PRODUCTIVITY OF TUBER CROPS UNDER ALLEY CROPPING OF TROPICAL TREES

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "Productivity of Tuber Crops under Alley Cropping of Tropical Trees" 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,
27th May 1988

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CERTIFICATE

Certified that this thesis entitled "Productivity of Tuber Crops under Alley Cropping of Tropical Trees" is a record of research work done independently by Smt. Bindu, R. under my guidance and supervision and that it has not previously formed the basis for award of any degree, fellowship or associateship to her.

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We, the undersigned, members of the Advisory Committee of Smt.Bindu, R. a candidate for the degree of Master of Science in Agriculture with major in Agronomy, agree that the thesis entitled "Productivity of Tuber Crops under Alley Cropping of Tropical Trees" may be submitted by Smt.Bindu, R. in partial fulfilment of the requirement for the degree.

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Introduction

INTRODUCTION

The natural forests in many countries are dwindling at an alarming rate as a result of deforestation, threatening the very existence of our ecosystem. In India, the forested area decreased from 40% in 1950-51 to 26.8% in 1986-87. The necessity to feed the exploding population and to supply raw materials of all kinds brings in further pressure on land, limiting the scope of preserving the natural forests. So to feed and sustain the growing population with minimum disturbance to the ecosystem it is necessary to develop farming systems which will sustain the natural resources. Multiple cropping with different tree components and annual food crops is the most viable and adaptive land use system which will be both productive and protective.

In Kerala because of the high density of population, the size of farm holding is very small, ranging from 0.02 ha to 1.00 ha. Coconut palm, the important component of most of the gardenland holdings due to its peculiar growth pattern permits the growing of many perennial and/or annual species in the interspace during the early and later phase of its growth cycle (Nelliat and Krishnaji, 1976).

A multistoreyed cropping system with coconut, cocoa, pepper and pineapple were also suggested for intensification of cropping in these regions (Nelliat *et al.*, 1974). Planting of multipurpose forest trees in farm lands are suggested to lessen our dependence on natural forests for the supply of raw materials, fuel wood, timber etc. In Kerala, such cropping systems are possible only on lands which are already under coconut or in lands which can be profitably put under coconut or other cash crops. Eucalyptus (*Eucalyptus tereticornis*), Subabul (*Leucaena leucocephala* (Lamk) de Wot, Glyricidia (*Glyricidia maculata*) and Ailanthus (*Ailanthus tryphysa*) (Roxb) are promising, fast growing multipurpose tropical tree species suited to the agroclimatic conditions of the State; the former two yielding fuel wood and/or raw material and the latter two yielding fuel wood, fodder and green manure. As a sustainable cropping system for the State, the feasibility of growing coconut with these multipurpose tropical tree crops and some annual food crops were investigated. Thus the objectives of the experiments were to assess

(i) the performance of various tuber crops under coconut - multipurpose tropical tree alleys

(ii) the influence of the alley crops on the tree components

(iii) the changes in microclimatic conditions due to alley cropping

(iv) the changes in chemical and physical properties of soil as influenced by alley cropping.

Review of Literature

REVIEW OF LITERATURE

Agroforestry, deliberate growing of annual field crops with woody perennials in mixtures is considered as a sustainable agricultural system. Alley cropping is one of the methods of agroforestry.

The term alley cropping was suggested by Wilson and Kang (1981) to describe a cropping system in which especially food crops are grown in alleys formed by trees or shrubs established mainly to hasten soil fertility restoration and enhance soil productivity. Alley cropping may be regarded as an organised form of bush fallow in which selected species are planted in organised patterns, designed to facilitate crop growth and easy crop management systems based on nutrient cycling by plants.

Several multipurpose tree species are being popularised in our country. Among these, eucalyptus, subabul, glyricidia and ailanthus are important in Kerala. Literature on the suitability and performance of these trees in Kerala, their feasibility in coconut gardens and alley cropping are very limited. The available information on the feasibility of these tree species in different agroforestry systems and the alley cropping practices are reviewed in this section.

2.1. Eucalyptus based - alley cropping

2.1.1. Performance of eucalyptus

Eucalyptus like tropical pines, subabul and mesquite (*Prosopis juliflora*) has attracted considerable attention in Indian forestry. Although its first introduction dates back to 1843, regular plantations commenced from 1956 only. Since then various eucalyptus species have been tried all over the country. As a fast growing species with light crown, eucalyptus hybrid (*Eucalyptus teretecornis*) found its place in social or agroforestry systems of land management (Gupta, 1986). Eucalyptus has been planted by the farmers on bunds, along field boundaries in rows, along water channels and in compact blocks in agricultural fields with variable spacings (Mathur *et al*., 1984). Singh, *et al*. (1983) observed that eucalyptus is adapted to heavy soils and the growth rate on light soil is very slow compared to heavy soils. In a young eucalyptus hybrid plantation of age 5 years George (1986) estimated a total biomass production of 68344 kg ha^{-1}. The productivity of non-photosynthetic biomass was 12,935 kg ha^{-1} $year^{-1}$. Among the various nutrients the uptake was maximum for N and Ca and the maximum retention was for P and Ca.

2.1.2. Influence of eucalyptus on soil fertility

There is an apprehension all over the country that eucalyptus plantations, especially as monocultures will deplete the soil. Kushalappa (1986) observed a general increment in moisture status, pH, organic carbon, phosphorus and potassium content of the soil cultivated with eucalyptus. Singhal (1986) from Uttar Pradesh State reported that the quantity of organic matter humified was more under eucalyptus. Since the humification rate was faster in the case of eucalyptus, the chances of loss of organic matter was also considerably reduced. Soni et al. (1985) observed that the infiltration rate of the soil was highest in eucalyptus plantations. Infiltration capacities under different vegetal covers were found to be positively correlated with soil porosity and negatively with bulk density.

2.1.2. Performance of alley crops

2.1.2.1. Cereals

The feeling that nothing grows under eucalyptus is not correct and this depends upon how closely and widely trees are planted (Sharma, 1983). He reported that some farmers in Kolar, space out eucalyptus and intercrop fingermillet for 1-3 years. Intercropping of 2 year old eucalyptus planted at 4.3 x 4.3 m spacing with wheat was reported from Pakistan. It was reported that the grain yields of wheat do not differ when grown 80-120 cm away from the base of the trees.

Eucalyptus are being planted with agricultural crops on field boundaries as effective wind breaks. Effects of eucalyptus along with neem (*Azadirachta indica*) and acacia (*Acacia nilotica*) on safflower and sorghum have shown that these two species do not affect the growth and yield of alley crops. Though the highest grain yield (510 kg ha^{-1}) of sorghum was recorded when grown without trees, it was followed by eucalyptus (420 kg ha^{-1}), neem (347 kg ha^{-1}) and acacia (286 kg ha^{-1}) (Chaturvedi, 1983).

2.1.2.2. Pulses and oilseeds

At Coimbatore the shade tolerance of 11 genotypes of blackgram raised within a stand of two year old *Eucalyptus tereticornis*, planted at a spacing of 1 x 1 m was studied by Ramachandran (1981). He observed two genotypes (JLU S-1) and (No.55) which performed well under shade and were suited for growing under eucalyptus. Couto *et al*. (1982) studied intercropping of soybean in *Eucalyptus grandis* in Southern Brazil. They observed that soybean planted along with seedling eucalyptus recorded grain yields ranging from 1.533 to 2.499 t ha^{-1} which was similar to the yield normally obtained in the region for a sole crop of soybean. The soybean also supressed the weeds in all the treatments.

2.1.2.3. Fodder grasses

Pant (1980) has reported the successful cultivation of several species of fodder grasses (guinea, rhodes, para, napier, bajra hybrid and blue panic grasses) under eucalyptus by a farmer in Gujarat. *Eucalyptus globulus* in Nilgiris hills similarly permits the growth of shade loving grasses during the first five years (Samraj, 1977). Sud *et al.* (1986) found that farmers can have an additional income of Rs.2500 per hectare in a year from the second year of planting eucalyptus by growing an intercrop of bhabber grass (*Eulaliopsis binata*). The bhabbar grasses did not affect the yield of eucalyptus as it occupied a different layer of soil. It reduced run off and sediment losses during monsoon period.

2.1.2.4. Tuber crops

Ghosh *et al.* (1985) observed that intercrops like cassava, cassava + groundnut or cassava + cowpea increased the height and girth of eucalyptus. It was noted that the total biomass production of cassava was minimum under eucalyptus. The uptake of nutrients in cassava was minimum when grown in association with eucalyptus.

2.1.3. Competitive effects of eucalyptus on intercrops

Wheat when grown with *Eucalyptus tereticornis* has shown normal yield in the first year (2900 kg ha^{-1}). However, the intercrop failed in the third year possibly due to the increase in root and crown cover of eucalyptus resulting in competition for moisture, nutrients and light (Chaturvedi, 1983). Sharma et al. (1981) opined that root competition can be controlled by digging trenches in between tree lines and agricultural crops and normal yields can be obtained. Adverse effect of the main crop of eucalyptus on maize grown as intercrop has also been reported from Brazil. Suresh and Rai (1987) reported that the germination, root length and drymatter production of sorghum, cowpea and sunflower were depressed when mulched with dry leaves of eucalyptus or irrigated with aqueous leaf extracts probably due to allelopathic effect. Sorghum proved most susceptible to these influences. Basu et al. (1987) conducted an experiment to find out whether the low production of potato and the deleterious effect on the growth of wheat growing in plots just adjacent or near to Eucalyptus tereticornis were due to competition for water, nutrient availability or due to the possibility of some allelochemical released by the litter accumulated nearby. The investigation revealed that the low production was due to chemical messengers (allelochemicals) as all other factors assessed were found to be favourable. Nambiar *et al.* (1986) found that *Eucalyptus tereticornis* planted in field boundary had adverse effect on yield of agricultural crops like tobacco and summer bajra. Eventhough there was not much effect of the trees on the yield of agricultural crops during the first year, eucalyptus caused 7.2% and 21% reduction in yield of tobacco and summer bajra respectively during the second year. A study conducted by Khybri *et al.* (1985) showed that eucalyptus had greater effect in depressing the yield of rainfed crops of kharif upland paddy and Rabi wheat.

From the foregoing review it is evident that a variety of cereals, pulses, oilseeds and fodder grasses can be successfully raised as intercrops in eucalyptus alleys. Competitive effects of eucalyptus in these cropping systems are reported. Considering the potential for expansion of eucalyptus cultivation in the country identification of popular food crops suited for alley cropping in eucalyptus needs priority in research.

2.2. Subabul based - alley cropping

2.2.1. Performance of subabul

Leucaena (Leucaena leucocephala Lamk de Wit) commonly known as 'subabul' in India is a tropical evergreen mimosoid leguminous tree. It was introduced to Phillippines from the native Central America by Spanish travellers having business connections in the colonies of Central America and South East Asia in 16th century. Later it spread to other South Asian Countries including India (Balasundaram and Mohammed Ali, 1987).

Subabul in recent times gained importance, particularly in developing countries because of its fast rate of growth, possibility of closer plantings, abundant biomass production, production of small timber and fuel wood and above all, production of protein rich fodder. This leguminous tree fixes atmospheric N and improves soil fertility also (NAS, 1977 and Torres, 1983).

The wood yield of the tree is upto 40 to 50 m^3 ha^{-1} $year^{-1}$. When regularly mowed large quantities of foliage, 6-8 t drymatter ha^{-1} $year^{-1}$ rich in proteins (25-30%) are obtained. Inspite of its high nutritive value; subabul feeding is a controversial issue because of the presence of mimosine. (β-(N-3-hydroxy-4-oxopyridyl)-DC-aminopropionic acid) a non-protein aminoacid, which can have deleterious effects on animals (Hegde, 1987). Mimosine causes epilation, weight loss and ill health in non-ruminants like horses, pigs, rabbits and poultry when fed at levels above 7.5% (dry matter) of diet. However, ruminants in most of the South East Asian Countries have stomach micro-organisms that render mimosine harmless (Balasundaram and Mohammed Ali, 1987).

Subabul's root reach deep, far and wide for nutrients and water. This allows the plant to tolerate a wide array of soil conditions. It thrives in soils with varying levels of rocks, clays and coral. Subabul grows well only in neutral to alkaline soil, growing best at pH 6 to 8 (Balasundaram and Mohammed Ali, 1987). Subabul is the most widely studied species for hedgerow intercropping (alley cropping) practice. Experimental data indicate that it can yield over 200 kg of N for application to alleys where annual crops are planted (Ssekabembe, 1985).

The experiments conducted by Prasad *et al.* (1984) at Chottanagpur revealed that green fodder yield of 550 q ha^{-1} $year^{-1}$ and dry matter yield of 175.9 q ha^{-1} $year^{-1}$ can be obtained from subabul. Agrawal *et al.* (1985) reported that it is an excellent fodder tree and the leaves contain 27 to 34 per cent protein.

2.2.2. Influence of subabul on soil fertility

Subabul improves soil fertility by atmospheric N fixation (Hogberg and Kvanstrom, 1982). All the ten species of subabul are reported to nodulate readily and annual N accumulation rates of 600 kg ha^{-1} and as high as 1 t ha^{-1} are on record but the annual N fixation has not been determined with precision (Halliday and Somesegaran, 1982). It was found that the tap root system of subabul penetrates even hard rocks. It fixes 500 to 550 kg atmospheric N ha^{-1} $year^{-1}$ and improves the fertility of barren land (Agrawal *et al.*, 1985). N fixation studies were carried out in 4 tree species under pot culture conditions. Maximum plant height, nodule biomass and nitrogenase activity were noticed in case of subabul followed by Albizia, Acacia and Dalbergia (Pokhriyal *et al.*, 1987). The studies conducted by Agrawal *et al.* (1985) revealed that aggressive tap root system of subabul fixes 500 to 550 kg of atmospheric N ha^{-1} $year^{-1}$ and improves soil fertility of barren land. This may increase the yield of crops grown in farm to the extent of 50%.

2.2.3. Subabul based - intercropping systems

Subabul has great potential for intercropping with food crops (Maghembe and Redhead, 1982). Many cereals, pulses, oilseeds and fodder grasses are reported to be successful as an intercrop in this tree crop alley.

2.2.3.1. Cereals

Kang *et al.* (1981) from Southern Nigeria reported that intercropping of maize in alleys between hedgerows of subabul planted 4 m apart gave sustained annual yields of about 3.8 t ha^{-1} without any supplimentary N and still higher yields with supplimentary N at 20-80 kg N ha^{-1}. The prunings from 5-6 year old subabul yielded 5-8 t ha^{-1} dry tops per year equivalent to 180-250 kg N ha^{-1} which was responsible for the sustained annual yields of maize.

Wilson and Kang (1981) who coined the term alley cropping to describe such intercropping systems reported the results of experiment in which subabul was established in association with maize or cassava. The initial phase of the 2 year rotation involving maize/subabul followed by yam/subabul was established in a similar manner. It was found that crop yield and subabul development was not atmost affected by intercropping. Verinumbe (1983) who studied the economics of small scale farming in Nigeria, reported that the maximum yearly net profit was obtained if a farmer produced a combination of 95% of the farm area under maize + subabul and 5% of the area under maize + stylo. This in essence underscores the success of maize intercropping in subabul.

Results of the experiments conducted at Dehradun indicated that intercropping subabul with wheat gave an additional yield of 2.901 kg ha^{-1} of wheat (Khybri et al., 1985). In an experiment, the effect of subabul planted on field boundary on the yield of agricultural crops like tobacco and summer bajra was studied. The result indicated that the tobacco and summer bajra under subabul recorded 8.4% and 2.8% increase in yield respectively (Nambiar et al., 1986).

2.2.3.2. Pulses and oilseeds

Experimental results on pigeonpea, castor and sorghum, alley cropping indicated that the intercrops yielded more grain as compared to the expected yield of sole crops. Increase in productivity was recorded in pigeonpea followed by castor and sorghum (Singh, 1983). Different silvopastoral and agripastoral systems have been studied by Singh (1983) at Jhansi. Intercropping of subabul with gingelly, groundnut and pigeon pea were found feasible. However, the gingelly yield was increased when grown in association with subabul whereas the groundnut and pigeon pea yields were reduced.

In red chalka soils at Hyderabad, castor and sorghum, castor and pearl millet yields were improved when interplanted with subabul which itself yielded considerable fodder (Venkateswarlu et al., 1981).

2.2.3.3. Tuber crops

Kabeerthumma et al. (1985) observed that intercropping of subabul with cassava on slopy lands (8-9%)

conserved soil and water effectively and gave an additional income. Swift (1982) from Papua New Guinea reported that the total biomass yield was considerably higher when sweet potato was intercropped with subabul.

2.2.3.4. Fodder grasses

The studies at Jhansi, confirmed that it is profitable to grow subabul in association with hybrid napier variety IGFRI-3 or IGFRI-6 and a biomass production of 875 q ha^{-1} can be achieved by this cropping system (Gill and Patil ~~et al.~~, 1985).

2.2.4. Competitive effects of subabul on intercrops

Ghosh et al. (1985) found that subabul adversly affected the growth and yield of cassava grown as alley crop. It is thus evident that alley cropping with different annual crops is successful in subabul also, but it has to be borne in mind that the height of main crop of subabul in alley cropping is restricted to about 1.5 m so that the annuals grown in the alleys are not shaded. The favourable effects of the legume tree on soil fertility makes it an ideal component in crop mixtures.

2.3. Glyricidia based - alley cropping

2.3.1. Performance of glyricidia

The role of glyricidia in agroforestry systems can be productive and or protective (Nair et al., 1984). In an alley cropping trial on degraded land at Nigeria Glyricidia sepium produced prunings of dry weight 5.5 t ha^{-1} $year^{-1}$ which could contribute 169.4, 11.0, 149.1, 66.0 and 17.6 kg ha^{-1} N, P, K, Ca and Mg respectively. Evaluation of a glyricidia germplasm collection from Costa Rica indicated that the early vigour and green leaf yield vary widely. Over 4 harvests, the 4 highest yielding accessions produced 3.7% more green leaves than Ibadan local. The ~~greatest~~ highest mulch yield was obtained with approximately 10 established trees m^{-1} (Sumberg, 1985). Nair (1979) reported that glyricidia is grown for shade or green manure in foot hills of Western Ghats plantations of coconut, pepper, rubber, coffee, cardamom and tea. Throughout Costa Rica Glyricidia sepium is used as a living fence posts. One of the most valuable and least acknowledged properties of these living fence posts is their ability to retard soil bank erosion by means of mechanical barrier and fine mat of surface roots which they produce (Beer *et al.*, 1981).

Reports of intercropping of glyricidia alley with annuals are rarely found in literature, but the trees' role as a high green leaf manure yielder is appreciated in many countries. Glyricidia plant grows 25 to 30 feet in height under favourable soil and climatic conditions, and gives annually two cuttings of 15 to 20 lb each of green leaves containing 30 per cent nitrogen on dry weight basis (Yawalkar *et al.*, 1962).

2.4.1. Performance of ailanthus

A large deciduous tree 60-80' in height and 6-8' in girth. The timber of some species is soft and light and that of *Ailanthus grandis* is found suitable for plywood and tea chests (Limaye, 1942). The timber is used for packing cases, fishing floats, boats, spear sheaths, sword handles, toys, drums etc. (Pearson and Brown, 1976).

The common species grown in Kerala are *Ailanthus tryphysa* Syn. *Ailanthus malabaricum*. *Ailanthus excelsa* also is grown at Valayar. In Kerala, the farmers plant these trees in coconut gardens, arecanut gardens, homesteads etc. The bark of the tree can be used to cure many diseases such as dysentry, indigestion, constipation etc. The bark of the roots soaked in gingelly oil is a good antidote for cobra bite. The latex of ailanthus is used as a mosquito repellent and also in perfumery (KFRI, 1985).

2.4.2. Ailanthus based - intercropping systems

Ailanthus comes up well even under very low soil fertility. Under this crop cassava can be raised which gives some profit to the farmer (KFRI, 1985).

Similar to glyricidia, the literature available on this tree or tree based cropping systems are limited. Much more attention of the researchers are needed to derive information on the feasibility of this tree in different cropping systems.

2.5. Coconut based - intercropping system

Coconut (Cocos nucifera) is one of the very few tree crops in which intercropping is extremely practiced, as it has a long life span of 60-80 years and the land is commutted to it for several decades, it is planted wide, usually about 7.5 m either way and it has been estimated that only 28% of the land area is utilised by it in a sole stand (Leela and Bhaskaran, 1978); it has a particular 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 practiced (Nair et al., 1974). Many annual crops are compatable with it as its root zone is concentrated literally to a radius of 2 m only (Kushwah et al., 1973) and vertically between the depths of 30 cm and 120 cm from the surface (CPCRI, 1973). A variety of crops were raised or have been tested for their suitability as intercrop with varying degrees of success. In Kerala state, banana is commonly raised as an intercrop in coconut gardens (Nelliat et al., 1974; Nair and Varghese, 1976; Nair et al., 1974). Other intercrops suggested for growing in coconut gardens are cassava (Nelliat, 1976; Nair and Varghese, 1976; Nelliat et al., 1974; Nair et al., 1974; Varghese et al., 1978; Potty, 1978; Ramanujam et al., 1984b;

Menon and Nair, 1978), amorphophallus (Nair and Varghese, 1976; Nelliat *et al.*, 1974; Nair *et al.*, 1974; Varghese *et al.*, 1978; Menon and Nair, 1978) greater yam (Nelliat, 1976; Nair *et al.*, 1974; Menon and Nair, 1978) and colocasia (Varghese *et al.*, 1978). In addition to this sweet potato, lesser yam, chinese potato, ginger, turmeric, pepper, upland rainfed rice, sorghum, finger millet, italian millet, black gram, green gram, red gram, horse gram, cowpea, groundnut, gingelly, forage crops, grasses and legumes, pineapple, sunflower, vegetables etc. were also found to be successful in coconut plantation (Varghese *et al.*, 1978).

Nair *et al.* (1974) reported the feasibility of intercropping of several tuber crops, rhizome crops, oilseeds, cowpea, banana and pineapple in coconut garden and stated that elephant foot yam and cassava had no adverse effect on coconut tree if the main crop and intercrops were adequately and separately manured.

In contrast Ramanujam *et al.* (1984a) reported that productivity of cassava is reduced in coconut gardens since the light infiltration to the coconut stand was only about 1/7th of the open field. Vergara and Nair, 1985 reported that the major cropping systems in the Pacific regions include various forms of combinations of tree crops such as coconut, coffee, cocoa with N fixing trees such as casuarina, glyricidia and subabul and food crops such as cassava, taro, sweet potato and yams.

Thus the tree species like eucalyptus, subabul, glyricidia and ailanthus holds great potential for growing as a source of soft wood/fuel/green manure in Kerala state. Considering the existing cropping pattern in the state the most feasible approach to develop these trees are to plant them in coconut gardens in mixtures. To develop our coconut gardens to a sustainable agroforestry system the need is to integrate the growing of coconut, other perennial tree species and annual food crops. Information on the alley cropping of these multipurpose tropical tree crops with annual food crops is very scarce except in the case of eucalyptus and subabul. Also there is no much reports available on the coconut based agroforestry systems. So to develop viable coconut based agroforestry systems suited for Kerala more experiments will have to be undertaken.

primarily on assessing the performance of various woody perennials in coconut gardens and the productivity of the annual food crops in the tree alleys.

Materials and Methods

MATERIALS AND METHODS

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

3.1. Experimental site

The experiment was conducted in the coconut gardens of the Agricultural Research Station, Mannuthy, Trichur, Kerala, India (12° 32' N, 74° 20' E) during the period from May 1987 to February 1988. Trichur enjoys a humid tropical climate. The weather data for the experimental season are given in Appendix-I.

3.2. Soil Characteristics

Composite soil samples from 0-15 cm depth were drawn treatmentwise before the commencement of the experiment. These soil samples were used for the determination of physical and chemical properties which are presented in Table 1. The soil of the experimental site was acid

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

Particulars		
Physical properties		
Sand	62 %	Hydrometer method (Piper, 1942)
Silt	12 %	
Clay	26 %	
Particle density	2.72 g/cm^3	Core method (Piper, 1942)
Bulk density	1.36 g/cm^3	
Maximum water holding capacity	36.07 %	Keen-Raczkowski box method (Keen and Raczkowski, 1921)
Chemical properties		
Organic carbon	1.25 %	Walkley and Black method (Jackson, 1958)
Total N	0.123 %	Modified microkjeldahl method (Jackson, 1958)
Available P	40 ppm	Chlorostannous reduced molybdophosphoric blue colour method in hydrochloric acid system (Jackson, 1958)
Exchangeable K	328 ppm	Flame photometry Neutral normal ammonium acetate extraction (Jackson, 1958)
Soil reaction (pH)	5.4	Soil water suspension of 1:2.5 (Hesse, 1971)
EC	0.07 millimhos/cm	Soil water suspension of 1:2.5 (Hesse, 1971)

laterite (oxisol) with a pH of 5.4. The textural class of the soil was sandy clay loam.

3.3. Cropping history

The experimental site was a coconut (*Cocos nucifera* L) plantation of age 50-60 years with under planted coconuts of age 5-6 years.

The coconut palms were planted at a spacing of 7.5 x 7.5 m. Two rows of multipurpose tree species viz. eucalyptus (*Eucalyptus tereticornis*), subabul (*Leucaena leucocephala* Lamk), glyricidia (*Glyricidia maculata*) and ailanthus (*Ailanthus tryphysa*) were planted at a spacing of 2.1 x 2.1 m in the inter-row space of coconut in August 1983. The cropping systems thus obtained are

a) coconut + eucalyptus

b) coconut + subabul

c) coconut + glyricidia

d) coconut + ailanthus

e) coconut alone

The interspaces of the alleys between two rows of these multipurpose tropical tree crop combinations were left fallow for 3 years prior to this experiment. The performance of the following tuber crops were compared as an intercrop in the above mentioned coconut multipurpose tropical tree alleys (Fig. I and II).

a) Amorphophallus (Amorphophallus campanulatus (Roxb) Bl. ex Decne)

b) Cassava (Manihot esculenta Crantz)

c) Taro (Colocasia esculenta L)

d) Greater yam (Dioscorea alata L)

Each coconut multipurpose tropical tree-alley was considered as an independant experimental unit and the performance of the above mentioned four tuber crops in coconut + eucalyptus, coconut + subabul, coconut + glyricidia, coconut + ailanthus and coconut alleys were studied in seperate experiments. The experiments were laid out in randomised block design with five replications. Sole crops of tuber crops were grown to work out relative yields. The size of the plots were 7.5 x 7.5 m gross (5.5 x 3 m net). The alley cropping systems evaluated under this investigation

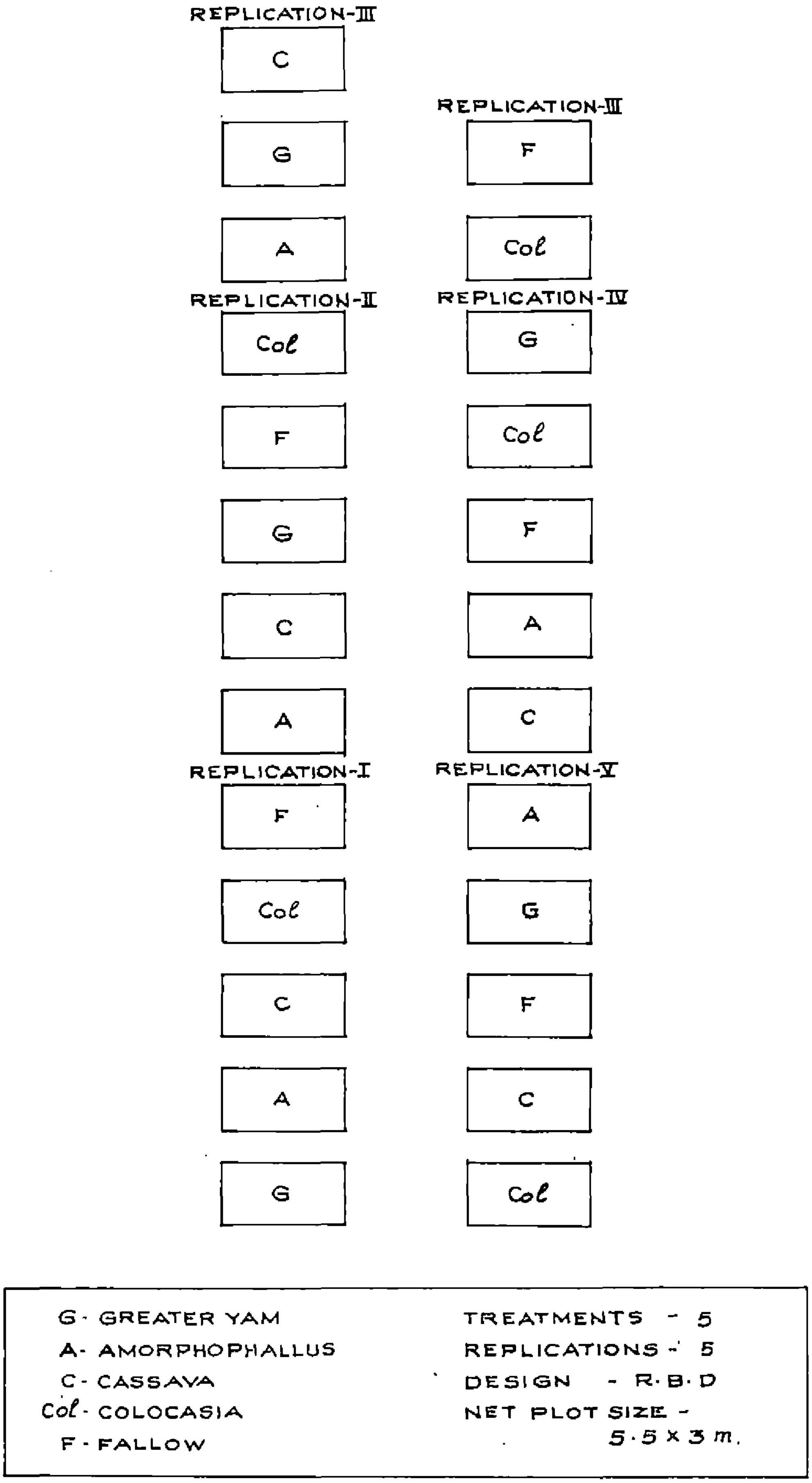

FIG. 1. PLAN OF LAY OUT.

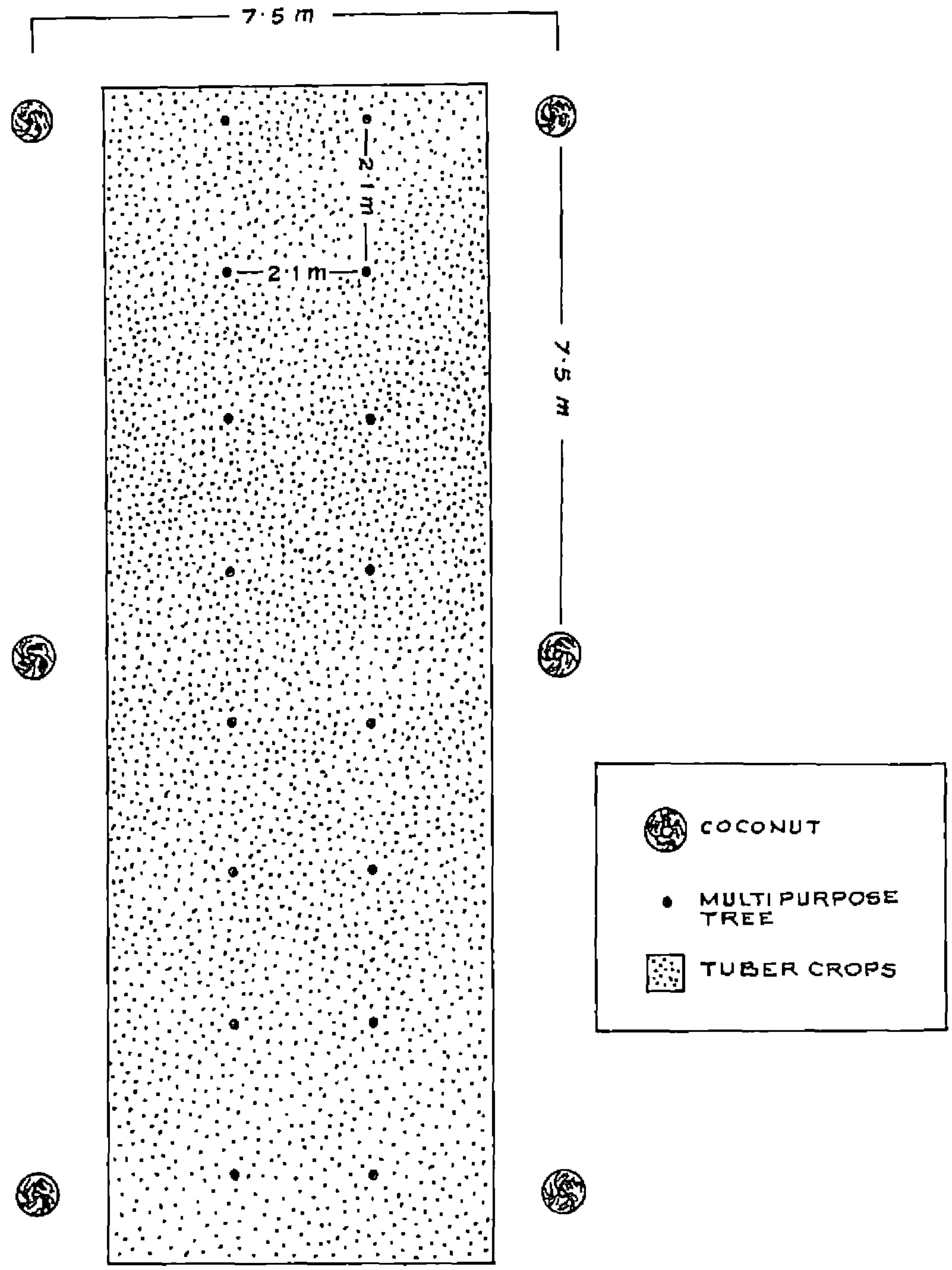

FIG. 2. PATTERN OF PLANTING OF COCONUT, MULTI-PURPOSE TREE AND THE TUBER CROPS IN MIXTURES.

are given below.

Alley cropping of tuber crops in coconut-eucalyptus mixture

a) coconut + eucalyptus + amorphophallus (Plate I a)

b) coconut + eucalyptus + cassava (Plate II)

c) coconut + eucalyptus + colocasia

d) coconut + eucalyptus + greater yam (Plate V)

e) coconut + eucalyptus

Alley cropping tuber crops in coconut-subabul mixture

a) coconut + subabul + amorphophallus (Plate I b)

b) coconut + subabul + cassava

c) coconut + subabul + colocasia (Plate IV)

d) coconut + subabul + greater yam

e) coconut + subabul

Alley cropping of tuber crops in coconut-glyricidia mixture

a) coconut + glyricidia + amorphophallus

b) coconut + glyricidia + cassava

c) coconut + glyricidia + colocasia

d) coconut + glyricidia + greater yam

e) coconut + glyricidia

Alley cropping of tuber crops in coconut-ailanthus mixture

a) coconut + ailanthus + amorphophallus (Plate I c)

b) coconut + ailanthus + cassava

c) coconut + ailanthus + colocasia (Plate III)

d) coconut + ailanthus + greater yam

e) coconut + ailanthus

Alley cropping of tuber crops with coconut trees

a) coconut + amorphophallus (Plate I d)

b) coconut + cassava

c) coconut + colocasia

d) coconut + greater yam

e) coconut alone

All the five experiments were statistically analysed together as in a multilocational trial so that a comparison of the performance of the tuber crops under different coconut - multipurpose tree crop alleys is possible.

3.4. Description of the cultural practices

3.4.1. Amorphophallus

Amorphophallus was planted in pits of size 60 x 60 x 45 cm at a spacing of 90 x 90 cm. Two kilogram cattle manure was mixed with the top soil of each pit which was then refilled to three-fourth of its volume and cut pieces of corm weighing one kilogram each were planted in the centre of the pits. Prior to planting corm pieces were dipped in cowdung and were dried under shade. The plants were mulched with dry leaves immediately after planting.

The basal dose of fertilizers were applied at the rate of 40 : 60 : 50 kg N, P_2O_5 and K_2O ha^{-1} respectively, at 45 days after planting. After that first weeding and earthing up were done. The second dose of fertilizers (40 kg N and 50 kg K_2O ha^{-1}) were applied one month after the first application after which the crop was harvested 8 months after planting.

3.4.2. Greater yam (Dioscorea)

Dioscorea was planted in pits of size 45 x 45 x 45 cm at a spacing of 1 m x 1 m. About three fourth of the pits were filled with 1-1½ kg cattle manure, mixed with top soil. Pieces of tuber weighing 250-300 g were planted at the centre of pits and mulched with dry leaves prior to planting. The cut pieces of tubers were dipped in cowdung

Table 2. The description of the crops, varieties, cropping season, spacing and plant population

Crops	Varieties	Cropping season	Spacing	No. of plants ha^{-1}
1. Amorphophallus	Local	Feb-March to Oct-November	90x90 cm	8,400
2. Greater yam	Local	March-April to Oct-November	1x1 m	6,600
3. Taro	Local	May-June to Oct-November	60x45 cm	25,000
4. Cassava	H-2304	April-May to Dec-January	90x90 cm	8,400
5. Coconut	West coast tall	Perennial	7.5x7.5 m	180
6. Eucalyptus	*Eucalyptus tereticornis*	Perennial	2.1x2.1 m	1,300
7. Subabul	*Leucaena leucocephala*	Perennial	2.1x2.1 m	1,300
8. Glyricidia	*Glyricidia maculata*	Perennial	2.1x2.1 m	1,300
9. Ailanthus	*Ailanthus triphysa*	Perennial	2.1x2.1 m	1,300

slurry and allowed to dry under shade before planting.

The first dose of fertilisers (40 : 60 : 40 kg N, P_2O_5 and K_2O ha^{-1}) were applied within a week after sprouting of the tubers. The second dose of fertilisers (40 kg each of N and K_2O ha^{-1}) were applied one month after the first application. Along with fertiliser application, weeding and earthing up were also done. Fifteen days after sprouting, the plants were trailed to the tree species. The crop was harvested by about 8 months when the vines showed the symptoms of yellowing and drying.

3.4.3. Taro (Colocasia)

The side corms weighing 25-35 g were planted at a spacing of 45 cm on ridges formed at a distance of 60 cm. Cattle manure at the rate of 12 t ha^{-1} was mixed with the soil while preparing the ridges for planting. A fertilizer dose of 80 : 50 : 100 kg N, P_2O_5 and K_2O ha^{-1} respectively was applied in 2 split doses. Full dose of P_2O_5 and half dose of N and K_2O were applied within a week after sprouting. The remaining half dose of N and K_2O were applied one month later. The crop was harvested after 6 months.

3.4.4. Cassava

Single cassava setts of size 15-20 cm prepared from the middle portion of healthy disease free stem were planted on soil mounds (45 x 45 x 45 cm) formed at a spacing of 90 x 90 cm. Cattle manure was applied at the rate of 12.5 t ha^{-1} during land preparation. The fertilizer dose given was 100 kg each N, P_2O_5 and K_2O ha^{-1} respectively. The N and K_2O were applied in 3 split doses, one third as basal, one third two months after planting and the rest one third three months after planting. The P fertiliser was given fully as basal. Excess shoots were removed at about 30 days after planting, retaining two shoots on each plant. The crop was harvested at nine months stage.

3.5. Observations recorded

3.5.1. Tuber crops

In each plot three plants were marked at random for recording the observations periodically.

3.5.1.1. Amorphophallus

The height was measured from the ground level to the tip of the leaves and also from the ground level to the point of forking at 60 days interval. Girth at the collar region was recorded at 60 days interval. The following regression equation was used for estimating the leaf area.

$$LA = -7594.94 + 259.36\ x \quad (R^2 = 0.973)$$

Where LA - leaf area per plant in cm^2

x - average size of the main branch

The average size of the main branch was obtained by measuring the length of three branches from the point of forking of pseudostem and calculating the mean value (Ashokan, 1986). The yield of corms were recorded from the net plots 7 months after planting and the average yield per hectare worked out.

3.5.1.2. Cassava

The plant height from the base of the stem to the tip was recorded at 60 days interval. The total number of leaves per plant was recorded at 2 months interval. Four months after planting the number of existing leaves and the number of leaves that had fallen were also recorded. The leaf area per plant was estimated using the method suggested by Ramanujam and Indira (1978).

The yield of tubers was recorded from the net plot 8 months after planting and the yield per hectare was worked out.

3.5.1.3. Colocasia

Leaf area per plant was estimated by using the empirical method by Sirdar et al. (1978). The yield of colocasia tuber was recorded from the net plots six months after planting and the yield per hectare was worked out.

3.5.1.4. Greater yam

The yield of greater yam tuber was recorded from the net plot eight months after planting and the yield per hectare was worked out.

3.5.2. Biomass production

Plants were selected at random at the time of harvest for the estimation of total biomass production. For this the samples of leaves, stem and tuber were taken and dried in the oven. From the oven dry weights of the samples the total dry matter production in kg ha^{-1} was worked out.

3.5.3.1. Growth characteristics of multipurpose tropical tree crops

The height and girth at the breast height (GBH) of the tree crops (eucalyptus, subabul, glyricidia and ailanthus) were recorded at the beginning and at the end of the experiment.

3.5.3.2. Green leaf manure yield from the trees

Pruning of glyricidia and subabul were done after 4 months of planting of tuber crops.

3.5.3.3. Litter fall from the trees

The leaves of eucalyptus and ailanthus (Plate III) were collected every week by spreading out a net to the tree. The weight of these fallen leaves were recorded and the litter fall worked out.

3.5.4. Growth characters of coconut

The number of leaves and the girth at the breast height (GBH) of the coconut were recorded prior to and after the experiment.

3.5.5. Root density and root distribution

When the tuber crops were 6 months old, soil cores (volume 100 cm^3) were collected from different depths (10, 20, 30 and 40 cm) and lateral distances from the tree (10, 20, 30, 40 and 50 cm). These soil samples were sieved and the roots were collected and dried in an oven. The oven dry weight of these roots were noted and expressed as milligrams per unit volume of soil. The vertical and lateral spread of roots of intercrops were studied by carefully digging out the plants and measuring the root spread and depth.

Distribution of roots at different distances from the tree trunks viz. 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130 and 140 cm and at different soil depths viz. 10, 20, 30 and 40 cm were studied using root excavation method (Athul ~~Chandra~~ and Yamadagni, 1983). The number of root tips occurring in 10 cm^2 were recorded for each multipurpose tree.

3.5.6. Micro-climatic observations

3.5.6.1. Light infiltration

An 'Aplab lux meter' was used to measure the light intensity. These readings were taken in the morning (8-9 a.m.) afternoon (12-1 p.m.) and evening (4-5 p.m.) at trimonthly intervals. In the case of tuber crops grown under the subabul and the glyricidia the readings were taken before and after pruning. From each plot, 5 readings were taken and the average of these readings were worked out.

3.5.6.2. Soil temperature

In one of the replications soil theremometers (5 cm) were installed in each plot when the intercrops were 4 months old. Soil temperatures were recorded two times daily at 7.25 a.m. and 2.25 p.m.

3.5.6.3. Relative humidity

The relative humidity was found out from whirling psychrometer readings taken at the heights of 30, 60, 120, 180 cm.

3.7. Physical and chemical properties of soil

3.7.1. Physical properties

3.7.1.1. Bulk density and particle density

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

3.7.1.2. Maximum water holding capacity

The physical constant of the soil was determined using Keen-Racskowski box before and after the experiment.

3.7.1.3. Aggregate stability

The unsieved composite samples were used for the determination of water stable aggregates prior to planting of tuber crops and after the harvest of the tuber crops. The Yoder's sieving apparatus was utilised for this (Yoder, 1937).

3.7.1.4. Infiltration rate

The infiltration characteristics of soils under different tree crops viz. eucalyptus, subabul, glyricidia, ailenthus, coconut were determined by ponding water in two metal cylinders installed in the field surface and observing the rate at which water level is lowered in the cylinder (Michael, 1978). The infiltration rate in fallow plots were also determined. The infiltration of water was recorded after 5, 10, 15, 30, 45, 60, 120, 180, 240 and 300 minutes.

3.7.2. Chemical properties

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

The organic carbon of the soil was determined by Walkley and Black method (Jackson, 1958). The alkaline permanganate method was used for determining available nitrogen content of the soil (Subbiah and Asija, 1956). Available P content of soil was determined using Bray I extractant and molybdophosphoric acid method in hydrochloric acid system (Jackson, 1958). The available K content was determined flame photometrically, using neutral normal ammonium acetate extract (Jackson, 1958).

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

The electrical conductivity (EC) of soil was determined in a 1 : 2.5 soil water suspension after allowing the soil particles to settle down. The EC of the supernatent liquid was read in a conductivity bridge.

3.8. Chemical analysis of plants

The plant samples dried in an oven at 70°C were ground to fine powder. The samples were used for the estimation of N, P and K. The nitrogen content was estimated in sulphuric acid digest of the plant samples by micro kjeldahl method (Jackson, 1958). The P content was estimated in a 1 : 1 $HClO_4$: HNO_3 digest colorimetrically by vanadomolybdate method (Jackson, 1958) and expressed as percentage. The potassium content was determined in a 1 : 1 $HClO_4$: HNO_3 digest using a flame photometer (Jackson, 1958) and expressed as percentage.

3.9. Statistical analysis

The means of the data from different observation plants were worked out. These data were statistically analysed by analysis of variance technique (Panse and Sukhatme, 1978).

Results & Discussion

RESULTS AND DISCUSSION

The results of the experiments conducted to evaluate the productivity of tuber crops alley cropped in coconut - multipurpose tropical tree mixtures are presented and discussed in this chapter.

4.1. Growth characters of tuber crops

4.1.1. Amorphophallus

4.1.1.1. Height

Intercropping of amorphophallus in coconut + eucalyptus, coconut + subabul, coconut + glyricidia, coconut + ailanthus and coconut alleys increased the height of amorphophallus significantly (Table 3). This trend was observed at all stages of growth. The increase in height observed in the intercrop amorphophallus may be attributed to the competition for light. Ashokan (1986) also observed that amorphophallus grown in banana garden was taller due to the shade from banana.

Table 3. Height, girth of pseudostem and leaf area of amorphophallus alley cropped in coconut - multipurpose tropical tree mixtures

Cropping system	Height from the base to the point of forking (cm)		Height from the base to the tip of leaves (cm)		Girth of pseudostem (cm)		Leaf area m^2 $plant^{-1}$
	Days after planting		Days after planting		Days after planting		Days after planting
	60	120	60	120	60	120	60
Co + Eu + A	45.6	68.2	67.1	136.2	13.1	18.2	1.14 (1.41)*
Co + Su + A	43.8	61.6	76.1	133.4	12.6	18.4	1.06 (1.31)
Co + Gl + A	65.2	86.2	115.3	160.0	15.9	17.4	1.29 (1.59)
Co + Ai + A	60.2	78.8	108.9	155.4	15.9	22.6	1.36 (1.68)
Co + A	43.0	62.4	83.4	107.4	13.5	18.2	1.02 (1.26)
A	38.6	50.0	80.1	113.0	13.3	18.4	1.11 (1.37)
CD (0.05)	6.1	4.3	11.4	13.1	2.1	2.3	0.20
SEm±	2.1	1.5	3.9	4.3	0.7	0.8	0.07

Co - Coconut
Eu - Eucalyptus
Su - Subabul

Gl - Glyricidia
Ai - Ailanthus
A - Amorphophallus

* Figures in parenthesis are leaf area index

4.1.1.2. Girth of pseudostem

The girth of the pseudostem of amorphophallus recorded at 60 days after planting (DAP) was significantly higher when it was intercropped in coconut + glyricidia and coconut + ailanthus alleys (Table 3). When it was intercropped in coconut + ailanthus alley, the girth recorded at 120 DAP was superior to the sole crop of amorphophallus.

4.1.1.3. Leaf area

The leaf area was highest when amorphophallus was intercropped in coconut + ailanthus alleys. There was no significant difference in the leaf area of amorphophallus when it was intercropped in the other alleys. The inter-space availability and the light infiltration to the interspace were more in coconut + ailanthus alley (Table 3) which could be the reason for the higher leaf area obtained.

4.1.1.4. Yield, dry matter production, harvest index and relative yield index

There was significant increase in corm yield of

Table 4. Dry matter production, corm yield and harvest index of amorphophallus alley cropped in coconut - multipurpose tropical tree mixtures

Cropping system	Dry matter production t ha^{-1}				Corm yield t ha^{-1}	Harvest index (%)
	Leaves	Stem	Tuber	Total		
Co + Eu + A	2.18	1.08	13.95	17.22	35.80 (0.99)*	81.0
Co + Su + A	2.06	7.27	12.56	15.36	28.24 (0.78)	81.8
Co + Gl + A	1.86	7.45	12.16	14.76	31.07 (0.86)	82.3
Co + Ai + A	2.25	1.64	19.90	23.79	44.96 (1.19)	83.6
Co + A	4.39	1.73	29.38	29.95	51.65 (1.28)	83.0
A	3.86	1.27	21.22	26.36	40.48	80.5
CD (0.05)	0.39	0.28	1.42	1.44	3.59	
S.Em±	0.13	0.09	0.48	0.49	1.21	

Co - Coconut
Eu - Eucalyptus
Su - Subabul

Gl - Glyricidia
Ai - Ailanthus
A - Amorphophallus

*Figures in parenthesis are relative yield indices

~~tuber crops~~ amorphophallus when it was grown in alleys of coconut and coconut + ailanthus (Table 4). A significant reduction in yield was observed when it was intercropped in coconut + subabul and coconut + glyricidia alleys. Similar trend was noticed in dry matter production also (Table 4). The relative yield index was greater than one when amorphophallus was intercropped in coconut and coconut + ailanthus alleys (Table 4). The difference between intercrop and sole crop amorphophallus was not perceptible as far as harvest index was concerned (Table 4).

The high yield recorded in the coconut and coconut + ailanthus alleys may be due to the high leaf area (Table 3) which enabled the crop to utilise more sun light for photosynthesis. The low yield and dry matter recorded in the amorphophallus grown in alleys of coconut + eucalyptus, coconut + subabul and coconut + glyricidia may be due to the shade cast by these tree crops (Table 23). Inter species root level interactions like competition for nutrients are also probable.

The relative yield index (Willey, 1979) of 1.19 and 1.28 observed in coconut and coconut + ailanthus alleys indicate the yield advantage of alley-cropping with amorphophallus.

Since the harvest index was not markedly different in intercrop and sole crop of amorphophallus it may be concluded that partitioning and translocation of photosynthates in amorphophallus was not remarkably influenced by the shade caused by these tree crops. The harvest index of 80 per cent observed in amorphophallus was very high compared to other tuber crops. This is due to the peculiar nature of the canopy. It is having only a single layer of leaves and the canopy does not expand once it is fully formed; so there is no chance of mutual shading. The full formation of the canopy takes only about 30 days from planting. After this period for about 210 days the major portion of the assimilates is used for the tuber formation and development only.

4.1.2. Cassava

4.1.2.1 Height

Intercropping of cassava in coconut + subabul, coconut + glyricidia alleys increased the height of cassava significantly (Table 5). This trend was noticed upto 60 days after planting. One hundred and twenty days after planting, the height of the intercrop cassava was

Table 5. Height and leaf area of cassava alley cropped in coconut - multipurpose tropical tree mixtures

Cropping system	Height (cm)		Leaf area m^2 $plant^{-1}$	
	Days after planting		Days after planting	
	60	120	60	120
Co + Eu + C	76.3	275.0	0.70 (0.86)*	1.94 (2.39)
Co + Su + C	81.3	281.2	0.97 (1.19)	2.25 (2.78)
Co + Gl + C	88.8	297.6	0.48 (0.59)	1.71 (2.11)
Co + Ai + C	77.8	280.0	0.66 (0.81)	1.84 (2.27)
Co + C	78.2	265.0	0.78 (0.96)	3.11 (3.84)
C	64.4	242.6	0.90 (1.11)	2.56 (3.16)
CD (0.05)	15.0	29.6	0.19	0.45
S.Em±	5.1	10.0	0.06	0.15

Co - Coconut
Eu - Eucalyptus
Su - Subabul

Gl - Glyricidia
Ai - Ailanthus
C - Cassava

*Figures in parenthesis are leaf area indices significantly more in all the coconut - multipurpose tropical tree crop alleys studied. The increase in height may be attributed to the shade caused by coconut and the multipurpose tropical trees. Increase in height of cassava consequent to shading was reported by Ramanujam *et al*. (1984b).

4.1.2.2. Leaf area

There was no significant reduction in the leaf area of cassava due to alley cropping, upto 60 days after planting (Table 5). But there was a significant increase in leaf area of cassava planted in coconut alleys. The leaf area of cassava intercropped in coconut + subabul alley was on par with that of the plants grown in coconut alleys. Eventhough the number of leaves were reduced (data not presented) due to alley cropping the leaf area was not reduced. The cassava grown in alleys probably produced thinner and broader leaves. This is evident from the dry weight of leaves (Table 6). In shade grown cocoa, Hardy (1958) observed thin and broader leaves leading to higher leaf area of the plant. Increase in leaf area of cassava consequent to shading was reported by Ramanujam *et al*. (1984b).

Table 6. Dry matter production, yield and harvest index of cassava alley cropped in coconut - multipurpose tropical mixtures

Cropping system	Dry matter production t ha^{-1}				Yield t ha^{-1}	Harvest index (%)
	Leaves	Stem	Tuber	Total		
Co + Eu + C	1.52	3.20	5.57	10.19	13.40 (0.80)*	54.2
Co + Su + C	1.64	1.97	6.41	10.00	15.40 (0.92)	63.9
Co + Gl + C	0.72	1.29	0.94	2.95	4.06 (0.24)	31.9
Co + Ai + C	1.33	2.49	3.76	7.58	10.98 (0.66)	49.6
Co + C	1.42	3.02	3.48	7.93	12.76 (0.68)	44.0
C	2.43	3.68	9.34	15.45	18.74	60.4
CD (0.05)	0.26	0.55	0.68	0.86	1.15	
S.Em±	0.89	0.19	0.23	0.29	0.39	

Co - Coconut
Eu - Eucalyptus
Su - Subabul

Gl - Glyricidia
Ai - Ailanthus
C - Cassava

*Figures in parenthesis are relative yield indices

4.1.2.3. Yield, dry matter production, harvest index and relative yield index

There was significant reduction in the yield of cassava in all the alley cropping situations as compared to the sole crop (Table 6) and (Fig. 3). Dry matter accumulation by cassava, like the tuber yield showed a significant reduction in all the alley cropping situations. The relative yields of cassava in all the coconut - multipurpose tropical tree alley cropping systems were less than one.

The interspecific competition for light and/or nutrients and moisture between cassava and the multipurpose tropical tree crops would have adversly affected the cassava crop. The tree crops were much taller than cassava. Hence, the cassava plants were shaded severely and this is indicated by the data on the relative light transmission (Table 20). The quantity of light reaching the cassava canopy in the alleys were only 40-50% of that received in the sole crop. Cassava was shaded severely in the initial stages of growth which resulted in poor tuber initiation and yield. Ramanujam et al. (1984a) observed poor tuberisation and yield in cassava under shaded situation prevailing in coconut gardens.

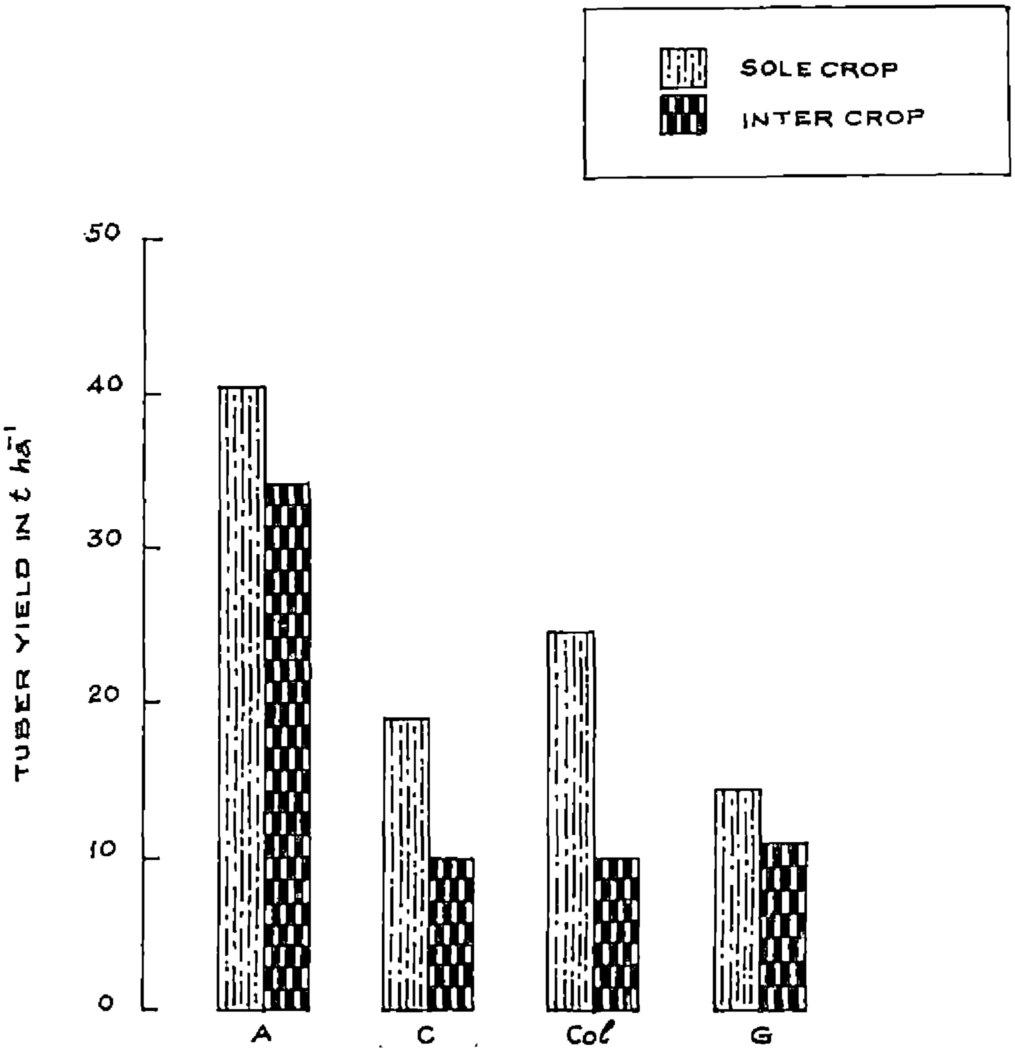

FIG.3. TUBER YIELD OF AMORPHOPHALLUS (A) CASSAVA (C), COLOCASIA (Col) AND GREATER YAM (G) ALLEY CROPPED IN COCONUT-MULTIPURPOSE TREE MIXTURES AS COMPARED TO THE RESPECTIVE SOLE CROPS.

The harvest index of cassava varied significantly (Table 6). Cassava intercropped in all the coconut - multipurpose tropical tree crop alleys except coconut + subabul alley showed a lower value. The lowest being recorded by cassava in coconut + glyricidia alley. In coconut + subabul alley the harvest index of cassava was similar to the sole crop. In coconut + glyricidia alley because of the prolific, thick and spreading growth of the canopy the light infiltration to the casseva canopy was very low (Table 20). As a result there was dominance of vegetative growth at the expense of tuber growth. The harvest index was higher in coconut + subabul alley as the subabul canopy was compact letting in more light to the alley crop canopy (Table 20). Moreover, the pollarding of subabul after 3 months increased the infiltration of light to the cassava canopy further which might have increased the tuber yield.

4.1.3. Colocasia

4.1.3.1. Leaf area

The leaf area of the alley crop of colocasia showed no significant difference from the sole crop except in

Table 7. Leaf area of colocasia alley cropped in coconut - multipurpose tropical tree mixtures

Cropping system	Leaf area m^2 $plant^{-1}$	
	Days after planting	
	60	120
Co + Eu + Col	0.32 (1.19)*	0.29 (1.07)
Co + Su + Col	0.28 (1.04)	0.34 (1.26)
Co + Gl + Col	0.30 (1.11)	0.26 (0.96)
Co + Ai + Col	0.17 (0.63)	0.17 (0.63)
Co + Col	0.23 (0.85)	0.41 (1.52)
Col	0.32 (1.19)	0.39 (1.44)
CD (0.05)	0.12	0.10
S.Em±	0.04	0.03

Co - Coconut
Eu - Eucalyptus
Su - Subabul

Gl - Glyricidia
Ai - Ailanthus
Col- Colocasia

*Figures in parenthesis are leaf area indices coconut + ailanthus alley at 60 days after planting and coconut + ailanthus and coconut + glyricidia alleys at 120 days after planting (Table 7). A decrease in leaf area was observed in coconut + ailanthus and coconut + glyricidia alleys. Unlike in cassava, alley crop of colocasia, produced a higher number of leaves (data not presented) but a lower leaf area per plant. Eventhough the exact reason for this behaviour was not evident from the data available, it may be noted that cassava is a shade sensitive plant (Ramanujam *et al.*, 1984b) and colocasia shade tolerant (Lalithabai and Nair, 1984).

4.1.3.2. Yield

The yield of colocasia grown as an intercrop in coconut - multipurpose tropical tree alleys was significantly less when compared to that of sole crop (Table 8) and (Fig. 3). The lowest yield was recorded in coconut + ailanthus alleys. The yield of colocasia grown in coconut alley was on par with that of the sole crop. Similar trend was observed in the dry matter production also (Table 8). As far as harvest index was concerned there was no remarkable difference between the alley crop and the sole crop (Table 8).

Table 8. Dry matter production, yield and harvest index of colocasia alley cropped in coconut - multipurpose tropical tree mixtures

Cropping system	Dry matter production t ha^{-1}			Yield t ha^{-1}	Harvest index (%)
	Shoot	Tuber	Total		
Co + Eu + Col	0.75	1.88	2.63	16.42 (0.745)*	71.5
Co + Su + Col	0.76	1.83	2.59	18.19 (0.823)	70.4
Co + Gl + Col	0.79	1.47	2.22	10.21 (0.463)	65.0
Co + Ai + Col	0.61	1.35	1.96	8.27 (0.375)	69.0
Co + Col	2.02	4.00	6.02	22.93 (0.925)	66.4
Col	2.07	4.29	6.36	24.81	67.5
CD (0.05)	0.13	0.41	0.44	2.07	
S.Em±	0.04	0.13	0.14	0.65	

Co - Coconut
Eu - Eucalyptus
Su - Subabul

Gl - Glyricidia
Ai - Ailanthus
Col - Colocasia

*Figures in parenthesis are relative yield indices

The relative yield index of colocasia was less than one when it was intercropped in the multipurpose tropical tree crop alleys (Table 8).

The yield reduction observed in colocasia may be due to the competition for light offered by coconut and the multipurpose tropical tree crops. Colocasia was very much at a disadvantage as far as light utilisation was concerned because of its shorter canopy. When colocasia was at its active vegetative growth light transmission to colocasia canopy was only 70% (Table 21). The influence of low light received on the alley crop of colocasia was reflected in the total dry matter production, but not in the harvest index. This indicates that the reduced light received on colocasia decreased the plant photosynthetic production in total but not its partitioning. Lalithabai and Nair (1984) classified colocasia as a shade tolerant crop from their studies under artificially shaded conditions. But in this experiment the reduction in yield of colocasia grown in the alleys was considerable. It may be remembered that unlike in the artificially shaded situation here the rhizosphere competition for nutrients or moisture also might have affected the colocasia yield.

Table 9. Dry matter production, yield and harvest index of greater yam alley cropped in coconut - multipurpose tropical tree mixtures

Cropping system	Dry matter production t ha^{-1}			Yield t ha^{-1}	Harvest index (%)
	Shoot	Tuber	Total		
Co + Eu + G	0.97	2.01	2.98	18.40 (1.40)*	67.5
Co + Su + G	0.81	1.67	2.48	10.37 (0.79)	67.3
Co + Gl + G	0.86	1.88	2.74	17.15 (1.30)	68.4
Co + Ai + G	0.56	0.77	1.33	4.48 (0.34)	58.0
Co + G	1.00	1.72	2.72	18.43 (1.25)	63.2
G	0.95	1.63	4.57	14.73	63.3
CD (0.05)	0.07	0.18	0.20	5.65	
S.Em±	0.02	0.06	0.07	1.90	

Co - Coconut
Eu - Eucalyptus
Su - Subabul
Gl - Glyricidia
Ai - Ailanthus
G - Greater yam

*Figures in parenthesis are relative yield indices

4.1.4. Greater yam

4.1.4.1. Yield, dry matter production, harvest index and relative yield index

The tuber yield of greater yam was not significantly different in alley cropping and sole cropping (Fig. 3) except when it was grown in coconut + ailanthus alley (Table 9). There was reduction in yield of greater yam to the extent of 30 per cent when it was grown in alleys of coconut + ailanthus alley. The dry matter production of greater yam showed similar trend as that of the tuber yield except in coconut + eucalyptus alley, where the dry matter production was higher. There was no considerable variation in the harvest index of greater yam due to alley cropping. However, in coconut + ailanthus a lower value was recorded. The lower yield of greater yam grown in coconut + ailanthus alley may be due to the lower percentage of light reaching its canopy in the cropping system (Table 22). Moreover, the ailanthus trees were short (Table 14) and trailing of the vines was not perfect. The increased dry matter production in coconut + eucalyptus alley may be due to the trailing of vines on the eucalyptus which enabled it to climb to a greater height and utilise the solar energy more efficiently.

Table 10. Nitrogen, Phosphorus and Potassium content of amorphophallus alley cropped in coconut - multipurpose tropical tree mixtures

Cropping system	Nitrogen (%)		Phosphorus(%)		Potassium (%)	
	Shoot	Tuber	Shoot	Tuber	Shoot	Tuber
Co + Eu + A	2.16 (106)*	1.26 (70)	0.83 (14.39)	0.47 (11.8)	1.21 (109)	1.01 (98)
Co + Su + A	2.01 (101)	1.01 (94)	0.77 (14.71)	0.48 (10.9)	1.33 (110)	1.12 (96)
Co + Gl + A	2.13 (105)	1.13 (92)	0.81 (14.39)	0.47 (10.4)	1.23 (108)	1.01 (98)
Co + Ai + A	2.01 (103)	1.01 (81)	0.78 (13.36)	0.47 (10.6)	1.42 (109)	1.12 (96)
Co + A	2.15 (107)	1.15 (90)	0.77 (14.71)	0.47 (10.6)	1.50 (112)	1.12 (98)
A	2.01 (110)	1.01 (93)	0.77 (14.20)	0.48 (11.20)	1.44 (109)	1.14 (97)
CD (0.05)	N.S.	0.16	0.01	N.S.	0.06	0.04
S.Em±	0.08	0.05	0.003	0.002	0.021	0.014

Co - Coconut
Eu - Eucalyptus
Su - Subabul

Gl- Glyricidia
Ai- Ailanthus
A - Amorphophallus

*Figures in parenthesis represents uptake in kg ha^{-1}

Since the harvest index was not markedly different from that of sole crop in most alley crop situation it may be deduced that partitioning and translocation of photosynthates in greater yam was not markedly influenced by the shade of these tree crops. It is reported that greater yam is a shade susceptible crop (Onwueme, 1978) and naturally a lower yield is expected in intercropped situations. However, in this experiment since the vines were trailed on the trees it must be presumed that the light received on their canopy was sufficient enough to proceed normal photosynthesis and partitioning of photosynthates.

4.2. Nitrogen, Phosphorus and Potassium content of the tuber crops

4.2.1. Amorphophallus

The nitrogen content of the amorphophallus shoot showed no significant difference due to alley cropping (Table 10). Amorphophallus tuber harvested from the coconut + eucalyptus alley showed higher nitrogen content. The amorphophallus in coconut + eucalyptus and coconut + glyricidia alley showed higher phosphorus content in their

Table 11. Nitrogen, phosphorus and potassium content of cassava alley cropped in coconut - multipurpose tropical tree mixtures

Cropping system	Nitrogen (%)		Phosphorus(%)		Potassium (%)	
	Shoot	Tuber	Shoot	Tuber	Shoot	Tuber
Co + Eu + C	2.48	1.15	0.77	0.47	1.43	1.16
	(117)*	(64)	(8.41)	(6.28)	(68)	(58)
Co + Su + C	2.61	1.04	0.78	0.48	1.38	1.12
	(94)	(66)	(7.22)	(6.21)	(70)	(60)
Co + Gl + C	2.11	1.12	0.78	0.46	1.91	1.20
	(42)	(10)	(6.31)	(4.22)	(64)	(57)
Co + Ai + C	2.14	1.12	0.77	0.48	1.57	1.14
	(81)	(42)	(7.33)	(6.08)	(69)	(56)
Co + C	2.50	1.22	0.80	0.48	1.62	1.18
	(111)	(49)	(8.41)	(6.28)	(68)	(58)
C	2.52	1.23	0.81	0.52	1.90	1.20
	(143)	(101)	(8.68)	(6.44)	(72)	(62)
CD (0.05)	0.15	0.12	0.01	0.02	0.04	0.05
S.Em±	0.05	0.04	0.002	0.005	0.014	0.018

Co - Coconut Gl - Glyricidia
Eu - Eucalyptus Ai - Ailanthus
Su - Subabul C - Cassava

*Figures in perenthesis represents uptake in kg ha^{-1}

shoot whereas the phosphorus content of the tuber showed no significant difference. The potassium content of the amorphophallus shoot was significantly less when it was alley cropped in coconut + eucalyptus, coconut + subabul and coconut + glyricidia alleys. In the corm also similar trend was observed except in the crop in coconut + subabul alley.

4.2.2. Cassava

The nitrogen content of the cassava shoot was significantly less when it was alley cropped in coconut - glyricidia and coconut + ailanthus alleys (Table 11). In the tuber such difference was not observed except in the plants alley cropped in coconut + subabul alley where a significantly lower value was recorded. The phosphorus content of the cassava showed a significantly lower value in all the coconut - multipurpose tropical tree alleys. The potassium content of the shoot also showed similar trend. The lowest potassium content was observed in the cassava grown in coconut + subabul alley. The potassium content of the tuber showed no significant difference.

Table 12. Nitrogen, phosphorus and potassium content of colocasia alley cropped in coconut - multipurpose tropical tree mixtures

Cropping system	Nitrogen (%)		Phosphorus (%)		Potassium (%)	
	Shoot	Tuber	Shoot	Tuber	Shoot	Tuber
Co + Eu + Col	2.41 (18)*	0.76 (14)	0.79 (5.9)	0.48 (4.2)	1.48 (60)	1.18 (52)
Co + Su + Col	2.37 (18)	0.86 (15)	0.78 (5.9)	0.47 (4.4)	1.50 (62)	1.19 (48)
Co + Gl + Col	2.45 (19)	0.76 (10)	0.77 (6.1)	0.46 (4.8)	1.48 (61)	1.20 (48)
Co + Ai + Col	2.47 (15)	0.78 (10)	0.76 (4.6)	0.47 (4.02)	1.79 (63)	1.21 (52)
Co + Col	2.69 (54)	0.84 (33)	0.78 (15.8)	0.47 (13.3)	1.55 (80)	1.24 (56)
Col	2.66 (55)	0.76 (32)	0.80 (16.6)	0.48 (12.6)	1.76 (82)	1.26 (60)
CD (0.05)	0.08	0.02	N.S.	N.S.	0.10	0.09
S.Em±	0.026	0.006	0.003	0.003	0.033	0.030

Co - Coconut
Eu - Eucalyptus
Su - Subabul

Gl - Glyricidia
Ai - Ailanthus
Col - Colocasia

*Figures in parenthesis represent uptake in kg ha^{-1}

4.2.3. Colocasia

Similar to cassava in colocasia also the nitrogen content of the shoot was significantly less when intercropped in the coconut - multipurpose tropical tree alleys (Table 12). The nitrogen content of the shoot of sole colocasia and that grown in coconut alleys were on par. The colocasia tuber from coconut + subabul and coconut alley showed higher N content. The phosphorus content of colocasia shoot showed a decreasing trend due to alley cropping. This difference was not observed with respect to the tuber. The potassium content of the colocasia shoot showed lower value as compared to sole colocasia except in the colocasia grown in coconut + ailanthus alley which was on par with sole colocasia. In the tuber such difference was not observed.

4.2.4. Greater yam

The N content of the shoot showed no significant difference due to alley cropping (Table 13). The tuber from the coconut + subabul alley showed a lower N content whereas that from the coconut + ailanthus allay showed a

Table 13. Nitrogen, phosphorus and potassium content of greater yam alley cropped in coconut - multipurpose tropical tree mixtures

Cropping system	Nitrogen (%)		Phosphorus(%)		Potassium (%)	
	Shoot	Tuber	Shoot	Tuber	Shoot	Tuber
Co + Eu + G	2.55 (97)*	1.30 (62)	0.78 (8.41)	0.48 (6.76)	1.45 (72)	1.12 (66)
Co + Su + G	2.48 (92)	0.98 (58)	0.81 (7.12)	0.48 (6.26)	1.55 (74)	1.20 (64)
Co + Gl + G	2.57 (86)	1.27 (57)	0.78 (7.12)	0.47 (5.76)	1.55 (70)	1.20 (62)
Co + Ai + G	2.47 (94)	1.43 (58)	0.77 (6.64)	0.49 (5.12)	1.68 (68)	1.14 (56)
Co + G	2.43 (98)	1.04 (60)	0.81 (6.98)	0.47 (4.88)	1.65 (68)	1.22 (58)
G	2.46 (94)	1.22 (59)	0.79 (6.54)	0.47 (5.21)	1.89 (66)	1.24 (62)
CD (0.05)	0.12	0.08	0.01	0.01	0.05	0.05
S.Em±	0.041	0.026	0.004	0.003	0.016	0.016

Co - Coconut
Eu - Eucalyptus
Su - Subabul
Gl - Glyricidia
Ai - Ailanthus
G - Greater yam

*Figures in parenthesis represents uptake in kg ha^{-1}

higher value as compared to the sole crop. The phosphorus content of the shoot was higher when the yam was intercropped in coconut - subabul and coconut alley. The phosphorus content was significently less in the yam shoot from coconut - ailanthus alley. The potassium content of the shoot of the plant was less when it was alley cropped. The same trend was observed in potassium content of the tuber from coconut - eucalyptus and coconut - ailanthus alleys, other values being on par.

4.2.5. Uptake of nitrogen, phosphorus and potassium by the tuber crops

The total uptake of nitrogen by amorphophallus, cassava, colocasia and greater yam alley cropped in coconut - multipurpose tropical trees was less than that of the sole crop (Fig. 4). The uptake of phosphorus by the tuber crops grown in alleys also showed a similar trend except in the case of greater yam. The uptake of potassium by the tuber crops grown in alleys also showed a similar trend as that of phosphorus.

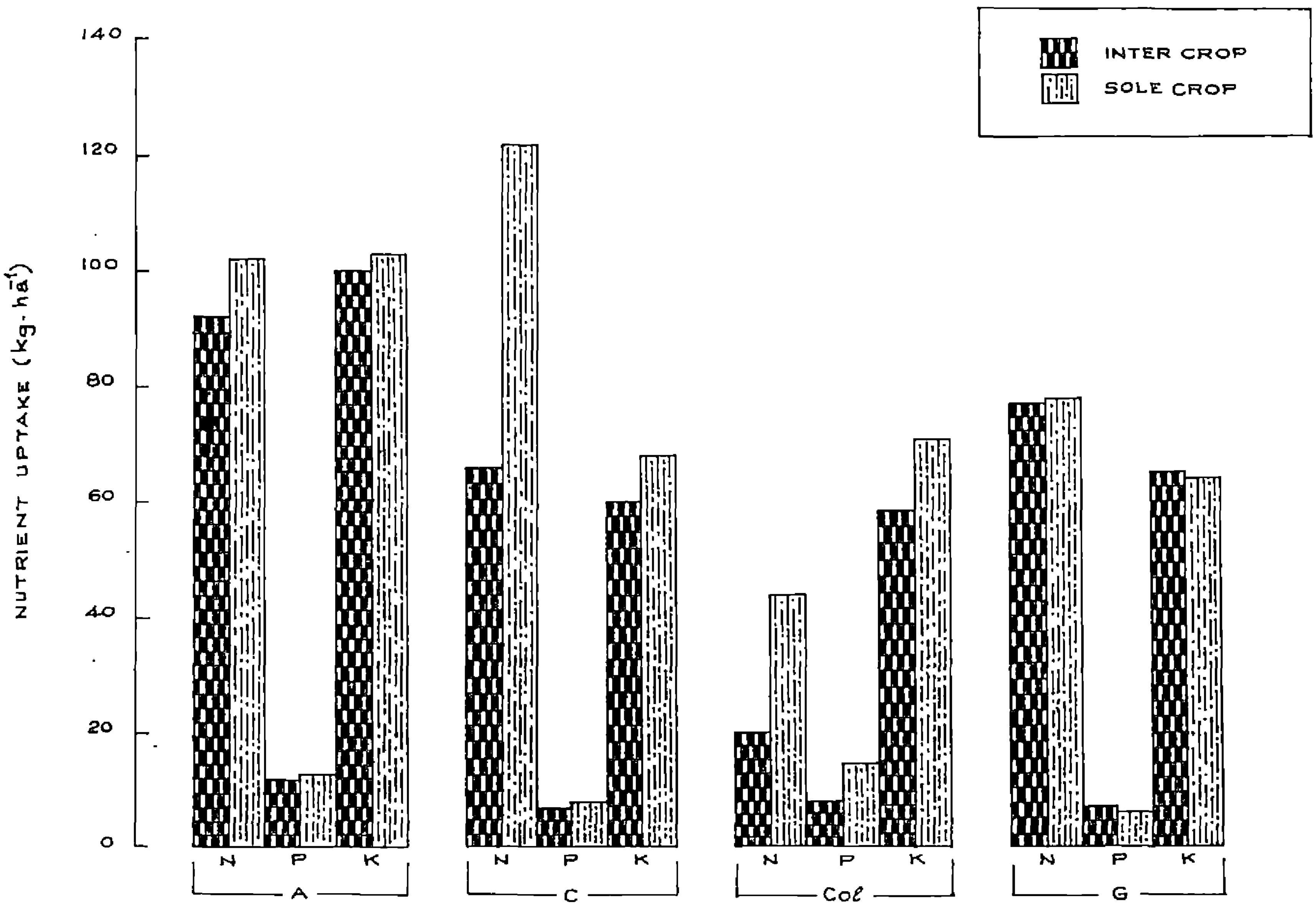

FIG. 4. UPTAKE OF NITROGEN (N), PHOSPHORUS (P) AND POTASSIUM (K) BY AMORPHOPHALLUS (A), CASSAVA (C), COLOCASIA (Col) AND GREATER YAM (G) ALLEY CROPPED IN COCONUT MULTI-PURPOSE TREE CROP MIXTURES AS COMPARED TO THE RESPECTIVE SOLE CROPS.

Table 14. The effect of alley cropping of tuber crops on increment in height of multipurpose tropical tree crops

Alley crop	Increment in height (cm)			
	Eucalyptus	Subabul	Glyricidia	Ailanthus
Amorphophallus	101.2	10.4	15.2	130.2
Cassava	165.2	13.8	20.6	109.0
Colocasia	81.2	19.4	5.6	110.6
Greater yam	75.0	10.6	10.0	93.4
Control	109.4	12.4	10.0	116.0
CD (0.05)	6.7	2.8	2.4	4.11
S.Em±	2.2	0.9	0.8	1.40

4.3. Growth characteristics of multipurpose tree crops

4.3.1. Height

There was significant increase in height of eucalyptus and glyricidia when cassava was grown as an alley crop (Table 14). A significant reduction in height of the eucalyptus was observed when the alley crop was amorphophallus, colocasia and greater yam. When subabul was alley cropped with amorphophallus, cassava and greater yam the height of the tree was not affected significantly. There was a significant increase in height of ailanthus when it was alley cropped with amorphophallus and a reduction in height when it was alley cropped with cassava, colocasia and greater yam.

The soils at the experimental site were quite uniform. So height differences due to site class variations were not probable. The difference in height can therefore be ascribed within plot competition. The cultivation operations for the alley crop may have given a better soil physical and chemical conditions which encouraged the growth of the trees.

Table 15. The effect of alley cropping of tuber crops on increment in girth of multipurpose tropical tree crops

Alley crop	Increment in girth (cm)			
	Eucalyptus	Subabul	Glyricidia	Ailanthus
Amorphophallus	4.4	2.9	2.8	3.4
Cassava	4.2	3.0	2.7	4.4
Colocasia	4.8	3.0	3.0	4.7
Greater yam	4.4	2.9	2.6	4.2
Control	4.6	3.0	3.0	4.1
CD (0.05)	0.6	0.4	0.4	0.5
S.Em±	0.2	0.1	0.1	0.2

4.3.2. Girth

There was no significant variation in Girth at Breast Height (GBH) of eucalyptus, subabul, glyricidia and ailanthus due to alley cropping with amorphophallus, cassava, colocasia and greater yam (Table 15). This indicate that the growth of the multipurpose tropical trees were not adversly affected by alley cropping with these annuals.

4.3.3. Root density and distribution

In the case of amorphophallus maximum root density was observed in the upper 20 cm of the soil. When the lateral distance was considered the root density was highest at 40 cm away from the plant. In cassava most of the roots were concentrated in the upper 10 cm and 10 cm away from the crop (Table 16). Most of the colocasia roots were seen at a depth of 10 cm and lateral distance of 30 cm away from the crop. For greater yam the roots were concentrated at the surface, the maximum root density being in the zone 10 cm deep and 10 cm away from the plant (Table 16).

Table 16. Root density of tuber crops (mg/100 cm^3 of the soil)

Alley crop	Lateral distance (cm)	Depth (cm)			
		10	20	30	40
	10	65	10	10	10
	20	290	150	330	890
Amorphophallus	30	4	20	2	10
	40	8	4	10	10
	50	60	2	1	10
	10	350	100	110	10
	20	20	20	20	10
Cassava	30	120	20	20	10
	40	10	8	6	8
	50	10	2	60	40
	10	10	20	75	10
	20	60	5	10	10
Colocasia	30	120	2	10	10
	40	20	40	10	10
	50	20	10	10	40
	10	210	20	2	1
	20	40	30	1	1
Greater yam	30	25	10	1	1
	40	10	50	1	1
	50	50	10	1	1

It is to be noted that on an average, the roots of amorphophallus were extended to a distance of 34 cm and to a depth of 38 cm. In greater yam the roots were spread to a length of 40 cm and depth of 68 cm. But for colocasia the corresponding figures were 9 cm and 39 cm respectively.

Majority of the roots of eucalyptus were found in the top 10 cm layer of the soil (Fig. 5). Similarly most of the roots were observed 50 cm away from the tree. The highest percentage of the roots (11%) was seen in the upper 10 cm of the soil at a distance of 10 cm from the tree. When the depth increased the number of roots decreased. Similarly, more number of roots were seen close to the eucalyptus trees. Most of the roots in subabul were confined to the top 30 cm of the soil (Fig. 6). Maximum percentage of the roots of subabul were seen in the upper 10 cm of the soil. Considerable number of roots were observed upto 90 cm lateral distance from the tree. As the depth increased, the number of roots decreased. At 50 cm depth only about 0.15 per cent of the roots was seen. In glyricidia the top 40 cm of the soil can be considered as the most active root zone. Maximum percentage of roots were seen in the upper 10 cm of the soil upto a lateral

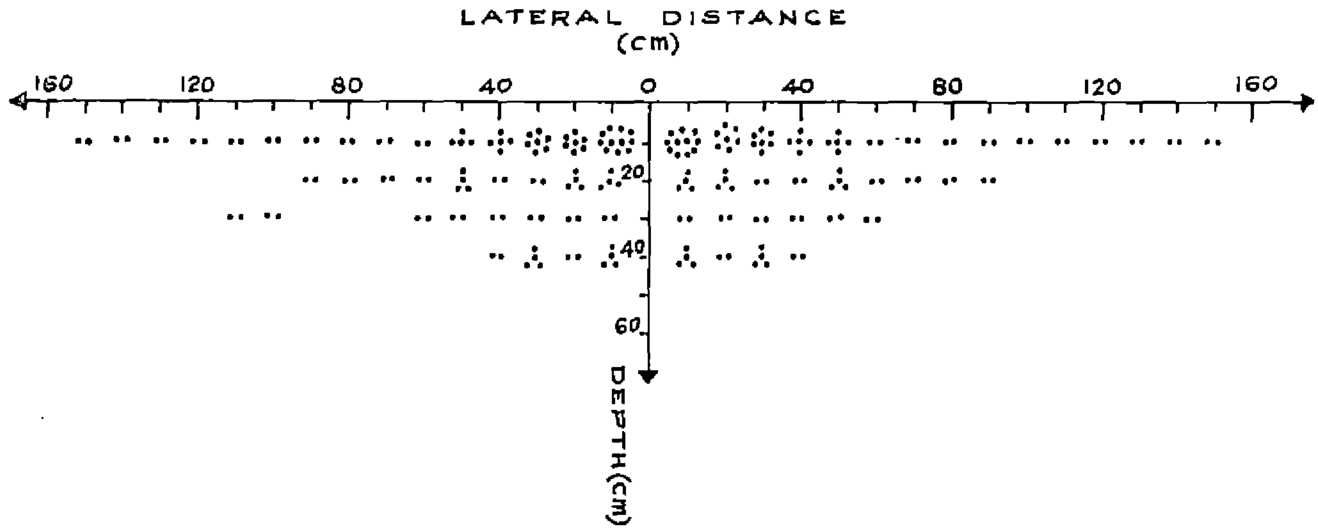

FIG. 5. ROOT DISTRIBUTION IN EUCALYPTUS.

EACH DOT REPRESENTS ONE PERCENTAGE OF ROOT

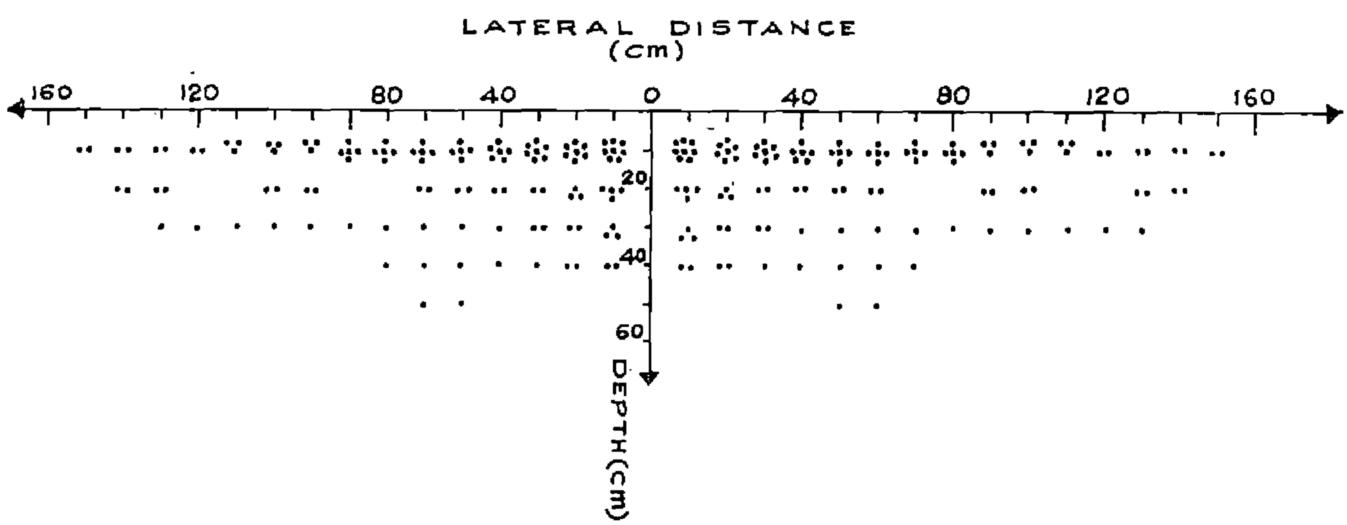

FIG. 6. ROOT DISTRIBUTION IN SUBABUL.

Table 17. Green leaf manure yield from subabul

Alley crop	Fresh weight ($t\ ha^{-1}$)			Dry matter production ($t\ ha^{-1}$)		
	Leaves	Stem	Total	Leaves	Stem	Total
Amorphophallus	15.41	6.70	22.11	4.44	3.37	7.81
Cassava	17.34	11.83	29.17	4.79	6.00	10.79
Colocasia	14.65	8.27	22.92	4.58	4.17	8.75
Bare	13.84	5.14	18.98	3.63	2.59	6.22

Table 17. Green leaf manure yield from glyricidia

Alley crop	Fresh weight ($t\ ha^{-1}$)			Dry matter production ($t\ ha^{-1}$)		
	Leaves	Stem	Total	Leaves	Stem	Total
Amorphophallus	27.38	35.52	62.90	6.74	12.64	19.38
Cassava	20.18	23.40	43.58	5.60	7.53	13.13
Colocasia	14.17	21.15	35.32	3.89	8.33	12.22
Bare	18.33	26.34	44.67	5.09	9.37	14.46

distance of 70 cm (Fig. 7). As the depth increased, the number of roots decreased considerably. Ailanthus is also a shallow rooted tree with most of the roots confined to the top 20 cm layer of the soil (Fig. 8). However, the lateral spread of roots wasw seen upto 120 cm. Here also the number of roots decreased as depth increased. At 50 cm depth no roots were observed.

Majority of the roots of a coconut palm will be distributed through a depth of 30-120 cm and lateral distance of 200 cm (Kushwah et al., 1973). So considering the root distribution patterns of the component crops of the cropping systems under study it can be stated that the chances for root level competition between species is limitted.

4.3.4. Green leaf manure and fuel wood yield from the trees

The green leaf manure yield from the trees increased due to alley cropping (Fig. 9). The maximum amount of green leaf manure of subabul was obtained when cassava was the alley crop (Table 17). The lowest quantity was obtained from the plots where no alley crops were raised. The

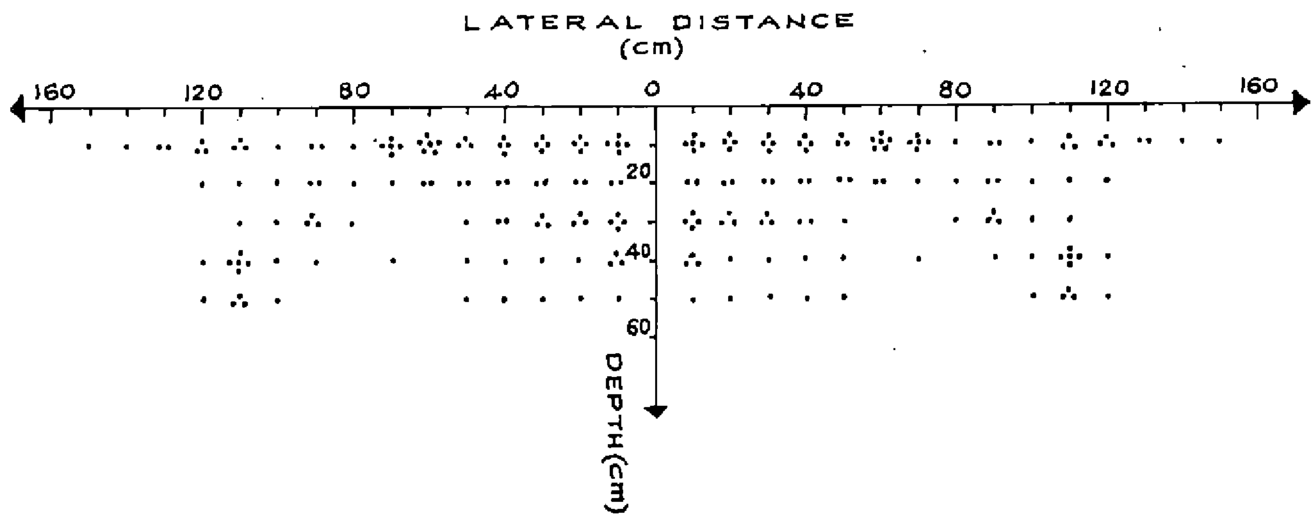

FIG. 7. ROOT DISTRIBUTION OF GLYRICIDIA.

EACH DOT REPRESENTS ONE PERCENTAGE OF ROOT

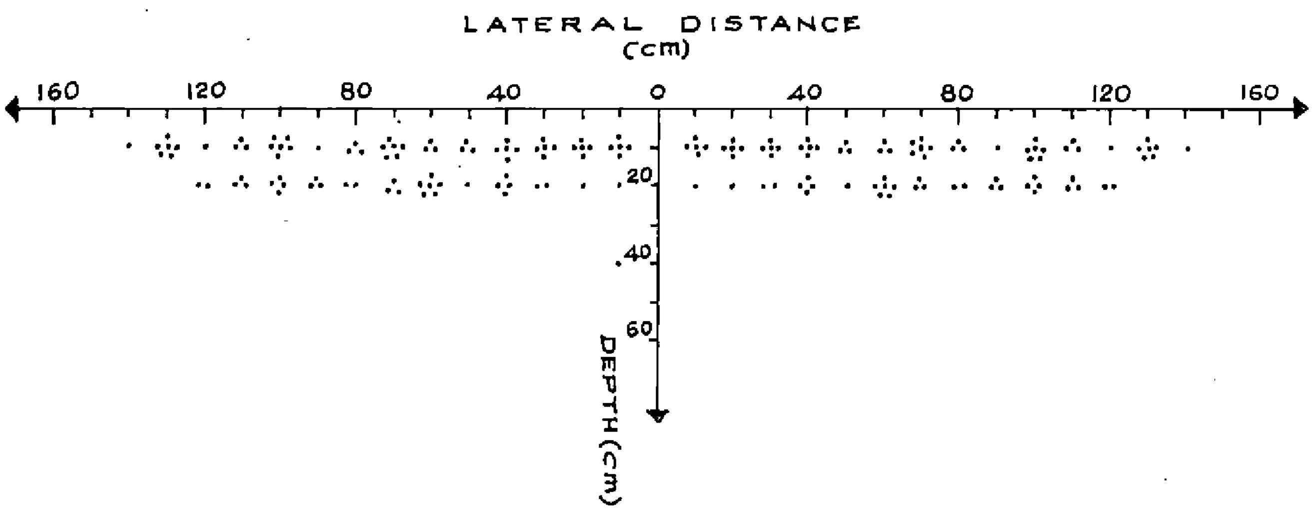

FIG. 8. ROOT DISTRIBUTION IN AILANTHUS.

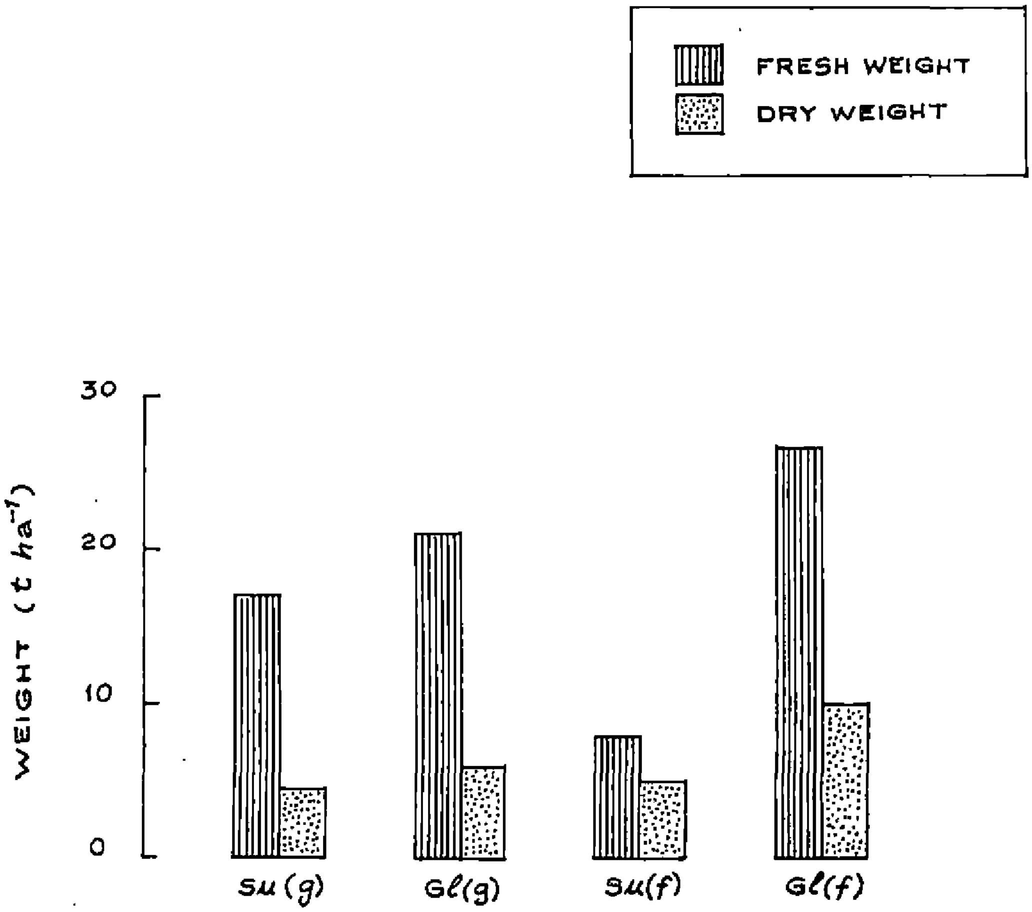

FIG. 9. GREEN LEAF MANURE (g) AND FUEL WOOD (f) FROM SUBABUL (Su) AND GLYRICIDIA (Gl) GROWN IN MIXTURE WITH COCONUT (Co).

maximum amount of green leaf manure from glyricidia was obtained when amorphophallus was taken as an alley crop. The lowest quantity of green leaf manure was obtained when colocasia was grown as an alley crop. Similar was the trend when the dry weight of green leaf manure was considered (Fig. 9).

The pruning from the glyricidia and subabul also gave fuel wood yield of 26.0 and 8.0 t ha^{-1} respectively (Fig. 9).

4.3.5. Litter fall from the trees

From the eucalyptus about 3.36 kg of litter per plant per year (7593.6 kg ha^{-1} $year^{-1}$) was obtained. The dry weight of this accounts to about 0.96 kg of litter per plant per year (2169.6 kg ha^{-1} $year^{-1}$). From ailanthus the corresponding figures were 5.4 kg (12,204 kg ha^{-1} $year^{-1}$) and 2.25 kg litter per plant per year (5085 kg ha^{-1} $year^{-1}$).

4.3.6. Nutrient content of green leaf manure/litter

The nutrient content of the leaves of all the trees

Table 18. Nitrogen, phosphorus and potassium content in the green leaf manure/litter from the multipurpose tropical trees

Multipurpose trees	Nutrient content in leaves (%)		
	N	P	K
Eucalyptus	1.20 (26)*	0.24 (5)	0.66 (14)
Subabul	2.31 (177)	0.13 (10)	1.96 (150)
Glyricidia	3.21 (282)	0.24 (21)	2.12 (186)
Ailanthus	1.12 (56)	0.10 (5)	0.55 (27)

* Parenthesis represents NPK in kg/ha

viz: eucalyptus, subabul, glyricidia and ailanthus were analysed (Table 18). The N content was maximum in glyricidia leaves (3.21%). The ailanthus and eucalyptus leaves have almost similar content of nitrogen. The green manure yield from glyricidia pruning was equivalent to 282 kg N, 21 kg P and 187 kg K per hectare. The corresponding values for subabul were 178, 10 and 151 kg ha^{-1} respectively. The NPK addition to the soil through the litter fall of eucalyptus and ailanthus were relatively less. Evidently, growing of subabul and glyricidia in mixture with coconut promote recycling of nutrient and symbiotic N fixation. So the use of the costly chemical fertilizers can be reduced. However the long term effect of these multipurpose tropical trees on coconut yield needs detailed investigation before making any such recommendation.

4.4. Observations on microclimate

4.4.1. Relative light transmission

There was considerable difference in the relative light transmission (RLT) to the various alleys. The RLT to the alley crop canopies varied from 55 to 95% of the full sunlight depending on the multipurpose tropical tree component. The RLT in coconut + subabul and coconut + glyricidia alleys were relatively less. But when these trees were pruned after 3 months the RLT to the tuber crops also increased substantially (Table 19, 20, 21, 22 and 23). The cropping systems, coconut + eucalyptus and coconut + ailanthus (Table 23) permitted more light infiltration to the alleys.

The RLT below the amorphophallus canopy was significantly reduced when it was alley cropped in coconut + ailanthus alley (Table 19). It may be recalled that amorphophallus grown in coconut + ailanthus alley recorded higher leaf area which might have enabled the crop to intercept more sunlight. The maximum RLT below the canopy of amorphophallus was observed when it was grown in alleys of coconut + eucalyptus and coconut + subabul before and after pruning. In cassava also the RLT below the canopy of cassava was more when it was grown as an intercrop in coconut + ailanthus alley (Table 20). The RLT below the canopy of greater yam was maximum when it was intercropped in coconut + eucalyptus alley.

Table 19. Relative light transmission percentage below the amorphophallus canopy in different coconut - multipurpose tropical tree crops - tuber crops alley cropping systems at 90 days after planting

Cropping system	8-9 a.m.	12-1 p.m.	4-5 p.m.	Mean
Co + Eu + A	60	64	52	59
Co + Su + A	67 (69)*	49 (57)	62 (64)	59 (64)
Co + Gl + A	23 (55)	26 (48)	27 (48)	25 (50)
Co + Ai + A	36	27	31	31
Co + A	52	49	46	49
A	54	50	52	52
CD (0.05)	10.47	13.79	12.08	12.11
S.Em±	3.61	4.76	4.17	4.17

Co - Coconut
Eu - Eucalyptus
Su - Subabul
Gl - Glyricidia
Ai - Ailanthus
A - Amorphophallus

* Figures in parenthesis are relative light transmission after pruning the multipurpose trees

Table 20. Relative light transmission percentage below the cassava crop canopy in different coconut - multipurpose tropical tree crop - tuber crop alley cropping systems at 90 days after planting

Cropping system	8-9 a.m.	12-1 p.m.	4-5 p.m.	Mean
Co + Eu + C	51	61	57	56
Co + Su + C	46 (59)*	41 (40)	39 (49)	42 (49)
Co + Gl + C	30 (65)	30 (48)	31 (62)	30 (58)
Co + Ai + C	43	36	41	40
Co + C	62	59	51	57
C	63	65	61	63
CD (0.05)	10.13	9.16	11.17	10.15
S.Em±	3.49	3.16	3.86	3.49

Co - Coconut
Eu - Eucalyptus
Su - Subabul
Gl - Glyricidia
Ai - Ailanthus
C - Cassava

*Figures in parenthesis are relative light transmission after pruning of the multipurpose trees

Table 21. Relative light transmission percentage below the colocasia crop canopy in different coconut - multipurpose tropical tree crop - tuber crop alley cropping systems at 90 days after planting

Cropping systems	8-9 a.m.	12-1 p.m.	4-5 p.m.	Mean
Co + Eu + Col	78	84	82	82
Co + Su + Col	83 (86)*	70 (85)	80 (85)	78 (85)
Co + Gl + Col	30 (76)	28 (73)	30 (74)	29 (74)
Co + Ai + Col	30	49	35	38
Co + Col	83	88	82	85
Col	90	86	86	87
CD (0.05)	16.04	15.10	13.71	15.07
S.Em±	5.28	4.98	4.52	4.96

Co - Coconut
Eu - Eucalyptus
Su - Subabul

Gl - Glyricidia
Ai - Ailanthus
Col - Colocasia

*Figures in parenthesis are relative light transmission after pruning of the multipurpose trees

Table 22. Relative light transmission percentage below the greater yam crop canopy in different coconut - multipurpose tropical tree crops - tuber crops alley cropping systems at 90 days after planting

Cropping system	8-9 a.m.	12-1 p.m.	4-5 p.m.	Mean
Co + Eu + G	55	52	45	51
Co + Su + G	41 (53)*	31 (46)	39 (48)	37 (49)
Co + Gl + G	30 (56)	22 (49)	26 (44)	26 (50)
Co + Ai + G	46	15	36	32
Co + G	63	47	36	49
G	41	36	42	40
CD (0.05)	9.99	10.68	7.70	9.46
S.Em±	3.36	3.59	2.59	3.18

Co - Coconut
Eu - Eucalyptus
Su - Subabul

Gl - Glyricidia
Ai - Ailanthus
G - Greater yam

*Figures in parenthesis are relative light transmission after pruning of the multipurpose trees

Table 23. Relative light transmission percentage to the tuber crop canopy in different coconut - multipurpose tropical tree - tuber crop alley cropping systems at 90 days after planting

Cropping system	8-9 a.m.	12-1 p.m.	4-5 p.m.	Mean
Co + Eu	95	93	94	94
Co + Su	90 (97)*	81 (94)	91 (97)	87 (96)
Co + Gl	61 (83)	54 (80)	60 (84)	59 (82)
Co + Ai	84	80	84	83
Co	90	92	94	92

Co - Coconut
Eu - Eucalyptus
Su - Subabul
Gl - Glyricidia
Ai - Ailanthus

*Figures in parenthesis are relative light transmission after pruning of the multipurpose trees

Thus it may be seen that among the different tuber crops grown in coconut - multipurpose tropical tree crop alleys, minimum light interception was by colocasia. The influence of this was reflected in soil temperature also (Table 24); colocasia alley cropped plots recorded a lower soil temperature.

4.4.2. Soil temperature

Raising the tuber crops in the coconut - multipurpose tropical tree crop alleys decreased the soil temperature considerably. This difference was most perceptible when the soil temperature in the afternoon was considered (Table 24) and (Fig. 10). These annual crops because of their close canopy were able to intercept large part of the insolation and prevent heating up of the soil. Among the alley crops greater yam showed maximum reduction of soil temperature, probably because of its climbing nature. The soil temperature was relatively more in colocasia alley cropped plots obviously because of the short and light canopy of the crop.

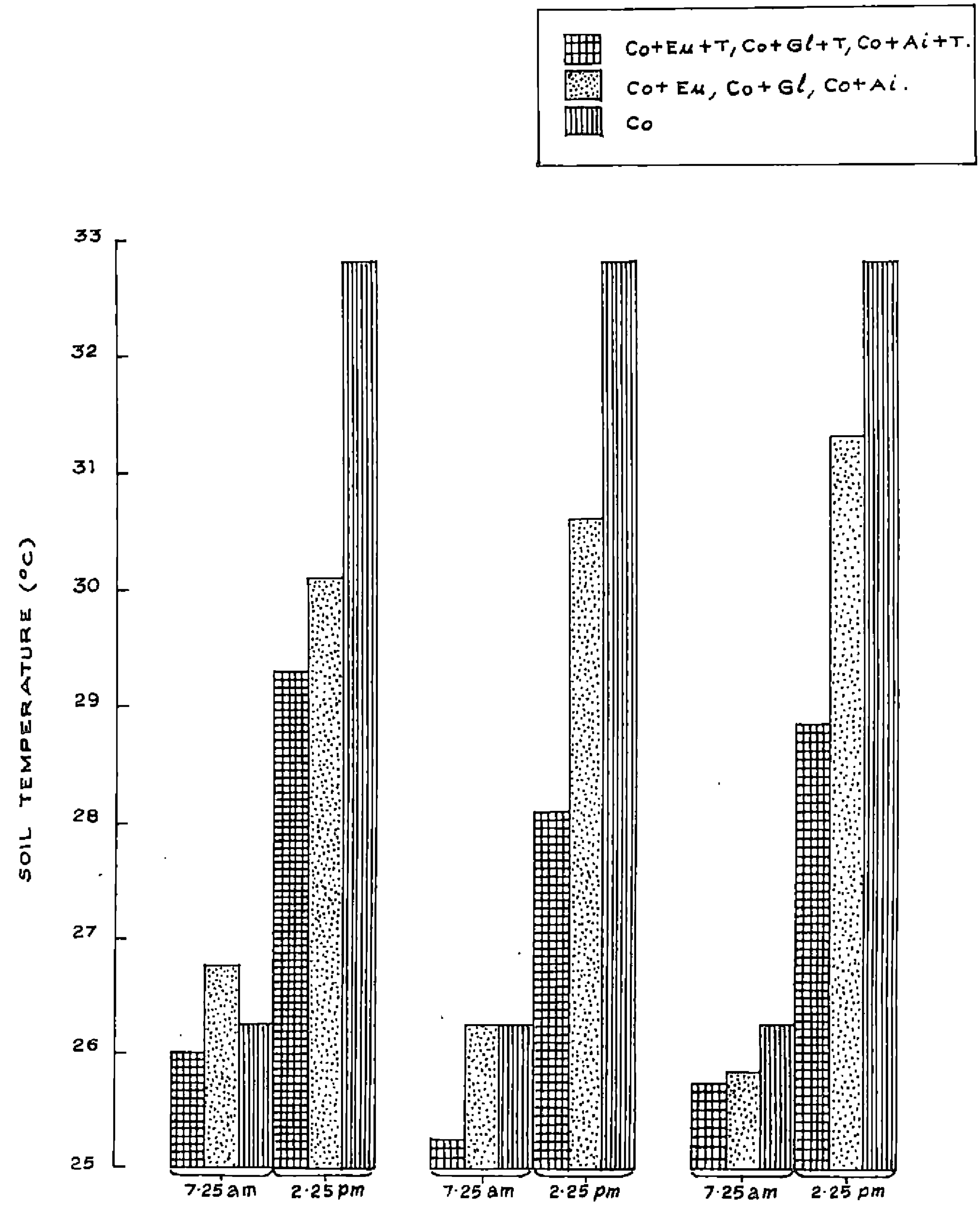

FIG.10. INFLUENCE OF COCONUT (Co), EUCALYPTUS (Eu), GLYRICIDIA (Gl), AILANTHUS (Ai) AND THE TUBER CROPS (T) GROWN IN MIXTURES ON SOIL TEMPERATURE.

Table 24. Soil temperature under different crop alley cropping systems

Cropping system	Soil temperature (°C) Time 7.25 am	Soil temperature (°C) Time 2.25 pm
Co + Eu + A	25.9	28.9
Co + Eu + C	25.8	28.8
Co + Eu + Col	26.2	31.4
Co + Eu + G	26.3	30.3
Co + Eu	26.8	31.5
Co + Su + A	25.9	28.3
Co + Su + C	25.6	30.5
Co + Gl + A	25.5	32.6
Co + Gl + C	25	28.4
Co + Gl + Col	25.8	29.5
Co + Gl + G	25.3	28.1
Co + Gl	26.3	30.1
Co + Ai + A	25.8	28.1
Co + Ai + Col	26.1	30.5
Co + Ai + G	25.8	29.5
Co + Ai	25.8	30.3

Co - Coconut
Eu - Eucalyptus
Su - Subabul
Gl - Glyricidia
Ai - Ailanthus
A - Amorphophallus

coconut - multipurpose tropical tree - tuber

Cropping system	Soil temperature (°C)	
	Time	
	7.25 am	2.25 pm
Co + A	25.8	28.9
Co + C	25.9	28.3
Co + Col	26.1	30
Co + G	25.8	28
Co	26.3	32.8
F + A	26	29.3
F + C	26.1	30.3
F	26.8	35.3

C - Cassava F - Fallow
Col - Colocasia
G - Greater yam

4.4.3. Relative humidity

In the morning hours there was no remarkable difference in the relative humidity recorded under different cropping systems. But there was considerable difference in the relative humidity recorded during the afternoon, when the tuber crops were raised as intercrops in the coconut - multipurpose tropical tree crop alleys (Table 25). Raising cassava as an intercrop in the alleys increased the relative humidity. Amorphophallus grown in the alleys also increased the relative humidity but it was not as high as cassava. These micro-climatic differences under the different cropping systems may influence the productivity of the system. This needs detailed investigation.

4.5. Physical properties of soil

4.5.1. Bulk density, particle density and water holding capacity

There was no significant difference in the bulk density, particle density and maximum water holding capacity of the soil, estimated before and after the

Table 25. Relative humidity under different coconut - multipurpose tropical tree - tuber crops alley cropping systems

Treatments	Relative humidity	
	Time	
	7.25 am	2.25 pm
Co + Eu + A	96.3	77.3
Co + Eu + C	97.5	77.3
Co + Su + A	96.2	77.0
Co + Su + C	97.7	79.5
Co + Gl + A	97.2	79.7
Co + Gl + C	96.2	75.3
Co + Ai + A	95.2	76.0
Co + A	97.3	75.3
Co + C	96.0	78.2
Co	95.5	74.0
F	93.3	72.7

Co - Coconut Gl - Glyricidia C - Cassava
Eu - Eucalyptus Ai - Ailanthus Col - Colocasia
Su - Subabul A - Amorphophallus F - Fallow

experiment. It can be stated that there was no significant alteration in the soil physical properties due to effect of alley cropping with tuber crops.

4.5.2. Aggregate stability

The data on the aggregate stability of the soil are presented in Table 26 and 27. The stability index was almost the same in all the alley cropped plots. But the stability index was lowest in the fallow plots. Similar was the trend with structural coefficient and mean weight diameter.

4.5.3. Infiltration rate

The infiltration rates recorded under the different cropping systems are presented in Tables 28 to 34. The initial infiltration rate was as high as 132 cm hr^{-1} in plots cultivated with coconut alone, in the first 5 minutes. This was followed by coconut + ailanthus alley and it was relatively less in coconut + eucalyptus alley. Steady state infiltrability of the soil was higher in the sole coconut followed by coconut + glyricidia alley. The value

Table 26. Aggregate size distribution in soil (%) as influenced by the different tuber crops grown in coconut - multipurpose tropical tree mixtures

Sieves used	Amorphophallus	Cassava	Colocasia	Greate yam	Control
1. 5 mm	1.97	2.00	2.08	2.00	1.99
2. 2-5 mm	3.93	3.88	3.90	4.03	3.90
3. 2-1 mm	6.08	5.99	6.20	6.19	6.28
4. 1-0.5 mm	19.00	20.00	19.20	19.08	18.29
5. 0.5-0.25 mm	41.71	40.67	39.98	38.88	40.63
6. 0.25-0.1 mm	2.00	2.17	1.99	2.18	2.00

Table 27. Stability index, structural coefficient, aggregate stability and mean weight diameter as influenced by the different tuber crops in coconut - multipurpose tropical tree mixtures

	Amorphophallus	Cassava	Colocasia	Greater yam	Control
Stability index	44.7	43.6	44.8	44.7	43.3
Structural Coefficient	0.61	0.61	0.63	0.64	0.61
Percentage aggregate stability	61.5	60.9	62.7	63.7	60.8
Mean weight diameter	0.66	0.64	0.66	0.65	0.64

Table 28. Infiltration rate in a coconut - eucalyptus alley

Elapsed time (min.)	Quantity of water infiltrated (cm)	Infiltration rate (cm ha^{-1})	Cumulative infiltration (cm)
5	4.4	52.8	4.4
10	4.0	48.0	8.4
20	7.8	46.8	16.2
30	7.6	45.6	23.8
45	7.6	30.4	31.4
60	7.4	29.6	38.8
90	9.6	19.2	48.4
120	9.4	18.8	57.8
180	15.8	15.8	73.6
240	15.6	15.6	89.2
300	15.6	15.6	104.8

Table 29. Infiltration rate in a coconut - subabul alley

Elapsed time (min.)	Quantity of water infiltrated (cm)	Infiltration rate (cm ha^{-1})	Cumulative infiltration (cm)
5	7.0	84.0	7.0
10	5.5	66.0	12.5
20	8.8	52.8	21.3
30	8.8	52.8	30.1
45	8.6	34.39	38.7
60	8.2	32.8	46.9
90	14.0	28.0	60.9
120	13.8	27.6	74.7
180	16.5	16.5	91.2
240	16.4	16.4	107.6
300	16.4	16.4	124.0

Table 30. Infiltration rate in a coconut - glyricidia alley

Elapsed time (min.)	Quantity of water infiltrated (cm)	Infiltration rate (cm ha^{-1})	Cumulative infiltration (cm)
5	6.8	81.6	6.8
10	5.5	66.0	12.3
20	9.0	54.0	21.3
30	8.6	51.6	29.9
45	8.0	32.0	37.9
60	16.0	64.0	53.9
90	15.6	31.2	69.5
120	15.5	31.0	85.0
180	18.5	18.5	103.5
240	18.0	18.0	121.5
300	18.0	18.0	139.5

Table 31. Infiltration rate in a coconut - ailanthus alley

Elapsed time (min.)	Quantity of water infiltrated (cm)	Infiltration rate (cm ha^{-1})	Cumulative infiltration (cm)
5	9.5	114.0	9.5
10	9.0	108.0	18.5
20	14.5	87.0	33.0
30	13.5	81.0	46.5
45	13.2	54.0	59.7
60	13.2	54.0	72.9
90	16.7	33.4	89.6
120	16.4	32.8	106.0
180	14.1	14.1	120.1
240	14.0	14.0	134.1
300	14.0	14.0	148.1

Table 32. Infiltration rate in a sole coconut plantation

Elapsed time (min.)	Quantity of water infiltrated (cm)	Infiltration rate (cm ha^{-1})	Cumulative infiltration (cm)
5	11.0	132.0	11.0
10	10.5	126.0	21.5
20	15.0	90.0	36.5
30	14.4	86.4	50.9
45	14.6	58.4	65.5
60	14.0	56.0	79.5
90	18.0	36.0	97.5
120	18.0	36.0	115.5
180	22.0	22.0	137.5
240	21.6	21.6	159.1
300	21.6	21.6	180.7

Table 33. Infiltration rate in a fallow plot

Elapsed time (min.)	Quantity of water infiltrated (cm)	Infiltration rate (cm ha^{-1})	Cumulative infiltration (cm)
5	5.0	60.0	5.0
10	4.2	50.4	9.2
20	7.8	46.8	17.0
30	7.4	44.4	24.4
45	7.3	29.2	31.7
60	7.3	29.2	39.0
90	10.2	20.4	49.2
120	10.0	20.0	59.2
180	12.0	12.0	71.2
240	11.4	11.4	82.6
300	11.4	11.4	94.0

Table 34. Moisture content of the surface soil and infiltration rate in different coconut - multipurpose tropical tree alleys

	Coconut + Eucalyptus	Coconut + Subabul	Coconut + Glyricidia	Coconut + Ailanthus	Coconut	Fallow plot
1. Average moisture content of upper 30 cm soil (%)	12.8	5.5	6.4	12.9	4.1	8.9
2. Initial infiltration rate for 5 minute (cm ha^{-1})	52.8	84.0	81.6	114.0	132.0	60.0
3. Steady state infiltrability (cm ha^{-1})	15.6	16.4	18.0	14.0	21.6	11.4
4. Cumulative infiltration for 300 minute (cm)	104.8	124.0	139.5	148.1	180.7	94.0

was minimum in fallow plot. Cumulative infiltration rate was also higher in sole coconut followed by coconut + ailanthus alleys. In this case also the minimum value was recorded in fallow plots.

Higher initial infiltration rate and cumulative infiltration are the reflection of the water absorptive capacity of the soil. Better aggregation and consequent porous nature of the soil might have increased the infiltration value. The lowest value of infiltration recorded in fallow plots can be justified following the findings of Uriyo (1979) and Hudson (1984). When there was no vegetative cover to provide protection to bare ground against the impact of rain drops, with each successive rainfall the infiltration reduced due to the increasing blockage of macropores by translocated soil particles.

4.6. Chemical properties of soil

The organic carbon content of the soil did not show significant difference when the multipurpose tree crops viz. eucalyptus, subabul, glyricidia and ailanthus were grown (Table 35) in coconut alleys. But a reduction in organic carbon content was noticed in ailanthus - coconut plots.

Table 35. Chemical composition of the soil after the experiment

Cropping system	Organic C (%)	Total N (%)	Available P (ppm)	Exchangeable K (ppm)
C + Eu	1.24	0.121	36	320
C + Su	1.27	0.124	40	330
C + Gl	1.21	0.126	41	337
C + Ai	1.19	0.122	38	335
C	1.26	0.124	39	330
Control	1.21	0.122	39	335

C - Coconut Gl - Glyricidia Eu - Eucalyptus
Ai - Ailanthus Su - Subabul

Table 36. Economics of intercropping of amorphophallus, cassava, colocasia and greater yam in coconut multipurpose tropical tree alleys

Crops	Gross return Rs. ha^{-1}	Cost of cultivation	Net return	Benefit cost ratio
Amorphophallus	51,000	29,280	20,720	1.7
Cassava	11,000	5,120	5,880	2.1
Colocasia	20,000	15,935	4,065	1.3
Greater yam	16,500	10,800	5,700	1.5

Total nitrogen content of the soil also remained almost the same in all the coconut - multipurpose tropical tree crop alleys (Table 35).

The available phosphorus and potassium also showed, a similar trend as that of total nitrogen (Table 35).

The data indicate that by alley cropping there was no remarkable change in the soil chemical characteristics.

4.7. Economics of alley cropping

When the tuber crops were intercropped in coconut - multipurpose tropical tree alleys, it gave an additional income ranging from Rs.4000/- to Rs.20,000/- (Table 36). The maximum net return was obtained when amorphophallus was grown as the intercrop in coconut - multipurpose tropical tree alleys. The minimum net return was obtained when colocasia was grown as the intercrop. Benefit cost ratio was maximum for cassava and minimum for colocasia.

Summary

SUMMARY

An investigation was conducted at College of Horticulture, Vellanikkara during 1987-88 on the productivity of amorphophallus, cassava, colocasia and greater yam under coconut - multipurpose tropical tree alleys. The experiment was laid out in RBD and replicated 5 times. The tuber crops were planted in May, 1987 and harvested in February, 1988. The results of the experiments are summarised below:

1) The height of all the four tuber crops increased when it was intercropped in coconut - multipurpose tropical tree alleys.

2) The leaf area development of amorphophallus was higher when it was intercropped in coconut + ailanthus alleys. But the leaf area development of colocasia and cassava was less in alley cropping as compared to the sole crops.

3) The yield of amorphophallus, cassava and colocasia decreased when it was grown in alleys of coconut - multipurpose tropical tree mixtures. But the yield of

greater yam was on par with the sole crop. The dry matter production by the tuber crops showed similar trend as that of the tuber yield. The relative yield index was less than one in amorphophallus, cassava and colocasia and greater than one in greater yam. The harvest indices of the tuber crops were not influenced by the alley cropping practice.

4) There was wide variation in the nitrogen, phosphorus and potassium content of the tuber crops when alley cropped.

5) Significant increase in height of eucalyptus and glyricidia were observed when cassava was alley cropped. Height of ailanthus increased when it was alley cropped with amorphophallus. But the height of subabul was not significantly influenced due to alley cropping with the tuber crops.

6) The girth at breast height (GBH) of multipurpose tropical trees were not significantly influenced by any of the tuber crops.

7) Most of the roots of tuber crops and multipurpose tropical tree crops were concentrated in the upper 30 cm

of the soil. The lateral spread of the roots of the tuber crop were 9 cm to 40 cm whereas that of the multipurpose tropical trees were upto 120 cm.

8) Green leaf manure yield from the trees increased due to alley cropping. The yield of green leaf manure from subabul and glyricidia were 28 and 34 t ha^{-1} respectively. This was equivalent to 177, 10, 150 and 282, 21 and 186 kg NPK ha^{-1} respectively.

9) Among the different tuber crops grown in coconut - multipurpose tropical tree crop alleys, the maximum light interception was by amorphophallus and minimum by colocasia.

10) The tuber crops in coconut - multipurpose tropical tree crop alleys decreased the soil temperature by 1.0 to 7.5 units.

11) The relative humidity at different heights within the canopy increased due to alley cropping with the tuber crops.

12) The soil physico-chemical properties like bulk density, particle density, maximum water holding capacity, total nitrogen, available phosphorus and exchangeable

potassium were not influenced by the different cropping systems.

13) The initial infiltration, steady state infiltrability and cumulative infiltration rate were higher in sole coconut and it was lowest in fallow plots.

14) The highest net income (Rs.20,000/-) was obtained when amorphophallus was alley cropped in coconut - multipurpose tropical tree crop alleys and the lowest (Rs.4000/-), when colocasia was the alley crop.

From the results of this investigation the following conclusions are derived.

a) Amorphophallus, cassava, colocasia and greater yam could be successfully alley cropped in coconut + eucalyptus/subabul/glyricidia/ailanthus alleys without affecting the tree component.

b) Large quantity of green leaf manure obtained from subabul and glyricidia, if judiciously used could reduce the cost on fertilizers. This will also sustain the long term productivity of the land.

c) The root distribution pattern of the component species indicate that the chances for interspecific competition for nutrients and water are limited. However, conclusive results can be derived only by a detailed investigation of the root distribution pattern of the component species.

d) The nutrient dynamics in such cropping systems also need detailed study. The N fixation by the legume component in the cropping system needs to be reliably estimated by any of the methods using ^{15}N.

e) The long term implications of the observed micro-climatic variation on the productivity of the system needs investigation.

f) The influence of the component crops on the productivity of the coconut and the multipurpose tropical tree component need detailed study.

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Plates

Plate No.I (a) Amorphophallus intercropped in coconut + eucalyptus alley

Plate No.I (b) Amorphophallus intercropped in coconut + subabul alley

Plate No.I (c) Amorphophallus intercropped in coconut + ailanthus alley

Plate No.I (d) Amorphophallus intercropped in coconut alley

Plate No.II Cassava intercropped in coconut + eucalyptus alley

Plate No.III Amorphophallus and colocasia intercropped in coconut + ailanthus alley. (The net for collecting the litter fall from ailanthus also is shown)

Plate No.IV Colocasia intercropped in coconut + subabul alley

Plate No. V Greater yam trailed on eucalyptus

Appendices

Appendix - I

Weather data (monthly averages) from May 1987 to February 1988

	Total rainfall (mm)	Number of hours of bright sunshine	Temperature °C		Relative humidity %
			Maximum	Minimum	
May	95.0	9.0	36.2	25.3	64
June	837.7	4.2	36.1	24.7	66
July	336.5	5.7	30.7	23.7	83
August	388.4	3.7	30.3	23.5	84
September	174	7.4	29.6	23.5	87
October	280.4	6.2	31.5	23.9	79
November	224.4	6.7	31.9	23.9	79
December	64.6	8.1	31.6	22.8	77
January	0	10.4	31.6	23.3	17
February	7.8	10	32.4	22.0	56

Appendix - 2
Soil Thermometer Readings in °C

Cropping systems	Dates											
	23rd Sep.		30th Sep.		7th Oct.		14th Oct.		21st Oct.		28th Oct.	
	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
1	2	3	4	5	6	7	8	9	10	11	12	13
Co + Eu + A	26	29	26.5	30.5	26.5	29	26	30	26.5	28.5	24	26.5
Co + Eu + C	26	29	26	30	26.5	29	25.5	29.5	26	29	24.5	26.5
Co + Eu + Col	26.5	31	26.5	33	26.5	31.5	26.5	33	26	31	25	29
Co + Eu + G	26.5	30	26	31.5	27	31	26.5	31.5	26.5	29.5	25	28
Co + Eu	27	31	27.5	33.5	27.5	32	26.5	32.5	27	31	25	29
Co + Su + A	26	29	26.5	29	26.5	28	26	28.5	26.5	29	24	26
Co + Su + C	25.5	28	26	28.5	26	28.5	25.5	33	26.0	32.0	24.5	26
Co + Gl + A	25.5	28	26	28.5	26	28	25.5	28	26	29	24	26
Co + Gl + C	25	28	25.5	29	25.5	27.5	25	28	25.5	29.5	23.5	28.5
Co + Gl + Col	26	29	26.5	30.5	26.5	29	25.5	31	26	30	24.5	27.5
Co + Gl + G	25.5	28	25.5	28.5	26	28	25.5	28	25	29.5	24	26.5
Co + Gl	26.5	29.5	27	31	26	30.5	25.5	31	27	32.5	25.5	29.5

Contd.

Appendix-2. Continued

1	2	3	4	5	6	7	8	9	10	11	12	13
Co + Ai + A	26	28	26	29.5	26.5	28	26	29	25.5	28	24.5	26
Co + Ai + Col	26.5	30.5	26.5	32	32	31.5	26.5	31.5	26	29.5	24.5	28
Co + Ai + G	26	30.5	26	30.5	26.5	30	26	31	26	29	24	26
Co + Ai	26	31	26.5	33.5	26.5	32	26	33	26.5	30	24	28.5
Co + A	26.5	29.5	26.5	31	26.5	29.5	26	29.5	25.5	28	24	26
Co + C	26	28	26.5	32	26.5	28.5	26	28	26	27	24.5	26
Co + Col	26.5	30.5	27	32.5	27	30.5	26	30.5	25.5	29.5	24.5	27.5
Co + G	26	29	26	29.5	26.5	28	26	28	25.5	27	24	26.5
Co	27	31	27	39	27	32.5	26	33.5	26	31.5	24.5	29
F + A	26	29.5	26.5	30.5	26.5	29.5	26	30.5	26.5	29	24.5	28
F + C	26.5	31	26.5	32	26.5	30.5	26	31	26.5	29.5	24.5	28
F	27.5	34.5	27.5	40.5	27.5	36	26.5	35.5	26.5	34	25.5	31.5

Co - Coconut
Eu - Eucalyptus
Su - Subabul
Gl - Glyricidia
Ai - Ailanthus
A - Amorphophallus
C - Cassava
Col - Colocasia
G - Greater yam
F - Fallow

Appendix - 3

Relative humidity

Treatments		23rd Sep. 1987		30th Sep. 1987		7th Oct. 1987		14th Oct. 1987		21st Oct. 1987		28th 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	7.25 am	2.25 pm	7.25 am	2.25 pm
1		2	3	4	5	6	7	8	9	10	11	12	13
Bare	1	92	100	96	61	96	77	96	58	85	77	92	52
	2	92	100	96	55	92	77	96	71	89	77	96	50
	4	92	96	96	61	92	73	96	74	89	73	96	52
	6	92	96	96	56	92	73	96	74	89	73	96	52
Coconut alone	1	100	96	100	66	96	76	96	74	89	76	100	57
	2	100	100	100	66	96	76	96	74	89	76	100	54
	4	100	96	96	66	96	76	96	77	89	76	100	54
	6	100	100	96	60	96	76	96	77	89	76	100	51
Coconut + Cassava	1	96	100	100	74	96	79	96	74	92	79	96	63
	2	96	100	100	85	96	79	96	74	92	79	96	60
	4	96	100	100	85	96	79	96	71	92	76	96	63
	6	96	100	100	74	96	76	96	74	92	76	96	55

Contd.

Appendix-3. Continued

1		2	3	4	5	6	7	8	9	10	11	12	13
Coconut + amorphophallus	1'	100	100	100	68	96	79	96	74	92	79	100	52
	2'	100	100	100	71	96	79	100	71	92	79	100	52
	4'	96	100	100	74	96	80	96	73	92	79	100	47
	6'	96	100	100	74	96	77	100	70	92	79	100	47
Eucalyptus + amorphophallus	1'	96	96	100	77	100	79	96	79	92	79	96	52
	2'	96	100	100	77	100	79	96	79	92	79	92	52
	4'	100	96	100	77	100	79	96	79	88	79	92	52
	6'	96	96	100	77	100	79	96	79	92	79	92	52
Eucalyptus + Cassava	1'	100	100	100	77	100	79	96	79	96	77	96	52
	2'	96	100	100	77	100	79	96	79	96	77	96	52
	4'	96	100	100	77	100	79	96	79	96	77	96	52
	6'	96	100	100	77	100	79	96	79	96	77	96	52
Subabul + Cassava	1'	96	100	100	77	100	79	100	82	92	76	96	72
	2'	100	100	100	77	100	82	100	82	92	76	96	52
	4'	96	100	100	77	100	82	100	82	92	76	96	59
	6'	100	100	100	77	100	82	100	82	92	76	96	56

Contd.

Appendix-3. Continued

1		2	3	4	5	6
Subabul + amorphophallus	1'	96	100	100	77	100
	2'	96	96	100	77	100
	4'	96	96	100	74	100
	6'	96	100	100	74	100
Glyricidia + Cassava	1'	96	100	100	66	100
	2'	96	100	100	66	100
	4'	96	100	100	66	100
	6'	96	100	100	66	100
Glyricidia + amorphophallus	1'	100	100	100	79	100
	2'	100	100	100	79	100
	4'	96	100	100	79	100
	6'	100	100	100	79	100
Ailanthus + amorphophallus	1'	92	100	100	74	100
	2'	92	100	100	74	100
	4'	96	96	100	74	100
	6'	96	96	100	74	100

7	8	9	10	11	12	13
66	100	82	88	66	96	52
66	100	86	88	79	92	47
83	100	86	88	76	92	56
83	100	86	88	76	92	56
79	96	69	88	79	96	52
82	100	71	88	79	96	47
82	96	71	88	82	96	56
82	96	71	88	74	96	56
79	100	86	88	79	96	56
79	100	84	88	79	96	56
82	100	84	88	79	96	56
82	100	84	88	79	96	56
66	92	69	88	66	100	62
86	92	71	88	79	96	59
86	92	71	88	76	96	59
82	92	71	88	76	96	59

CROP ; Amorphophallus

1. ABSTRACT OF ANOVA

Source	df	Height from the base to the point of forking 60	Height from the base to the point of forking 120	Height from the base to the tip of leaves 60	Height from the base to the tip of leaves 120	Girth of pseudostem 60	Girth of pseudostem 120	Leaf area 60	Dry matter production: Leaves	Dry matter production: Stem	Dry matter production: Tuber	Dry matter production: Total
		Mean squares (Days after planting)										
Block	4	8.55	4.54	53.93	107.9	0.70	1.12	0.02	0.46	0.08	17.11	20.21
Treatments	5	569.6	844.1	1839.7	3470.1	10.84	17.41	0.09	15.66	2.51	341.6	405.2
Error	20	21.13	10.73	74.39	166.94	2.41	2.99	0.02	0.24	0.13	3.13	4.66

Source	df	Yield	NPK Content: Nitrogen (%) Pseudo-shoot	Nitrogen (%) Tuber	Phosphorus(%) Pseudo-shoot	Phosphorus(%) Tuber	Potassium(%) Pseudo-shoot	Potassium(%) Tuber	Relative light transmission: 8-9 am	12-1 pm	4-5 pm	DF
Block	4	35.85	0.018	0.022	0.000	0.000	0.001	0.001	273.80	47.35	23.21	4
Treatments	5	89.27	0.028	0.052	0.003	0.000	0.133	0.072	1199.1	919.97	860.73	7
Error	20	40.04	0.040	0.632	0.000	0.000	0.002	0.001	65.32	113.31	86.97	28

CROP : Cassava

2. ABSTRACT OF ANOVA

Source	DF	Mean squares								
		Height		Leaf area		Dry matter production				Yield
		Days after planting				Leaves	Stem	Tuber	Total	
		60	120	60	120					
Block	4	251.24	474.25	0.017	0.033	0.064	0.42	0.52	0.717	2.12
Treatments	5	1403.0	698.3	0.153	1.394	3.21	8.42	92.77	112.87	303.16
Error	20	128.49	501.71	0.020	0.117	0.86	0.27	0.52	0.722	2.08

Source	DF	Mean squares									
		NPK Content						DF	Relative light transmission		
		Nitrogen(%)		Phosphorus(%)		Potassium(%)			8-9 am	12-1 pm	4-5 pm
		Shoot	Tuber	Shoot	Tuber	Shoot	Tuber				
Block	4	0.011	0.011	0.000	0.002	0.002	0.002	4	201.15	40.03	107.71
Treatments	5	0.227	0.196	0.001	0.002	0.262	0.105	7	737.53	831.04	609.34
Error	20	0.014	0.014	0.000	0.000	0.001	0.002	28	61.15	49.98	74.32

CROP : Greater yam

3. ABSTRACT OF ANOVA

Source	DF	Mean squares: Dry matter production: Shoot	Dry matter production: Tuber	Yield	NPK Content: Nitrogen (%): Shoot	Nitrogen (%): Tuber	Phosphorus(%): Shoot	Phosphorus(%): Tuber	Potassium(%): Shoot	Potassium(%): Tuber
Block	4	0.007	0.058	6.08	0.000	0.000	0.002	0.004	0.002	0.049
Treatments	5	0.358	2.59	406.9	0.006	0.002	0.116	0.019	0.015	0.143
Error	20	0.006	0.056	5.72	0.002	0.001	0.001	0.001	0.008	0.045

Source	DF	Mean squares: Relative light transmission: 8-9 am	12-1 pm	4-5 pm
Block	4	93.41	46.87	66.47
Treatments	7	571.22	927.19	240.82
Error	28	59.44	67.93	35.86

CROP : Colocasia

4. ABSTRACT OF ANOVA

Source	DF	Mean squares				
		Leaf area		Dry matter production		Yield
		60	120	Shoot	Tuber	
Block	2	0.003	0.000	0.003	0.238	11.57
Treatments	5	0.018	0.023	3.798	14.17	346.31
Error	10	0.004	0.003	0.016	0.139	10.58

Source	DF	Mean squares									
		NPK content						DF	Relative light transmission		
		Nitrogen (%)		Phosphorus(%)		Potassium(%)					
		Shoot	Tuber	Shoot	Tuber	Shoot	Tuber		8-9 am	12-1 pm	4-5 pm
Block	2	0.003	0.003	0.000	0.000	0.005	0.133	2	148.19	218.84	75.32
Treatments	5	0.316	0.055	0.003	0.001	0.053	0.125	7	1842.81	1383.31	1604.61
Error	10	0.030	0.023	0.000	0.000	0.002	0.026	14	83.87	74.35	61.29

PRODUCTIVITY OF TUBER CROPS UNDER ALLEY CROPPING OF TROPICAL TREES

By

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ABSTRACT OF A THESIS

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ABSTRACT

An experiment was conducted in the coconut gardens of Agricultural Research Station, Mannuthy during the period from May 1987 to February 1988 to evaluate the productivity of various tuber crops under the alleys of coconut (Cocos nucifera L) + eucalyptus (Eucalyptus tereticornis), coconut + subabul (Leucaena leucocephala (Lamk) de Wit), coconut + glyricidia (Glyricidia maculata) and coconut + ailanthus (Ailanthus tryphysa Roxb). The tuber crops raised in the alleys were amorphophallus (Amorphophallus campanulatus (Roxb) Bl. ex Decne), Cassava (Manihot esculenta Crantz), colocasia (Colocasia esculenta L) and greater yam (Dioscorea alata L). The experiment was laid out in randomised block design in plots of size 7.5 x 7.5 m and replicated 5 times.

The results showed that height of the tuber crops was increased when grown as an alley crop. Similarly, the leaf area of all the tuber crops also increased except that of colocasia. The tuber yield of amorphophallus increased significantly when it was grown in alleys of coconut and coconut + ailanthus. The yield of cassava and colocasia decreased when they were intercropped in the alleys whereas that of the greater yam was not significantly reduced. The dry matter production by the tuber crops showed similar trend as that of the tuber yield. The harvest index of the

tuber crops were not influenced by the alley cropping practice. The nitrogen, phosphorus and potassium content of the leaf and tuber of these crops showed variation due to alley cropping.

The height of eucalyptus, glyricidia and ailanthus increased due to alley cropping whereas that of subabul was not significantly influenced. The girth at breast height (GBH) of multipurpose trees were not significantly influenced by any of the tuber crops.

Majority of the roots of multipurpose tree crops were confined to the top 30 cm of the soil and to a lateral distance of 120 cm. The green manure yield from glyricidia and subabul were 28 and 34 t ha^{-1} which was equivalent to 177, 10, 150 and 282, 21, 186 kg NPK ha^{-1} respectively. The N, P, K addition to the soil through the litter fall of eucalyptus and ailanthus were relatively less.

The soil physico-chemical properties like bulk density, particle density, maximum water holding capacity, total N, available P and exchangeable K were not influenced by the different cropping systems.

Amorphophallus, cassava, colocasia and greater yam were successful as intercrop in the coconut - multipurpose tropical tree alleys and generated an additional income of Rs.4,000-20,000/-.