BIOMASS PRODUCTIVITY AND INFLUENCE OF INTERCROPS IN A PRE-BEARING COCONUT-CASUARINA AGROFORESTRY SYSTEM

By

USHA, T.

THESIS

Submitted in partial fulfilment of
the requirement for the degree

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture
Kerala Agricultural University

Department of Agronomy
COLLEGE OF HORTICULTURE
Vellanikkara - Trichur
Kerala - India

1990

DECLARATION

I hereby declare that this thesis entitled "Biomass productivity and influence of intercrops in a pre-bearing coconut-casuarina agroforestry system" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Vellanikkara,

USHA, T.

CERTIFICATE

Certified that this thesis entitled "Biomass productivity and influence of intercrops in a pre-bearing coconut-casuarina agroforestry system" is a record of research work done independently by Smt.Usha, T. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

Vellanikkara,

Dr.R. Vikraman Nair,
Chairman,
Advisory Committee,
Professor of Agronomy.

CERTIFICATE

We, the undersigned, members of the Advisory Committee of Smt. Usha, T. a candidate for the degree of Master of Science in Agriculture with major in Agronomy, agree that the thesis entitled "Biomass productivity and influence of intercrops in a pre-bearing coconut-casuarina agroforestry system" may be submitted by Smt. Usha, T. in partial fulfilment of the requirement for the degree.

Chairman: Dr.R. Vikraman Nair

Members : Dr.P.V. Balachandran

Sri.V.K.G. Unnithan

Sri. V.R. Krishnan Nair

ACKNOWLEDGEMENT

I place on record my deep sense of gratitude to Dr.R. Vikraman Nair, Professor of Agronomy and Chairman of my Advisory Committee for his guidance.

I am obliged to Prof. T.F. Kuriakose, former Project Co-ordinator (Rice), Agricultural Research Station, Mannuthy who was the major advisor from the early stages of planning to the completion of this experiment.

I am grateful to Dr.C.Sreedharan, Dean, College of Agriculture, Vellayani for his help and timely advice.

I am very much indebted to Dr.P.K.Ashokan, Assistant Professor of Agronomy who was a constant source of inspiration in the post experimental analysis and preparation of the manuscript.

I am also indebted to Dr.P.V.Balachandran, Associate Professor of Agronomy for the great pains he has taken to help me in the preparation of the thesis.

I would like to record my heartfelt thanks to Sri.V.K.G. Unnithan, Associate Professor of Agricultural Statistics for his timely advice and suggestions.

I am obliged to Sri.V.R. Krishnan Nair, Special Officer (Agroforestry) for his valuable advice and suggestions.

I place on record my sincere thanks to Dr.A.V.R.Kesava Rao, Assistant Professor of Agricultural Meteorology for his timely advice.

I express my thanks to Dr.M.Achuthan Nair, Associate Professor of Agronomy who helped me during the initial stages of planning.

I also express my gratitude to Dr.V.K.Venugopal, Associate Professor of Soil Science and Agricultural Chemistry for his guidance during the chemical analysis.

My sincere thanks are also due to Sri.Joy for the neat typing and prompt service.

I also express my sincere thanks to all the other staff members of the Department of Agronomy for their assistance.

My thanks are due to the workers of Agricultural Research Station, Mannuthy for their co-operation in conducting the experiment.

I also express my deep sense of gratitude to Smt.Bindu,R. for her assistance during the course of this study.

USHA, T.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

Introduction

INTRODUCTION

Agriculture is the mainstay of people in our country. Eventhough we have made big leap with respect to agricultural production since independence by introducing technological innovations in the field of agriculture, the ecological, economic and social impact of these modern agriculture have often been ignored. The future agricultural progress in the country will depend very much on the adoption of agricultural technologies which will increase productivity without creating undesirable ecological impact.

It is no longer tolerable to consider separately agriculture and forestry in the tropics and to manage forest resources as an isolated ecosystem. Multipurpose forest trees are an essential commodity for any society. Apart from its protective and aesthetic values, these forest trees provide fuel wood, food, fodder and timber to the people.

In India the forested area decreased from 40% in 1950-51 to 23% in 1981. A comparison of satellite pictures taken about ten years ago with those taken recently has revealed that the present forest cover of the country may represent only 10% of the land area; substantial areas have vanished since 1950 (GOI, 1984). The population in the country is increasing at the rate of 25% in every 10 years. The per capita land availability declined from 0.44 ha in 1921 to 0.29 ha in 1971. The per capita forest area in the country is one of the lowest in the world that it supports 15 per cent of the world population with only one per cent of the forested area of the world.

In Kerala, the most densely populated state in the country, the average size of holding is only 0.22 ha. The per capita forest availability of 0.04 ha is one of the lowest in the country. The pressure on the forest lands is bound to increase with the ever increasing population unless alternate sources are developed to meet the local demands on fuel wood, raw material, timber, fodder etc. One of the progressive methods suggested is to grow multipurpose trees of local demand in farm land itself, mixed with other agricultural crops. In Kerala growing of multipurpose trees is possible only on land which is under coconut or other cash crops. Coconut is the most important garden land crop of Kerala occupying 23.56% of the total cropped area. Thus the coconut palm is found to be amenable to intensive crop combination with many perennial and/or annual species in the inter-spaces during the early and later phases of its growth cycle (Nelliat and Krishnaji, 1976).

A multistoreyed cropping system with coconut, cocoa, pepper and pineapple was found successful in coconut gardens. Bindu (1988) observed that growing of multipurpose trees like Eucalyptus, Subabul, Glyricidia and Ailanthus is feasible in the coconut gardens of Kerala. Many annual crops were found successful in coconut gardens of Kerala (amorphophallus, cassava, greateryam, taro). So an experiment has been planned to study the feasibility of growing casuarina, a multipurpose tree and some annual crops mixed with coconut.

In this investigation, casuarina has been selected as the tree crop due to its various advantages. The wood of casuarina burns with great heat and has been called the best firewood in the world both as domestic and industrial fuel. Also its timber is strong, heavy and very tough and it is being widely used for houseposts, electric poles, tool handles, yokes etc. Eventhough casuarina is a multipurpose tree recommended for agricultural lands, there is no scientific report available on its performance in coconut gardens. Thus the objectives of this experiment were to assess

(i) the feasibility of casuarina as an intercrop in coconut gardens

(ii) the biomass production and economics of various annual crops in coconut - casuarina alleys

(iii) the influence of various component crops on soil productivity and on micro-meteorological parameters.

Review of Literature

2. REVIEW OF LITERATURE

Agroforestry has been defined as a sustainable land management system which increases the yield from the land, combines the production of crops (including tree crops) and forest plants and/or animals simultaneously or sequentially on the same unit of land, and applies management practices of the local population (Bene et al., 1977; King and Chandler, 1978).

According to Narayana (1986) it is a socially, culturally and ecologically acceptable integrated form of land use involving trees that improve or do not degrade the soil and permit increased and sustained production of plant and animal produce including wood.

The literature pertaining to the research topic is reviewed in this section under the following heads.

2.1. Agroforestry systems and practices

2.2. Intercropping of annuals with multipurpose trees

2.3. Mixed cropping in coconut gardens

2.4. Casuarina - its growth habit and multiple uses

2.5. Intercropping of coconut with seasonal crops

2.5.1. Tuber crops and intercrops

2.1. Agroforestry systems and practices

King (1978) has pointed out agroforestry as a generic term which embraces the following components.

Agrisilviculture: The conscious and deliberate use of land for the concurrent production of agricultural crops (including tree crops and forest crops).

Silvo-pastoral systems: Land management systems in which forests are managed for the production of wood as well as for the rearing of domesticated animals.

Agro-silvo-pastoral systems: Systems in which land is managed for the concurrent production of agricultural and forest crops and for the rearing of domesticated animals.

Multipurpose forest tree production systems: Systems in which forest tree species are regenerated and managed for their ability to produce not only wood, but leaves and/or fruit that are suitable for food and/or fodder.

The major agroforestry systems in the Pacific region include various forms of combination of tree crops such as coffee, coconut, cocoa, with N fixing trees such as casuarina, glyricidia and leucaena and food crops such as cassava, taro, sweet potato and yam (Vergara and Nair, 1985). Beer (1979) investigated the agroforestry practices in the wet tropics and this included the use of *Psidium guajava* as a pasture shade tree, the use of *Yucca elephantipes*, *Glyricidia sepium* and *Erythrina berteroana* as living fence posts and growing of *Cordia alliodora* for timber in coffee and sugarcane plantations. Bourke (1985) described the agroforestry system which included numerous species of annual and perennial food crops (especially bananas), Arabica coffee and *Casuarina oligodon*. It provides food, a cash crop and timber for construction and fuel and also returns on labour inputs are very favourable. Watson (1980) described the intercropping of annual fodder crops with rubber and oil palms, multistorey cropping in coconuts, mixed cropping with food trees and the taungya system with teak planting and with *Gmelina arborea*.

Inorder to reduce the loss of forest land to agriculture, Vanalakshmi, an agroforestry project was introduced in Kerala for the introduction of pepper, cocoa and medicinal plants as intercrops in plantations of teak, Grevillea robusta, Bombax sp. and aini (Artocarpus hirsutus). Initial results are promising and an internal rate of 15% was anticipated. Additional employment was also generated (Nair, 1980). Nair and Sreedharan (1986) evaluated the stability, productivity and sustainability of agroforestry homegardens in Kerala, which combine the cultivation of tree crops, plantation crops, seasonals and biennials in intimate mixture on the same piece of land. Farm animals, poultry and sometimes fisheries are also components of the system. The system is characterized by optimum utilization of available resources of land, solar energy and technological inputs and efficient recycling of farm wastes.

2.2. Intercropping of annuals with multipurpose trees

Multipurpose trees grown in agricultural lands can be intercropped with seasonal crops. Several workers have reported successful intercropping of field crops under tree species like Eucalyptus, Subabul, Glyricidia, Ailanthus etc. They include crops like blackgram (Ramachandran, 1981); soybean (Couto *et al.*, 1982); safflower, sorghum, wheat (Chaturvedi, 1983); finger millet (Sharma, 1983); fodder grasses like Guinea, Rhodes, Para, Napier, bajra hybrid and blue panic grass (Samraj, 1977; Pant, 1980); cassava (Ghosh *et al.*, 1986); cassava + groundnut or cassava + cowpea (Ghosh *et al.*, 1985), all under Eucalyptus plantations. Subabul (Leucaena) has great potential for intercropping with food crops (Maghembe and Redhead, 1982). The reports on intercropping under Leucaena include crops like maize (Kang *et al.*, 1981; Verinumbe, 1983), maize/cassava (Wilson and Kang, 1981), pigeonpea, castor, sorghum, gingelly, groundnut (Singh, 1983); hybrid napier (Gill & Patil, 1985); castor, sorghum and pearl millet (Venkateswarlu *et al.*, 1981); sweet potato (Swift, 1982); wheat (Khybri *et al.*, 1985); tobacco and summer bajra (Nambiar *et al.*, 1986). Mohatkar (1987) reported a fresh herbage yield of 80-150 t/ha/year from *Panicum maximum* intercropped in *Leucaena* grown for wood production and of 30-40 t from each of the two species when leucaena was also grown for fodder production. Kabeerathumma *et al.* (1985) reported minimum soil loss (0.25 t/ha) in Leucaena + cassava while in cassava monoculture the soil loss was 0.85 t/ha.

Tomas and Gupta (1985) suggested planting of tree species like *Casuarina equisetifolia*, *Tamarix articulata* and *Prosopis juliflora* in areas where high salinity or high water table conditions exist separately or simultaneously. Suresh and Rai (1987) studied the intercropping of Casuarina with annual crops of sorghum, cowpea and sunflower and reported that the dry matter production of the intercrops was depressed.

2.3. Mixed cropping in coconut gardens

Inter or mixed cropping in coconut gardens is very popular in the important coconut growing states in India. Intercropping is a source of subsidiary or additional income from the coconut plantations (Pillai, 1985). Thus overall productivity of land under this long duration crop can substantially be increased (Liyanage *et al.*, 1984).

The pattern of development and arrangement of leaves of the coconut crown is very important from the point of view of intercropping. The transmission of light through the coconut canopy is one of the most important factors affecting the success of intercropping programmes. Coconut has the advantage of having two periods (initially upto 8-10 years after planting and again 20 years after planting upto senescence of the crop) in its life span during which it allows sufficient light to penetrate to the ground when intercropping could be practised (Nair et al., 1974). It has been estimated that only 28% of the land area is utilized by the coconut palm (Leela and Bhaskaran, 1978). It has been shown that the rootzone of coconut palm is concentrated laterally to a radius of 2 m only and vertically between the depths of 30 cm and 120 cm from the surface (Kushwah et al., 1973).

Multi-storeyed cropping represents the most intensive type of land management in coconut areas. The concept of multistoreyed cropping is not solely based on the canopy orientation of component species at different positions to tap solar energy at vertical intervals. The root systems of the crops are also localized at distinct zones so as to explore the soil volume more thoroughly at various layers and columns than is possible under sole cropping (Nair, 1979). A combination of coconut + black pepper + cocoa + pineapple is a typical example of a multi-storeyed crop combination (Nelliat et al., 1974; Nair and Varghese, 1976). In a crop building, the top floor determines the nature and type of crops that could be combined. Multi-storeyed cropping is only possible under irrigated conditions with adequate and timely availability of inputs and other resources, and is suitable for farmers with sufficient skill and technical know-how for managing different crops (Nair, 1979).

A variety of crops have been suggested for intercropping in coconut gardens such as cassava, amorphophallus, colocasia, greater yam (Nelliat et al., 1974; Varghese et al., 1978; Ramanujam et al., 1984a). Also crops like sweet potato, lesser yam, chinese potato, ginger, turmeric, pepper, upland rainfed rice, sorghum, finger millet, Italian millet, blackgram, green gram, red gram, horse gram, cowpea, groundnut, gingelly, forage crops - grasses and legumes, pineapple, sunflower, vegetables, banana etc. were found to be successfully grown in coconut gardens (Nair et al., 1974; Nelliat, 1976; Nair and Varghese, 1976).

The practice of growing trees or shrubs of perennial nature such as coffee, papaya, plantain, clove, cinnamon, arecanut, mango and jack along with coconut is also in vogue among coconut growers (Pillai, 1985).

2.4. Casuarina - its growth habit and multiple uses

Popularly known as Beaf wood *Casuarina equisetifolia* , is exotic to mainland of India, it was first introduced in the Karwar Coast in 1668. Prior to that, it had its natural vegetation in Andamans, Bangladesh and Burma Coast. Casuarina is a large, fast growing evergreen tree with graceful appearance which attains a height upto forty metres and diameter upto sixty centimetres. It is short lived, with a natural span of life of about 50 years (Troup, 1986).

According to present concept, a fast growing species is one which yieldsa minimum yield of about 10 cu m per hectare per annum (Dwivedi, 1980). Casuarina equisetifolia grows fast in both height and girth and produces more wood and has greater productivity potential than other tree species like Acacia nelotica, Albizzia labbek, Acacia procera, Cassia siamea, Dalbergia sissoo and Prosopis juliflora. In parts of the Philippines, Casuarina equisetifolia has been known to outgrow Leucaena leucocephala and Gmelina arborea. In India, Casuarina equisetifolia saplings have been measured as growing 3 metres a year (Kulkarni and Seth, 1968).

Casuarina equisetifolia has multiple uses in modern life. Its value as a fuel of high calorific value has been exploited in India for the past two decades. It is of particular importance in afforesting vast areas of sandy beaches and shifting sand dunes along the seacoast (NAS, 1980). The main objectives of casuarina plantations are fuel supply, wood belts, stabilisation of sand dunes and aesthetics as green belts (Narayana, 1986). Casuarina species is an example of species chosen for large-scale industrial plantations in India, mainly for fuel wood (Evans, 1982). The calorific value of the wood is 4950 calories (Krishna and Ramaswami, 1932). It burns readily, even when green, and the ashes retain heat for a long time. It is often claimed to be the best fire wood in the world (Burkill, 1966). Casuarina wood is used for house posts, rafters, electric poles, masts in canoes, yokes of wheels, hammer handle etc. (CSIR, 1950).

The bark of Casuarina equisetifolia is astringent and is useful in diarrhoea and dysentry. A lotion of it is reported to be efficacious in beri-beri (Burkill, 1966). A decoction of leaves which is used in colic and powdered seeds are applied as balm in headaches (CSIR, 1950).

Casuarina is a useful rotation crop for improving poor soils of low fertility, particularly if grown with protection to allow build-up of its N-rich litter to enhance soil organic matter content (Prakash and Hocking, 1986). It is effective in improving the soil by virtue of its vigorous root nodulation with N fixing bacteria. Many species of Casuarina have bacterial nodules, the greatest number of nodules being found where the soil pH was neutral. It is also reported that some Casuarina species fix about 60 kg N/ha/year. A symbiotic fungus, *Phomopsis casuarinae* has been recorded in all organs of Casuarina. It is seen that the soil N gradually increases under Casuarina at the rate of 0.015-0.018% per year (Huxley, 1981). According to Elkan (1987), the organism responsible for nitrogen fixation in casuarina is an actinomycete belonging to the genus Frankia.

2.5. Intercropping of coconut with seasonal crops

2.5.1. Tuber crops as intercrops

Among the different annual intercrops of coconut cassava is of utmost importance in the state of Kerala. Marar (1964) studied the extent of intercropping in coconut gardens and stated that in 20% of the coconut gardens, cassava was found as an intercrop. From a very recent survey, it was reported that 40% of the cassava area in Trivandrum district of Kerala state is under the upland coconut gardens (CTCRI, 1984). A very conservative estimate shows that about 1.5 lakh ha of coconut gardens in Kerala are intercropped with cassava which constitutes about 50% of the total area under cassava (Kannan and Nambiar, 1976; Gopalasundaram and Nelliat, 1979).

Increase in height of cassava consequent to shading was reported by Ramanujam et al. (1984b). He also observed higher shoot weight in cassava planted in the shade of coconut garden and on the contrary, he observed poor tuberisation and yield in cassava under the shaded situation prevailing in coconut gardens. Pillai et al. (1985) recorded tuber yield of cassava in coconut stand as 4.3 t/ha compared to 35.7 t/ha in the open. The cassava tubers had bitter taste even after cooking. Varghese (1976) recorded 10.51 t/ha of tapioca intercropped in coconut gardens. According to Nair (1986) the productivity of cassava intercropping in coconut garden ranges from 40% to 50% of the sole crop.

The effect of intercropping cassava in coconut gardens was investigated by many research workers and it was reported that there was no perceptible deleterious effect on the productivity of coconut palms, due to the above practice, provided both crops are separately and adequately manured (Kannan and Nambiar, 1976; Gopalasundaram and Nelliat, 1979). Nair et al. (1974) also did not observe any adverse effects on growth and yield of coconut, provided both the main crop and intercrop were adequately and separately manured. Bavappa et al. (1986) reported an increase in the yield of coconut to the extent of 176% in a high density multispecies cropping system. He also observed a substantial increase in coconut biomass while the biomass of other crops remained more or less the same. Trials at CPCRI since 1972 have shown that the female flower production, setting percentage and yield of coconut have not been affected adversely by intercropping (CPCRI, 1973).

2.5.2. Fodder grasses as intercrops

Screening trials conducted by Sahasranaman and Pillai (1976) at Kasargod showed that guinea grass (*Panicum maximum*) gave green fodder yield of 50 to 60 t/ha under coconut shade. Of the several varieties and types of guinea grasses available, the plants having a more prostrate growth habit are most suitable for coconut gardens (Weightman, 1977). In a trial with guinea and hybrid napier var. Pusa giant, in coconut garden under different doses of N it was observed that guinea was superior to hybrid napier (Anonymous, 1980). The shade tolerance and high yields of guinea grass coupled with drought resistance and tolerance to less fertile soils have caused it to be used under coconuts in a number of countries (Plucknett, 1979). Erickson (1977) evaluated forage yields of 6 grasses and 6 legumes at 100, 70, 45 and 27% day light using polypropylene netting. The most shade tolerant grasses were guinea, cori and signal. Sreedharan (1975) observed that tiller production in most crop plants will be higher under higher intensities of sunlight. Mullakoya (1982) obtained maximum number of tillers in guinea grass under full sunlight and minimum number with 75 per cent shade. Myhr and Saebo (1969) observed that in some grass species, the crude protein and ash contents were approximately doubled by shading from 10 to 15% of light intensity and serious lodging occured as a result of reduction in fibre content. K contents were approximately doubled and Ca and Mg contents were increased under shade. In case of guinea grass increase in crude protein was noticed due to shading (Mullakoya, 1982). Sreedharan (1975) and Ramanagowda (1981) reported that under shade, conditions are more favourable for protein synthesis than in open area.

Studies done in coconut gardens showed that there was no adverse effect on nut yield by intercropping coconut with pasture provided both crops are adequately fertilized and supplied with enough moisture (Ferdinandez, 1973).

2.5.3. Legumes as intercrops

Tremendous potentialities and possibilities of intercropping with promising legumes exist in coconut plantations (Nair et al., 1974). Grain legumes are potential intercrops because of the relatively short duration and high protein content. Crops like blackgram, horsegram, cowpea, groundnut were found to be successfully grown in coconut gradens (Nair, 1979). Nair et al. (1974) recommended shade tolerent short duration crop of pulses such as horsegram, blackgram, greengram etc. to be raised under coconut trees taking advantage of north east monsoon rains. Zakra et al. (1986) suggested groundnut as a suitable intercrop in coconut garden. Ayyangar (1942) found that intercropped legumes increased the available phosphorus, potassium and calcium in the soil. However almost all tropical grain legumes are very sensitive to the partial shade existing in coconut gardens (Nair, 1979). Artificial shade of 40-50% reduced sunlight caused a yield reduction of 30% compared to that in full sunlight for soybeans and about 70% for mungbeans (*Vigna radiata* L.) (Catedral and Lantican, 1977).

2.5.4. Cereals as intercrops

One of the earliest reports on raising rice as an intercrop in coconut gardens is from Nileshwar (Anonymous, 1934) and it was not very encouraging as the grain yield was only 160 kg/ha. However, upland rice variety Kattamodan was successfuly grown as an intercrop in coconut garden at Coconut Research Station, Pilicode and among the various grain crops tried, rice sown in June was found to be 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. Pillai (1985) also reported successful inter-cropping of rice in coconut gardens. Martin (1984) showed that rice and maize are suitable as intercrops under mature stands of coconut. Also crops like sorghum, finger millet, and Italian millet were found to be successful (Pillai, 1985). Zakra et al. (1986) recommended maize as one of the intercrops in a coconut-food crop intercropping trial, in which the intercrop was found to favour coconut growth and development. Baker (1978) reported that intercropping of cereals with groundnuts gave 27.7% greater cash returns than sole cropping. Pascual et al. (1978) showed that it was feasible to grow grain sorghum after low land rice in the dry season even without supplemental irrigation. In field trials, greengram, blackgram, cowpea or redgram were grown in relay or sequential cropping systems with rice cultivar Triveni where the rice yields (2.3-2.5 t/ha) were uneffected by cropping system (Joy et al., 1986).

2.6. Cassava-groundnut intercropping

Intercropping cassava with other short duration crops has been in practice since the beginning of this century (Marcus, 1935). As cassava is a widely spaced crop and takes about four months to attain full canopy, there is possibility of raising some legumes as intercrops with cassava (Mohankumar and Hrishi, 1978). Intercropping tapioca with seasonal crops has been proved to be the most effective method for increasing the net income by the use of available light and nutrients more effectively (Suryatna and Hardwood, 1976).

In an intercropping trial in cassava it was seen that groundnut gave the most satisfactory performance (Singh and Mandal, 1970; Mohankumar, 1975; Mohankumar and Hrishi, 1978). Companion cropping trials conducted in the rainfed uplands indicated that both cassava and groundnut are ideally suited to the resource pattern of the small farmer and that groundnut could be raised as a companion crop in the marginal lands where monoculture of cassava is the present rule (Thomas and Nair, 1979). Trials conducted in Kerala Agricultural University indicated the suitability of groundnut varieties like JL-24, Pollachi-1, Pollachi-2, PSB-7-2 and TMV-2 as intercrops in cassava (KAU, 1984).

Ekmahachai <u>et al</u>. (1978) reported that cassava intercropped with two rows of groundnut (30 x 20 cm) between cassava rows was found to be more profitable than the cassava monocrop and cassava intercropped with three rows of peanuts between its rows. Favourable effects of double row planting of cassava on groundnut productivity was also reported by Ezumah and Okigbo (1980).

It was reported that there was no significant reduction in yield of cassava when intercropped with groundnut (Patanothi et al., 1977; Sheela, 1981). Thomas and Nair (1979) reported an additional production of tuber on account of growing groundnut as a companion crop. Bridgit (1985) also observed an increase in tuber yield of cassava when intercropped with groundnut. Sheela (1981) reported that the growth of cassava was suppressed by legume intercropping in the early stages, but later it recouped its vigour and growth and by the time of harvest no difference was perceptible.

But contrary to this, experiments conducted at CTCRI, Trivandrum invariably showed that the yield of cassava was reduced by growing intercrops such as groundnut (Mohankumar, 1980; CIAT, 1982; Anilkumar, 1984). Prabhakar et al. (1979) reported that the reduction in the yield of cassava consequent to intercropping was due to interspecies competition and the resultant reduction in tuber number and weight.

Kawano and Thung (1982) were of the opinion that cassava could be planted in association with short duration crops without sacrificing much of the yield of either crop, and high yielding cassava genotypes with low vegetative vigour would bring about high combined yields of cassava and the associated crops. Suggestions for improving cassava productivity in mixed cropping and intercropping systems include the use of late maturing cassava varieties, reducing the population of associated crop and allowing long recovery intervals after the harvest of intercrop (Okoli and Wilson, 1986).

2.7. Maize-cowpea intercropping

Leather (1897) was the pioneer scientist in India to ponder over the speculation that legumes might benefit non-legumes growing alongside them. Relwani (1970) reported that leguminous crops are rich in proteins while cereal fodders constitute an excellent source of energy. It has been observed that the presence of succulent feed, particularly green leguminous forages like lucerne, berseem and cowpea can increase the palatability of the fodder and can help to digest crude fibre present in the straw (Singh, 1975).

Singh and Relwani (1978) found that in association with maize, cowpea was significantly superior to velvet bean in green matter, dry matter, ether extract, Ca, Mg, P and ash yields and was on par with velvet bean in crude protein yield. Kassam (1976) reported that cowpea, when grown mixed with other crops was adapted more to lower light intensity. Permeti (1969) observed that maize-cowpea mixture gave higher yield than maize-soybean mixture under identical conditions of soil and climate. Morachan *et al.* (1977) reported cowpea as the best intercrop giving maximum yield.

Arthur (1971) reported that grasses yield more when competing with legumes than when competing with each other. It was observed that maize plants grew taller as mutual shading increased which in turn increased the leaf stem ratio (Duncan, 1975). Ahlawat *et al.* (1964) recorded increased fodder yield due to association with legumes. Remison (1978) found that mixtures of maize and cowpea outyielded the mean yields of the pure stands. Kassam (1976) reported that cowpea, when grown mixed with other crops was adapted more to lower light intensity. Guljaev and Ronsal (1962) observed that growth of maize was stimulated by secretions from the roots of cowpeas. An increase in growth and growth characters of plants in a maize-legume intercropping system was observed by Chand (1977). In a maize-cowpea mixture the yield of each crop was nearly as great as that of their monocrops (Anonymous, 1955). Syarifuddin *et al.* (1974) obtained decreased yield of legumes which were grown as intercrops in maize but the high yields of maize compensated for the reduction in yields of these legumes. Ahmed and Gunasena (1979) reported that as a general rule maize yields were some what decreased by intercropping particularly at lower N levels. It was reported that the maize + cowpea mixture produced higher green and dry matter yield than maize + velvet bean (Singh and Relwani, 1978).

Ahmed and Gunasena (1979) found that the crude protein content of the intercrop system was much higher than that of the maize monocrop. Crude protein content in cowpea grown with maize was higher than that grown with sorghum (Anonymous, 1974).

Madok (1940) observed no beneficial effect of legumes on non-legumes in 20 out of 26 experiments. Blackman and Black (1959) found that physiological and ecological aspects, especially light, limit the growth of the crops in mixtures. Donald (1963) reported that in a mixed cropping the yield of legume was depressed more than that of non-legumes. Sharma and Singh (1972) observed that the total dry matter yield of maize-cowpea in alternate rows decreased in comparison with planting of maize alone. Agboola and Fayemi (1971) observed competition for light between maize and legume, wherein legume was suppressed by maize shade. Willey and Osiru (1972) found that mixtures of fodder crops require a higher population pressure to produce their maximum yield.

Haizel (1974) noticed that when maize was intercropped with cowpea, the former was found to be more competitive than the latter upto the time of tasseling. There after cowpea was more competitive than maize. Meenakshi *et al.* (1974) reported no adverse effect on the maize crop when it was intercropped with cowpea. Singh and Chand (1969) found that yields of a pure crop of maize and maize-legume mixture were more or less the same. Agboola and Fayemi (1970) observed no suppression of legume by maize when they were grown together and also found that maize yield was not decreased by intercropping.

In an intercropping system involving a legume and a non-legume, part of the N fixed in the root nodule of the legume may become available to the non-legume component ([illegible], [illegible]; Palaniappan *et al.*, 1976; Morachan *et al.*, 1977; Soundararajan and Palaniappan, 1979). Very low rates of N transfer from legumes to non-legumes over periods of six months to two years was observed by Henzell

(1962). He also observed that the quantity of N transferred to non-legume by different legumes varied irrespective of the quantity fixed by each legume (Henzell, 1970).

2.8. Residual effect of intercropping on soil

Bavappa *et al*. (1986) reported that there was a build up of phosphorus and potassium nutrients in the coconut and arecanut based high intensity multispecies cropping system. There was improved microbial activity in the systems and no serious pest and disease management problems were indicated due to high density cropping system approach. Pillai (1985) noted a reduction in soil pH due to intercropping. He also found a reduction in the available nitrogen content of the soil and phosphorus and potassium content of the soil were not affected much by intercropping.

Singh and Chatterji (1968) reported that nitrogen accumulated in the soil wherever legumes grow well. Skerman (1977) recorded more nitrogen fixation in shade than in open area. White *et al*. (1976) reported that total nitrogen content of the soil was increased by growing forage grasses. Ayyangar (1942) found that intercropped legume increased the available phosphorus, potassium and calcium in the soil.

Conclusion

Agroforestry is now receiving renewed attention by agricultural scientists. The real increase in the quantity and variety of food stuffs due to agroforestry in addition to its role in soil rehabilitation and in conjunction with other land use agents are now widely recognised. There is little doubt that in the initial stages of a forest plantation existence, trees can be grown together with annual agricultural crops. There is also evidence that generally most agricultural crops have no adverse effect on forest crops and vice versa (Ogbe, 1967). Also it is seen that mixed cropping of annual crops is a more efficient means of utilising land area than pure stands. It would appear, therefore, that there are sufficient grounds for assuming that agri-silvicultural systems might provide one of the answers to the maximum utilisation of fragile ecosystems (Francis, 1986).

Materials and Methods

3. MATERIALS AND METHODS

The details of the materials used and the techniques adopted during the course of the investigation are presented in this chapter.

3.1. Experimental site

The experiment was conducted in the pre-bearing coconut gardens of the Agricultural Research Station, Mannuthy, Trichur district. The station is situated at 12° 32' N latitude and 74° 20' E longitude and at an altitude of 22.25 m above MSL. This area enjoys a humid tropical climate with an annual rainfall of 3406 mm per annum. The meteorological data during the crop periods are presented in Appendix-I.

3.2. Season

The experiment was conducted during the period May 1987 to May 1988.

3.3. Soil characteristics

Composite soil samples from 0-15 cm depth were drawn before the commencement of the experiment and were used for the determination of physical and chemical properties which are given in Table 1.

Table 1. Physical and chemical properties of the soil before the experiment

Particulars	Value	Method employed
<u>Physical properties</u>		
Sand (%)	62	
Silt (%)	12	Hydrometer method (Piper, 1942)
Clay (%)	26	
Particle density	2.41	Core method (Piper, 1942)
Bulk density (g/cm^3)	1.33	
Maximum water holding capacity (%)	34.07	Keen-Raczkowski box method (Keen and Raczkowski, 1921)
<u>Chemical properties</u>		
Organic carbon (%)	1.3	Walkley and Black method (Jackson, 1958)
Available nitrogen (%)	0.125	Alkaline permanganate method (Subbiah and Asija, 1956)
Available phosphorus (ppm)	34	Chlorostannous reduced molybdophosphoric blue colour method in hydrochloric acid system (Jackson, 1958)
Exchangeable potassium (ppm)	135	Flame photometry neutral normal ammonium acetate extraction (Jackson, 1958)
Soil reaction (pH)	5.4	Soil water suspension of 1:2.5 (Hesse, 1971)
EC (millimhos/cm)	0.07	Soil water suspension of 1:2.5 (Hesse, 1971)

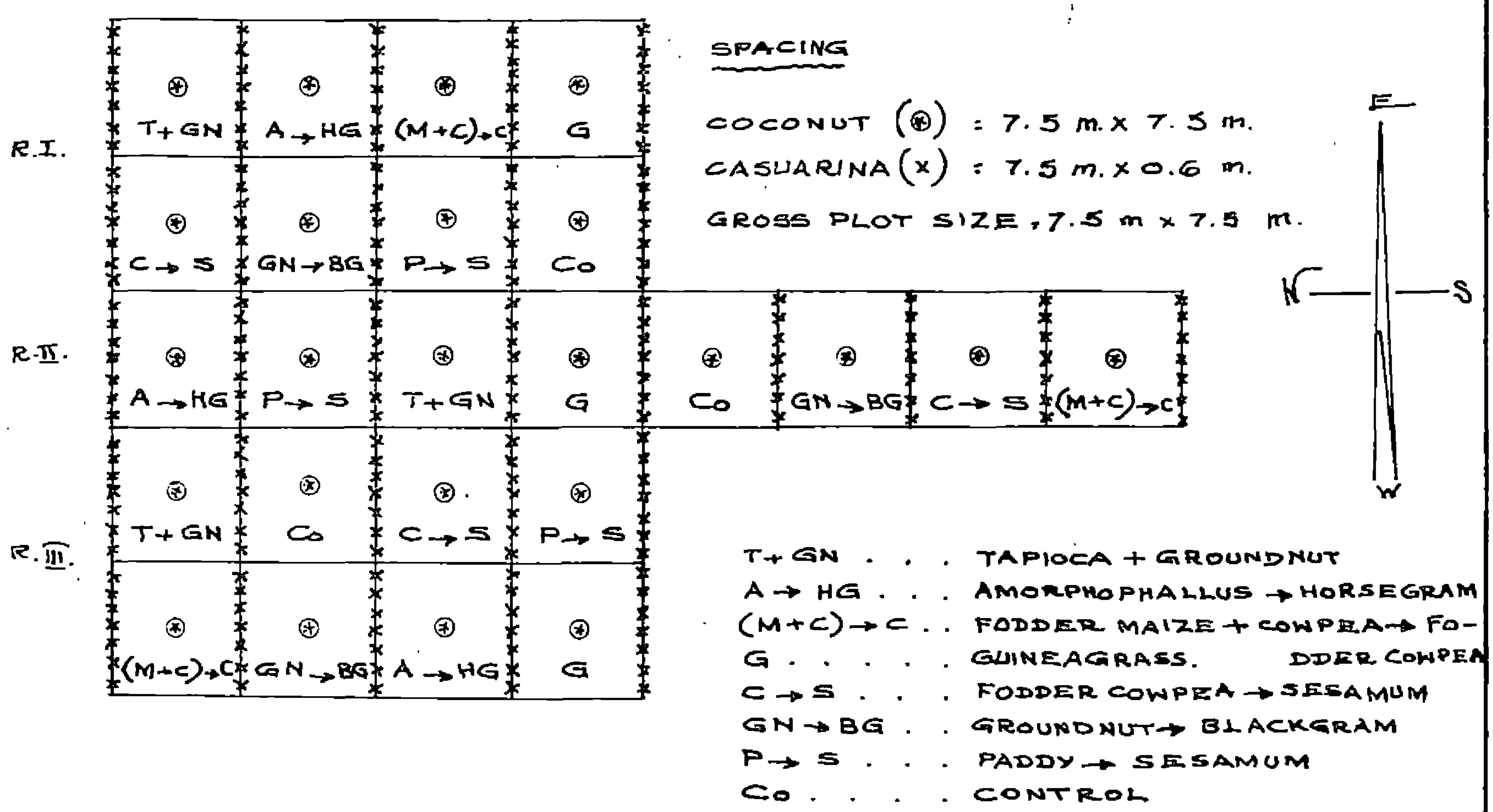


FIG. 1. PLAN OF LAYOUT

3.4. Cropping history

The experimental field was a three year old Laccadive ordinary coconut plantation established at the station in the year 1984. Six months old casuarina seedlings were planted in single row at a spacing of 60 cm in between two rows of coconut trees which had a spacing of 7.5 m x 7.5 m (Fig. 1). The planting of the casuarina plants was done in June 1985. The interspaces were left fallow previous to the experiment.

3.5. Treatments

The treatments of the investigation were inter-cropping of the coconut-casuarina alleys with the following annuals.

Treatments	Notations used*
1. Cassava intercropped with groundnut	T + GN
2. Amorphophallus followed by horsegram	A → HG
3. Fodder maize-cowpea mixture followed by fodder cowpea	(M+C) → C
4. Guinea grass throughout the year	G
5. Fodder cowpea followed by sesamum	C → S
6. Groundnut followed by blackgram	GN → BG
7. Modan paddy followed by sesamum	P → S
8. Control (without any intercrops)	CO

*These notations will be used hereafter in this dissertation wherever necessary.

Table 2. Details of the intercrops

Crop	Variety	Duration	Spacing	Plant population (thousand per hectare)
1. Tapioca (*Manihot esculenta* Crantz.)	M_4	8 months	90 x 90 cm	11.66
2. Groundnut (*Arachis hypogaea* Linn.)	TMV-2	110 days	15 x 15 cm*	419.64
3. Amorphophallus (*Amorphophallus companulatus* Roxb.)	Local	8 months	90 x 90 cm	11.66
4. Horsegram (*Dolichos biflorus* Linn.)	Local	75 days	25 x 25 cm	151.07
5. Fodder maize (*Zea mays* Van Houtte)	HGT-3	60 days	30 x 15 cm	209.82
6. Fodder cowpea (*Vigna unguiculata* Linn.)	Kanakamony	60 days	25 x 15 cm**	251.78
7. Guineagrass (*Panicum maximum* Jacq.)	Mackueni	Perennial	50 x 30 cm	62.95
8. Sesamum (*Sesamum indicum* Linn.)	Thilothama	75 days	15 x 15 cm	419.64
9. Blackgram (*Vigna mungo* Linn.)	T_9	90 days	25 x 15 cm	251.78
10. Modan paddy (*Oryza sativa* Linn.)	Suvarnamodan	115 days	20 x 15 cm	314.73

* 30 x 20 cm, when intercropped with tapioca (plant population in thousand/ha - 157.37)
** 30 x 15 cm, when grown with fodder maize (plant population in thousand/ha - 209.82)

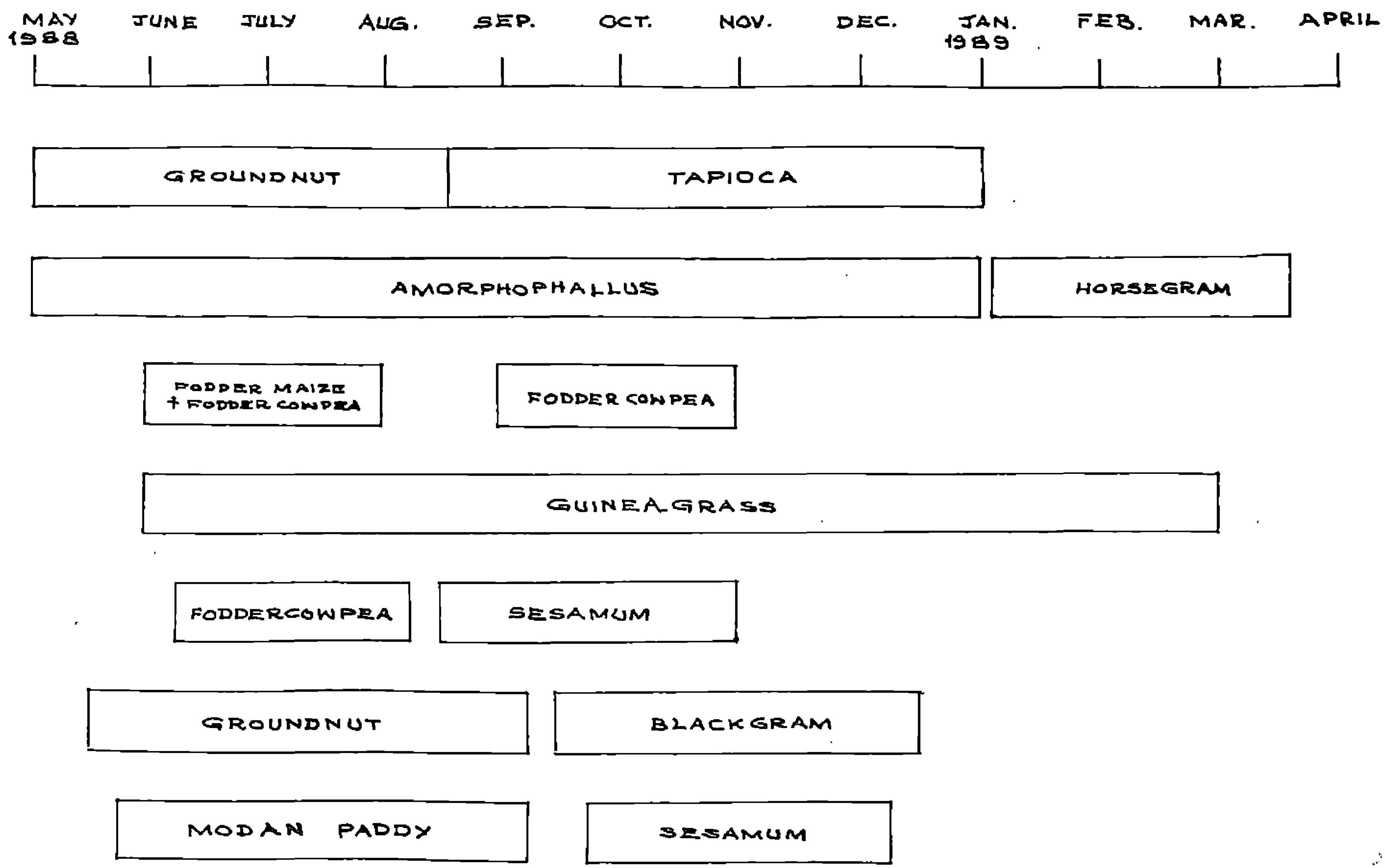


FIG. 2. SCHEDULE OF THE INTERCROPS IN THE COCONUT-CASUARINA ALLEYS

The alley cropping pattern is illustrated in Fig. 2.

The experiment was laid out in RBD, replicated thrice. Each experimental plot thus had a coconut palm in the centre and casuarina plants on the two sides. The gross size of the plot was 7.5 m x 7.5 m. The details on varieties, duration and plant population are given in Table 2.

3.6. Cultural operations

The cultural practices and manurial practices recommended for the state (KAU, 1986) were followed with respect to the main crop as well as the alley crops.

3.6.1. Tapioca intercropped with groundnut

Single tapioca setts were planted on soil mounds formed at a spacing of 90 x 90 cm. Groundnut seeds were sown at a spacing of 30 x 20 cm, in the interspace between tapioca. Two rows of groundnut were planted between the rows of tapioca. Cattle manure was applied at the rate of 12.5 t/ha during land preparation. The basal fertilizer dose 50:100:50 kg N, P_2O_5, K_2O/ha was broadcast uniformly in the field. One month after sowing, a fertilizer mixture containing 20 kg P_2O_5 and K_2O and 10 kg N/ha was given to the intercrop, groundnut and earthing up was done. All the excess shoots on tapioca plants were removed after retaining two shoots in opposite direction. At the time of harvest of groundnut the haulms were incorporated into the soil along with a top dressing of 50 kg each of N and K_2O per hectare for tapioca. Groundnut was harvested 110 days after planting and the tapioca after 240 days.

3.6.2. Amorphophallus followed by horsegram

Amorphophallus was planted in pits of size 60 x 60 x 45 cm at a spacing of 90 cm apart. Two kilograms of cattle manure was mixed with the top soil of each pit and the pits were refilled. Cutpieces of corm weighing one kg each were planted in these pits. Before planting, the corm pieces were dipped in cowdung and dried under shade. The pits were mulched with dry leaves immediately after planting. Forty five days after planting 40:60:50 kg each N, P_2O_5, K_2O/ha were applied along with intercultivation and weeding. The second dose of fertilizer, 40 kg N and 50 kg K_2O/ha were applied one month after the first application along with second weeding and earthing up. The crop was harvested after 8 months.

After the harvest of amorphophallus, the land was prepared for sowing horsegram seeds. P was applied at the rate of 25 kg/ha. The seeds were dibbled in rows spaced at 25 cm. The crop was harvested after 75 days. The haulm of horsegram was incorporated into the soil.

3.6.3. Fodder maize-cowpea mixture followed by fodder cowpea

Fodder maize seeds were dibbled on beds at a spacing of 30 x 15 cm. In between rows of maize, cowpea seeds were sown 15 cm apart. Farm yard manure was applied at the rate of 10 t/ha during land preparation. A basal dressing of N, P_2O_5 and K_2O at the rate of 25:60:30 kg/ha and top dressing of N, P_2O_5 and K_2O at the rate of 120:60:40 kg/ha respectively were given. Fodder cowpea and fodder maize were harvested after 60 days.

The land was ploughed and levelled and fodder cowpea seeds were dibbled at a spacing of 25 x 15 cm. Basal dressing of N, P_2O_5 and K_2O at the rate of 25:60:30 kg/ha respectively was done. The crop was harvested after 60 days and the yield was recorded.

3.6.4. Guinea grass

After ploughing and levelling, 10 cm wide and 20 cm deep trenches were made at a spacing of 50 cm. These were refilled with farm yard manure at the rate of 10 t/ha and P_2O_5 and K_2O at the rate of 50 kg each along with the top soil. The trenches were reformed to ridges of 15 cm height on which the grass slips were planted at a spacing of 30 cm. First cutting of the crop was taken after 45 days. Ammonium sulphate at the rate of 100 kg N/ha was applied after the first cutting. Another dose of N (100 kg/ha) was given during the north east monsoon period (80 days after planting). A total of six cuttings were taken from this crop.

3.6.5. Fodder cowpea followed by sesamum

The land was ploughed and levelled. The cowpea seeds were dibbled at a spacing of 25 x 15 cm. Basal dressing of N, P_2O_5 and K_2O at the rate of 25:60:30 kg/ha was applied. The crop was cut after 60 days and yield recorded.

After the harvest of fodder cowpea, the land was again ploughed and levelled. The sesamum seeds were broadcast evenly after mixing with sand 2-3 times its volume. A fertilizer dose of 30:15:30 kg/ha of N, P_2O_5 ar K_2O respectively were given at the time of sowing. Thinning of the crop was done in order to give a spacing of 15-25 cm between plants. The crop was harvested after 75 days.

3.6.6. Groundnut followed by blackgram

The soil was ploughed to fine tilth and cattle manure was applied at the rate of 2 t/ha. A fertilizer dose of 10:75:75 kg N, P_2O_5 and K_2O per hectare respectively was also applied and groundnut seeds were dibbled at a spacing of 15 x 15 cm. Lime was applied at the rate of 1000 kg/ha 30 days after planting. The lime was incorporated in to the soil by raking. Groundnut was harvested 110 days after planting.

After the harvest of groundnut, the land was ploughed and levelled and the blackgram seeds were sown at a spacing of 25 x 15 cm. 10 kg N/ha, 30 kg each of P_2O_5 and K_2O/ha were applied at the time of ploughing. 10 kg N/ha was given as top dressing at two equal doses in the 15th day and 30th day after sowing. The crop was harvested 90 days after sowing.

3.6.7. Modan paddy followed by sesamum

At the time of preparation of land farm yard manure was applied at the rate of 5 t/ha. The paddy seeds were dibbled so as to get a spacing of 20 x 15 cm. The recommended N fertilizer (60 kg/ha) was applied in three equal split doses - first as basal dressing, second at tillering stage and third at panicle initiation stage. The entire P and K fertilizer was applied basally (30 kg/ha each). The crop was harvested when 80% of the panicles turned yellow and the yield recorded.

After the harvest of the paddy the land was ploughed to fine tilth and cattle manure was applied at the rate of 5 t/ha. Sesamum seeds were sown and managed as explained earlier.

3.7. Observations on growth and yield

3.7.1. Growth characters of coconut and casuarina

3.7.1.1. Height and girth

The height, girth (at a height of 10 cm from the ground level) of coconut and casuarina were recorded at monthly interval from the beginning to the end of the experiment. The number of leaves per coconut tree and the canopy spread of casuarina trees were also recorded.

3.7.1.2. Volume and fuel wood productivity of casuarina

The tree volume was calculated by employing the formula,

$$V = BA \times h \times F.f$$

where V = Volume in cum

BA = basal area in m^2

h = height in m

F.f = form factor which was taken as 0.9

The fuel wood productivity in t/ha was found out by dividing the volume in cum by a factor 2 (Recknagel and Bentley, 1985).

3.7.2. Growth characters of the intercrops

3.7.2.1. Tapioca

In each plot 5 plants were selected at random for recording the following observations.

a. Height of plants: The height of plants in cm was recorded at 60, 120, 180 and 240 days after planting. The heights of the plants were taken from the bottom of the sprout to the tip of the leaves. The average height of plant was worked out from the height of the five sample plants.

b. Number of leaves: The number of leaves were recorded at two months, four months, six months after planting and at harvest. The number of functional leaves and the number of leaves that had fallen were also recorded.

c. Yield: The weight of clean tubers was recorded at the time of harvest and expressed as t/ha.

d. Number of tubers: The total number of tubers per plant was recorded at harvest.

e. Length of tubers: The length of all the tubers of a plant was measured and the average value recorded in cm.

f. Girth of tubers: The girth at the centre of all the tubers from a plant was measured and the average value recorded in cm.

3.7.2.2. Groundnut

a. Height of plants: The plant height was measured from the base to the growing tip at 30, 60, 90 days after sowing and at harvest and was expressed in cm.

b. Number of branches: The number of branches produced by the observational plants was counted at 30, 60, 90 DAS and at harvest.

c. Total number of nodules: Total number of nodules per plant were counted at 30, 60, 90 DAS and at harvest. Plants for destructive sampling were used for the nodule count.

d. Date of flowering: The date on which 50 per cent of the plants in the plot had flowered was taken as the date of flowering.

e. Yield of pods: The pods harvested from each plot were sun dried to the desired moisture level for safe storage. The weight of unshelled pods was taken and the yield expressed in kg/ha.

f. Yield of haulm: The haulm obtained from each plot was sun dried and total weight was recorded. Yield was expressed in kg/ha.

g. Number of pods per plant: Average number of pods per plant was worked out by counting the total number of pods from the observation plants.

h. Weight of pods per plant: Average weight of pods per plant was calculated from the total weight of all the pods from the observation plants.

i. Hundred seed weight: From each plot, 100 dry seeds were taken at random and their weight recorded.

3.7.2.3. Amorphophallus

a. Height: The height of the plant was measured from the ground level to the point of forking at 2 months interval. The average height per plant was worked out and recorded in cm.

b. Girth: Girth at the base of the stem was recorded for 5 plants at 2 months interval and the average value worked out and presented in cm.

c. Yield: The corms were cleaned after harvest and their weight was recorded and presented in t/ha.

3.7.2.4. Horsegram

a. Height: Height of plants were recorded for 10 plants and the average value per plant was worked out at the time of harvest.

b. Number of branches: The number of branches were counted for 10 plants and the average number of branches per plant was recorded.

c. Number of pods: The total number of pods per plant was counted for 10 plants and the average value per plant was worked out.

d. Number of seeds per pod: Pods were taken at random and the total number of seeds in each pod were recorded and the average number of seeds per pod was worked out.

e. Yield of grain: The grain yield per plot was recorded at the time of harvest. The per hectare yield was worked out from this.

f. Yield of haulm: The fresh yield of haulm at harvest was recorded and expressed in kg/ha.

3.7.2.5. Fodder maize

a. Plant height: The height was recorded from each plot at 20, 40 and 60 days (at harvest) after planting. The height from the base of the plant to the tip of the growing point was measured in ten observation plants and the mean worked out.

b. Number of leaves: The total number of leaves in the observation plants of maize was recorded on 20th day, 40th day and 60th day (at harvest) and the mean number per plant was worked out.

c. Leaf-stem ratio: The samples taken for dry matter estimation at harvest were separated into leaf and stem and the ratio was recorded.

d. Green fodder yield: The green fodder yield of maize from each plot was recorded and expressed in t/ha.

3.7.2.6. Fodder cowpea

a. Height of plant: The height from the base of the plant to the tip of the growing point was measured on the ten observation plants at three stages of growth viz., 20th day, 40th day and 60th day (harvest) after sowing. The mean height of the plants was worked out and recorded.

b. Number of leaves: The mean number of leaves per plant was worked out from the total number of leaves in the observation plants. This was recorded on the 20th day, 40th day and 60th day after sowing.

c. Green fodder yield: The green fodder yield of the crop from each plot was recorded and expressed in t/ha.

3.7.2.7. Guinea grass

a. Height of plants: The height of the plants was recorded prior to each cutting. The height was measured from the base of the plant to the tip of the longest leaf.

b. Tiller count: The number of tillers were counted prior to each harvest and recorded.

c. Leaf-stem ratio: The samples taken for dry matter estimation were separated into leaves and stem. Their weight was recorded and the ratio calculated.

d. Green fodder yield: The green fodder yield from each plot was recorded immediately after each harvest. A total of six cuttings were taken at 45 days intervals and the yields were expressed in t/ha.

3.7.2.8. Sesamum

a. Height of plants: The height of the plants was measured on ten observation plants at the time of harvest and the mean worked out. The height was measured from the base of the plants to the tip of the growing point.

b. Number of branches: Total number of branches of the observation plants were noted and the average value recorded.

c. Number of days to flowering: The number of days taken for 50 per cent of the plants to flower was recorded.

d. Number of pods per plant: The total number of pods from the observation plants was counted and the average worked out.

e. Seed yield: The pods harvested from each plot were sun dried, threshed, winnowed, cleaned and the weight of seeds was recorded and expressed in kg/ha.

f. Number of seeds per pod: Twenty pods were selected at random from the observation plants, the total number of seeds counted and the average worked out.

g. Thousand seed weight: From each plot, thousand dry seeds were taken at random and their weight recorded in grams.

3.7.2.9. Blackgram

Ten plants were taken at random after eliminating the border rows and all the biometric observations were recorded from these plants at 30 days interval.

a. Plant height: From the observation plants marked for biometric observations, the height of the plant was measured from the base of the plant to the growing tip and the average worked out and expressed in cm.

b. Number of branches: The average number of branches per plant was worked out by counting the number of branches on the observation plants.

c. Number of pods per plant: The total number of pods from the observation plants was counted and the average worked out.

d. Number of seeds per pod: Twenty pods were selected at random from the observation plants, the total number of seeds counted and the average worked out.

e. Yield of grain: The pods harvested from each plot were sun dried, threshed, winnowed, cleaned and weight of clean seeds was recorded. Yield was expressed in kg/ha.

f. Yield of haulm: Stover obtained from each plot was sun dried, total weight recorded and yield expressed in kg/ha.

3.7.2.10. Modan paddy

a. Height of plant: The plant height was recorded on the day of harvest. Height of plant was measured in centimetres from the bottom of the culm to the tip of the earhead.

b. Number of tillers: The total number of tillers was counted from 10 hills at harvest and the average was expressed as number of tillers per hill.

c. Productive tillers: At harvest, the number of productive tillers was counted from 10 hills and their average expressed as number of productive tillers per hill.

d. Percentage of productive tillers: From the total number of tillers and number of productive tillers, percentage of productive tillers was calculated.

e. Length of panicle: The length from the neck to the tip of the panicle was measured and expressed in cm.

f. Number of grains per panicle: The number of filled grains per panicle in each plot was recorded.

g. Weight of thousand grains: Thousand grains were counted from the cleaned produce from each plot and the weight recorded in g.

h. Grain yield: The grain harvested from each net plot was dried, cleaned, winnowed and weighed and expressed in kg/ha at 14% moisture level.

i. Straw yield: The straw from each net plot was dried under sun and the weight recorded in kg/ha.

3.7.2.11. Biomass production by the intercrops

Plants were selected at random at the time of harvest and the samples were dried in the oven. From the oven dry weights of these samples, total dry matter (biomass) production in kg per hectare was worked out. The per day biomass productivity was also worked out by dividing the total biomass production by the duration (in days) of the cropping system.

3.8. Plant analysis

3.8.1. Crude protein yield from the intercrops

Crude protein yield of the intercrops was calculated from the biomass production and the crude protein content of the intercrops. The crude protein content was estimated by multiplying the N percentage with 6.25 (AOAC, 1950).

3.8.2. Nutrient uptake

The plant samples were dried in an oven at 70°C and ground to fine powder. Total nitrogen content was estimated by microkjeldahl method (Jackson, 1958) and expressed as percentage. The phosphorus content was estimated colorimetrically by the vanado-molybdate method (Jackson, 1958). The potassium content was determined using a flame photometer and expressed as percentage (Jackson, 1958). The calcium and magnesium content in plant digests were estimated by atomic absorption spectrophotometry (Jackson, 1958).

The total uptake of N, P and K was worked out from the nutrient content and dry matter production.

3.9. Soil Analysis

The physical and chemical properties of the soil were studied before and after the experiment.

3.9.1. Physical properties

a. Bulk density and particle density:

The conventional core method (Piper, 1942) was used for determining the bulk density and particle density of the soil prior to and after the experiment.

b. Maximum water holding capacity:

This physical constant of the soil was determined using Keen Raczkowski box before and after the experiment (Keen and Raczkowski, 1921).

c. Percentage of pore space:

Using Raczkowski box, the percentage of pore space for the soil was determined before and after the crops.

3.9.2. Chemical properties

Composite soil samples were taken from each plot prior to the experiment and after the harvest of the crops. Samples were taken at 0-15 cm depth. The soil samples were then air dried and passed through a 2 mm sieve.

a. Organic carbon:

Walkley and Black method (Jackson, 1958) was used for the determination of organic carbon content of the soil.

b. Available nitrogen:

The alkaline permanganate method was used for determining the available nitrogen content of the soil (Subbiah and Asija, 1956).

c. Available phosphorus:

Available phosphorus content of the soil was determined colorimetrically using Bray I extractant and molybdophoric acid method in hydrochloric acid system (Jackson, 1958).

d. Exchangeable potassium:

The exchangeable potassium content was determined flame photometrically, using neutral normal ammonium acetate extract (Jackson, 1958).

e. Exchangeable calcium:

Exchangeable calcium content of the soil was determined by atomic absorption spectrophotometry using neutral normal ammonium acetate extract (Jackson, 1958).

f. Exchangeable magnesium:

Exchangeable magnesium content of the soil was estimated by atomic absorption spectro photometry using neutral normal ammonium acetate extract (Jackson, 1958).

g. Available sulphur:

Available sulphur content of the soil was determined by turbidimetry (Jackson, 1958).

h. pH:

The pH of the soil was determined in a 1:2.5 soil-water suspension using a pH meter.

i. Electrical conductivity (E.C.)

The E.C. of soil was determined in a 1:2.5 soil-water suspension after allowing the soil particles to settle down. The readings were taken in supernatent liquid using a conductivity bridge.

3.10. Root distribution of casuarina

Distribution of roots of casuarina at different lateral distances from the tree trunk viz., 0 to 20 cm, 40 cm, 60 cm, 80 cm, 100 cm, 120 cm, 140 cm, 160 cm, 180 cm, 200 cm, 220 cm, 240 cm, 260 cm, 280 cm and soil depths viz., 10 cm, 20 cm, 30 cm, 40 cm, 50 cm were studied using root excavation method (Athul Chandra and Yamadagni, 1983). The number of root tips occuring in $100cm^2$ at these various distances were counted and was later expressed as percentage over the total number of root tips recorded.

3.11. Economics

The economics of cultivation of the different annuals in coconut - casuarina alleys were calculated. Cost-benefit ratios were also worked out for the different cropping systems.

3.12. Micro-meteorological observations

The influence of the different component crops on the soil temperature and relative humidity at 30 cm, 60 cm, 120 cm and 180 cm heights were recorded periodically.

3.12.1. Soil temperature

Soil thermometers (5 cm) were installed during September, 1987 in all the treatments in one of the replications at randomly selected location. Soil temperatures were recorded twice a day at 7.25 AM and 2.25 PM at weekly intervals.

3.12.2. Relative humidity

Whirling psychrometer readings were taken at heights of 30 cm, 60 cm, 120 cm and 180 cm from all the plots in which soil thermometers were installed. This was also taken twice a day at 7.25 am and 2.25 pm at weekly intervals. The maximum and minimum temperatures from the whirling psychrometers were noted and relative humidity calculated.

3.13. Statistical analysis

The data recorded were statistically analysed by analysis of variance technique (Panse and Sukhatme, 1978).

Results and Discussion

4. RESULTS AND DISCUSSION

The results obtained in the present experiment to evaluate the biomass productivity and influence of intercrops in coconut-casuarina alleys are presented and discussed in this chapter under the following heads.

4.1. Performance of the component crops in the coconut-casuarina alleys

4.1.1. Growth and yield attributes

4.1.2. Total biomass productivity

4.1.3. Plant analysis and uptake studies

4.1.4. Influence on physical and chemical properties of soil

4.1.5. Economics of the different cropping systems under coconut-casuarina alleys

4.2. Growth and root distribution pattern of casuarina

4.3. Growth of coconut

4.4. Influence on micro-meteorological parameters

4.4.1. Soil temperature

4.4.2. Relative humidity

4.1. Performance of the component crops in the coconut-casuarina alleys

4.1.1. Growth and yield attributes

4.1.1.1. Tapioca

The plant height of tapioca intercropped in coconut-casuarina alleys increased from 65 cm at 60 DAP to 248 cm at 240 DAP (Table 3). The number of leaves increased from 35 to 225 during this period. The plants in the coconut-casuarina alleys were relatively taller and the number of leaves were less compared to the sole crop data reported by Bridgit (1985) for the same variety. The average number of tubers observed per plant was 5. This is much less than the number of tubers generally observed for this variety under sole crop situation. In an earlier experiment in this location with the same variety, Bridgit (1985) had observed nine tubers per plant for the sole crop. The length of the tuber was comparable with those of the sole crop data, but the girth of the tubers was lower. The tuber yield of 10.3 t/ha recorded for the alley cropped tapioca was much lower than the reported sole crop yield of this variety. Bridgit (1985) recorded a sole crop yield of 19.6 t/ha and Bindu (1988) reported a sole crop yield of

Table 3. Biometric observations on tapioca intercropped with groundnut in the coconut-casuarina alleys (T + GN)

Growth/yield attributes	Days after planting			
	60	120	180	240 (at harvest)
Plant height (cm)	65	125	187	248
Number of leaves	35.44	78.62	155.66	224.88
Number of tubers/ plant				5.10
Length of tuber (cm)				23.86
Girth of tuber (cm)				10.30
Tuber yield (t/ha)				10.30

18.64 t/ha. The decrease in yield in the intercropped situation was to the extent of 45 percentage. It can be deduced from the data that the yield reduction in alley cropped tapioca was mainly due to reduction in number of tubers. This can be attributed to the reduction in photosynthesis following the decrease in leaves which is the assimilating surface. Similar reduction in yield due to shaded conditions had been reported by Ramanujam et al. (1984a) also.

4.1.1.2. Groundnut

The height of groundnut intercropped in coconut-casuarina alleys increased from 25 cm at 30 DAP to 87 cm at 110 DAP (Table 4). The pattern of increment in height of groundnut intercropped with tapioca in these alleys was comparable with that of the groundnut grown alone in the alleys. The number of branches was relatively less when groundnut was grown mixed with tapioca in the tree crop alleys. The number of nodules per plant increased from 9 to 34 depending on the stage of growth of the plant. The maximum number of nodules per plant was recorded at 60 DAP. There was no perceptible difference between the two cropping systems with respect to the number of nodules produced by groundnut.

Table 4. Biometric observations on groundnut sole cropped (GN) and mixed cropped with tapioca (T+GN) in coconut - casuarina alleys

4a. Growth attributes

Growth attributes	Days after planting							
	30		60		90		110	
	GN	T+GN	GN	T+GN	GN	T+GN	GN	T+GN
Plant height(cm)	24.74	23.8	30.42	59.27	86.80	85.71	88.30	87.42
Number of branches/plant	2.87	2.29	4.08	3.57	4.11	3.60	4.11	3.61
Total number of nodules/plant	9.12	8.77	34.51	35.18	19.06	18.70	17.40	17.69

4b. Yield attributes

Yield attributes	GN	T+GN
Days to 50% flowering (DAS)	17.77	17.0
Days to maturity (DAS)	107.33	107.67
Yield of pods (kg/ha)	2541.68	915.00
Yield of haulm (kg/ha)	3131.26	1341.00
No. of pods/plant	15.66	9.39
Weight of pods (g/plant)	4.16	2.93
100 seed weight (g)	36.69	31.06

The number of days to flowering and the days to maturity of groundnut did not vary in the two cropping systems. The yield of pods and haulm of groundnut was low when it was intercropped with tapioca as compared to the groundnut grown alone in coconut-casuarina alleys. The yield recorded in the former case was only 915 kg/ha whereas in the latter, it was 2542 kg/ha. Similar trend was observed with respect to other biometric observations like number of pods per plant, weight of pods per plant and hundred seed weight. So it is evident that the yield reduction observed when groundnut is grown with tapioca in the tree crop alleys is contributed by the reduction of the different yield attributes. This yield reduction observed when groundnut and cassava are intercropped in the tree alleys may be due to the cumulative effect of the shade from the trees and tapioca. Competition for soil factors offered by the trees and tapioca also might have reduced groundnut yield. Yield reduction in groundnut due to shade was reported by George (1982) and the reduction subsequent to intercropping in tapioca was reported by Bridgit (1985).

4.1.1.3. Amorphophallus

The plant height of amorphophallus intercropped in coconut - casuarina alleys (Table 5) increased from 49 cm at 60 DAP to 60 cm at 120 DAP. The girth of the pseudostem increased from 15.2 cm at 60 DAP to 20.0 cm at 120 DAP The plants were relatively taller and the girth of the stem was higher as compared to those of the sole crop data reported by Bindu (1988) for the same variety at the same location. The corm yield of 38.2 t/ha recorded for intercropped amorphophallus was comparatively low as compared to the reported sole crop yield of 40.5 t/ha (Bindu, 1988). Similar reduction in the yield of amorphophallus have been reported when it was intercropped in coconut-eucalyptus, coconut-subabul and coconut-glyricidia alleys (Bindu, 1988). This yield reduction may probably be due to the competition offered by the alley crops, for light, moisture and nutrients.

4.1.1.4. Horsegram

The data on the biometric observations of horsegram is presented in Table 6. There was a slight reduction in the vegetative as well as yield attributes when this crop was grown in coconut-casuarina alleys compared to the sole crop data. While the yield of alley cropped horsegram was

Table 5. Biometric observations on amorphophallus (A) intercropped in coconut - casuarina alleys

Growth/yield attributes	Days after planting		
	60	120	240 (at harvest)
Plant height (cm)	49.16	59.50	
Girth (cm)	15.24	20.00	
Tuber yield (t/ha)			38.18

Table 6. Biometric observations on horsegram grown after amorphophallus (A→HG) in coconut - casuarina alleys

Character	Value
Plant height (cm) at harvest	52.63
Number of branches/plant at harvest	2.37
Number of pods/plant at harvest	18.67
Number of seeds/pod at harvest	6.13
Grain yield (kg/ha)	593.50
Haulm yield (kg/ha)	1992.68

594 kg/ha, that of sole crop reported by Swadija (1984) was around 754 kg/ha. However the yield of the alley cropped horsegram was much higher than the average yield of 400 kg/ha reported for this crop for Kerala State (Anon, 1980).

4.1.1.5. <u>Fodder maize</u>

The mean values on plant height, number of leaves, leaf stem ratio and green matter yield of fodder maize intercropped with cowpea in coconut - casuarina alleys are given in Table 7. The plant height of 83 cm at 20 DAP increased to 280 cm at 60 DAP, while the number of leaves increased from 6 to 15. The leaf stem ratio at harvest was 0.72 and the green fodder yield was 39 t/ha. The height of the plant, the number of leaves, the leaf stem ratio and the fodder yield recorded by fodder maize in fodder maize + cowpea mixture were relatively higher than that reported by George (1981). The green fodder yield of maize reported in fodder maize + cowpea mixture intercropped in coconut garden was 12.15 t/ha (George, 1981). Increased fodder yield due to association with legumes have been reported by many workers (Ahlawat <u>et al</u>., 1964; Arthur, 1971; Singh and Relwani, 1978). The increased fodder yield of maize observed in coconut - casuarina alleys than in

Table 7. Biometric observations on fodder maize intercropped with cowpea (M+C) in coconut - casuarina alleys

Growth/yield attributes	Days after planting		
	20	40	60
Plant height (cm)	82.80	208.45	279.53
Number of leaves	5.71	8.67	15.27
Leaf-stem ratio at harvest			0.72
Green fodder yield (t/ha)			39.0

Table 8. Biometric observations on fodder cowpea sole cropped (C), mixed cropped with maize (M+C) and grown after maize-cowpea mixture (M+C→C) in coconut - casuarina alleys

Cropping system	Plant height (cm)			Number of leaves			Green fodder yield (t/ha)
	Days after sowing						
	20	40	60 (at harvest)	20	40	60 (at harvest)	
C	31.10	82.25	153.87	4.55	7.86	15.49	27.13
M + C	25.64	55.69	123.58	3.62	6.38	12.62	4.59
M+C→C	29.97	73.0	135.69	3.77	6.62	13.83	12.00

coconut gardens reveals the fact that casuarina does not have any adverse effect on the maize crop and that it favours the maize crop considerably to produce a higher yield.

4.1.1.6. Fodder cowpea

The plant height of fodder cowpea grown in the coconut-casuarina alleys increased from 31 cm at 20 DAS to 154 cm at 60 DAS (Table 8). The increase in the plant height of fodder cowpea grown mixed with fodder maize in the alleys was only from 26 cm to 124 cm and of that grown after this mixture was from 30 cm to 136 cm. From these it is evident that the cowpea plants were depressed when grown mixed with fodder maize. The same trend was observed with regard to the number of leaves also.

The highest yield of green fodder was obtained when cowpea was grown alone in the coconut-casuarina alleys (27 t/ha). This was considerably higher than the fodder yield of cowpea grown mixed with maize (4.5 t/ha) and that grown after this mixture (12 t/ha). Thus it can be seen that maize had exerted an adverse effect not only on the companion crop of cowpea, but also on the succeeding crop. The adverse effect may be due to the cumulative effect of competition for light, nutrients and moisture among the component crops. Agboola and Fayemi (1971) and Syarifuddin *et al.* (1974) also obtained decreased yields of legumes when grown with maize.

4.1.1.7. Guinea grass

The data on biometric observations of guinea grass grown in coconut-casuarina alleys are presented in Table 9. The plant height taken just before each cutting was found to range from 48 cm to 185 cm. These values are higher than the values observed for guinea grass grown in the open (Chandini, 1980). However, not much difference was observed between alley cropped and sole cropped guineagrass with respect to the number of tillers and leaf-stem ratio. The mean green fodder yield of the alley cropped guineagrass (13 t/ha) was found to be much higher than the mean yield of 7 t/ha observed for sole cropped guineagrass (Chandini, 1980). The increase in yield may be due to the fact that the alley cropped fodder was taller than the sole cropped one. Such successful intercropping of annual fodder crops with rubber, oilpalm, eucalyptus etc. have been reported by many workers (Samraj, 1977; Pant, 1980).

Table 9. Biometric observations on guineagrass (G) intercropped in coconut - casuarina alleys

Observations	Cuttings						Mean
	1 (45 DAP)	2 (90 DAP)	3 (135 DAP)	4 (180 DAP)	5 (225 DAP)	6 (270 DAP)	
Plant height (cm)	185.87	167.82	176.37	48.74	75.48	170.74	137.50
Tiller count	7.73	8.83	14.31	16.63	15.71	15.61	13.14
Leaf stem ratio	1.15	1.71	2.14	2.24	2.29	2.23	1.96
Green matter yield (t/ha)	24.22	13.51	17.40	4.56	6.35	9.88	12.65

Table 10. Biometric observations on sesamum (S) grown after fodder cowpea (C→S) and modan paddy (P→S) in coconut - casuarina alleys

Cropping system	Plant height (cm) (at harvest)	Number of branches (at harvest)	Number of days to flowering (DAS)	Number of days to maturity (DAS)	Number of locules per pod	Number of seeds per plant	Number of pods per plant	Seed yield (kg/ha)	1000 seed weight (g)
C → S	84.87	2.47	30.83	75.23	4	55.67	11.41	302.54	2.81
P → S	86.83	2.77	30.97	75.07	4	54.52	17.40	364.35	2.81

4.1.1.8. Sesamum

The data on biometric observations of sesamum preceded by fodder cowpea and modan paddy are presented in Table 10. The height of sesamum grown after fodder cowpea was lower than that grown after modan paddy in coconut-casuarina alleys. There was no perceptible difference between the number of branches, number of days to flowering and maturity and number of seeds per pod. The number of pods per plant (11.4) was comparatively low in the sesamum crop raised after fodder cowpea. The higher seed yield thus obtained in the sesamum crop raised after modan paddy may be contributed by the increased plant height and number of pods per plant. Though the yield of sesamum grown in the coconut-casuarina alleys succeeding paddy as well as fodder cowpea (364 and 302 kg/ha) was found to be slightly less than the sole crop yield of sesamum (416 kg/ha) as reported by Geetha (1984), it is higher than the average yield reported for this crop in Kerala (Thakur, 1980).

4.1.1.9. Blackgram

The data on the biometric observations of blackgram grown after groundnut in coconut-casuarina alleys are

Table 11. Biometric observations on blackgram grown after groundnut(GN→BG) in coconut - casuarina alleys

Characters	Observations	
	30 DAS	90 DAS (at harvest)
Plant height (cm)	19.42	68.77
Number of branches/plant	0.43	2.23
Number of pods/plant		19.20
Number of seeds/pod		5.85
Grain yield (kg/ha)		450.00
Haulm yield (kg/ha)		985.36

Table 12. Biometric observations on modan paddy (P) intercropped in coconut - casuarina alleys

Cropping system	Plant height (cm)	Number of tillers/hill	Productive tillers (No./hill)	Percentage of productive tillers	Length of panicle (cm)	Number of grains/panicle	1000 grain weight (g)	Grain yield (kg/ha)	Straw yield (kg/ha)
P → S	123.91	8.06	6.99	86.68	24.25	92.18	20.90	1475.55	3111.07

presented in Table 11. The plant height increased from 19 cm at 30 DAS to 69 cm at harvest. This is much higher (23 cm) than that reported for the sole crop (Syriac, 1983). However there was not much difference with respect to the number of branches. The grain yield of the alley cropped blackgram (450 kg/ha) was slightly less than the sole crop yield (688 kg/ha) reported by Syriac (1983). The feasibility of blackgram as an alley crop in eucalyptus and subabul were reported by Ramachandran (1981) and Prasad and Verma (1985).

4.1.1.10. Modan paddy

The grain yield of modan paddy grown in the coconut-casuarina alleys (Table 12) was rather low (1476 kg/ha) compared to the pure crop yield (3440 kg/ha) of the same variety (RARS, 1977). However the yield of the alley cropped paddy is comparable to that (1646 kg/ha) grown alone in coconut gardens (Nelliat and Bhat, 1979). This indicates that casuarina has no adverse effect on the growth of paddy.

4.1.2. Total biomass productivity

The dry matter produced by the component annual crops in different intercropping systems is given in Table 13 and depicted in Fig. 3.

Table 13. Biomass productivity and per day biomass productivity (at the time of harvest) of the different cropping systems in coconut - casuarina alleys

Cropping system	Duration of the cropping system (days)	Biomass production of component crops (kg/ha)		Total biomass (kg/ha)	Per day biomass productivity (kg/ha)
T + GN	350	T	10,659	11,539	32.97
		GN	880		
A → HG	330	A	13,001	14,538	44.05
		HG	1,537		
(M+C) → C	180	M (with C)	9,737.5	11,978	66.54
		C (with M)	559.87		
		C	1,680		
G	270	G	12,524	12,524	46.38
C → S	135	C	2,912	3,138	23.24
		S	226		
GN → BG	200	GN	2,212	2,527	12.64
		BG	315		
P → S	190	P	3,276	3,550	18.68
		S	273		
CD (0.05)				2,690.83	NS
SEm±				873.20	40.65

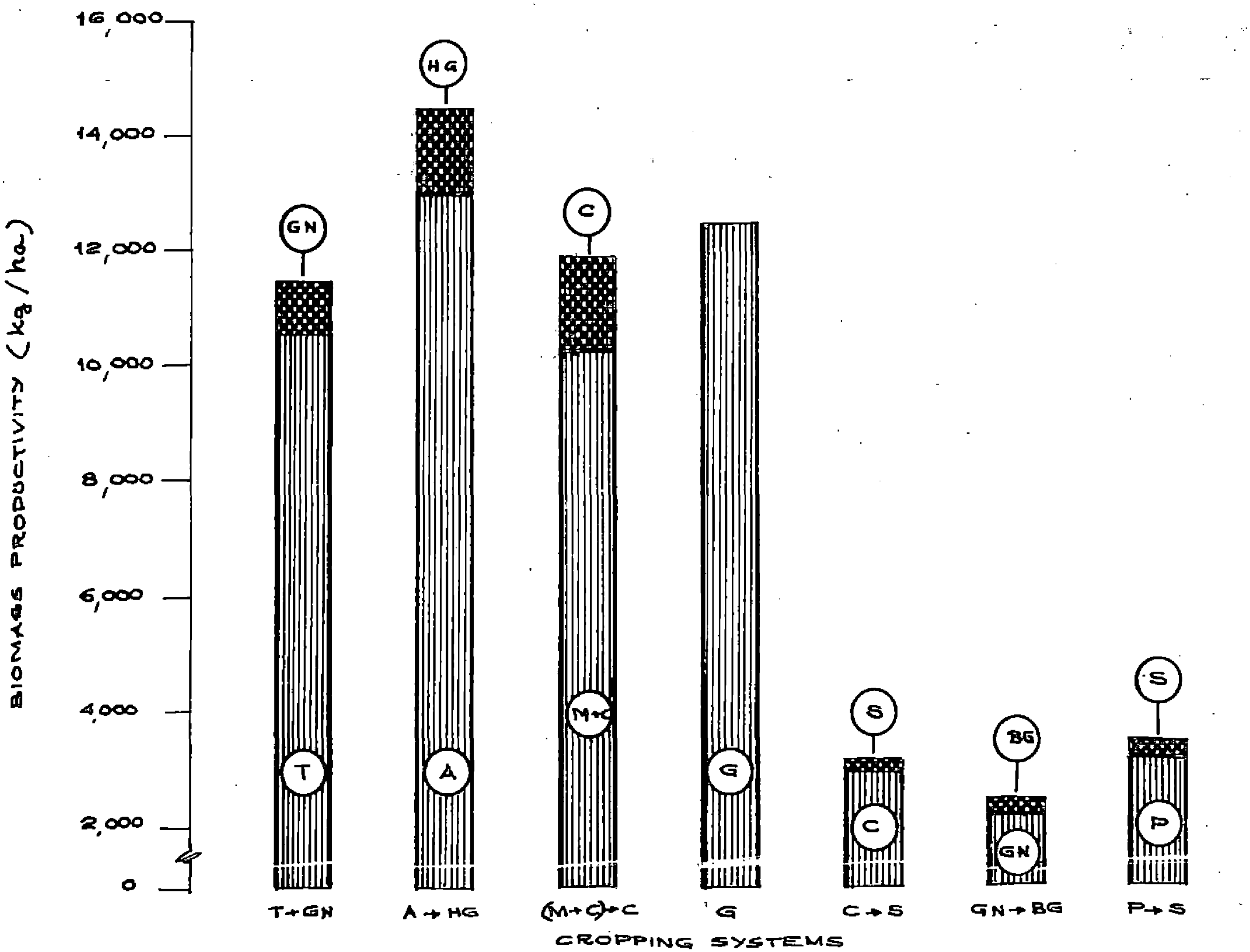


FIG. 3 BIOMASS PRODUCTIVITY OF THE DIFFERENT CROPPING SYSTEMS IN THE COCONUT–CASUARINA ALLEYS

Among the different cropping systems in coconut-casuarina alleys, highest biomass production was recorded from the cropping system where amorphophallus was succeeded by horsegram (A → HG). This was followed by guineagrass grown throughout (G) and fodder maize + cowpea mixture succeeded by fodder cowpea (M + C → C). Though these were at par, the A → HG cropping system was significantly superior to all other cropping systems. The tapioca-groundnut mixture (T + GN) also gave fairly good biomass yield and was on par with M + C → C and G. It was also observed that all these four cropping systems were significantly superior to cowpea-sesamum, groundnut-blackgram and paddy-sesamum cropping systems. While the biomass production of the latter ranged from 2500 to 3500 kg/ha only that of former ranged from 11,000 to 14,500 kg/ha.

The highest dry matter yield produced by the A HG cropping system may be attributed to the shade tolerant character of the crops (Nelliat and Krishnaji, 1976; Varghese, 1976 and Pillai et al., 1985). The poor biomass production of fodder cowpea-sesamum, groundnut-blackgram and paddy-sesamum cropping systems should be expected as these crops were less vigorous in their growth habits. The high biomass yield of tapioca + groundnut cropping system is due to the fact that tuber crops are normally less affected by the shady conditions than the grain crops (Nair, 1979). Bridgit (1985) observed an increase in tuber yield of cassava when intercropped with coconut. The tapioca + groundnut intercropping system is often beneficial for cassava. Thomas and Nair (1979) observed an additional tuber yield of 486 kg/ha on account of growing groundnut as a companion crop. The biomass production of fodder maize + cowpea - fodder cowpea was found to be on par with the tapioca + groundnut cropping system. An increase in the fodder yield of maize consequent to intercropping of cowpea were also reported by Chauhan et al., 1971; Remison, 1978 and Chauhan and Dungarwal, 1980. In such a crop combination, growth of maize might have been stimulated by the root secretions of cowpea (Guljaev and Ronsal, 1962). The dry matter production of guineagrass which corresponds to a green fodder yield of 76 t/ha is in accordance with that (50-60 t/ha) obtained under coconut shade by Sahasranaman and Pillai (1976). The high yield of guineagrass may be attributed to shade tolerant nature of the crop (Plucknett, 1979).

One of the factors which was not taken into consideration in calculating the total biomass productivity was the duration of the cropping system. The cropping systems which yielded a higher biomass had a longer duration ranging from 270 to 350 days. However, an exception in this respect is the fodder maize-cowpea mixture followed by fodder cowpea which recorded a high biomass within a duration of 180 days. Hence this had the highest per day biomass productivity of 66.54 kg/ha/day (Table 13). Though amorphophallus-horsegram and guineagrass alone grown in the coconut-casuarina alleys gave comparable values (44 and 46 kg/ha/day) of per day biomass productivity the tapioca + groundnut mixture was rather poor in this respect. Also, the performance of cowpea-sesamum cropping system was much better from this angle than groundnut-blackgram and paddy-sesamum cropping systems.

4.1.3. Plant analysis and uptake studies

4.1.3.1. Total crude protein yield from different intercrops

The crude protein content and the protein yield of the intercrops as well as for the cropping systems are given in Table 14 and illustrated in Fig. 4. While the protein content varied from 1.2% to 16.6%, the protein yield ranged from 385 kg/ha to 1955 kg/ha.

Table 14. Crude protein yield of the different cropping systems in the coconut-casuarina alleys

Cropping system	Component crops	Crude protein content of the whole plant (%)	Crude protein yield (kg/ha)	
			For component crops	Total for cropping system
1. T + GN	T	8.37	1585.16	1743.32
	GN	12.62	158.16	
2. A → HG	A	1.18	1769.54	1955.16
	HG	12.62	185.62	
3. (M+C) → C	M (with C)	8.62	840.34	1169.76
	C (with M)	14.65	80.50	
	C	14.65	248.91	
4. G	G	11.37	1425.25	1425.25
5. C → S	C	14.65	436.81	506.93
	S	16.56	70.11	
6. GN → BG	GN	12.62	410.14	455.84
	BG	14.50	45.69	
7. P → S	P	7.50	300.66	384.82
	S	16.56	84.15	
CD (0.05)				363.11
SEm±				117.83
CV				18.70

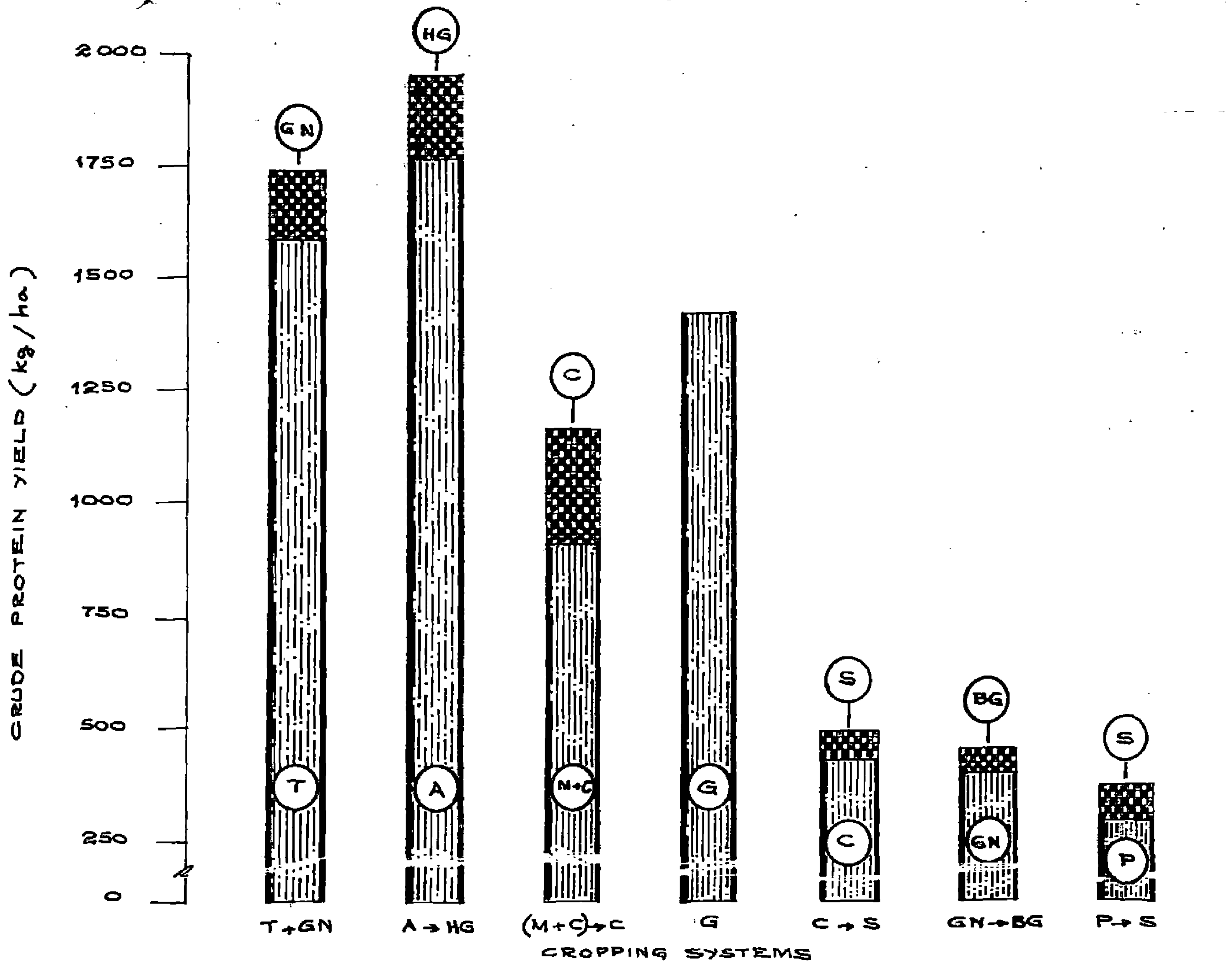


FIG. 4. CRUDE PROTEIN YIELD OF THE DIFFERENT CROPPING SYSTEMS IN THE COCONUT – CASUARINA ALLEYS

Fairly high protein yields were recorded by amorphophallus-horsegram, tapioca + groundnut, guineagrass and fodder maize + cowpea-fodder cowpea cropping systems. However the protein yields were rather low for the cowpea-sesamum, groundnut-blackgram and paddy-sesamum cropping systems. Thus it can be seen that there are two distinct groups of cropping systems with respect to the total protein yield. The protein yield of the former group ranged from 1100 to 1900 kg/ha and that of latter group ranged from 380 to 500 kg/ha. The main reason for such a large difference between these two groups is the variation in the protein content of the component crops as well as in the total biomass production.

The highest protein yield was obtained from an amorphophallus-horsegram cropping system. Though amorphophallus had the least crude protein content, this was very well compensated by the relatively high protein content of horsegram which succeeded amorphophallus. Also, this crop combination had the highest biomass production. Though the protein yield of this cropping system was on par with the tapioca + groundnut cropping system, it was significantly superior to that of all other cropping systems. The tapioca + groundnut mixture had the benefit of a fairly high protein content of the component crops and a relatively high biomass production. The guineagrass grown in the alley also recorded a high protein yield which was on par with that of tapioca + groundnut cropping system. The guineagrass might have been benefitted by the shaded condition. Mullakoya (1982) observed an increase in crude protein content of guineagrass due to shading. According to Sreedharan (1975) and Ramanagowda (1981) shaded conditions are more favourable for protein synthesis in guineagrass. The protein yield of guineagrass was on par with that of fodder maize + cowpea - fodder cowpea cropping system. This must be expected as the cowpea in this cropping system can serve as a rich source of protein. This is in confirmity with the finding of Ahmed and Gunasena (1979) who also observed increased protein yield when maize was intercropped with a legume compared to the sole crop of maize. There are also reports that shaded conditions can favour higher nitrogen fixation (Skerman, 1977). This could be the reason for the better performance of this cropping system in the coconut-casuarina alleys. The poor protein yield of cowpea-sesamum, groundnut-blackgram and paddy-sesamum despite the fact that these were fairly rich in protein content can be attributed to the poor biomass yields.

4.1.3.2. Uptake of nutrients

The uptake of nitrogen, phosphorus and potassium by the different cropping systems are given in Table 15 and Fig. 5. The uptake of nitrogen (254 kg/ha), phosphorus (9 kg/ha) and potassium (81 kg/ha) of the alley cropped tapioca was higher than the reported sole crop uptake of nitrogen (101 kg/ha), phosphorus (7 kg/ha) and potassium (65 kg/ha) (Ashokan, 1986). This higher uptake may be consequent to the higher vegetative growth of the alley cropped plant under shaded conditions. Uptake of nitrogen, phosphorus and potassium by groundnut when intercropped with tapioca in coconut + casuarina alleys (Table 15) was less than the values recorded for groundnut grown with tapioca in the open (Bridgit, 1985). The uptake of alley cropped groundnut was also less than the groundnut grown alone in the coconut gardens (George, 1982). This low uptake of the alley cropped groundnut could probably be due to the poor growth of groundnut under the shaded conditions. The uptake of nitrogen (283 kg/ha) and phosphorus (16 kg/ha) by amorphophallus intercropped in coconut + casuarina alleys were higher than the sole crop uptake of 108 and 11.8 kg/ha as reported by Ashokan (1986). However the potassium uptake (64 kg/ha) was less than the the sole crop uptake of 109 kg/ha (Ashokan, 1986).

Table 15. Nutrient uptake at the time of harvest by the different cropping systems in the coconut - casuarina alleys

Cropping system	Component crops	Nutrient uptake (kg/ha)					
		For component crops			Total for cropping system		
		N	P	K	N	P	K
1. T + GN	T	253.59	8.55	80.61	271.36	10.26	93.27
	GN	17.77	1.71	12.66			
2. A → HG	A	283.15	15.89	64.19	312.85	19.73	84.48
	HG	29.70	3.84	20.29			
3. (M+C) → C	M (with C)	134.37	12.66	84.72	187.08	17.13	105.43
	C (with M)	12.87	0.95	5.59			
	C	39.83	3.52	15.12			
4. G	G	227.93	28.81	146.53	227.93	28.81	146.53
5. C → S	C	69.89	6.41	29.12	74.82	11.91	31.53
	S	4.93	5.50	2.41			
6. GN → BG	GN	44.69	4.31	31.85	52.00	5.16	36.23
	BG	7.31	0.85	4.38			
7. P → S	P	33.20	5.48	65.87	39.12	12.19	68.77
	S	5.92	6.71	2.90			

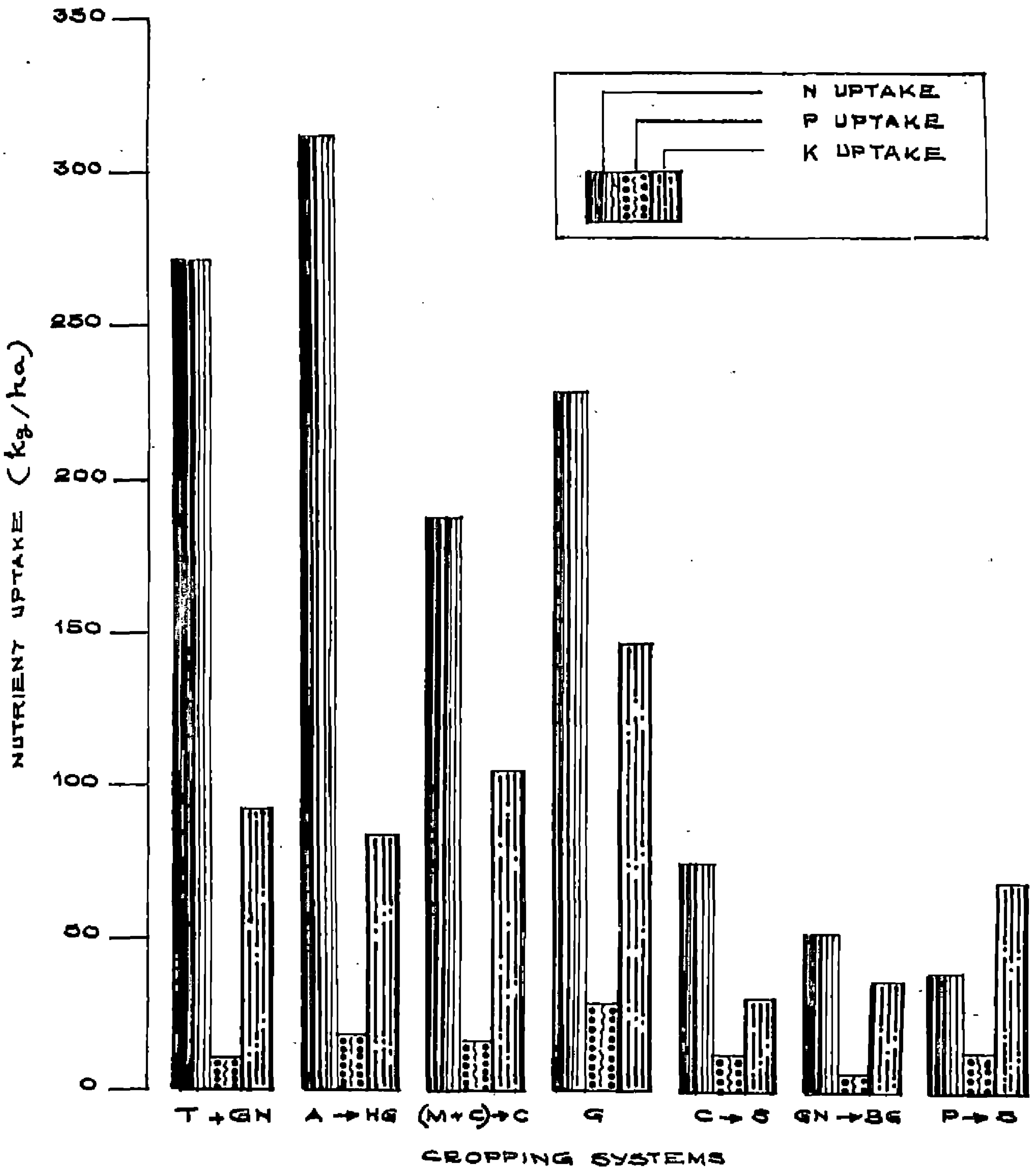


FIG. 5. TOTAL UPTAKE OF NITROGEN, PHOSPHORUS AND POTASSIUM BY THE DIFFERENT CROPPING SYSTEMS IN THE COCONUT - CASUARINA ALLEYS

The uptake of nitrogen, phosphorus and potassium by fodder maize intercropped with fodder cowpea in coconut + casuarina alleys were considerably higher than those recorded by the fodder maize crop intercropped with fodder cowpea in coconut gardens (George, 1981). The higher uptake of nutrients may be due to the higher dry matter (9.7 t/ha) production of the crop in coconut + casuarina alleys compared to that obtained in coconut gardens (4.61 t/ha). Thus the higher dry matter production establishes its success as an intercrop in coconut + casuarina alleys. The uptake of nutrients by the fodder cowpea grown in coconut-casuarina alleys was higher than the uptake of fodder cowpea in the fodder maize + cowpea mixture and that raised after the fodder maize + cowpea mixture. The lowest uptake was by the cowpea raised in combination with fodder maize in the coconut + casuarina alleys. These differences in uptake can be justified by the differences in the biomass production of the crop in the different cropping systems. The lower uptake of nutrients by the fodder cowpea in conjunction with fodder maize crop shows the depression effect of fodder maize on fodder cowpea. This conclusion is in accordance with the results reported by Agboola and Fayemi (1971) and Syarifuddin _et al._ (1974).

The nutrient uptake of alley cropped guineagrass was higher than the sole crop uptake reported by Pillai (1986) which could be attributed to the higher dry matter production by the alley crop. The uptake of nutrients by the sesamum crop raised after fodder cowpea crop was lower than that by the same crop raised after modan paddy. A similar pattern was seen in the production of dry matter also. The nutrient uptake of blackgram intercropped in coconut + casuarina alleys was rather low compared to that grown alone in coconut gardens (George, 1982).

A comparison on the nutrient uptake by the different cropping systems reveals that though the nitrogen uptake was highest for the amorphophallus-horsegram cropping system, the uptake of phosphorus and potassium were highest by the guineagrass. The lowest nitrogen uptake was recorded by paddy-sesamum cropping system, lowest phosphorus uptake by groundnut-blackgram cropping system and lowest potassium uptake by cowpea-sesamum cropping system. In general, the nutrient uptake by cowpea-sesamum, groundnut-blackgram, paddy-sesamum cropping systems were lower than that of tapioca + groundnut, amorphophallus-horsegram, fodder maize + cowpea - fodder cowpea and guineagrass. This can be attributed to the lower dry matter yield of the former compared to the latter.

4.1.4. Influence on physical and chemical properties of soil

4.1.4.1. Physical properties of soil

There was no significant difference in the bulk density, particle density and maximum water holding capacity of the soil, estimated before and after the experiment (Table 16). Thus there was no variation in the soil physical properties due to alley cropping of the different intercrops.

4.1.4.2. Chemical properties of soil

4.1.4.2.1. Organic carbon content of the soil

The mean values of the organic carbon content of the soil estimated before and after the experiment are given in Table 17.

The different cropping systems had no significant influence on the organic carbon content of the soil. However, certain cropping systems rendered the soil slightly richer in organic carbon content when compared to the pre-experimental values. Such cropping systems were amorphophallus - horsegram, fodder maize + cowpea - fodder cowpea, fodder cowpea - sesamum, groundnut - blackgram and paddy - sesamum. While the organic carbon content of all these plots increased, a decrease was noticed in the control plots of coconut-casuarina alleys where intercrops were not taken. The

Table 16. Physical properties of soil as influenced by different cropping systems in coconut - casuarina alleys

Cropping system	Bulk density g/cc		Particle density		Maximum water holding capacity(%)		Percentage of pore space	
	*	**	*	**	*	**	*	**
T + GN	1.33	1.32	2.42	2.45	34.61	34.63	48.33	48.30
A → HG	1.38	1.38	2.40	2.43	33.90	34.01	48.26	48.31
(M+C) → C	1.31	1.30	2.39	2.40	34.20	34.27	47.99	48.01
G	1.30	1.31	2.43	2.45	34.80	34.78	48.56	48.53
C → S	1.32	1.33	2.42	2.42	33.41	34.00	48.27	48.30
GN → BG	1.32	1.32	2.40	2.39	33.80	34.10	48.39	48.35
P → S	1.30	1.31	2.45	2.43	34.90	34.95	48.74	48.69
CO	1.34	1.33	2.40	2.41	33.00	32.98	48.30	48.29

* - Before the experiment
** - After the experiment

Table 17. Organic carbon, available nitrogen, phosphorus and potassium content of the soil as influenced by the cropping systems in coconut - casuarina alleys

Cropping system	Organic carbon (%)		Available nitrogen (%)		Available phosphorus (ppm)		Exchangeable potassium (ppm)	
	*	**	*	**	*	**	*	**
1. T + GN	1.25	1.18	0.12	0.12	38.64	20.10	162	163
2. A → HG	1.41	1.43	0.14	0.14	40.71	35.66	175	241
3. (M+C) → C	1.10	1.48	0.11	0.15	38.51	31.19	74	112
4. G	1.19	0.98	0.12	0.09	39.75	42.68	148	78
5. C → S	1.28	1.99	0.13	0.20	13.54	44.50	147	230
6. GN → BG	1.28	1.71	0.13	0.17	34.87	45.14	130	134
7. P → S	1.14	1.29	0.11	0.13	35.44	36.78	136	126
8. CC	1.39	1.13	0.14	0.11	32.99	44.15	111	114
SEm±	0.12	0.13	0.01	0.01	3.88	3.63	10.90	44.66
CD (0.05)	NS	0.38	NS	0.04	11.77	11.0	33.10	135.30

* - Before the experiment
** - After the experiment

cropping systems which led to decrease in the organic carbon content were tapioca + groundnut mixture and guineagrass grown alone in the coconut-casuarina alleys. It was only in the guineagrass plots, the organic carbon content of the soil was found to be less than the control plots.

4.1.4.2.2. Available nitrogen content of the soil

The influence of different cropping systems on the available nitrogen content of the soil was very similar to that of organic carbon (Table 17). Though there were no significant differences, all the cropping systems excepting tapioca + groundnut and guineagrass left the soil slightly richer in nitrogen content. At the same time, in the control plots of coconut-casuarina alleys, where no intercrops were taken, a decrease in soil nitrogen content was recorded. This clearly indicates that a high density cropping system with the inclusion of a legume crop will enrich the soil instead of depleting it. Several workers have also reported an increase in the nitrogen content of the soil subsequent to growing legume crops (Nair et al., 1979; Giri and De, 1979).

4.1.4.2.3. Available phosphorus content of the soil

The different cropping systems had a significant influence on the available phosphorus content of the soil. Unlike in the case of organic carbon and available nitrogen, there was a decrease in the phosphorus content subsequent to tapioca + groundnut, amorphophallus-horsegram and fodder maize + cowpea - fodder cowpea cropping systems (Table 17). The residual phosphorus content in the plots was also considerably less than that of control plot. However the rest of the cropping systems left the soil richer in available phosphorus content. In the control plot also, where no intercrop was taken, an increase in the available phosphorus content of the soil was recorded. Also it is interesting to note that while the guineagrass rendered the soil poorer with respect to almost all other nutrients, it registered a favourable effect on the available phosphorus content. This is in confirmity with the finding of Singh et al. (1977) who also observed an increase in P content following long term cultivation of fodder grasses. The increase in the available phosphorus content could be due to the conversion of unavailable form of phosphorus to available forms. Some of the legumes have been claimed to have this property (Raheja, 1966).

4.1.4.2.4. Exchangeable potassium content of the soil

The influence of the different cropping systems on exchangeable potassium was very similar to that of organic carbon and available nitrogen content. There was an increase in the exchangeable potassium content following all the cropping systems except guineagrass and paddy-sesamum cropping systems (Table 17). The highest increase in the exchangeable potassium content was recorded by fodder cowpea-sesamum cropping system. Also the exchangeable potassium content was higher than the control plot subsequent to the different cropping systems except guineagrass. Thus it can be seen that the alley cropping systems including different food crops and legumes render the soil richer in exchangeable potassium instead of depleting it.

4.1.4.2.5. Exchangeable calcium, magnesium and sulphur content of the soil

The data on the influence of the cropping systems on the secondary nutrients, calcium, magnesium and sulphur are given in Table 18. With respect to exchangeable calcium while all the cropping systems had a favourable influence, tapioca + groundnut and guineagrass cropping systems resulted in a decrease. The decrease in calcium content

Table 18. Exchangeable calcium, exchangeable magnesium and available sulphur content of the soil as influenced by the cropping systems in coconut - casuarina alleys

Cropping system	Calcium content (ppm)		Magnesium content (ppm)		Sulphur content (ppm)	
	*	**	*	**	*	**
1. T + GN	425	416	71	88	21.1	18.1
2. A → HG	464	746	108	255	19.6	32.5
3. (M+C) → C	244	531	68	95	16.6	25.4
4. G	662	530	87	87	21.2	15.8
5. C → S	224	686	187	291	19.9	16.5
6. GN → BG	327	600	302	154	25.3	21.3
7. F → S	517	526	304	227	26.8	11.8
8. CO	269	539	380	301	32.6	20.5
SEm±	55.74	97.29	45.57	44.16	1.90	3.54
CD (0.05)	169.10	NS	138.24	133.95	5.74	10.75

* - Before the experiment
** - After the experiment

following tapioca + groundnut cropping system can be attributed to the high calcium requirement of groundnut (Walker, 1975). In the case of soil magnesium content, while tapioca + groundnut, amorphophallus-horsegram, fodder maize + cowpea-fodder cowpea, fodder cowpea-sesamum cropping systems led to an increase, the groundnut-blackgram and paddy-sesamum cropping systems registered a decrease. In the control plots also there was a decrease in the magnesium content. There was a slight reduction in the available sulphur content of the soil subsequent to most of the cropping systems. A similar reduction was noticed in the control plot also.

In general it can be stated that almost all the cropping systems tried in the coconut-casuarina alleys, with the exception of guineagrass led to an increase in primary and secondary nutrient contents of the soil. Also in most of the cases, the nutrient contentsof the soil in the cropped plots were higher than the control plot where no intercrops were taken. This indicates that a high density cropping system can not only increase the net returns but also can render the soil richer in nutrients, if proper crop combinationsare selected. The slight depletion of nutrients following the cultivation of guineagrass can be attributed to the crop removal of nutrients by repeated cuttings. In the present study, as many as six cuttings were taken in an year. The decline in soil nutrient content following fodder cultivation has been reported by Singh et al. (1977) also.

4.1.5. Economics of the different cropping systemsunder coconut - casuarina alleys

The details of the cost of production of different intercrops are given in Appendix III and the abstract of the economics is presented in Table 19. Economically, all the cropping systems were seen to be viable.

Among the different component crops, amorphophallus recorded the highest net return (Rs.21,100/-) followed by fodder maize (Rs.13,000/-), groundnut grown alone (Rs.9,500/-) and cowpea (Rs.5,500/-). The net return of the other intercrops ranged from Rs.200/- to Rs.5,000/- except for cowpea grown with maize which recorded a net loss. With respect to the benefit-cost ratio, fodder maize recorded the highest value and the least by cowpea grown with maize.

When the different cropping systems were considered as a whole, there were significant differences with respect

Table 19. Economics of the different cropping systems in coconut-casuarina alleys

Cropping system		For the component crops: Gross return (Rs.)	For the component crops: Net return (Rs.)	For the component crops: Benefit cost ratio	Total for the cropping system, after logarithmic transformation: Gross return (Rs.)	Total for the cropping system, after logarithmic transformation: Net return (Rs.)	Total for the cropping system: Benefit cost ratio
1. T + GN	T	15,000	4,964	1.4	4.339 (21,405)*	3.798 (5,818)	1.39
	GN	6,405	854	1.15			
2. A → HG	A	57,270	21,106	1.58	4.772 (59,347)	4.319 (21,583)	1.56
	HG	2,077	477	1.29			
3. (M+C)→C	M (with C)	19,475	13,016	2.01	4.400 (25,281)	4.054 (12,873)	1.80
	C (with M)	1,606	-377	0.81			
	C	4,200	234	1.06			
4. G	G	15,184	2,096	1.16	4.180 (15,184)	3.218 (2,096)	1.16
5. C → S	C	9,495	5,529	2.39	4.426 (14,033)	3.781 (6,491)	1.86
	S	4,538	962	1.26			
6. GN → BG	GN	17,791	9,509	2.14	4.426 (26,791)	4.044 (11,313)	1.73
	BG	9,000	1,804	1.25			
7. P → S	P	3,884	173	1.05	3.698 (9,349)	3.248 (2,062)	1.28
	S	5,465	1,889	1.53			
SEm±					0.12	0.13	0.11
CD (0.05)					0.36	0.41	0.35

* The values given in brackets show the actual figures

to gross income, net income and benefit-cost ratio. The range of profit varied from Rs.2,062/- to Rs.21,583/- ha/year. The maximum net return was observed in amorphophallus - horsegram cropping system and the minimum in paddy - sesamum cropping system. Though the gross income derived from amorphophallus - horsegram cropping system was on par with groundnut - blackgram cropping system, the former was significantly superior to all the other cropping systems. All the other cropping systems except paddy - sesamum cropping system were at par. The paddy - sesamum cropping system yielded the least gross income.

The highest net income was also derived from amorphophallus - horsegram cropping system which was on par with fodder maize + cowpea - fodder cowpea and groundnut - blackgram cropping systems. The least net income was obtained from guineagrass cropped plots. With respect to benefit-cost ratio, significant differences did not exist among fodder cowpea - sesamum, fodder maize + cowpea - fodder cowpea, groundnut - blackgram and amorphophallus - horsegram cropping systems. Guineagrass recorded the least benefit-cost ratio of 1.16. Though the amorphophallus - horsegram gave highest gross as well as net income, its benefit-cost ratio was not markedly superior to others. This was mainly due to the high cost of planting material and a fairly high labour input (Appendix III). Similarly in the case of guineagrass also, despite a high gross return, it recorded rather low net income as well as benefit-cost ratio. This also was due to the high cost of planting material and the relatively higher labour input. The cropping system which recorded fairly high gross income, net income as well as benefit-cost ratios were amorphophallus - horsegram, groundnut - blackgram and fodder maize + cowpea - fodder cowpea.

4.2. Growth and root distribution pattern of casuarina

4.2.1. Growth of casuarina

The growth pattern of casuarina (Three year old) was studied by observing the increase in plant height, canopy spread and girth at a height of 10 cms from the ground level. The mean values of these are given in Table 20. The height, canopy spread and girth of casuarina have been found to follow a linear growth pattern over time and the following regression equations were found to be of good fit to the data (Fig. 6).

$Y = 236.76 + 18.03\,x$ ($R^2 = 0.998$) for the height

$Y = 182.10 + 3.39\,x$ ($R^2 = 0.96$) for canopy spread

$Y = 6.85 + 0.73\,x$ ($R^2 = 0.999$) for the girth of the trees

Table 20. Growth characters of casuarina intercropped in coconut alleys

Month	Height (cm)	Girth at a height of 10 cm (cm)	Canopy spread (cm)
May 1987	253	7.5	185
June	278	8.3	187
July	293	9.0	189
August	309	9.8	193
September	318	10.5	197
October	341	11.3	207
November	362	12.0	209
December	380	12.7	212
January 1988	399	13.4	214
February	417	14.1	216
March	436	14.9	218
April	454	15.6	220
May	472	16.3	222

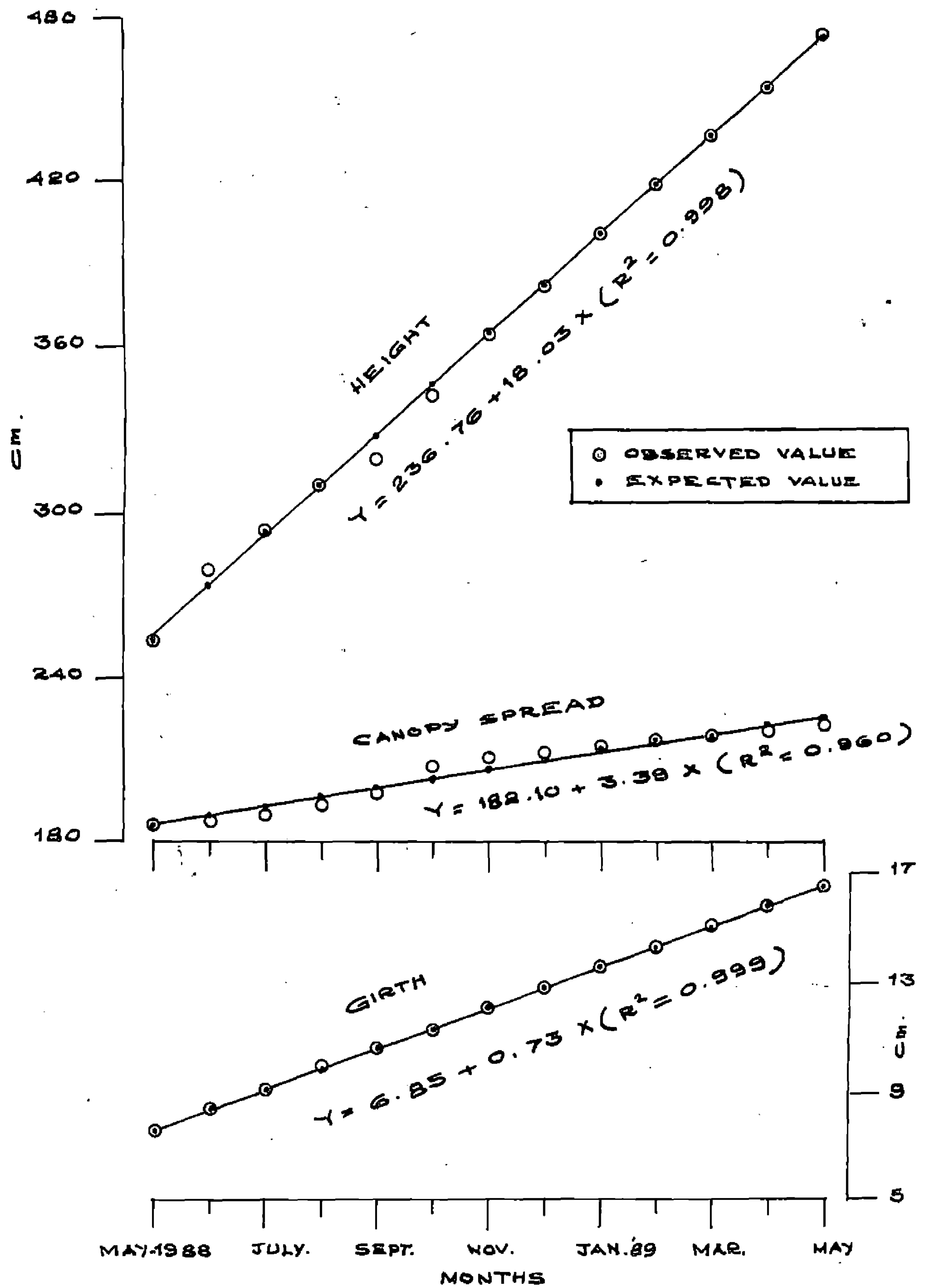


FIG.6. GROWTH PATTERN OF CASUARINA OVER A PERIOD OF ONE YEAR

The monthly growth rate of casuarina trees was estimated to be 18.03 cm for height, 3.39 cm for canopy spread and 0.73 cm for girth. The observed and estimated values are plotted in the Fig. 6 and the lines obtained are those fit for the above given regression equations.

According to Evans (1982) a fast growing species is one which has a height increment of not less than 60 cm/ annum. In the present study, the increase in the height of casuarina planted in coconut garden was about 219 cm. The mean girth also recorded an increase from 7.5 cm to 16.3 cm during this period. These values are comparable to those reported by other workers for sole crop of casuarina. The mean girth and height of a 2-2½ year old casuarina was reported to be 8.57 cm and 330 cm respectively (Kalpage, 1974). The growth rate of casuarina in the present study was found to be just above 2 m/year. Growth of casuarina tree at the rate of 2-3 m/year has been reported from other countries like Malaysia and Philippines (Kalpage, 1974). Such a fast rate of growth can give a fairly good yield of fuel wood. The current annual volume increment of casuarina in this experiment was 0.0079 cum/ tree and the same which was worked out for an hectare was around 21.38 cum per annum. According to the present concept, a fast grown species is one which gives a minimum yield of 10 cum/ha/annum (Dwivedi, 1980). The yield of casuarina obtained in this experiment clearly reveals the fast growing nature of it in coconut alleys also.

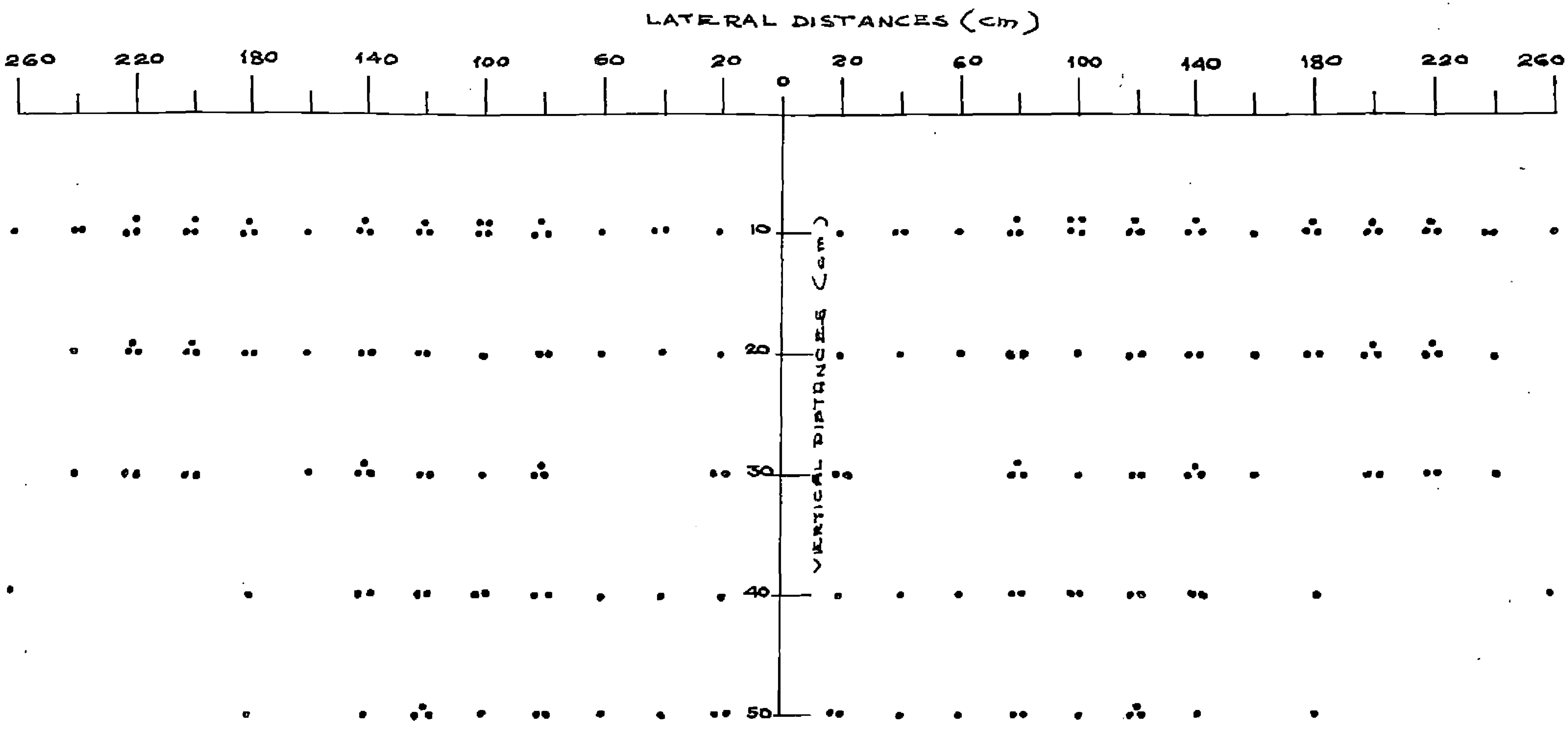
The yield of fuel wood of casuarina was worked out and was found to be around 10.7 t/ha/annum, the value of which comes to about Rs.4,200/-. A fuel wood yield of 75-200 t/ha has been reported for casuarina on a rotation of 7-10 years in Malaysia (NAS, 1980). In the present experiment the intercropped casuarina can generate a fuel wood yield of around 85 t (worth Rs.34,000/-) for a rotation period of 8 years. Thus it can be seen that casuarina can be successfully intercropped in coconut gardens and raising food crops in coconut - casuarina alleys does not bring about any reduction in the fuel wood yield of casuarina. Casuarina also possesses the added advantage that it can enrich the soil nitrogen by way of nitrogen fixation and organic matter content by litter deposition (Prakash and Hocking, 1986). Another advantage of casuarina is the fairly large amount of solar radiation which infiltrates through its canopy which infact may be one of the main reasons for the success of the component crops grown in the coconut - casuarina alleys. However some reduction in the yield of alley crops was observed compared to the sole crop yield. Any such reduction can very well be compensated by the fuel wood yield generated by the casuarina. From the economic point of view also, these cropping systems are viable as is evident from the gross and net returns. The soil analysis studies also reveal that these dense cropping systems leave the soil richer in most of the nutrients than the control plots where no intercrops are grown.

4.2.2. Root distribution of casuarina

The lateral as well as the vertical spread of the roots were studied and the data are presented in Table 21 and illustrated in Fig. 7. The roots of casuarina were found to extend upto a lateral distance of 260 cm. In the top 30 cm the highest concentration of the roots was observed to be at a lateral distance of 80-220 cm. The lateral spread decreased with increase in depth. Almost 70% of the roots were concentrated in the top 30 cm. The percentage of root distribution at 40 cm and 50 cm depth were only 14 and 12, respectively. The root excavation could not be extended beyond 50 cm depth because of the hard and rocky nature of the land.

Table 21. Root distribution of casuarina intercropped in coconut alleys (%)

Depth (cm)	Lateral distances (cm)														Total
	20	40	60	80	100	120	140	160	180	200	220	240	260	280	
10	1.06	1.76	1.41	3.17	3.87	3.17	3.17	0.70	3.52	3.52	2.82	1.76	1.06	0.35	31.34
20	1.06	1.06	1.06	2.11	1.41	2.11	2.46	1.41	1.76	2.82	2.82	1.41	0.35	-	21.84
30	2.11	0.35	-	3.17	1.41	2.11	3.52	1.06	0.35	2.46	2.46	1.41	-	-	20.41
40	1.41	0.70	1.06	2.11	1.76	2.46	1.76	0.35	0.70	0.70	-	-	0.70	0.35	14.06
50	2.11	0.70	0.70	1.76	1.41	2.82	1.41	0.35	0.70	0.35	-	-	-	-	12.31
Total	7.75	4.57	4.23	12.32	9.86	12.67	12.32	3.87	7.03	9.85	8.1	4.58	2.11	0.7	99.96



EACH DOT (•) REPRESENTS ONE PERCENTAGE OF ROOT

FIG. 7. ROOT DISTRIBUTION PATTERN OF CASUARINA

As the roots of casuarina are mainly concentrated at 0-30 cm depth the root level competition with coconut will be limited as the roots of coconut palm are mainly distributed through a depth of 30-120 cm (Kushwah et al., 1973).

4.3. Growth of coconut

The increment in the height, girth and the number of leaves of coconut trees are presented in Table 22. In general, the growth of the coconut trees was slow where there was no intercropping. All the cropping systems had a favourable influence on the height of coconut. The influence of tapioca + groundnut, fodder maize + cowpea - fodder cowpea, guineagrass and groundnut - blackgram cropping systems were significantly superior to the other cropping systems with respect to the height of coconut. The increment in the girth of the coconut trees was found to be higher in all the cropping systems compared to the control plot where no intercrops were grown. The different cropping systems had a favourable influence on the number of leaves of coconut trees also. Thus it can be seen that growing of the different intercrops in the coconut - casuarina alleys infact had a favourable influence on the base crop of coconut. Davappa et al. (1986) had observed

Table 22. Increment in the growth characters of coconut as influenced by the different cropping systems

Cropping system	Height (cm)	Girth (cm)	Number of leaves
T + GN	218.67	34.00	7.67
A → HG	116.67	28.00	8.67
(M+C) → C	243.33	33.67	5.00
G	206.67	33.00	7.67
C → S	160.33	34.33	5.33
GN → BG	238.67	32.00	5.67
P → S	195.33	32.33	7.67
CO	68.33	18.33	3.33
SEm±	43.81	2.16	1.13
CD (0.05)	NS	6.56	3.42
CV	41.92	12.19	30.64

a substantial increase in coconut biomass production following intercropping, while the biomass of the intercrops remained the same. Improved coconut yields due to intercropping have been reported by many other workers also (Sahasranaman, 1964; Kotalawala, 1968; Kuttappan, 1971). The increase in the growth of coconut following intercropping may be due to the indirect effect of fertilisers and cultural operations done on the intercrops (Nair *et al.*, 1974).

4.4. Influence on micro-meteorological parameters

4.4.1. Soil temperature

The soil temperatures as influenced by the different cropping systems for the period 30th September, 1987 to 14th January, 1988 in the coconut - casuarina alleys are given in Table 23 and illustrated in Fig. 8 (weekly changes are presented in Appendix IV).

Raising the intercrops in the coconut - casuarina alleys decreased the soil temperature considerably. This difference was most noticeable in the case of afternoon soil temperature. The intercrops because of their canopy were able to intercept large part of the insolation and prevent heating up of the soil. Though the morning soil

Table 23. Average soil temperature and relative humidity for the period 30th September 1987 to 14th January 1988 as influenced by the annual crops intercropped in coconut - casuarina alleys

Cropping system	Soil temperature (°C)		Relative humidity (%)	
	7.25 am	2.25 pm	7.25 am	2.25 pm
T	24.8	33.6	90.1	67.8
A → HG	25.3	31.2	91.6	66.3
C	25.5	33.1	92.1	74.3
G	26.1	30.6	92.9	67.6
S	25.1	33.5	94.1	68.3
BG	25.2	31.0	89.6	65.5
S	25.0	32.3	94.5	68.9
CO	25.8	34.1	90.1	61.8

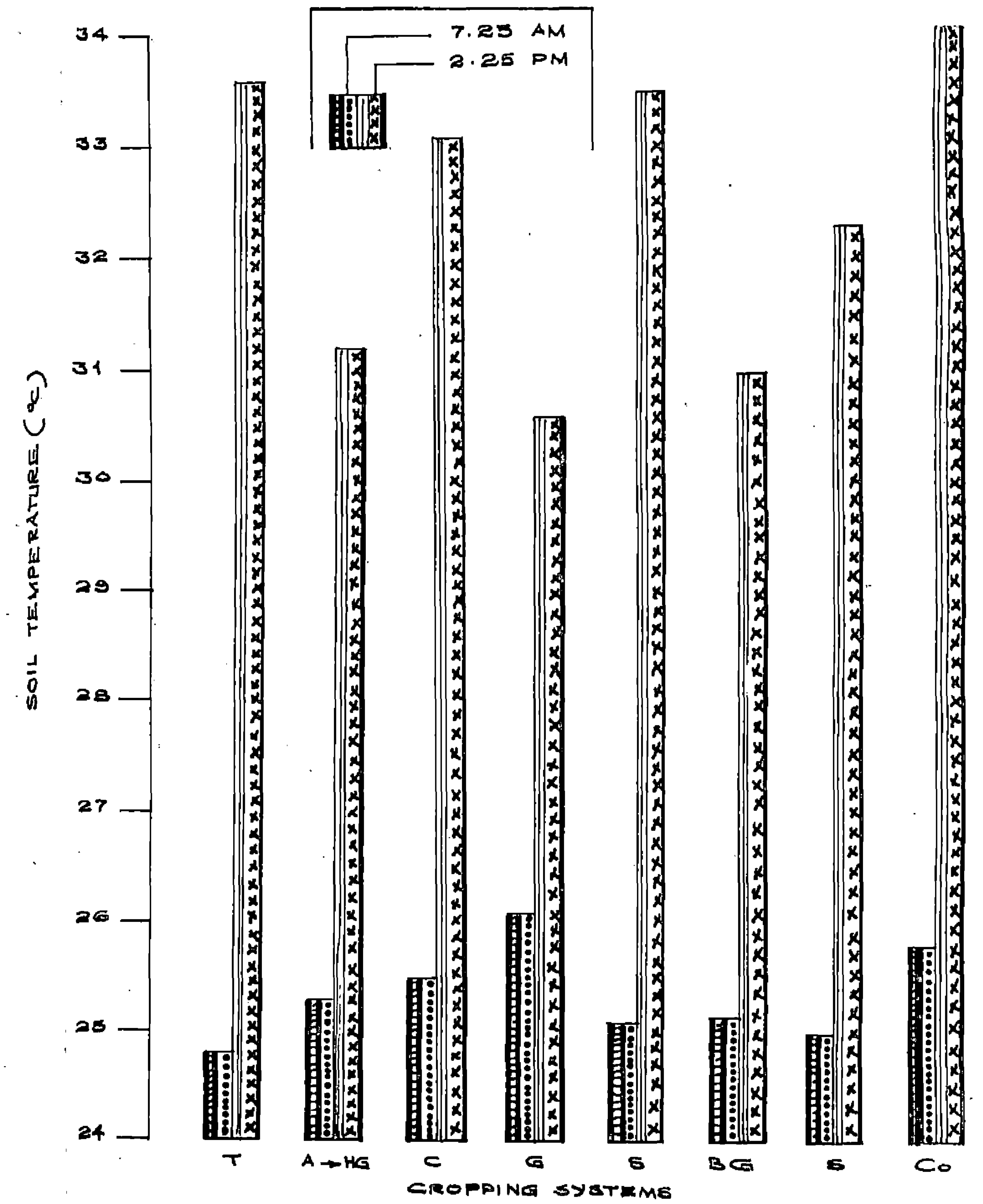


FIG.8. SOIL TEMPERATURE AS INFLUENCED BY THE DIFFERENT COMPONENT CROPS IN THE COCONUT-CASUARINA ALLEYS

temperature was relatively higher in guineagrass plots, it had the least afternoon soil temperature. All the cropped plots had a lower afternoon soil temperature than the control where no intercrops were grown.

The results obtained are found to support the observation that the maximum day temperature was always higher in the open area and lowest within the crop combination (Balakrishnan *et al.*, 1976). Thus shading and reduced air temperature in the crop combination cause considerable reduction in the rate of evaporation in the ecoclimate of crop combination (Nair and Balakrishnan, 1977).

4.4.2. Relative humidity

The average relative humidity values noted in the different cropping systems in the coconut - casuarina alleys during the period 30th September, 1987 to 14th January, 1988 are given in Table 23 and illustrated in Fig. 9. The weekly Whirling Psychrometer readings are given in Appendix V and the relative humidity values are given in Appendix VI.

In the morning hours, though there was no remarkable difference in relative humidity recorded under different

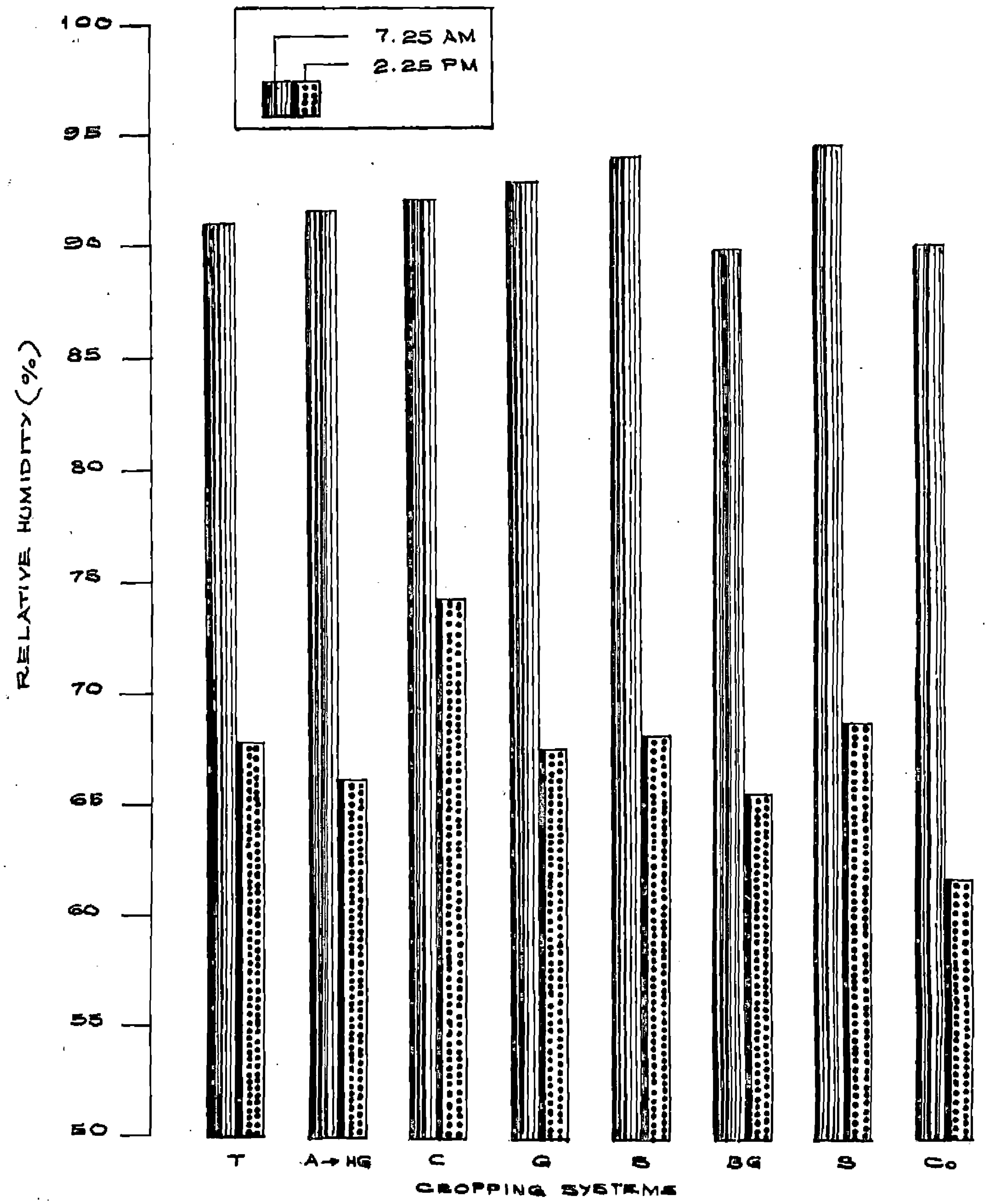


FIG. 9. RELATIVE HUMIDITY AS INFLUENCED BY THE DIFFERENT COMPONENT CROPS IN THE COCONUT - CASUARINA ALLEYS

cropping systems, almost all the intercropped plots had a higher relative humidity than the control plot. There was considerable difference in the relative humidity recorded during the afternoon. All the intercropped plots had a much higher relative humidity than the control plot. Nair and Balakrishnan (1977) observed that variation in relative humidity was much less and the ecoclimate was much more humid in crop combinations than in the open area.

These microclimatic differences under different cropping systems may influence the productivity of the systems which require detailed investigation. It is likely that the higher relative humidity and lower soil temperature can reduce the evapo-transpiration demand of the cropping system and thus can increase the water use efficiency.

Summary

SUMMARY

An investigation was conducted at College of Horticulture, Vellanikkara during 1987-88 on the biomass productivity of different annual crops under coconut - casuarina alleys. The experiment was laid out in RBD and replicated 3 times. The results of the experiments are summarised below:

The height increment of alley cropped tapioca was higher than the sole crop when it was intercropped in coconut - casuarina alleys. The pattern of increment in the height of groundnut grown along with tapioca in these alleys was comparable with that of groundnut grown alone in the alleys. The crop of amorphophallus was relatively taller and the girth of the stem higher in coconut - casuarina alleys when compared to sole crop. The height increment of fodder maize in fodder maize + cowpea mixture was higher when it was intercropped in coconut - casuarina alleys. The plant height of fodder cowpea was depressed when grown mixed with fodder maize. The plant height observed immediately before each cutting of guineagrass was found to be more in coconut - casuarina alleys.

The height of sesamum grown after cowpea was lower as compared to the height of sesamum grown after modan

paddy in coconut - casuarina alleys. The plant height of blackgram in coconut - casuarina alleys was higher than the sole crop.

The yield of tapioca decreased when it was grown in coconut - casuarina alleys. The yield of groundnut grown mixed with tapioca was lower than the groundnut grown alone in the coconut - casuarina alleys. The corm yield of amorphophallus decreased in coconut - casuarina alleys. Fairly high fodder yields of maize (mixed with cowpea) and guineagrass were observed when grown in coconut - casuarina alleys. Sesamum crop yielded more when raised after modan paddy in coconut - casuarina alleys. A decrease in the yield of blackgram was noticed when it was grown in coconut - casuarina alleys compared to sole crop yield. The yield of modan paddy was rather low in coconut - casuarina alleys.

The highest dry matter yield was produced by the amorphophallus - horsegram cropping system and the lowest by the groundnut - blackgram cropping system.

Among the different cropping systems, amorphophallus - horsegram cropping system yielded the maximum crude protein and paddy - sesamum cropping system, the minimum.

The nitrogen uptake was highest for amorphophallus - horsegram cropping system and phosphorus and potassium uptake were highest for guineagrass (throughout) cropping systems. The lowest uptake of nitrogen was by paddy - sesamum, phosphorus by groundnut - blackgram cropping system and lowest potassium uptake was by cowpea - sesamum cropping system.

The soil physical properties like bulk density, particle density and maximum water holding capacity were not influenced by the different cropping systems.

The highest net income (Rs.21,583/-) was obtained from amorphophallus - horsegram cropping system in coconut - casuarina alleys and the lowest (Rs.2,062/-) from paddy - sesamum cropping system in coconut - casuarina alleys. Fodder cowpea grown with fodder maize proved to be uneconomical with a benefit cost ratio of 0.81.

A linear growth pattern over time was observed with respect to height, canopy spread and girth of casuarina grown in coconut alleys. The current annual volume increment of casuarina was observed to be 21.38 cum/ha/annum which can generate a fuel wood yield of 10.7 t/ha/annum. Most of the roots of casuarina were concentrated in the upper 30 cm of the soil and upto a lateral distance of 240 cm from the base of the tree.

The growth of coconut trees was found to be slow where there was no intercropping.

Intercropping in coconut - casuarina alleys decreased the soil temperature considerably. The relative humidity at different heights within the canopy increased due to intercropping in coconut - casuarina alleys.

The results indicate that intercropping in coconut - casuarina alleys can be successfully conducted. The cropping systems which recorded fairly high biomass production were amorphophallus - horsegram, guineagrass, fodder maize + cowpea - fodder cowpea, tapioca + groundnut. Similarly fairly high gross income, net income and benefit cost ratios were derived from amorphophallus - horsegram, fodder maize + cowpea - fodder cowpea and groundnut - blackgram cropping systems. It was also observed that the different component crops grown in the alleys did not adversely affect the growth of both the tree species, coconut and casuarina. The root distribution pattern of the casuarina tree indicates that the chances for inter-specific competition with coconut for nutrients and water are limited.

Casuarina also possesses the added advantage that it can enrich the soil by way of nitrogen fixation and improve organic matter content by litter deposition. The slight reduction observed in the yield of the component crops can be compensated by the fuel wood generation of casuarina to the tune of 10-11 t/ha/annum. It was also seen that most of these high density cropping systems involving legumes left the soil richer with respect to most of the nutrients.

References

REFERENCES

Agboola, A.A. and Fayemi, A.A. (1970). 1. Intercropping maize with legumes. 2. Effect of phosphorus and intercropping of tropical legumes on the yield of maize. W. Afr. J. Biol. Appl. Chem. 13(2):31-38.

Agboola, A.A. and Fayemi, A.A. (1971). Preliminary trials on the intercropping of maize with different legumes in Western Nigeria. J. agric. Sci. Camb. 77:219-225.

Ahlawat, M.R., Saini, S.S. and Jindia, J.R. (1964). Effect of nitrogen on the yields of some early kharif fodders grown alone or mixed with legumes. J. Res. Punjab Agric. Univ. 1(1):106-110.

Ahmed, S. and Gunasena, H.P.M. (1979). Nitrogen utilisation and economics of some intercropped systems in tropical countries. Trop. Agric. 56(2):115-125.

Anilkumar, A.S. (1984). Crop geometry studies in tapioca based intercropping systems. M.Sc.(Ag.) thesis submitted to Kerala Agricultural University, Trichur, Kerala, India.

Anonymous (1934). Madras Agricultural Station's report for 1932-33. Dept. of Agriculture, Madras, India. pp.267-308.

Anonymous (1942). Madras Agricultural Station's Report for 1940-41. Dept. of Agriculture, Madras, India. pp.375-384.

Anonymous (1955). Cowpeas. Annual report. Nigeria Department of Agriculture. pp.31-33.

Anonymous (1974). Annual Report of All India Co-ordinated Project for Research on Forage Crops. Tamil Nadu Agric. Univ., Coimbatore:30-31.

Anonymous (1980). Report on the Timely Reporting Survey of Agricultural Statistics in Kerala - 1977-78. The Bureau of Economics and Statistics, Govt. of Kerala, pp.33.

Anonymous (1980). Ten years' report of All India Co-ordinated Project for Research on Forage Crops. Kerala Agricultural Univ. College of Agriculture, Vellayani, Kerala. pp.88.

A.O.A.C. (1950). Official Methods of Analysis of Association of Official Agricultural Chemists. 7th edn. Washington DC, pp.1-343.

Arthur, D.L. (1971). Competition between grass and legume species on dry land. Agron. J. 63(3):359-362.

Ashokan, P.K. (1986). Production potential of cassava based cropping systems. Ph.D. thesis submitted to Kerala Agricultural University, Vellanikkara, Trichur.

Athul, Chandra and Yamadagni, R. (1983). Determination of root distribution in Tangelo cv. Pearl by root excavation. Phil. Agr. 66:190-197.

Ayyangar, C.N.R. (1942). Mixed cropping in India. Indian Fmg. 3:255-276.

Baker, E.F.I. (1978). Mixed cropping in Northern Nigeria. 1. Cereals and groundnuts. Expl. Agric. 14(4): 293-298.

Balakrishnan, T.K., Nair, P.K.R. and Nelliat, E.V. (1976). Microclimate of coconut varieties and cacao and cinnamom grown as mixed crops with coconut. Indian J. Met. Hydrol. and Geophysics. 27:71-74.

Bavappa, K.V.A., Kailasam, C., Khader, K.B.A., Biddappa, C.C., Khan, H.H., Kasthuri Bai, K.V., Ramadasan, A., Sundararaju, P., Bopaiah, B.M., Thomas, G.V., Misra, L.P., Balasimha, D., Bhat, N.T. and Bhat, K.S. (1986). Coconut and arecanut based high density multi species cropping systems. J. Plantation Crops. 14(2):74-87.

Beer, J. (1979). Traditional agroforestry practices in the wet tropics, the La Suiza case study. Proc. Symposis International Solerelas Ciencias Forestales Y Su Contribucion al Desaurollo de la America Tropical, San Jose Costa Rica. 7(3):2-5.

Bene, J.G., Beall, H.W. and Cote, A. (1977). Trees, Food and People, IDRC, Ottawa, Ont. pp.52.

Bindu, R. (1988). Productivity of tuber crops under alley cropping of tropical trees. M.Sc.(Ag.) Thesis submitted to Kerala Agricultural University, Vellanikkara, Trichur.

Blackman, G.E. and Black, J.N. (1959). Physiological and Ecological studies in the analysis of plant environment. 12. The role of the height factor in limiting growth. Ann. Bot. Lond. 23:131-145.

Bourke, R.M. (1985). Food coffee and casuarina and agroforestry system from the Papua New Guinea highlands. Agroforestry Systems. 2. pp.273-279.

Bridgit, T.K. (1985). Fertilizer management in cassava - groundnut intercropping system. M.Sc.(Ag.) thesis submitted to Kerala Agricultural University, Trichur, Kerala.

* Burkill, I.H. (1966). A dictionary of the Economic Products of the Malay Peninsula - Governments of Malaysia and Singapore by the Ministry of Agriculture and Co-operatives, Kuala Lumpur, Malaysia.

Catedral, I.G. and Lantican, R.M. (1977). Evaluation of legumes for adaptation to intensive cropping systems: II Soybeans, Glycene max, Philippine J. Crop Sci. 2:67-71.

CPCRI (1973) Central Plantation Crops Research Institute. Annual Report for 1972. CPCRI, Kasargod, India.

CTCRI (1984) Central Tuber Crops Research Institute. Annual Report. CTCRI, Trivandrum, India. pp.75-77.

* CIAT (1982). Centro Internacional de Agricultura Tropical. Annual Report for 1981. (Cassava program). CIAT, Cali, Colombia, pp.28-43.

*Chand, P. (1977). Studies on the effect of intercropping of maize with grain legumes and its impact on nitrogen economy and yield in Kulu valley. Thesis Abstr. 4(3):178.

Chandini, S. (1980). Fodder production potential of Grass-legume mixtures. M.Sc. (Ag.) Thesis submitted to Kerala Agricultural University, College of Agriculture, Vellayani, Trivandrum.

Chaturvedi, N. (1983). Eucalyptus for farming in Uttar Pradesh. Forest Bull. 48:1-48.

Chauhan, D.S., Mahajan, J.M. and Tomar, U.P.S. (1971). Cowpea for forage in Himachal Pradesh. Indian Fmg. 21:39.

Chauhan, G.S. and Dungarwal. (1980). Companion cropping of maize with legumes for forage. Madras agric. J. 67(4):233-238.

Couto, L., De Barros, N.P. and Rezende, G.C. (1982). Interplanting soybean with eucalyptus as a 2 tier agroforestry venture in South Eastern Brazil. Australian Forest Res. 12:329-332.

CSIR (1950). Wealth of India: Raw Materials Vol.II. Casuarina Linn. Council of Scientific and Industrial Research, New Delhi, India. pp.101-103.

Donald, C.W. (1963). On various aspects of plant competition. Adv. Agron. 15:147.

Duncan, W.G. (1975). Maize: Crop Physiology, Some Case Histories. Cambridge University Press. pp.23-51.

Dwivedi, A.P. (1980). Forestry In India. Jugal Kishore and Company, Dehradun. pp.343.

Ekmahachai, P., Maneekaow, A., Tougham, A., Tirapon, C. and Sintuprama, S. (1978). Methods of intercropping cassava with peanuts. Cassava Res. Report of the Thailand Ministry of Agriculture, Field Crop Division, Bangkok. pp.33-37.

Elkan, G.H. ed. (1987). <u>Symbiotic Nitrogen Fixation Technology</u>. Marcel Dekker, Inc. New York. pp.30-31.

Erickson, F.I. (1977). The effect of different light intensities on morphology, yield and nitrogen fixation rates of tropical grasses and legumes. Ph.D. dissertation. Univ. of Hawaii, Honolulu, U.S.A.

Evans, J. (1982). <u>Plantation Forestry in the Tropics</u>. Oxford Univ. Press, New York. pp.124-125; 356; 382.

Ezumah, H.C., and Okigbo, B.N. (1980). Cassava planting systems in Africa. <u>Proceedings of a workshop on cassava cultural practices held in Salvador</u>, Bahia, Brazil. pp.44-49.

Ferdinandez, D.E.F. (1973). Utilization of coconut lands for pasture development. <u>Ceylon Cocon</u>. <u>Planters' Rev</u>. <u>7</u>(1):14-19.

Francis, C.A. (1986). Multiple cropping with legumes and starchy roots. <u>Multiple Cropping Systems</u>. Macmillan Publishing Company, New York. pp.150.

Geetha, P. (1984). Genotype x environment interaction for yield and its components in sesamum. M.Sc.(Ag.) Thesis submitted to Kerala Agricultural University, College of Agriculture, Vellayani, Trivandrum.

George, M. (1981). Fodder production potential of maize-legume mixtures in coconut gardens. M.Sc.(Ag.) Thesis submitted to Kerala Agricultural University, Vellayani, Trivandrum.

George, S. (1982). Shade Response of Common Rainfed Inter-crops of Coconut. Part II. Legumes. M.Sc.(Ag.) Thesis submitted to Kerala Agricultural University, Vellanikkara, Trichur.

Ghosh, S.P., Pillai, K.S. and Thankappan, M. (1986). Cassava based multiple cropping system - Incidence of pests and diseases. J. Root Crops. 12(2): 83-89.

Ghosh, S.P., Pillai, N.G., Pal, T.K., Ramanujam, T., Kabeerathumma, S., Pillai, K.S., Thankappan, M., Mohankumar, B., Nair, G.M. and Lakshmi, K.R. (1985). Cassava based cropping system. Annual Report. Central Tuber Crops Research Institute, Trivandrum, Kerala. pp.104-108.

Gill, A.S. and Patil, B.D. (1985). Subabul for forage production under intercropping. A new approach. Indian Fmg. 35(6):37.

Giri, G. and De, Rajat. (1979). Effect of preceding grain legumes on dry land pearl millet in N.W. India. Expl. Agric. 15:169-172.

Gopalasundaram, P. and Nelliat, E.V. (1979). Intercropping in coconut. In "Multiple Cropping in Coconut and Arecanut Gardens". Tech. Bull No.3, CPCRI, Kasargod, Kerala pp. 6-23.

GOI (1984). Government of India, Report of the Committee of Rights and Concessions in Forest Areas of India.

Guljaev, E.I. and Ronsal, G.A. (1962). The effect of root secretions of annual legumes on intercropped maize. Bot. Z.SSSR. 47(8): 1152-1159.

*Haizel, K.A. (1974). The agronomic significance of mixed cropping I. Maize interplanted with cowpea. Abstr. Trop. Agric. 1(12): 141.

Henzell, E.F. (1962). Nodulation and nitrogen fixation of tropical legume. Adv. Agron. 22: 23-26.

*Henzell, E.F. (1970). Problems in comparing the nitrogen economics of legume based and nitrogen fertilized pasture systems. Proc. XI Int. Grasslds. 112-120.

Hesse,P.R. (1971). A Text Book of Soil Chemical Analysis. Ied. John Murray Publishers Ltd., London pp. 520.

Huxley, P.A. (1981). The place of fast growing nitrogen fixing trees in agroforestry - Discussion paper presented to National Academy of Sciences Programme Planning Meeting, Washington. pp.8.

IRRI (1975). International Rice Research Institute, Los Banos Philippines. Annual Report. pp. 15-34.

Jackson, M.L. (1958). Soil Chemical Analysis. Ied. Prentice Hall Inc., U.S.A. pp. 498.

Joy, P.P., Rajaram, K.P., and James, K.I. (1986). A rice-grain legume cropping system. IRRI Newsletter. 11(6):37-38.

Kabeerathumma, S., Ghosh, S.P. and Lakshmi, K.K. (1985). Soil erosion and surface run off - Multiple systems compared. Cassava Newsletter. 9(2):5.

Kalpage, F.S. (1974). Tropical Soils - Classifications Fertility and Management, St. Martin, New York.

Kannan, K. and Nambiar, K.P.P. (1976). Studies on inter-cropping coconut garden with annual crops. Cocon. Bull. 7(9):1-3.

Kang, B.T., Wilson, G.F. and Sipkens, L. (1981). Alley cropping maize (Zea maya L.) and leucaena (Leucaena leucocephala Lam.) in Southern Nigeria. Plant and Soil. 63:165-197.

Kassam, A.H. (1976). Crops of the West African semi-arid tropics. ICRISAT Annual Report, Hyderabad. pp.37-40.

Kawano, K. and Thung, M.D. (1982). Intergenotypic competition and competition with associated crops in cassava. Crop Sci. 22(1):59-63.

Keen, B.A. and Raczkowski, H.J. (1921). Relationship between clay contents and certain physical properties of soils. J. Agric. Sci. Camb. 11:441-449.

KAU (1984). Kerala Agricultural University Research Report for 1981-82. KAU, Trichur, Kerala, India. pp.433-451.

KAU (1986) Kerala Agricultural University. Package of Practices Recommendations. Directorate of Extension, Mannuthy, Trichur, Kerala, India.

Khybri, M.L., Sewa, R. and Bhardwaj, S.P. (1985). Management of eroded lands for agriculture (corrective measures). Soil Conservation Annual Report. Central Soil and Water Conservation Research and Training Institute, Research Centre, Vasad. pp.55-56.

King, K.F.S. (1978). Agroforestry. Proc. of the 50th Symposium on Tropical Agriculture. RTI Bulletin 303. pp.1-10.

King, K.F.S. and Chandler, M.T. (1978). The Wasted Lands. ICRAF, Nairobi, pp.36.

Kotalawala, J. (1968). Pineapple cultivation in coconut land in the low-country wet zone. Ceylon Coconut Planters' Review. 5(3):112-114.

Krishna, S. and S. Ramaswamy. (1932). Calorific value of some Indian woods. Indian Forestry Bull. No.79.pp.1-27.

Kulkarni, D.H. and Seth, S.K. (1968). Selection and evaluation of quick growing forest species with special reference to Indian conditions. Proc. of the ixth Common Wealth Forestry Conference.

Kushwah, B.L., Nelliat, E.V., Markose, V.J. and Sunny, A.E. (1973). Rooting pattern of Coconut. Indian J. Agron. 18:71-74.

Kuttappan, M. (1971). Banana - beneficial intercrop in coconut gardens. Cocon. Bull. 1(2):2-4.

Leather (1897). Effect of legume and non-legume grown pure and mixed on yield and quality of forage. Indian Agric. 12(1):62-63.

Leela, K. and Bhaskaran, U.P. (1978). Effect of inter-cropping coconut stands with groundnut on soil fertility and plantation management. PLACROSYM I (1978). Proc. of the 1st annual symposium on plantation crops. Central Plantation Crops Research Institute, Kasargod, Kerala, India. pp.393-398.

Liyanage, M.D.E.S., Tejwani, K.G. and Nair, P.K.R. (1984). Intercropping under coconuts in Sri Lanka. Agro-forestry Systems. 2:215-228.

Madok, M.R. (1940). Association of legumes and non-legumes. J. Agric. Sci. 49:419-432.

Maghembe, J.A. and Redhead, J.F. (1982). Agroforestry: Preliminary results of intercropping Acacia, Eucalyptus and Leucaena with maize and beans. Proc. 2nd symposium on intercropping in semi arid areas. (Ndunguru, B.J. and Keswani, C.L., eds.) I.D.R.C., Ottawa, Canada. pp.186.

Marar, K. (1964). Intercropping in coconut plantations in India - problems and prospects. Proc. of 2nd session FAO. Tech. Wkg. Pty. Cocon. Prod. Prot. Processg., Colombo. pp.393-398.

Marcus, A. (1935). Maniok, Manihot utilissima. Tropeno-flanzer. 38: pp.144-157.

Martin, M.P.L.D. (1984). Coconut agronomic and breeding research in Fiji. Fiji agric. J. 46(2):1-7.

Meenakshi, K., Fazlullakhan, A.K. and Appadurai, R. (1974). Studies on intercropping of short duration vegetables with maize. Madras agric. J. 61:398-401.

Mohankumar, C.R. (1975). Studies on intercropping. Central Tuber Crops Research Institute (CTCRI), Annual Report. Kerala, India. pp.24-26.

Mohankumar, C.R. and Hrishi, N. (1978). Intercropping systems with cassava in Kerala State. Proc. of an International workshop on intercropping with cassava. Central Tuber Crops Research Institute, Trivandrum, India.

Mohankumar, C.R. (1980). Intercropping studies with legumes and non-legumes with cassava, Annual Report. Central Tuber Crops Research Institute, Trivandrum, Kerala. pp.25-27.

Mohatkar, L. (1987). Intercropping of guineagrass with subabul. Seeds and Farms. 1(13):24-26.

Morachan, Y.B., Palaniappan, S.P., Theetharappan, T.S. and Kamalam, N. (1977). A note on the studies on intercropping in sorghum with pulses. Madras agric. J. 64(9):607-608.

Mullakoya, P. (1982). Shade tolerance of guineagrass (Panicum maximum) under different levels of potassium. M.Sc.(Ag.) Thesis submitted to Kerala Agricultural University, College of Agriculture, Vellayani, Trivandrum.

Myhr, K. and Saebo, S. (1969). The effect of shade on growth, development and chemical composition in some grass species. Forsk. Fors. Landbr. 20: 297-315.

Nair, K.P.P., Patel, U.K., Singh, R.P. and Kaushik, M.K. (1979). Evaluation of legume intercropping in conservation of fertiliser nitrogen in maize culture. J. agric. Sci. Camb. 93:189-194.

Nair, M.A. and Sreedharan, C. (1986). Agroforestry farming systems in the homesteads of Kerala. Agroforestry Systems. 4(4):339-363.

Nair, P.K.R. (1979). Intensive Multiple Cropping with Coconuts in India - Principles, programmes and Prospects. Verlag Paul Parey, Berlin. pp.147.

Nair, P.K.R. and Balakrishnan, T.K. (1977). Ecoclimate of a coconut + cacao crop combination on the West Coast of India. Agric. Meteorology. 18:455-462.

Nair, P.K.R., Rama Varma and Nelliat, E.V. (1974). Intercropping for enhanced profits from coconut plantation. Indian Fmg. 24(4):11-13.

Nair, P.K.R. and Varghese, T. (1976). Crop diversification in coconut plantations. Indian Fmg. 25(11):17-21.

Nair, P.N. (1980). Vanalakshmi, an agroforestry project in Kerala. Indian Forester. 106(12):829-836.

Nair, T.V.R. (1986). Production potential of cassava intercropped in coconut gardens. Ph.D. Thesis submitted to K.A.U., Vellanikkara, Trichur.

Nambiar, K.T.N., Singh, H.B. and Chinnamani, S. (1986). To study the effect of raising fast growing tree species around agricultural crops on crop production. Soil conservation annual report. Central Soil Water Conservation Research and Training Institute, Research Centre, Vasad. 111p.

Narayana, G.V. (1986). Training and education in agroforestry. My Forest 22(1):33-36.

NAS (1980) National Academy of Sciences. Firewood Crops: Shrub and Tree Species for Energy Production. NAS Washington. pp.38-41.

Nelliat, E.V., Bavappa, K.V.A. and Nair, P.K.R. (1974). Multistoreyed cropping - A new dimension in multiple cropping for coconut plantations. Wld. Crops. 26(6):262-266.

Nelliat, E.V. (1976). Garden land management. Indian Fmg. 25(11):6-7.

Nelliat, E.V. and Bhat, K.S. eds. (1979). Multiple Cropping In Coconut and Arecanut Gardens. Tech. Bull. CPCRI, Kasargod, Kerala. pp.6-24.

Nelliat, E.V. and Krishnaji, N. (1976). Intensive cropping in coconut gardens. Indian Fmg. 27(9):9-12.

Ogbe, G.A.E. (1967). Tectona grandis L. Min. Agric. Nat. Res., Mid - Western Nigeria, Mineo, pp.4.

Okoli, P.S.O. and Wilson, G.F. (1986). Response of cassava to shade under field condition. Field Crops Res. 14(4):349-359.

Palaniappan, S.P., Balasubramanian, A. and Ramaswami, C. (1976). Intercropping of sorghum with legumes for saving nitrogen. Sorghum Newsletter. 19:86.

Panse, V.G. and Sukhatme, P.V. (1978). Statistical Methods. for Agricultural Workers. 3rd edn. ICAR, New Delhi. pp.347.

Pant, M.M. (1980). The impact of social forestry on the national economy of India. International Tree Crops. J. 3:69-92.

Pascual, P.P., Mabbayad, B.B., Quintana, R.V. (1972). Studies on cultural practices for sorghum grown after rice. Philippine J. Crop Sci. 3(1):38-45.

Patanothi, A., Laohasiriwong, S. and Wickham. (1977). A comparison on single rows vs. double row inter-cropping patterns of cassava - legume intercropping Annual Report. Khonkane Univ. Thailand, pp.31-35.

*Permeti, M. (1969). The increase of protein in green bulk of summer crops, maize and sorghum through their mixture with bean plants. Herb. Abstr. 41(1):166.

Pillai, G.R. (1986). Production potential of two fodder grasses under different management practices. Ph.D. Thesis submitted to Kerala Agricultural University, College of Agriculture, Vellayani, Trivandrum.

Pillai, M.D. (1985). Inter and multiple cropping with coconuts - a bibliography. Indian Cocon. J. 15(11):15-24.

Pillai, N.G., Ravindran, C.S. and Kailasam, C. (1985). Intercropping tuber crops with coconut. Annual Report. Central Tuber Crops Research Institute, Trivandrum, Kerala. pp.100-101.

Piper, C.S. (1942). Soil and Plant Analysis. I edn. Academic Press, New York. 368p.

Plucknett Donald, L. (1979). Managing Pastures and Cattle under Coconuts. Westview Tropical Agriculture Series No.2, West View Press, Inc. USA.

Prabhakar, M., Mohankumar, C.R., and Nair, G.M. (1979). Intercropping of legumes, vegetables and medicinal plants and cassava. Central Tuber Crops Research Institute, Trivandrum, Kerala, India. Annual Report. pp. 25-30.

Prakash, R. and Hocking, D. (1986). Some Favourite Trees For Fuel and Fodder. Soc. for Promotion of Waste lands Development, New Delhi. pp. 55-62.

Prasad, S.N. and Verma, B. (1985). Intercropping of field crops with fodder crop of subabul under rainfed condition. Soil Conservation Annual Report. pp. 90-91.

Raheja, P.C. (1966). Soil Productivity and Crop Growth. Asia Publishing House, Bombay.

Ramachandran, K. (1981). Comparative physiology of blackgram (Vigna mungo L. Wilizek) genotypes under tree canopy. Ph.D. Thesis submitted to Tamil Nadu Agricultural University, Coimbatore, India.

Ramanagowda (1981). Production potential of fodder cowpea varieties in coconut garden at different levels of nitrogen and lime. Ph.D. Thesis submitted to Kerala Agricultural University, Vellanikkara, Trichur.

Ramanujam, T., Indira, P. and Nair, G.M. (1984a) Productivity of cassava under shade. Indian Fmg. 33 (12) : 39-42.

Ramanujam, T., Nair, G.M. and Indira, P. (1984b). Growth and development of cassava (Manihot esculenta, Crantz) genotypes under shade in a coconut garden. Turrialba, 34(3): 267-274.

Recknagel, A.B. and Bentley, J. (1985). Forest Management. International Book Distributors, Dehradun. pp.52-53.

RARS (1977) Regional Agricultural Research Station. Annual Report. RARS, Pattambi, Kerala.

Relwani, L.L. (1970). Cropping patterns for high milk production. Indian Fmg. 20:15.

Remison, S.U. (1978). Neighbour effects between maize and cowpea at various levels of N and P. Expl. Agric. 14(3):205-212.

Sahasranaman, K.N. (1964). It pays to grow groundnut in coconut gardens. Cocon. Bull. 18(4):123-130.

Sahasranaman, K.N. and Pillai, N.G. (1976). Mixed farming in coconut garden. Intensive Agric. 14(9): 6-10.

Samraj, P. (1977). The blue gum (Eucalyptus globulus Labill) tree an ideal species for farm forestry in the higher hills of Nilgiris. Soil Conservation Digest. 5(2):48-52.

Sharma, Y.M.L. (1983). Social forestry and eucalyptus. "The Hindu", daily newspaper dated 18th Oct. 1983. p.17.

Sharma, S.C. and Singh, H.G. (1972). Effect of methods of intercropping maize with cowpea on the production of animal feed. Indian J. agric. Sci. 42(10): 904-908.

Sheela, K.R. (1981). Nutritional requirement of tapioca based intercropping system. M.Sc.(Ag.) Thesis submitted to Kerala Agricultural University, Trichur, Kerala.

Singh, C.M. and Chand, P. (1979). Nitrogen accumulation in maize intercropped with grain legume under varying levels of nitrogen. Food Fmg. Agric. 10(9):314-316.

Singh, D., Mannikar, N.D., Srivas, N.C. and Saxena, D.C. (1977). Changes in soil fertility under long-term cultivation of fodder crops and grasses. J. Indian Soc. Soil Sci. 25(1):28-32.

Singh, D. and Relwani, L.L. (1978). Mixed cropping of maize with cowpea and velvet bean on the yield and chemical composition of fodder. Indian J. Dairy Sci. 31(1):28-33.

Singh, G.B. (1983). Role of agroforestry in improving the environment. Indian Fmg. 33(3):15-19.

Singh, H.K. (1975). Inter and multiple cropping of fodder and feed crops. Indian J. Genet. Pl. Breed. 35(2):276.

Singh, K.D. and Mandal, R.C. (1970). Intercropping in cassava. Central Tuber Crops Research Institute (CTCRI) Annual Report. Trivandrum, Kerala, India. pp.25.

Singh, R.D. and Chatterjee, B.N. (1968). Growth analysis of perennial grasses in tropical India. II. Herbage growth in mixed grass - legume swards. Expl. Agric. 4:127-134.

Skerman, P.J. (1977). Tropical Forage Legumes. Food and Agriculture Organisation of the United Nations, Rome. pp.609.

Soundararajan, D. and Palaniappan, S.P. (1979). Effect of intercropping on growth and yield components of redgram. Indian J. agric. Res. **13**:127-132.

Sreedharan, C. (1975). Studies on the influence of climatological factors on rice under different water management practices. Ph.D. thesis, Orissa Univ. of Agriculture and Technology, Bhubaneswar.

Subbiah, B.V. and Asija, G.L.A. (1956). A rapid procedure for the estimation of available nitrogen in soils. Curr. Sci. **25**:259-260.

Suresh, K.K. and Rai, V.R.S. (1987). Studies on the allelopathic effects of some agroforestry tree crops. International Tree Crops J. **4**(2):108-117.

Suryatna, E.S. and Hardwood, R.R. (1976). Nutrient uptake of two traditional intercrop combinations and insect and disease incidence in three intercrop combinations. IRRI Saturday Seminar, Feb. 18, 1976.

Swadija, K.O. (1984). Nutritional requirement for horse-gram (Dolichos biflorus Roxb.). M.Sc.(Ag.) Thesis submitted to Kerala Agricultural University, College of Agriculture, Vellayani, Trivandrum.

Swift, J.F. (1982). Intercropping of two Leucaena sp. with sweet potato. Leucaena Research Reports. **3**:52-53.

Syarifuddin, A., Suryatna, E.S., Ismail, I.G. and Mc Intosh, J.L. (1974). Performance of corn, peanut, mung bean and soybean in monoculture and intercrop combinations of corn and legumes in dry season, 1973. Contr. Centr. Inst. Agric. Bofor. 12, 1-13.

Syriac, E.K. (1983). Influence of the method of application of nitrogen and phosphorus on the growth, yield and quality of blackgram (*Vigna mungo* (L.) Hepper) M.Sc.(Ag.) Thesis submitted to Kerala Agricultural University, College of Agriculture, Vellayani, Trivandrum.

Thakur, C. (1980). Scientific Crop Production (3rd edn.) Metropolitan Book Co. Pvt. Ltd., Delhi. pp.426.

Thomas, A.I. and Nair, R.R. (1979). Companion cropping in the rainfed uplands. Agric. Res. J. Kerala. **17**(1):122-123.

Tomas, O.S., Gupta, R.K. (1985). Performance of some forest tree species in saline soils under shallow and saline water table conditions. Plant and Soil. **87**(3):329-335.

Troup, R.S. (1986). The Silviculture of Indian trees Vol. III. Lauraceae to Coniferae. Clarendon Press, Oxford, England.

Varghese, P.T. (1976). Intercropping in coconut gardens. Intensive Agriculture. **14**(8):12.

Varghese, T.P., Nelliat, E.V. and Balakrishnan, T.K. (1978). Beneficial interactions of coconut - cocoa crop combination. PLACROSYM I (1978). Proc. of the 1st annual symposium on Plantation Crops. Central Plantation Crops Research Institute, Kasargod, Kerala, India. pp.383-392.

Venkateswarlu, J., Reddy, N.V., Das, R.B. and Rao, V.M.B. (1981). Role of Leucaena in intercropping in dryland farming. Leucaena Research Reports. 2: 30.

Vergara, N.T. and Nair, P.K.R. (1985). Agroforestry in South Pacific region - an over view. Agroforestry Systems. 3:363-379.

Verinumbe, I. (1983). Economic evaluation of some zero tillage systems of land management for small scale farmers in South Western Nigeria. Ph.D. thesis submitted to the University of Ibadan, Nigeria. Forestry Abst. 44(10):609-610.

Walker, M.E. (1975). Calcium requirements for peanuts. Comm. Soil Sci. Pl. Analy. 6(3):299-313.

Watson, G.A. (1980). Tree intercropping possibilities. Proceedings of the Agricultural Sector Symposium. pp.139-159.

* Weightman, B.L. (1977). Pasture research and development in the New Hebrides. Proc. Regional Seminar Pasture Research, Ministry of Agriculture and Lands, Honiara, Solomon Islands. pp.252-257.

White, E.M., Kruerger, C.R. and Moore, R.A. (1976). Changes in total nitrogen, organic matter, available phosphorus and bulk densities of cultivated soil 8 years after time pastures were established. Agron. J. 68(4):581-583.

Willey, R.W. and Osiru, D.S.D. (1972). Studies on mixtures of maize and beans (Phaseolus vulgaris) with particular reference to plant population. J. Agric. Sci. Camb. 79:517-529.

*Wilson, G.F. and Kang, B.T. (1981). Developing stable and productive biological cropping systems for the humid tropics. In Biological Husbandry - A Scientific Approach to Organic Farming. Stonehouse, B. (ed.), Butterworths. pp.198.

*Zakra, A.N., Pomier, M., Taffin, G.DE. (1986). First results of an intercropping trial of coconuts and food crops in the Middle Ivory Coast. Oleagineux. 41(8/9):381-387.

* Originals Not Seen

Appendices

Appendix I

Meteorological observations of the period from 1987 May to 1988 May

	Temperature (°C)		Mean RH (%)	Rainfall (mm)	Mean sunshine hours
	Maximum	Minimum			
May 1987	36.1	24.7	66	95.0	9.0
June	30.7	23.7	83	837.7	4.2
July	30.3	23.5	84	336.5	5.7
August	29.6	23.5	87	388.4	3.7
September	31.5	23.9	79	174.0	7.4
October	31.9	23.9	79	280.4	6.2
November	31.6	22.8	77	224.4	6.7
December	31.6	23.3	70	64.6	8.1
January 1988	32.4	22.0	56	0	10.4
February	35.8	23.1	56	7.8	10.0
March	35.7	24.4	67	37.9	9.1
April	34.1	24.3	70	145.4	8.8
May	33.7	25.4	76	242.6	6.2

Appendix II

Nitrogen, phosphorus, potassium, calcium and magnesium content (at the time of harvest) of the different intercrops alley cropped in coconut - casuarina alleys

Intercrop	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Calcium (%)	Magnesium (%)
Tapioca	1.34	0.80	0.76	0.48	0.25
Groundnut	2.02	0.19	1.44	0.14	0.76
Amorphophallus	0.19	0.76	1.48	0.01	1.30
Horsegram	2.02	0.25	1.32	1.17	0.94
Fodder maize	1.38	0.13	0.87	0.34	0.28
Fodder cowpea	2.32	0.20	0.26	0.70	0.61
Guineagrass	1.82	0.23	1.17	0.32	0.48
Sesamum	2.65	0.33	0.75	0.79	0.69
Blackgram	2.32	0.27	1.39	0.73	0.47
Paddy	1.20	0.16	2.05	0.70	0.22

Appendix III

Cost of cultivation of different crops intercropped in coconut + casuarina alleys

Crops	Cost of seed (Rs.)	Cost of fertilizer (Rs.)	Labour charges (Rs.)	Total expenses (Rs.)	Yield (t/ha)	Cost/unit (Rs./kg)	Total income (Rs.)	Net income (Rs.)	Benefit cost ratio
Tapioca	600	1259	8177	10036	10	1.50	15000	4964	1.49
Groundnut (with tapioca)	600	151	4800	5551	0.915	15.00	13725	8174	2.47
Amorphophallus	24000	727	11437	36164	38.18	1.50	57270	21106	1.58
Horsegram	75	100	1600	1775	0.59	3.50	2077	302	1.17
Fodder maize	200	532	4859	8059	38.95	0.50	19475	11416	2.41
Fodder cowpea (mixture)	140	243	1600	1983	4.59	0.35	1606	-377	0.81
Fodder cowpea (pure)	280	486	3200	3966	12	0.35	4200	234	1.06
Guineagrass	6250	379	6459	13088	75.92	0.20	15184	2096	1.16
Fodder cowpea (pure)	280	486	3200	3966	27.13	0.35	9495	5529	2.39
Sesamum	60	316	3200	3576	0.30	15.00	4538	962	1.26
Groundnut (pure)	1200	623	6459	8282	2.54	7.00	17791	9509	2.14
Blackgram	400	337	6459	7196	0.45	20.00	9000	1804	1.25
Paddy	160	351	3200	3711	1.48 (grain)	2.00	2951		
					3.11 (straw)	0.30	933		
							3884	173	1.05
Sesamum	60	316	3200	3576	0.36	15.00	5465	1889	1.53

Appendix IV

Weekly soil temperature for the period 30th September 1987 to 14th January 1988 as influenced by the annual crops grown in coconut - casuarina alleys

	Tapioca		Amorpho-phallus		Fodder cowpea		Guinea-grass		Sesamum		Blackgram		Sesamum		Control	
	7.25 am	2.25 pm	7.25 am	2.25 pm	7.25 am	2.25 pm	7.25 am	2.25 pm	7.25 am	2.25 pm	7.25 am	2.25 pm	7.25 am	2.25 pm	7.25 am	2.25 pm
30th Sept. 1987	25.0	29.5	25.5	30.5	-	-	25.5	30.0	-	-	-	-	-	-	26.0	34.0
8th Oct. 1987	26.0	28.5	26.0	28.0	-	-	28.0	30.0	-	-	-	-	-	-	26.0	34.5
15th Oct. 1987	25.5	29.5	26.0	30.5	-	-	25.5	30.0	-	-	-	-	-	-	27.0	33.0
22nd Oct. 1987	25.5	27.5	25.5	28.5	-	-	27.5	30.0	-	-	-	-	-	-	27.0	32.0
29th Oct. 1987	24.5	26.0	26.0	28.5	26.5	31.5	25.5	29.0	26.5	33.5	27.0	37.0	-	-	26.5	32.5
5th Nov. 1987	26.0	35.0	26.0	32.5	26.5	33.5	27.0	29.0	26.5	34.5	27.0	37.0	-	-	26.5	32.5
12th Nov. 1987	25.0	33.0	25.0	30.0	25.5	32.0	26.5	31.0	25.0	30.5	25.0	31.5	-	-	25.5	32.5
			(Horsegram)													
19th Nov. 1987	24.5	30.5	24.0	29.0	24.5	31.0	25.0	31.0	25.0	31.0	24.5	29.0	24.5	30.5	25.5	32.5
25th Nov. 1987	24.5	35.5	25.0	34.5	25.5	35.0	26.0	32.0	25.0	36.0	25.0	29.0	25.0	31.0	25.5	35.0
3rd Dec. 1987	26.0	34.5	26.0	33.5	25.5	33.0	27.0	31.0	25.5	34.5	25.5	29.5	25.5	31.0	25.5	32.5
10th Dec. 1987	24.0	34.0	25.0	23.5	25.5	33.0	25.5	31.5	25.0	35.0	24.5	28.5	24.5	31.5	25.0	36.5
17th Dec. 1987	24.5	39.0	24.0	35.0	24.5	35.0	25.5	31.0	24.5	33.0	24.5	28.0	25.0	35.0	25.5	36.0
24th Dec. 1987	25.0	34.0	26.0	32.5	25.5	32.0	26.0	32.0	25.5	32.0	25.5	30.0	25.5	31.0	25.5	32.0
31st Dec. 1987	24.0	37.5	24.0	33.5	25.0	33.5	25.0	31.5	23.5	34.5	23.5	24.0	24.0	25.0	25.0	37.5
7th Jan. 1988	24.0	40.0	24.5	35.0	25.5	35.0	25.5	31.5	24.0	36.5	24.0	34.0	25.0	38.0	24.5	38.0
24th Jan. 1988	22.5	41.0	27.0	34.5	26.5	33.0	26.5	31.0	25.0	31.5	26.0	34.5	26.0	38.0	26.0	34.5
Mean	24.8	33.6	25.3	31.2	25.5	33.1	26.1	30.6	25.1	33.5	25.2	31.0	25.0	32.3	25.8	34.1

Appendix V

Whirling Psychrometer readings at weekly intervals during the period 30th September 1987 to 14th January 1988 as influenced by the annual crops grown in coconut - casuarina alleys

	Height at which reading taken (in feet)	30th Sept. 1987				8th Oct. 1987				15th Oct. 1987				22nd Oct. 1987			
		7.25am		2.25pm		7.25am		2.25pm		7.25 am		2.25pm		7.25am		2.25pm	
		WB	DB	WB	DB	WB	DB	WB	DB	WB	DB	WB	DB	WB	DB	WB	DB
Tapioca	1	25.0	26.0	28.0	32.0	25.0	25.5	26.5	30.0	25.0	25.0	29.0	32.5	24.5	25.0	27.0	31.0
	2	25.5	26.0	26.5	30.5	24.5	25.0	26.0	29.5	25.0	25.0	28.0	32.0	24.5	25.0	26.0	30.5
	4	25.0	26.0	27.0	30.5	25.0	26.0	26.5	29.5	25.0	25.0	28.0	32.0	24.0	24.5	26.0	30.5
	6	26.0	26.5	27.0	30.5	25.5	26.5	26.5	29.5	25.0	25.0	28.0	32.0	24.0	25.0	26.0	30.5
Amorphophallus	1	25.0	26.0	28.0	32.5	24.5	25.0	26.0	30.0	25.0	25.0	30.0	32.5	24.5	25.5	27.0	30.0
	2	25.0	25.5	28.0	33.0	24.5	25.0	27.0	30.0	24.5	24.5	28.5	32.5	24.5	25.5	27.5	30.0
	4	25.0	26.5	28.0	32.5	25.0	25.5	26.5	30.0	24.5	24.5	28.5	33.0	24.5	25.5	27.0	30.0
	6	24.5	25.5	28.0	32.0	25.0	25.5	26.0	30.0	24.5	24.5	28.0	33.0	24.5	25.5	26.5	30.0
Guinea-grass	1	25.0	26.5	27.5	32.0	25.5	26.0	26.5	30.5	25.5	25.5	29.5	33.0	24.0	25.0	27.5	30.5
	2	26.5	27.0	29.5	33.0	25.0	25.0	27.0	30.5	25.0	25.0	28.0	32.5	24.0	25.0	26.5	31.0
	4	25.5	26.5	28.0	32.5	24.5	25.5	26.5	30.5	25.0	25.0	27.5	32.5	24.5	25.0	27.0	30.5
	6	25.5	26.0	28.0	32.5	24.5	25.0	26.5	30.0	24.5	24.5	28.0	32.5	24.5	25.0	28.0	30.5
Control	1	25.0	26.0	27.0	30.0	25.0	26.0	26.5	29.5	25.0	25.0	30.5	31.5	24.5	25.5	27.0	30.5
	2	25.0	26.0	26.0	30.0	25.0	26.0	26.0	29.5	25.0	25.0	28.5	31.5	24.5	25.5	26.0	30.0
	4	25.5	26.5	26.5	30.0	24.5	26.0	26.0	29.0	25.0	25.0	28.0	32.0	24.5	25.5	25.5	30.0
	6	25.0	26.5	27.0	29.0	25.0	26.0	26.0	29.0	24.5	24.5	28.0	32.0	24.5	25.5	25.5	30.0

WB - Wet bulb reading
DB - Dry bulb reading

Contd.

Appendix V. Continued

	Height at which reading taken (in feet)	29th Oct. 1987				5th Nov. 1987				12th Nov. 1987				19th Nov. 1987				26th Nov. 1987			
		7.25am		2.25pm		7.25am		2.25pm		7.25am		2.25pm		7.25am		2.25pm		7.25am		2.25pm	
		WB	DB	WB	DB	WB	DB	WB	DB	WB	DB	WB	DB	WB	DB	WB	DB	WB	DB	WB	DB
Tapioca	1	25.0	25.5	27.0	28.5	25.5	27.0	28.5	32.5	24.0	24.5	27.0	28.0	24.0	24.0	26.0	28.5	23.5	24.5	27.0	31.5
	2	24.5	25.5	26.0	29.0	25.5	27.0	27.5	32.0	23.5	24.5	26.5	27.0	23.5	24.0	25.0	28.5	23.0	25.0	26.0	31.5
	4	25.0	25.5	26.5	29.0	25.5	27.0	27.0	32.0	23.5	24.0	26.5	27.0	23.5	24.0	25.5	28.5	23.0	25.0	26.0	31.5
	6	25.0	25.5	27.0	29.5	26.0	27.0	27.0	32.0	23.5	24.0	26.5	27.5	23.5	24.0	25.5	28.5	23.0	25.0	25.5	31.5
										Horsegram											
Amorphophallus	1	25.0	25.0	27.5	31.0	25.5	26.0	28.0	32.0	25.0	27.0	27.5	30.5	24.5	25.0	27.0	29.5	24.0	25.0	27.5	31.5
	2	25.0	25.0	26.0	[illegible]	25.5	26.0	27.0	32.0	24.5	25.0	26.5	31.5	24.0	24.5	26.0	29.0	23.5	25.0	26.5	31.5
	4	25.0	25.0	27.0	30.5	25.5	26.0	26.5	32.5	24.5	25.5	25.5	32.0	24.0	24.5	26.0	29.0	23.5	25.0	26.0	31.0
	6	25.0	25.0	27.0	31.0	25.5	26.0	26.0	32.5	25.0	25.5	25.5	31.5	23.5	24.5	25.5	29.0	23.0	24.5	26.0	31.0
Fodder Cowpea	1	25.0	26.0	27.0	31.0	26.0	26.0	29.0	32.5	25.0	26.0	28.0	28.5	23.5	24.0	26.0	28.0	23.0	25.0	27.5	32.0
	2	25.0	25.0	26.0	30.0	26.0	26.0	28.0	32.5	25.0	27.0	27.5	30.5	23.5	24.0	25.5	28.0	23.0	25.0	27.0	32.0
	4	25.0	25.0	26.0	30.0	26.0	26.0	28.5	33.0	25.0	27.5	28.0	31.5	23.0	24.0	25.0	28.0	23.0	25.0	26.0	31.5
	6	24.5	25.0	25.5	30.0	26.0	26.0	28.0	33.0	25.0	27.5	28.0	32.0	23.0	24.0	24.5	28.0	23.0	25.0	26.0	31.5
Guinea-grass	1	25.5	25.5	27.5	29.5	26.0	26.0	28.0	33.0	25.0	25.0	25.5	26.5	23.5	24.0	26.5	28.5	23.0	24.5	28.0	32.0
	2	25.0	25.5	27.5	30.0	26.0	26.0	29.0	32.5	24.5	25.0	25.0	25.0	23.5	24.0	25.0	28.5	23.0	24.5	26.0	32.0
	4	25.0	25.0	26.5	30.5	25.5	25.5	27.0	32.5	25.5	25.5	25.0	26.0	23.5	24.0	25.5	28.5	23.5	24.5	26.0	32.0
	6	25.0	25.0	26.0	31.0	25.5	25.5	27.0	32.5	24.5	24.5	25.0	27.5	23.5	24.0	25.0	28.5	23.5	24.5	26.0	32.0

Appendix V. Continued

	Height at which reading taken (in feet)	29th Oct. 1987 7.25am WB	29th Oct. 1987 7.25am DB	29th Oct. 1987 2.25pm WB	29th Oct. 1987 2.25pm DB	5th Nov. 1987 7.25am WB	5th Nov. 1987 7.25am DB	5th Nov. 1987 2.25pm WB	5th Nov. 1987 2.25pm DB	12th Nov. 1987 7.25am WB	12th Nov. 1987 7.25am DB	12th Nov. 1987 2.25pm WB	12th Nov. 1987 2.25pm DB	19th Nov. 1987 7.25am WB	19th Nov. 1987 7.25am DB	19th Nov. 1987 2.25pm WB	19th Nov. 1987 2.25pm DB	26th Nov. 1987 7.25am WB	26th Nov. 1987 7.25am DB	26th Nov. 1987 2.25pm WB	26th Nov. 1987 2.25pm DB
Sesamum	1	26.0	26.0	29.0	32.5	25.5	26.0	28.5	32.0	24.5	25.0	26.5	30.5	23.5	24.0	25.5	28.0	23.5	25.0	27.5	32.0
	2	26.0	26.0	28.0	32.5	25.5	26.0	27.0	32.0	24.5	25.0	26.0	30.5	23.5	24.0	25.0	28.0	23.0	25.0	26.0	32.0
	4	26.0	26.0	28.5	33.0	25.5	26.0	26.0	32.0	24.0	25.0	26.0	31.0	23.0	24.0	25.0	29.0	23.0	25.0	25.5	31.5
	6	26.0	26.0	28.0	33.0	25.5	26.0	26.5	31.5	24.0	25.0	26.0	30.5	23.0	24.0	25.0	27.5	23.0	24.5	26.0	31.5
Blackgram	1	26.0	26.0	28.5	33.0	26.0	26.0	28.5	33.0	25.0	25.0	27.5	29.0	24.5	25.0	26.5	29.0	23.5	25.0	28.0	31.0
	2	25.5	26.0	27.0	32.5	25.5	26.0	27.0	32.5	25.0	26.0	27.5	28.0	24.0	24.5	26.0	28.5	23.0	24.5	26.0	31.0
	4	25.5	26.0	26.5	32.0	25.5	26.0	26.5	32.0	24.5	26.0	26.5	28.0	23.5	24.0	25.5	28.5	23.0	24.5	26.0	31.0
	6	25.5	26.0	27.0	32.0	25.5	26.0	27.0	32.0	24.5	26.0	26.5	28.0	23.5	24.0	25.0	28.0	23.0	24.5	26.0	31.0
Sesamum	1	-	-	-	-	-	-	-	-	-	-	-	-	24.0	25.0	27.0	31.5	24.0	25.0	27.0	31.5
	2	-	-	-	-	-	-	-	-	-	-	-	-	23.5	25.0	26.0	31.0	23.5	25.0	26.0	31.0
	4	-	-	-	-	-	-	-	-	-	-	-	-	23.5	25.0	26.0	31.0	23.5	25.0	26.0	31.0
	6	-	-	-	-	-	-	-	-	-	-	-	-	23.0	25.0	25.5	31.0	23.0	25.0	25.5	31.0
Control	1	26.0	26.5	30.0	31.5	26.0	26.5	30.0	31.5	25.0	26.5	29.5	30.5	23.5	24.0	26.5	29.0	23.5	25.5	29.0	31.5
	2	25.5	26.5	28.0	31.5	25.5	26.5	29.0	31.5	25.5	26.5	29.5	30.5	23.5	24.0	25.5	29.0	23.0	26.0	26.0	31.5
	4	25.5	26.5	27.5	32.0	25.5	26.5	27.5	32.0	25.5	26.5	29.5	31.5	23.5	24.0	25.0	29.0	23.0	25.0	26.0	31.5
	6	25.5	26.5	27.0	31.0	25.5	26.5	27.0	31.0	25.5	26.5	29.0	31.0	23.5	24.5	25.0	29.0	23.0	25.0	26.0	31.5

Contd.

Appendix V. Continued

Crop	Height at which reading taken (in feet)	3rd Dec. 1987				10th Dec. 1987				17th Dec. 1987				24th Dec. 1987				31st Dec. 1987			
		7.25am		2.25pm		7.25am		2.25pm		7.25am		2.25pm		7.25am		2.25pm		7.25am		2.25pm	
		WB	DB	WB	DB	WB	DB	WB	DB	WB	DB	WB	DB	WB	DB	WB	DB	WB	DB	WB	DB
Tapioca	1	25.0	25.0	27.0	32.0	23.5	24.5	27.0	31.0	22.5	23.5	26.5	32.0	24.0	25.0	27.0	32.5	20.0	23.5	25.5	32.0
	2	24.5	24.5	26.5	31.5	23.5	24.5	26.0	31.0	22.5	23.5	25.0	32.0	24.0	25.0	26.0	32.0	20.0	23.5	23.0	32.0
	4	24.5	24.5	26.0	31.5	23.5	24.5	26.0	31.0	22.5	23.5	24.5	32.5	23.5	24.5	25.5	31.5	19.5	23.0	23.0	32.0
	6	24.0	24.5	25.5	31.5	23.0	24.5	26.0	31.0	22.5	23.5	24.5	32.0	23.5	24.5	25.0	31.5	19.5	23.0	22.5	32.0
Horsegram	1	24.5	25.0	27.0	32.0	23.5	24.5	27.5	31.0	23.0	23.0	26.0	32.0	24.0	24.0	27.5	33.0	20.0	23.0	25.0	32.0
	2	24.5	25.0	26.0	31.5	23.5	24.5	27.0	30.5	23.0	23.0	25.0	32.0	24.0	24.0	26.5	32.5	20.0	23.0	23.5	31.5
	4	24.5	24.5	25.5	31.0	23.0	24.5	26.5	30.5	22.5	22.5	24.0	32.0	23.5	23.5	26.0	32.0	20.0	23.0	23.0	31.0
	6	24.0	24.5	25.5	31.0	23.0	24.5	26.0	30.5	22.5	22.5	24.0	32.0	23.5	23.5	25.5	32.0	19.5	23.0	22.5	31.0
Fodder cowpea	1	24.5	25.0	27.0	31.0	23.5	24.5	27.0	31.0	23.0	23.5	26.0	32.0	24.0	24.5	27.0	32.0	29.5	23.5	24.0	30.0
	2	24.5	25.0	26.0	31.0	23.0	24.5	26.0	31.0	22.5	23.5	25.0	32.0	24.0	24.5	26.5	32.0	19.5	23.5	23.0	30.5
	4	24.0	25.0	25.5	31.0	23.0	24.5	25.5	30.5	22.5	23.0	24.5	32.0	23.5	24.5	26.5	32.0	19.5	23.5	23.0	30.5
	6	24.5	25.0	25.5	31.0	23.0	24.0	25.5	30.5	22.0	23.0	24.5	31.5	23.5	24.5	26.5	32.0	19.0	23.0	23.0	31.0
Guinea-grass	1	24.5	25.0	27.0	32.0	23.0	24.0	28.0	31.5	23.0	23.0	27.0	32.5	24.0	24.0	29.0	32.5	20.0	23.0	25.0	32.0
	2	24.5	24.5	26.0	32.0	23.0	24.0	27.5	31.0	22.5	22.5	25.0	32.5	24.0	24.0	28.5	32.5	20.0	23.0	24.5	32.0
	4	24.5	24.5	26.0	32.0	23.0	24.0	26.0	31.0	22.5	22.5	24.5	32.5	24.0	24.0	27.5	33.0	19.5	23.0	23.5	32.0
	6	24.5	24.5	26.0	32.0	23.0	24.0	26.0	31.0	22.5	22.5	24.5	32.5	24.0	24.0	27.0	33.0	19.5	23.0	23.5	32.0

Contd.

Appendix V. Continued

Height at which reading taken (in feet)		3rd Dec. 1987				10th Dec. 1987				17th Dec. 1987				24th Dec. 1987				31st Dec. 1987			
		7.25am		2.25 pm		7.25am		2.25pm		7.25am		2.25pm		7.25am		2.25pm		7.25am		2.25pm	
		WB	DB	WB	DB	WB	DB	WB	DB	WB	DB	WB	DB	WB	DB	WB	DB	WB	DB	WB	DB
esamum	1	24.5	25.0	27.0	32.0	23.5	24.5	27.0	31.0	23.0	23.5	26.0	32.0	24.0	24.5	27.5	32.0	20.0	23.0	24.0	30.5
	2	24.5	25.0	27.0	32.0	23.5	24.5	27.0	31.5	22.5	23.5	25.0	32.0	24.0	24.5	27.0	32.0	19.5	23.0	23.5	30.5
	4	24.5	25.0	26.5	32.0	23.5	24.5	27.0	31.0	22.5	23.5	24.5	32.0	24.0	24.5	26.5	32.0	19.5	23.0	23.5	31.0
	6	24.5	25.0	26.0	32.0	23.0	24.5	26.0	31.0	22.5	23.0	24.5	32.0	23.5	24.0	26.0	32.0	19.5	23.0	23.0	31.5
lackgram	1	24.5	25.0	26.5	31.0	23.5	24.5	27.0	31.0	23.0	23.5	26.0	33.0	24.0	24.0	28.0	33.0	20.0	23.0	24.0	30.0
	2	24.5	24.5	26.0	31.0	23.5	24.5	26.5	30.5	23.0	23.5	25.5	33.0	24.0	24.0	27.0	33.0	19.5	23.0	23.5	30.5
	4	24.5	24.5	25.5	30.5	23.0	24.5	26.0	30.5	23.0	23.5	25.0	32.5	23.5	24.0	26.5	32.5	19.5	23.0	23.0	30.5
	6	24.5	24.5	25.0	30.5	23.0	24.0	25.5	30.5	23.0	23.5	24.5	32.5	23.5	24.0	26.0	32.0	19.5	23.0	22.5	30.5
esamum	1	24.5	25.0	27.0	31.0	24.0	24.5	27.0	31.0	23.0	23.0	25.0	32.0	24.0	24.0	26.5	32.0	20.0	23.5	24.0	31.0
	2	24.5	24.5	26.0	31.0	23.5	24.5	26.5	31.0	22.5	22.5	24.5	32.0	24.0	24.0	26.0	32.0	20.0	23.5	23.5	30.5
	4	24.5	24.5	25.5	31.0	23.5	24.5	26.0	30.5	22.5	22.5	24.5	32.0	24.0	24.0	25.5	31.5	19.5	23.5	22.5	30.5
	6	24.5	24.5	25.0	35.0	23.5	24.5	25.5	30.5	22.5	22.5	24.5	32.0	23.5	24.0	25.0	31.5	19.5	23.5	22.0	30.0
ontrol	1	24.5	25.5	25.5	29.0	23.5	25.0	27.0	31.0	23.0	24.0	26.5	32.0	24.0	25.0	28.0	31.0	21.5	23.5	25.0	28.0
	2	24.0	25.0	26.5	29.0	23.0	24.5	26.0	31.0	22.0	23.5	24.5	32.0	23.5	24.5	25.5	31.0	19.5	23.5	23.5	28.5
	4	24.0	25.0	26.0	29.0	23.0	24.5	25.5	30.5	22.0	23.5	24.5	32.0	23.5	24.5	25.5	31.0	19.5	23.5	23.0	28.5
	6	24.0	25.0	26.0	30.0	23.0	24.5	25.5	30.0	22.0	23.5	25.0	32.0	23.5	24.5	25.0	31.0	19.5	23.0	22.5	29.0

Contd.

Appendix V. Continued

	Height at which reading taken (in feet)	Tapioca		Horsegram		Fodder cowpea		Guinea-grass		Sesamum		Blackgram		Sesamum		Control	
		WB	DB	WB	DB	WB	DB	WB	DB	WB	DB	WB	DB	WB	DB	WB	DB
7.25 am 7th Jan. 1988	1	19.0	23.0	19.5	23.0	19.0	23.0	19.0	22.5	19.5	23.0	19.5	23.5	19.0	23.0	19.5	23.0
	2	18.5	23.0	19.0	23.0	18.5	23.0	18.5	22.5	19.0	23.0	19.0	23.0	18.5	23.0	18.5	23.0
	4	18.5	23.0	18.5	23.0	18.5	23.0	18.5	22.5	18.5	22.5	18.5	23.0	18.5	23.0	18.5	23.0
	6	18.0	23.0	18.5	23.0	18.0	23.0	18.5	22.5	18.0	22.5	18.5	23.0	18.5	23.0	18.0	23.0
2.25 pm 7th Jan. 1988	1	24.5	32.5	24.5	32.5	23.0	32.5	24.0	32.5	24.5	33.0	24.0	32.0	22.5	32.0	26.0	32.0
	2	22.5	32.0	24.0	33.0	22.5	32.5	23.0	32.5	23.0	33.0	23.0	32.0	22.0	32.0	24.5	32.0
	4	22.0	32.0	23.5	33.0	22.5	32.5	22.5	32.5	22.5	33.0	22.0	32.0	22.0	32.0	22.0	32.0
	6	21.0	32.0	23.0	33.0	22.0	32.5	22.5	32.5	22.0	32.5	22.0	32.0	22.0	32.0	22.0	32.0
7.25 am 14th Jan. 1988	1	21.5	23.5	21.0	23.0	21.0	22.5	21.5	23.0	21.5	22.5	21.5	23.0	21.0	22.5	22.0	23.0
	2	21.0	23.0	21.0	22.5	21.0	22.5	21.0	23.0	21.5	22.5	21.0	23.0	21.0	22.5	21.0	23.0
	4	21.0	23.0	20.5	22.5	20.5	22.5	21.0	23.0	21.0	22.5	21.0	22.5	21.0	22.5	21.0	22.5
	6	21.0	23.0	20.5	22.5	20.5	22.5	20.5	22.5	20.5	22.5	20.5	22.5	21.0	22.5	20.5	22.5
2.25 pm 14th Jan. 1988	1	27.0	35.0	27.5	34.5	26.5	34.0	26.5	34.0	26.5	34.5	27.0	33.0	26.5	34.0	27.5	34.0
	2	26.0	35.0	25.5	34.0	25.0	34.0	25.0	35.0	25.0	34.5	25.5	33.0	25.0	34.0	25.0	33.0
	4	26.0	35.5	24.5	34.0	24.5	33.5	24.5	35.0	25.0	34.5	24.5	33.5	24.5	34.0	24.5	33.0
	6	25.5	35.0	24.5	34.0	24.5	33.5	24.0	35.0	25.0	35.0	24.0	33.5	24.0	33.5	24.5	33.0

Appendix VI

Relative humidity values (%) for the period 30th September 1987 to 14th January 1988 as influenced by the annual crops grown in coconut - casuarina alleys

	Height at which reading taken (in feet)	30th Sept. 1987		8th Oct. 1987		15th Oct. 1987		22nd Oct. 1987	
		7.25 am	2.25 pm	7.25 am	2.25 pm	7.25 am	2.25 pm	7.25 am	2.25 pm
Tapioca	1	100	74	96	76	100	77	96	73
	2	96	73	96	76	100	74	96	70
	4	96	76	92	79	100	74	96	70
	6	96	76	92	79	100	74	92	70
Amorphophallus	1	92	71	96	76	100	77	92	79
	2	96	69	96	79	100	74	92	83
	4	89	71	96	76	100	71	92	79
	6	92	74	96	73	100	69	92	76
Guneagrass	1	89	71	96	73	100	77	92	79
	2	96	77	96	76	100	71	92	70
	4	92	71	96	76	100	68	96	76
	6	96	71	96	76	100	71	96	83
Control	1	92	79	92	79	100	93	92	76
	2	92	73	92	76	100	80	92	73
	4	92	76	88	79	100	74	92	70
	6	89	86	92	79	100	74	92	70

Contd.

Appendix VI. Continued

	Height at which reading taken (in feet)	29th Nov. 1987		5th Nov. 1987		12th Nov. 1987		19th Nov. 1987		26th Nov. 1987	
		7.25am	2.25pm	7.25am	2.25pm	7.25am	2.25pm	7.25am	2.25pm	7.25am	2.25pm
Tapioca	1	96	89	89	74	96	93	100	82	92	71
	2	92	79	89	71	92	96	96	75	84	65
	4	96	82	89	68	96	96	96	79	84	65
	6	96	82	85	68	96	92	96	79	84	62
						HORSEGRAM		HORSEGRAM		HORSEGRAM	
Amorphophallus	1	100	77	96	74	85	79	96	82	92	74
	2	100	70	96	68	96	68	96	79	88	68
	4	100	76	96	63	92	60	96	79	88	67
	6	100	73	96	60	96	62	92	76	88	67
Fodder cowpea	1	92	73	100	77	92	96	96	78	84	71
	2	100	73	100	71	85	79	96	82	84	68
	4	100	73	100	71	82	77	92	78	84	65
	6	96	70	100	69	82	74	92	75	84	65
Guineagrass	1	100	86	100	69	100	92	96	86	88	74
	2	96	83	100	71	96	100	96	75	88	62
	4	100	73	100	65	100	92	96	79	92	62
	6	100	67	100	69	100	82	96	75	92	62

Contd.

Appendix VI. Continued

	Height at which reading taken (in feet)	29th Oct. 1987		5th Nov. 1987		12th Nov. 1987		19th Nov. 1987		26th Nov. 1987	
		7.25am	2.25pm	7.25am	2.25pm	7.25am	2.25pm	7.25am	2.25pm	7.25am	2.25pm
Sesamum	1	100	77	96	77	96	73	96	82	88	71
	2	100	71	96	68	96	70	96	78	84	62
	4	100	71	96	62	92	67	92	78	84	62
	6	100	69	96	68	92	70	92	82	88	65
Blackgram	1	100	71	100	71	100	96	96	82	88	80
	2	96	65	96	65	92	96	96	82	88	67
	4	96	65	96	65	88	89	96	79	88	67
	6	96	68	96	68	88	89	96	75	88	67
Sesamum	1	-	-	-	-	-	-	92	71	92	71
	2	-	-	-	-	-	-	88	67	88	67
	4	-	-	-	-	-	-	88	67	88	67
	6	-	-	-	-	-	-	84	64	84	64
Control	1	96	90	96	90	89	93	96	89	88	77
	2	92	77	92	77	92	93	96	82	84	65
	4	92	71	92	71	92	86	96	78	84	65
	6	92	73	92	73	92	86	92	78	84	65

Contd.

Appendix VI. Continued

	Height at which reading taken (in feet)	3rd Dec. 1987		10th Dec.1987		17th Dec. 1987		24th Dec.1987		31st Dec.1987	
		7.25am	2.25pm	7.25am	2.25pm	7.25am	2.25pm	7.25am	2.25pm	7.25am	2.25pm
Tapioca	1	100	68	92	73	92	65	92	65	72	60
	2	100	68	92	67	92	57	92	62	72	46
	4	100	65	92	67	92	52	92	62	72	46
	6	96	62	88	67	92	54	92	59	72	44
Horsegram	1	96	68	92	77	100	62	100	66	76	57
	2	96	65	92	76	100	57	100	63	76	51
	4	100	64	88	73	100	51	100	62	76	50
	6	96	64	88	70	100	51	100	60	72	48
Fodder cowpea	1	96	73	92	73	96	62	96	68	69	61
	2	96	67	88	67	96	57	96	65	69	53
	4	92	64	88	67	96	52	92	65	69	53
	6	96	64	92	67	92	56	92	65	69	50
Guineagrass	1	96	68	92	77	100	65	100	77	76	57
	2	100	62	92	77	100	55	100	74	76	54
	4	100	62	92	67	100	52	100	66	72	49
	6	100	62	92	67	100	52	100	63	72	49

Contd.

Appendix VI. Continued

	Height at which reading taken (in feet)	3rd Dec. 1987		10th Dec. 1987		17th Dec. 1987		24th Dec. 1987		31st Dec. 1987	
		7.25am	2.25pm	7.25am	2.25pm	7.25am	2.25pm	7.25am	2.25pm	7.25am	2.25pm
Sesamum	1	96	68	92	73	96	62	96	71	76	58
	2	96	68	92	71	92	57	96	62	72	55
	4	96	65	92	73	92	54	96	65	72	53
	6	96	62	88	67	96	54	96	62	72	48
Blackgram	1	96	70	92	73	96	58	100	69	76	61
	2	100	67	92	73	96	55	100	63	72	55
	4	100	67	88	70	88	55	96	63	72	53
	6	100	64	92	67	88	52	96	62	72	50
Sesamum	1	96	73	96	73	100	57	100	65	72	56
	2	100	67	92	70	100	54	100	62	72	55
	4	100	64	92	70	100	54	100	62	69	50
	6	100	44	92	67	100	54	96	59	69	50
Control	1	92	96	84	73	92	62	92	80	84	78
	2	92	82	88	67	88	54	92	64	69	66
	4	92	79	88	67	88	54	92	64	69	63
	6	92	73	88	70	88	57	92	62	72	57

Contd.

Appendix VI. Continued

	Height at which reading taken (in feet)	Tapioca	Horsegram	Fodder cowpea	Guinea-grass	Sesamum	Blackgram	Sesamum	Control
7.25 am 7th Jan. 1988	1	69	72	69	72	72	69	69	72
	2	65	69	65	68	69	69	65	65
	4	65	65	65	68	68	65	65	65
	6	62	65	62	68	65	65	65	62
2.25 pm 7th Jan. 1988	1	52	52	44	49	50	51	44	62
	2	44	47	42	44	42	46	41	54
	4	41	45	42	42	40	41	41	41
	6	37	42	40	42	40	41	41	41
7.25 am 14th Jan. 1988	1	84	84	88	88	92	88	88	92
	2	84	82	88	84	92	84	88	84
	4	84	84	84	84	88	86	88	88
	6	84	84	84	84	84	84	88	84
2.25 pm 14th Jan. 1988	1	54	59	56	56	54	63	56	61
	2	49	51	48	44	46	55	48	52
	4	47	45	48	43	46	48	46	50
	6	47	45	48	40	44	45	45	50

Appendix VII

a. ANOVA for the total biomass productivity per day biomass productivity and crude protein yield of the different cropping systems in coconut - casuarina alleys

Source	df	Mean squares		
		Biomass productivity	Per day biomass productivity	Crude protein yield
Replication	2	1542382.2	60.48	23026.10
Treatment	6	81446784.0	1057.67	1266743.66
Error	12	2287430.0	40.65	41653.50

b. ANOVA for the organic carbon, available nitrogen, available phosphorus and exchangeable potassium contents of the soil

Source	df	Mean squares							
		Organic carbon		Available nitrogen		Available phosphorus		Exchangeable potassium	
		*	**	*	**	*	**	*	**
Replication	2	0.016	0.004	0.000	0.000	130.86	0.10	19.02	2328.13
Treatment	7	0.037	0.329	0.000	0.003	232.16	224.87	2960.40	10102.50
Error	14	0.046	0.048	0.000	0.000	45.14	39.49	356.44	5967.72

* - Before the experiment
** - After the experiment

c. ANOVA for the exchangeable calcium, exchangeable magnesium and available sulphur contents of the soil

Source	df	Mean squares					
		Exchangeable calcium		Exchangeable magnesium		Available sulphur	
		*	**	*	**	*	**
Replication	2	2358.50	4919.00	15022.19	9445.87	27.16	52.97
Treatment	7	70532.96	32249.36	46291.71	25472.42	77.22	123.41
Error	14	9322.02	28393.96	6229.80	5849.77	10.75	37.64

* - Before the experiment
** - After the experiment

d. ANOVA for the economics of the different cropping systems in coconut - casuarina alleys

Source	df	Mean squares		
		Gross income	Net income	Benefit cost ratio
Replication	2	0.035	0.052	0.059
Treatment	6	0.325	0.517	0.219
Error	12	0.042	0.053	0.038

e. ANNOVA for the biometric observations on coconut

Source	df	Mean squares		
		Height	Girth	Number of leaves
Replication	2	18722.38	4.17	7.63
Treatment	7	11465.81	86.90	9.85
Error	14	5757.47	14.02	3.82

BIOMASS PRODUCTIVITY AND INFLUENCE OF INTERCROPS IN A PRE-BEARING COCONUT-CASUARINA AGROFORESTRY SYSTEM

By

USHA, T.

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of
the requirement for the degree

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture
Kerala Agricultural University

Department of Agronomy
COLLEGE OF HORTICULTURE
Vellanikkara - Trichur
Kerala - India

1990

ABSTRACT

An experiment was conducted in the pre-bearing coconut gardens of Agricultural Research Station, Mannuthy during the period from May 1987 to May 1988 to assess the biomass productivity of different intercrops grown in coconut - casuarina alleys and their effect on the growth of tree components and on the micro-meteorological parameters.

The different cropping systems tried in coconut - casuarina alleys were tapioca + groundnut, amorphophallus - horsegram, fodder maize + cowpea - fodder cowpea, guineagrass (throughout), fodder cowpea - sesamum, groundnut - blackgram, modan paddy - sesamum and control (without any intercrops). The experiment was laid out in randomised block design in plots of size 7.5 x 7.5 m and replicated thrice.

The plant height of all the crops excepting that of fodder cowpea and sesamum showed an increase when grown in coconut - casuarina alleys. The yields of tapioca, groundnut (grown mixed with tapioca), amorphophallus, blackgram and paddy were rather low in coconut - casuarina alleys compared to sole crop yields. Fairly high fodder yields of maize (mixed with cowpea) and guineagrass

were obtained when grown in coconut - casuarina alleys. Regarding the total biomass production of different cropping systems, amorphophallus - horsegram cropping system recorded the highest and groundnut - blackgram cropping system yielded the lowest.

The soil physical properties like bulk density, particle density, maximum water holding capacity were not influenced by the different cropping systems. It was seen that most of the cropping systems except that involving guineagrass left the soil richer with respect to organic carbon content and most of the primary and secondary nutrients. The cropping system which recorded fairly high gross income, net income and benefit-cost ratios were amorphophallus - horsegram, fodder maize + cowpea - fodder cowpea and groundnut - blackgram. The different component crops grown in the alleys had no adverse effect on coconut or casuarina. Casuarina which was intercropped with coconut was found to be capable of generating a fuel wood yield of 10-11 t/ha/annum.