribution of substantial amounts of $N_2$ to the cropping system by way of biological nitrogen fixation. The isolates from coconut roots were identified as *Azospirillum brasilense* and those from black pepper as *Azospirillum lipoferum* based on biochemical and morphological features of the isolates.

The symbiotic arbuscular-mycorrhizal association formed between fungi and plant roots is advantageous to the crops in the uptake of immobile elements particularly phosphorus, imparting tolerance to drought under water stress conditions and biocontrol of soilborne diseases. In the high density multispecies cropping system, roots of

**Table 11: Incidence of associative $N_2$ fixing *Azospirillum* spp. in coconut and black pepper roots under various cropping systems**

| Croping system | Crop | *Staining reaction | | ** Culturing | | Mean nitrogenase activity nm $C_2H_4ml^{-1}h^{-1}$ | Speciation (No. of isolates) |
|---|---|---|---|---|---|---|---|
| | | No. of root bits stained | % positive | No. of bits inoculated | % positive | | |
| 1. High density multispecies cropping | Coconut | 76 | 71 | 36 | 25 | 4.04 | Ab(5)*** |
| | Black Pepper | 72 | 86 | 36 | 33 | 7.81 | Al(1)**** Nl(1) |
| 2. Multi-storeyed cropping | Coconut | 72 | 46 | 36 | 17 | 9.37 | Ab(1) |
| | Black pepper | 72 | 29 | 36 | 19 | 6.67 | Al(1) |
| 3. Mixed farming | Coconut | 72 | 85 | 36 | 17 | - | - |
| | Black pepper | 72 | 96 | 36 | 17 | - | - |

* 2, 3, 4 triphenyl tetrazolium chloride reduction

** Sub-surface pellicular growth in N-free semi-solid malate medium

*** *Azospirillum brasilense*

**** *Azospirillum lipoferum*

**(Source: Ghai and Thomas, 1989)**

coconut and black pepper had higher level of arbuscular mycorrhizal association as revealed by the percentage of root infection and the extent of root colonisation (infection grading).

One-third dose of fertilizer application supported the maximum activity when compared to two third and full dose of recommended fertilizer inputs (Rohini Iyer *et al.* 1993).

## Diseases and pests

Adoption of integrated management practices for diseases and pests is very essential in coconut-pepper and arecanut-pepper mixed cropping systems. The microclimate in the mixed crop models provides ideal environmental conditions for the multiplication and survival of pests and disease causing microbes and affects the crops health. The major diseases noticed on black pepper are *Phytophthora* foot rot, slow decline and anthracrose diseases. Effect of climatic factors on the occurance of foliar infection in black pepper caused by *Phytophthora palmivora* MF4 was studied during the years 1984-86 in arecanut-black pepper mixed cropping system at CPCRI, RC, Kannara. The correlation studies between the disease recorded at weekly intervals and the meteorological factors prevailing during the preceeding seven days showed a positive correlation between the rainfall, number of rainy days and relative humidity whereas temperature and sunshine hours had a negative correlation. Average climatic factors worked out during increasing and decreasing phases of the disease showed that factors such as low temperature (22.7-29.6°C), shorter duration of sunshine (2.8-3.5h/day), high rainfall (15.8-23.0 mm/day) and high relative humidity (81-99%) contributed to the increase in disease (Ramachandran *et al.*, 1988). The insect pests of black pepper are pollu beetle, top shoot borer, leaf gall thrips and scale insects. Regular monitoring and timely plant protection measures as per recommended package of practices will help to control pests and diseases and realize optimum yields.

## Conclusion

The coconut and arecanut farming communities in the country are in crisis due to the crash in price of the produce. One of the easy tasks to make the cultivation of these crops more competitive is the adoption of cropping system approach to increase per palm productivity as well as productivity of unit holding. Crop diversification and intensive cropping will enable optimum utilization of natural resources, generate more labour opportunities and reduce the over dependence on one crop. Trials conducted in different agroclimatic zones of the country have established the suitability of black pepper as a remunerative crop in various cropping models involving coconut and arecanut as the main crops. Mixed cropping with black papper will be advantageous particularly to the great majority of small farmers to ehnance productivity and profitability from their coconut and arecanut holdings.

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