FUNCTIONAL DYNAMICS OF AN AGRISILVICULTURAL SYSTEM INVOLVING COCONUT PALMS, MULTIPURPOSE TREES AND KACHOLAM

By

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THESIS

Submitted in partial fulfilment of the
requirement for the degree

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DECLARATION

I hereby declare that this thesis entitled ***Functional dynamics of an agrisilvicultural system involving coconut palms multipurpose trees and kacholam*** *is a bonafide record of research work done by me during the course of research and that this 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*

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S SURESHKUMAR

DEDICATED TO

THE LOVE OF MY PARENTS

CONTENTS

LIST OF TABLES

LIST OF TABLES

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

LIST OF APPENDICES

Introduction

INTRODUCTION

Coconut (*Cocos nucifera* L Family Palmaceae) is one of the most important plantation crops grown in the state of Kerala The crop is grown in an area of 8 77 lakh ha with a total annual production of 5144 3 million nuts (KSLUB 1995) Polycultural systems involving coconut and a wide spectrum of intercrops is a unique feature of the coconut based production system prevailing in the state

In a coconut plantat on a substantial portion of the incoming solar radiation is probably not utilized by the palms (Abraham 1993) Limited lateral spread (20 30% of land area) of coconut roots may lead to incomplete utilization of below ground resources also (Anilkumar and Wahid 1988) Consequently a wide spectrum of annual seasonal and perennial crops are grown as intercrops in coconut plantation both in the intra row and inter row spaces (Thomas and Nair 1996)

Often intercrops in a coconut plantation includes perennial horticultural crops and medicinal plants besides many herbaceous species It may even include fast growing multipurpose trees Considering the scarcity and the soaring prices of wood in the state intercropping fast growing multipurpose trees has got special s gn ficance

2 To evaluate the performance of three fast growing multipurpose trees in the agrisilviculture system involving coconut

3 To assess the growth and productivity of kacholam as a field crop component in the agrisilviculture system involving coconut and multipurpose trees

4 To characterise the nature of above and below ground interactions between coconut multipurpose trees and the field crop components in intensive integrated land use systems involving coconut and other crop species

Review of Literature

REVIEW OF LITERATURE

Agroforestry is a relatively new name for a set of old practices Before being accepted as a concept there existed a lot of ambiguity and confusion as to what is Agroforestry ? Because of this agroforestry was variously defined and interpreted by different people Of late the concept of agroforestry is internationally accepted as a collective name for land use systems in which woody perennials are grown in association with herbaceous plants and/or livestock in a spatial arrangement a rotation or both and in which there are both ecological and economic interactions between the tree and non tree components (Young 1987) Basic attributes of all agroforestry systems are productivity sustainability and adaptability (Nair and Dagar 1991)

Agroforestry systems are variously classified based on structural functional socio economic and ecological attributes Based on the nature of components agroforestry is subdivided into agrisilviculture (crops and trees) silvopastural (pasture/animals and trees) and agrosilvo pastural (crops pasture/animals and trees) (Nair 1985) Literature on coconut based agrisilvicultural systems are reviewed here

2 1 Agrisilviculture

Agrisilviculture is the branch of agroforestry which incorporates fast growing multipurpose tree species in the crop fields Alley cropping improved fallow home gardens taungya, multi tiered tree gardens multipurpose trees on croplands plantation crop combinations shelter belts and wind breaks are examples of agrisilviculture Such systems are capable of or aimed at meeting the food fuel fodder green manure and timber requirements of the society (Nair 1985) In addition to the socio economic objectives trees in managed crop mixture have the potential for soil conservation fertility improvement and microsite enrichment (Huxley 1985a) Presence of woody perennials has inspite of these and several other advantages few disadvantages due to competitive interactions with the crops However the role of trees (fast growing multipurpose tree species) in an agrisilvicultural system is a fundamental issue in agroforestry which needs further investigation before being scientifically proved

2 1 1 Coconut based agrisilviculture systems

Coconut (*Cocos nucifera* L Family Palmaceae) is one of the most widely grown trees crops in the tropics It is often eulogised as Kalpavriksham or the tree of the Heaven Implicit in this vernacular epithet is that all parts of the tree are useful to mankind in one way or other Although coconut is assigned the status of a plantation crop it is essentially a crop of small and marginal farmers In such situations sole crop of coconut often fails to provide adequate income to sustain the dependent families Hence to generate additional income from the limited land holdings annual or/and other perennial crops are often integrated with the coconut production systems (Thampan 1993)

2 1 1 1 Intercropping in coconut

Intensification and a greater integration of land use systems is accepted as a motor of additional or subsidiary income generation (Liyanage 1993) In view of the constraints in increasing operational farm size and prevailing agro-climatological factors the only option for increasing productivity is through intercropping crops under coconut to give immediate economic returns (Nair 1979) Moreover in all coconut growing regions some form of integrated farming systems have been traditionally in practice

This is of special significance in the Kerala context where the root (wilt) disease is taking a heavy toll of the crop The disease is prevalent in about 4 10 000 ha area of the total 8 77 012 ha By now this debilitating disease has spread to eight of the 14 districts in the state It causes an annual estimated loss of 968 million nuts (CPCRI 1985) Quality of copra oil content leaf size etc are adversely affected causing considerable revenue loss to the growers As it stands there are no remedies available to this serious malady However multiple cropping and/or mixed farming practices if adopted may enhance productivity of the plantations Menon and Nayar (1978) found that intercropping cassava, elephant foot yam and greater yam for five years in a 16 year old coconut garden gave an overall increase in nut yield of root (wilt) affected palms to the extent of 5 15 and 8 per cent respectively Mixed farming with cacao also increased the yield of coconut in a root (wilt) affected garden by 27 to 35 per cent (Amma *et al.* 1983) Sahasranaman *et al.* (1983) also reported reduction in root (wilt) disease intensity consequent to mixed farming In addition it increased the net yield of affected palms by about 28%

Thus it is clearly established that the future of coconut cultivation depends in the maintenance of productivity through crop intensification and/or multiple cropping practices

2 2 Scope of interplanting multi purpose trees in coconut plantations

Although intercropping in coconut grove primarily concern seasonal crops many perennial tree crops are also grown along with coconut Cacao clove nutmeg coffee arecanut and papaya are the most commonly planted species (Pillai 1985) Fruit crops like sapota mango citrus guava and jack are reported from coconut gardens in different regions (Srinivasan and Caulfield 1989) The combination of coconut + cacao + blackpepper + pineapple is a widely accepted multistoreyed crop combination in several coconut growing regions (Nair and Varghese 1976) In some areas cacao is replaced by clove or nutmeg (Nair and Varghese 1980)

But for these tree crops inclusion of multipurpose trees in coconut based farming systems is a recent practice Incorporation of multipurpose trees in coconut holdings is done with the primary objective of obtaining green manure fodder and as a support for pepper *Gliricidia sepium* (Jack) Kunth *Erythrina indica* Lamk *Pajnelia rheedi* Wt and *Leucaena leucocephala* (Lamk) de Wit are important in this respect (Liyanage *et al* 1990 Nair and Sreedharan 1986 Ghosh *et al* 1989)

In recent years however with a view to develop low input sustainable production systems several multipurpose trees have been planted in the interspaces of coconut (Nair 1985 1993 Harold and Warlito Nair and Sreedharan 1986) *Ceiba pentandra* (L) Gaertn *Gmelina arborea* Roxb *Tamarindus indica* L *Azadiracta indica* A Juss *Calliandra calothyrsus* Meissn *Adanthus triphysa* (Dennst) Alston *Eucalyptus tereticornis* Sm *Acacia nilotica* (L) Del *Grevillea robusta* A Cunn *Casuarina equisetifolia* J R & G Frost *Paraserianthus falcataria* (L) Fosberg *Dalbergia latifolia* Roxb *Prosopis juliflora* *Acacia auriculiformis* A Cunn exBenth *Sesbania grandiflora* and *Hardwickia binata* Roxb are reported from different coconut growing regions of the tropics (Jambulingam and Fernandes 1986 Liyanage *et al* 1984 Dagar and Kumar 1992 Hazra and Tripathi 1986 Nair and Sreedharan 1986 Liyanage *et al* 1988 Nair 1985 Bindu 1988 Usha 1990 Salam and Sreekumar 1991) Intercropping multipurpose trees in coconut based land use systems quite apart from the indirect ecological benefits may improve the availability of wood resources and thereby increase net returns on unit area basis This is of special significance in Kerala where wood from agricultural lands account for about 74 84% of the society s total wood requirements (Krishnankutty 1990)

Inter crops like cacao clove pineapple banana and pepper do not affect coconut production adversely (Dwiwarni *et al* 1987) Moreover increase in coconut production is also reported when the loppings from leucaena is used as a green manure (Liyanage *et al* 1993) Nut yield increased by 29 per cent and copra yield by 5 per cent in a 22 year old coconut plantation following this practice

2 3 Factors favouring intercropping in coconut

Light water and nutrients are the three basic resources required for plant growth Availability of these resources under the canopy influences the success of crops in the lower profiles of an intercropping system In coconut gardens these resources as such are not considered to be limiting It has been estimated that only about 28 per cent of the land area is utilized by coconut palms in spaced plantations (Leela and Bhaskaran 1978)

Transmission of light to lower profiles and the general pattern of coverage of the ground depends on the pattern of development and arrangement of leaves Crown architecture of coconut is found to favour light infiltration to the under storey (Silva and Abeyawarden 1970) Nelliat *et al* (1974) reported that except for a period of 8 to 25 years of palm growth sufficient light reaches under storey for the growth of compatible species However Abraham (1993) found that age/height of palms are not limiting the light infiltration significantly and the daily mean value of light infiltration ranged from 7 to 86 percentage Therefore intercropping may be feasible in coconut gardens regardless of palm age

As regards to root competition studies on rooting pattern of coconut revealed that majority of roots are found near the bole within a radius of two meters In plantations with regular cultivation and manuring over 82 percent of active roots is found in 30 to 120 cm depth and laterally 74 per cent of roots limited to two meter radius (Kushwah *et al* 1973) Radio isotopic studies also revealed that the overlapping of root systems of palms and intercrops is minimal in a well spaced coconut garden (IAEA 1975 Wahid *et al* 1993) Like light availability the root distribution pattern is also independent of the palm age

In short the available reports indicate that in a spaced (7 5 m x 7 5 m) coconut plantation about 70 to 80 per cent of the surface horizons of soil has very little roots thus offering great potential for intercropping Furthermore much of the above ground site resources are also under utilized by the coconut palms

2 4 Crops grown under coconut

Coconut is grown in diverse edaphic and climatic conditions Spacing planting pattern and age of palm is not uniform in most cases Because of this a large number of crops are interplanted with coconut There is no regularity or systematic pattern as far as these intercropping practices are concerned (Nair and Varghese 1976) It often includes rainfed tuber crops like cassava and yams (Nair and Sreedharan 1986 Nelliat *et al* 1974 Ramanujam *et al* 1984 Varghese *et al* 1979) sweet potato chinese potato blackgram (Ramachandran 1981) amorphophalus greengram cowpea horsegram (George 1982) redgram soyabean (Couto *et al* 1982) upland rice sorghum millets (Sharma 1983) ginger turmeric (Bai and Nair 1982 Nair and Varghese 1976) pineapple (Chaturvedi 1983) vegetables and banana (Ghosh *et al* 1986 Nelliat 1976 Nair *et al* 1975) Black pepper is a potential perennial intercrop in coconut (Nair and Sreedharan 1986) Additionally several fodder grasses are also planted in coconut gardens Guinea grass para rhodes bajra hybrid napier lemon grass stylo and blue panic grass are common in this respect (Dagar and Kumar 1992 Samraj 1977 Pant 1980 George 1993 Sharma *et al* 1980)

2 5 Characteristics of multipurpose trees in agrisilviculture systems

Trees used in agroforestry systems are often fast growing multipurpose species Important characteristics of such trees is the ability to utilize incoming solar radiation which might otherwise be lost capacity to enrich the site and modify the microclimate (Huxley 1983) Rate of growth adaptability to soils and climate ability to withstand adversities palatability as fodder and freedom from pest and disease also are important parameters in this respect (Nair 1985)

Crown growth pattern root distribution shelter effect and nutrient cycling by the trees should be advantageous to the component crops (Nair 1985) Nature and magnitude of interspecific interactions in polycultural systems are dependent on these factors Nitrogen fixing capacity and ability for microsite enrichment are also preferred

Toky and Bisht (1992) Mathew *et al* (1992) George (1993) and Jamaludheen (1994) reported the influence of canopy architecture and crown characteristics of tree components on the productive efficiency of agroforestry systems Canopy architecture and crown structure play an important role in the interception of incoming solar radiation (Norman and Jarvis 1974) Leaf area index foliage aggregation and branch/leaf orientation are also considered to be important in determining the extent of light interception by tree canopies (Kuppers 1989 Sampson and Smith 1993)

2 6 Characteristics of field crops in agrisilviculture systems

Shade tolerance of under storey crop is considered to be a cardinal factor determining their productivity in agroforestry systems Shade relationships of many field crops were evaluated in the past

Ramadasan and Sathesan (1980) found positive influence of shade on plant height and drymatter accumulation in ginger and turmeric Aclan and Quisumbing (1976) reported higher yield for turmeric in open than under shade whereas in another study (KAU 1991) turmeric gave maximum yield at 50 per cent shade intensity For ginger highest yield was recorded at 25 per cent shade (Varghese 1989 KAU 1991) Jayachandran *et al* (1992) George (1992) Paul (1992) and Nair *et al* (1991) also recommended ginger and turmeric as shade loving crops suitable for intercropping under coconut

Ravishankar and Muthuswamy (1986) found that ginger when grown as intercrop in aeracanut plantation with a light intensity of 15 K lux recorded highest dry matter production In an agrisilvicultural system involving ailanthus and ginger Thomas (1996) found that ginger grown in interspaces of ailanthus had better growth as compared to that in open Ginger grown in interspaces of the stand with 2500 trees per hectare area showed better all round performance with maximum fresh ard dry rhizome yield

Based on the shade response studies Bai (1981) classified sweet potato as shade sensitive coleus as shade tolerant colocasia as shade intolerant and ginger and turmeric as shade loving In a similar study cowpea blackgram redgram and groundnut was found to be shade sensitive (George 1982) Tomato chilli chickpea cucumber bean okra and capsicum also responded positively to partial shade (Clark, 1905 El Aidy 1984) Cardamom coffee and tea are crops found to be shade demanding for its growth and development (Singh *et al* 1989 Kumar *et al* 1995)

Growth and yield attributes of kacholam grown under shade were comparable to that grown in the open (Nair *et al* 1991) Latha (1994) found that while fresh rhizome yield was more in open dry rhizome yield was comparable However yield reductions due to shade has been reported in the case of cassava (Ramanujan *et al* 1984) and winter wheat (Mc Master *et al.* 1987)

Literature on kacholam though limited suggests great scope of its cultivation under a coconut over storey The exact shade level and planting geometry which can give maximum yields however needs to be evaluated

2 7 Factors affecting productivity of agrisilviculture systems

In any agroforestry system availability of space alone may not always permit crop intensification Rather it is essential to consider various factors which can positively or negatively influence the production process in a mixed species system

A major consideration in this regard is the extent of plant to plant interactions in the sharing of same pool of environmental resources at aerial and root levels (Connor 1983)

Higher productivity for mixed plant communities is reported by several scientists Donald (1963) suggested that morphologically and physiologically contrasting species can together exploit the environment more effectively and thereby give increased yields

2 7 1 Nature of resource sharing

Plant growth requires continuous and balanced access to light water and nutrients At the system level sharing of these resource pools encompasses competitive differential and complementary aspects Knowledge of the size of resource pools their accessibility to crop components and the concepts of resource sharing are important to design and manage agroforstry systems (Buck, 1986)

In an agrisilvicultural system the growth patterns of component crops differ in time so that crops make their major demands for resources at different times thus reducing mutual competition (Chatterjee and Maiti 1984) Complementary effects of component crops also favours increased productivity When legumes are interplanted other crops are found to increase the yield in comparison with monoculture (Raintree 1985)

Growth response of different tree/crop components in an agroforestry system has to be co ordinated both spatially and temporarily Horizontal resource sharing is attained by manipulation of the spatial dispersion and proportion of different crops in a mixture (Trenbath 1976) Vertical sharing is achieved by different spatial and temporal planting methods Selection of species with differential root system behaviour is essential for effective resource sharing of water and nutrients (Huck, 1983)

2 7 2 Stage of stand development

Age of the woody perennial component is an important factor in determining the magnitude of inter specific competition for light water and nutrients Interspecific root competition is minimal during the initial years (Dhyani *et al* 1990) As the age increases interspecific competition may intensify leading to reduced crop yields (Dhukia *et al* 1988 Roy and Gill 1991a) The age at which competition results in considerable reduction in understorey crop yield may vary with species and site conditions (Srinivasan *et al* 1990)

2 7 3 Light availability

Increased production under mixed population results from efficient use of solar radiation (Panje 1973) In traditional agroforestry systems the trees shrubs and herbs form different canopies and are arranged in different vertical layers without causing much overlapping (Srinivasan and Caulfield 1989) High productivity and sustainability of homestead agroforestry systems are thus explained by many authors

In agroforestry shade tolerant species are preferred as understorey crops for the effective utilization of light In some cases shade can be beneficial when it reduces soil temperature during crop establishment and growth in hot climate (Ong *et al* 1991a) If the hedge rows of trees are well managed and regularly pruned the availability of light is not a limiting factor in agroforestry Mixed canopies with vertical stratification of canopy is proved to intercept more solar energy than sole crops (Ong *et al* 1991a)

2 7 4 Root interactions

Chances for below ground competition is high in agroforestry Vandenbeldt *et al* (1990) reported that soil nutrition and competition for soil water is dependent on root distribution pattern Plants with deep root system generally decrease competition whereas shorter thick roots quickly deplete adjacent nutrient pools promoting steep and extensive nutrient gradients (Gillespie 1989) Ong *et al* (1991b) found that tree roots can exploit water and nutrients below the shallow roots of field crops By the inclusion of trees utilization of rainfall and ground water is also enhanced Thus making agroforestry systems more efficient in water use than sole crops

Since coconut is generally grown under rainfed conditions with medium to high rainfall there is little competition for moisture between coconut and rainy season intercrops Moreover intercropping is found to enhance efficiency of water harvest (Liyanage 1985)

After detailed studies on competition for moisture and nutrients between trees and crops in various agroforestry systems it is found that a combination of deep and shallow rooting species is ideal to make the best use of available site resources (Nair 1984) Selection of trees and crops with different rooting depth and adopting different spacing is therefore recommended in agroforestry to reduce root competition

2 7 5 Microsite enrichment by trees

In agroforestry the tree component is believed to exert a marked influence on system productivity through microsite enrichment Huxley (1985b) and Nair (1984) elucidated the role of trees in microsite enrichment According to them microsite enrichment processes include efficient cycling of plant nutrients nutrient pumping and biological nitrogen fixation The mechanism of nutrient pumping responsible for microsite enrichment involves loading the surface layers with nutrients taken up from deeper profiles (Nair 1984)

Soils under trees tend to have favourable structural stability and water holding capacity (Young 1987 1989) Reduction in pH and improved microbial activity is also reported under intercropping (Pillai 1985 Skerman 1977)

Apart from soil enrichment trees also helps in soil conservation by effectively controlling erosion and soil loss (Young 1986) Guinea grass (*Panicum maximum*) is grown along *Grevillea robusta* tree lines for soil conservation in slopes

(Wilson and Kang 1981) Agarwal *et al* (1976) reported higher total returns due to improvement of soil fertility moisture conservation and the synergistic effects of root exudates in agrisilviculture systems

Growing double rows of *Leucaena leucocephala* in coconut plantations resulted in substantial soil improvement in terms of increased organic carbon content waterholding capacity and reduced bulk density (Liyanage *et al* 1993) Vergara and Nair (1985) also suggested incorporation of nitrogen fixing trees along with intercrops in coconut gardens to make the system more productive and sustainable

2 8 Advantages of agrisilviculture system in coconut

Theoretical considerations of plant interactions in multispecies combinations involving coconuts have been discussed by Nair (1983) When the species multiplicity and functional diversity of natural ecosystems are simulated in agricultural holdings (agrobiodiversity) it will have a positive impact on the environment and may lead to the evolution of ecologically sustainable land use systems

Additionally the requirement of external inputs in coconut culture is substantially reduced through nutrient recycling and organic matter build up (Markose 1995) Presence of more plant cover and larger rooting volume is found to increase the nutrient use efficiency (Nair 1989 Khanna and Nair 1980) Use of inorganic nitrogenous fertilizers can be considerably reduced by planting nitrogen fixing trees like leucaena and gliricidia and incorporating their leaf as green manure (Liyanage *et al* 1988)

Increase in coconut yield due to intercropping with clove and cacao was reported by Anilkumar and Pillai (1988) In addition to improving production intercropping is found to reduce incidence of pest and disease (Skerman 1977) and reduce weed growth (Alvim and Nair 1986 Markose 1995) in coconut plantations

A well managed intercropping system in coconut is found to result in increased overall returns from unit land area without adversely affecting current productivity of the main crop At the same time the additional crop may also contribute to the long term productivity of the system Moreover diverse crop and/or animal components in coconut based agroecosystems will spread the income and insure against sudden market fluctuations in commodity prices (Bavappa 1995)

In the special context of Kerala where more than 50 per cent of coconut areas are badly affected by root (wilt) disease intercropping has additional advantage of sustaining the productivity of land There are several reports indicating the role of intercropping in ameliorating the effect of root (wilt) disease Menon and Nayar (1978) Amma *et al* (1983) Nair *et al* (1975) CPCRI (1988) and Sahasranaman *et al* (1983) reported reduction in the intensity of root(wilt) disease due to the effect of mixed farming

Thus coconut based agrisilviculture systems can on one had combat problems associated with modern agriculture like soil erosion depletion of soil fertility excessive use of chemical fertilizers and agro chemicals and inturn reduce environmental pollution On the otherhand it can enhance diversity and system productivity by reducing external inputs and increasing outputs Additionally multipurpose trees in coconut based agroforestry may improve the wood resource availability in the rural areas

Material and Methods

MATERIALS AND METHODS

3 1 Location

An agrisilvicultural experimental set up situated at the Instructional Farm College of Horticulture Kerala Agricultural University Vellanikkara Thrissur Kerala (13° 31 N latitude and 76° 13 E longitude at an elevation of 40 29 m above sea level) was used for the present study The experiment was laid out in June 1992 and the period of present investigation ranged from March 1995 to August 1996

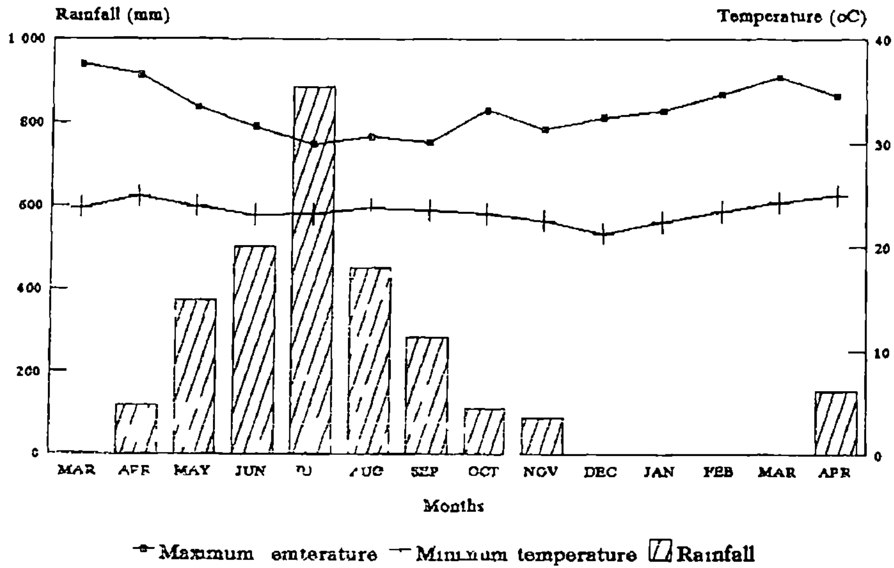
3 1 1 Climate

Vellanikkara experiences a warm humid climate having mean annual rainfall of 2668 6 mm (corresponding to the 12 year period from 1981 1993) (Fig 1) Much of the rainfall is received during the south west monsoon season (June to August) The mean maximum temperature ranges from 28 6°C (July) to 36 2°C (March) and the mean minimum temperature from 22 2°C (December) to 24 7°C (May) The total rainfall during the study period (March 95 to April 96) was 2959 1 mm (Appendix I)

3 1 2 Soil

The experiment site is characterised by soils of lateritic origin (Oxisol) Texturally it is sandy clay loam with a bulk density of 1 34 g cm^3 (Latha 1994) and pH 5 3 5 5

Fig 1 Weather parameters during the experimental period
(March 1995 April 1996)



3 2 Field experiment

A randomised complete block experiment (replicated thrice) involving two factors multipurpose tree species and planting geometry was initiated in June 1992 It involved laying out of 21 experimental plots of size 20 m x 20 m in an existing coconut plantation (Fig 2) Each plot consisted of nine coconut palms Coconuts were planted in this area during 1978 at a spacing of 7 5 m x 7 5 m Survival was generally good (over 95%) The experimental variables included combinations of three fast growing multipurpose trees (*Vateria indica* L *Ailanthus triphysa* (Dennst) Alston and *Grevillea robusta* A Cunn) in two planting geometries (single row and double row)

The single row system involved a row of multipurpose tree in the middle of two adjacent rows of coconuts in both directions (Fig 3a) As regards to the double row system two rows of multi purpose trees were planted in the middle of two adjacent rows of coconut palms by adopting an east west orientation (Fig 3b) Tree population dens ty was thus kept constant at 72 trees per plot (1800 trees ha) in both the treatments Between tree spacing was 2 m x 2 m in both geometries and row spacing in the double row planting system was 1 m

Kacholam (*Kaempferia galanga* L) was planted as an under storey crop in all treatments on beds of 3 m x 1 m size made in the interspaces of coconut and multipurpose trees There were six beds per plot Three additional kacholam

Fig 2 Layout plan of the experimental plots

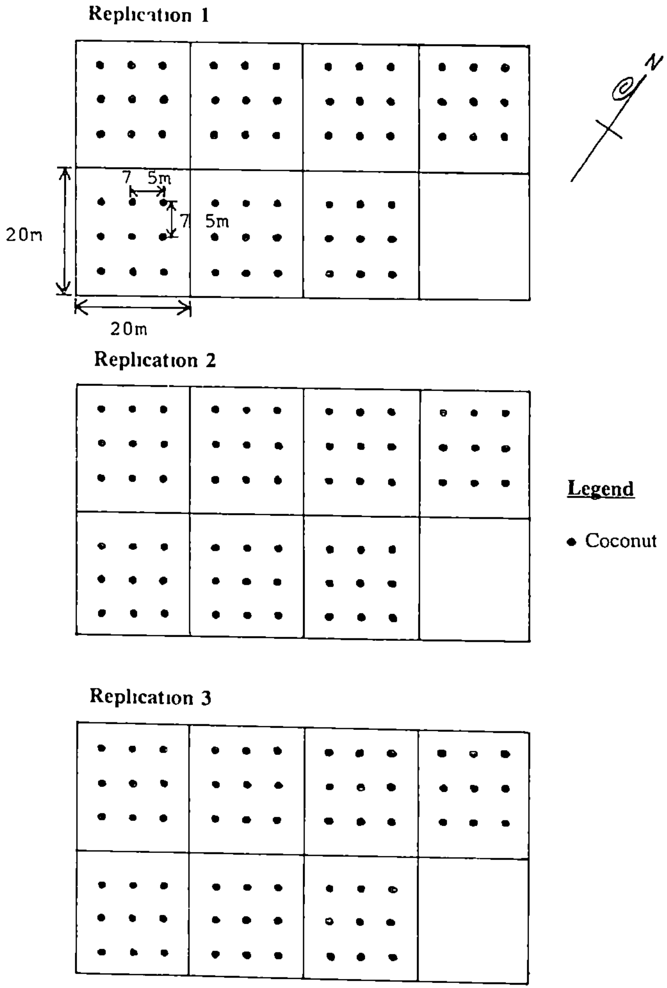


Fig 3a Diagram showing single hedge planting geometry of multipurpose trees

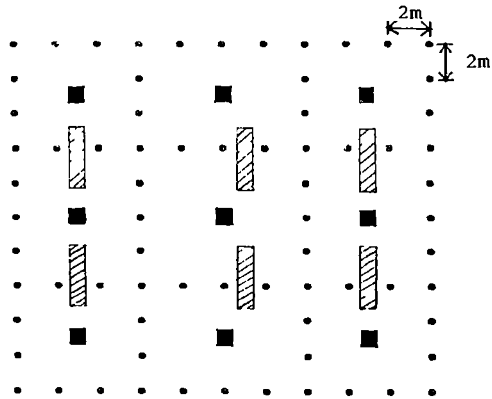
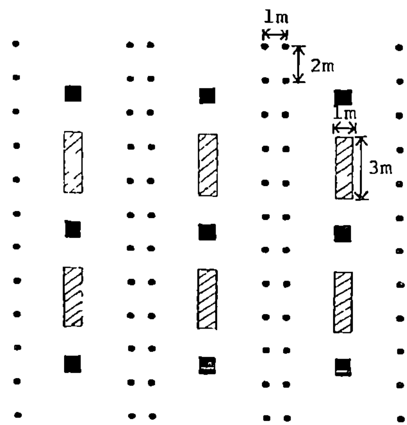


Fig 3b Diagram showing double hedge planting geometry of multipurpose trees



Legend

- Multipurpose trees
- Coconut
- Kacholam beds

plots (sole crop) were established in the adjacent open area for comparative purpose Details of the experimental variables are as follows

T Coconut + *Vateria indica* in single row + kacholam

T Coconut + *V indica* in double row + kacholam

T Coconut + *Ailanthus triphysa* in single row + kacholam

T_4 Coconut + *A triphysa* in double row + kacholam

T_5 Coconut + *Grevillea robusta* in single row + kacholam

T_6 Coconut + *G robusta* in double row + kacholam

T_7 Coconut + kacholam

T_8 Kacholam sole crop

3 3 Multipurpose tree crop components

(a) *Ailanthus triphysa* (Dennst) Alston

(Family Simaroubaceae)

Ailanthus is a medium sized deciduous tree with cylindrical bole and narrow crown reaching a maximum height of 30 m The tree is a strong light demander especially during the initial stages of growth (Troup 1921) Ailanthus is a dominant woody perennial component in the homesteads of Kerala (Kumar *et al* 1994) This fast growing multipurpose tree species is used in match wood packing case paper and pulp industries (NAS 1980)

(b) *Grevillea robusta* A cunn (Family Proteaceae)

A fast growing tree species native to Australia and introduced to Indian sub continent during the early 1860s as shade tree for tea in the High Ranges It is widely grown in the Indo gangetic alluvial plains and humid/sub humid regions In good soils with suitable climate annual increment of 2 m in height and 2 cm in dbh is reported over the first 5 10 years (Harwood and Getahun 1990)

(c) ***Vateria indica*** **I (family Dipterocarpaceae)**

Vateria is a large elegant evergreen tree indigenous to the evergreen forests of western ghats Its timber and the resin commercially known as white dammar are highly valued in the market Vateria is reported to be a shade bearer thriving well in damp rich soils with free drainage (Kadambi 1957)

3 3 1 Tree planting

One year old hybrid coconut seedlings (Laccadive Ordinary x Gangabondam) were planted with a spacing of 7 5 m x 7 5 m in 1978 (25 to 28 July) as per the package of practices recommendations of Kerala Agricultural University Regarding multi purpose trees 4 5 months old containerised seedlings of *Ailanthus triphysa* and *Grevillea robusta* were planted (10 17 June 1992) following the experimental protocol For *Vateria indica* wildlings collected from Vazhachal forest area and maintained in polybags for about 4 5 months in the College nursery were used for planting in June 1992

3 4 Field crop component

Kacholam (*Kaempferia galanga* L) a potential medicinal herb belonging to the family Zingiberaceae was planted as the under storey crop Kacholam is widely distributed in the tropics and subtropics of Asia and Africa The humid tropical climate of Kerala is reported to be ideal for its growth Earlier studies have indicated that kacholam is shade tolerant and can be incorporated in coconut based land use systems without considerable loss in yield (Nair *et al* 1991 Latha 1994)

3 4 1 Crop planting

Kacholam was planted in the interspaces of coconut multipurpose tree system in May 1995 when the coconut palms and multipurpose trees were 17 and 3 years old respectively Prior to planting the entire area was weeded In addition the area was ploughed using tractor in March 1995 Six beds of size 3 m x 1 m and 30 cm height were made in the interspaces of each plot (Fig 3a and 3b)

Farm yard manure at the rate of 20 t ha was applied on the beds and incorporated by light hoeing Kacholam rhizomes procured from the AICRP Scheme of Medicinal and Aromatic Plants College of Horticulture Kerala Agricultural University were planted in the beds during the period from 18th to 30th May 1995 shortly after the receipt of pre monsoon showers following Package of Practices Recommendations (KAU 1993) For this small pits of 4 5 cm depth were made on the beds at a spacing of 20 x 15 cm Healthy rhizomes with two or three viable buds (15 20 g) were then planted in the pits at the rate 700 800 kg rhizomes per hectare

Immediately after sowing the rhizomes were covered with a fine layer of soil The beds were then mulched with green leaves at the rate of 15 t ha (4 5 kg per bed)

Prophylactic measures to check disease and pest incidence as per the package of practices recommendations (KAU 1993) were also carried out

3 4 2 Crop management

The beds were weeded on 45 and 90 days after planting Additionally weeds were removed as and when found necessary NPK fertilizers at the rate 50 50 50 kg ha were applied at the time of first and second weeding (45 and 90 days after planting) as per the package of practices recommendations (KAU 1993) Light earthing up was done after each application

To control leaf drying and leaf rot disease (caused by Rhizoctonium and *Coliotrichum leosporiods* respectively) observed in some plots during heavy rains (August September 1995) Bavistin 0 1% (1 g per lt) and Fytolan (3 g per lt) were applied as soil drenching

3 5 Observations

3 5 1 Coconut

To evaluate the yield response nut yield of all palms in the experimental area was recorded from 1991 to 1996 Mean yield of palms for two successive years were computed to avoid any possible error associated with alternate bearing tendency of the palms $\sqrt{(x+1)}$ transformation was done before analysis of variance

3 5 2 Allometric observations on multipurpose trees

Tree height and basal stem diameter (collar diameter) of all trees except border trees were measured at six monthly intervals initially (from September 1992 to June 1995) and at four monthly intervals subsequently (June 1995 to July 1996) Height was measured using a graduated pole and diameter with a measuring tape

Crown widths of trees were measured once when the trees were of 4 years and 2 months age (August 1996) by projecting the crown on the ground in two perpendicular directions (North South and East West) and computing their means Height to the first crown forming branch also was simultaneously measured using a graduated pole

Stand leaf area index was estimated with a plant canopy analyser (Licor 2000 Licor Lincoln Neberaska USA) in March 1996 (at a stand age of 3 years and 9 months)

3 5 3 Root count of coconut

To estimate the density of coconut roots on the kacholam beds (presumably produced after kacholam planting) vertical cuts of 30 cm depth and one meter width were made across the beds on both sides of the central palm in all plots at distance 25 cm and 100 cm from the edge of the bed facing the palm Three random quadrats of 10 cm x 10 cm were demarcated on the cut surface (30 cm deep and 100 cm long) and all cut ends of coconut roots were counted Based on diameter the roots were classif ed into two broad categories as primary roots (First order roots having diameter greater than 0 5 cm) and secondary roots (second and other higher order roots having diameter less than 0 5 cm)

For comparative purposes similar observations were made in coconut stands devoid of the intercrops also In this case vertical cuts were made at 2 5 m and 3 25 m lateral distances (corresponding to the 25 cm and 100 cm distances on the bed) from the palm basin Average number of roots for an area of 10 cm x 10 cm were then worked out The data was subjected to log $_0$ (x+1) transformation before analysis

3 5 4 Biometric observations on Kacholam

Kacholam plants were destructively sampled on 90th 150th and 210th days after planting One meter quadrats were randomly selected from any three of the six beds in each plot Each sampling unit had a plant population of 35 hills per m^2 Number of tillers number of green leaves (functional leaves) and plant height from the soil surface to the tip of the plant were recorded for all plants

All plants in the sampling units were then uprooted carefully and taken to the lab for weight measurements Samples were pooled plot wise after cleaning above ground and below ground portions were separated and their fresh we ghts recorded Random samples of leaf and rhizome were weighed out (100 150 g) in triplicate in paper bags for moisture estimation These samples were oven dried at 70 C until constant weight and dry weight was estimated

Known weights (150 200g) of triplicate leaf samples from each plot after removing dust and moisture were collected for estimating leaf area (at 90 and 150 days after planting) Leaf area was measured in a Licor model 3100 Leaf Area Meter Based on the relationships between sample leaf area and total fresh weight crop leaf area indices (LAI) were computed (at 90 days and 150 days after planting)

During the final harvest (210 days after planting) in addition to the above biometric observations number of rhizomes per plant and length of rhizomes of ten randomly selected clumps from each plot were also recorded and the mean worked out

3 6 Solar radiation measurements

Light measurements were made during 11th January to 14th February 1996 Integrated values (at hourly intervals from 7 am to 6 pm) of photosynthetically active radiations (P A R) in the open and under the canopy at 50 cm and 150 cm heights were recorded using a Point Quan um Sensor and Line Quantum Sensor (Licor model Ll 1000) with a Data Logger attachment (Licor Lincoln Neberaska USA) respectively Light measurements were made in two of the three replications in the original experiment (Fig 2) and using the two sets of observations mean percentage light infiltration rates were worked out

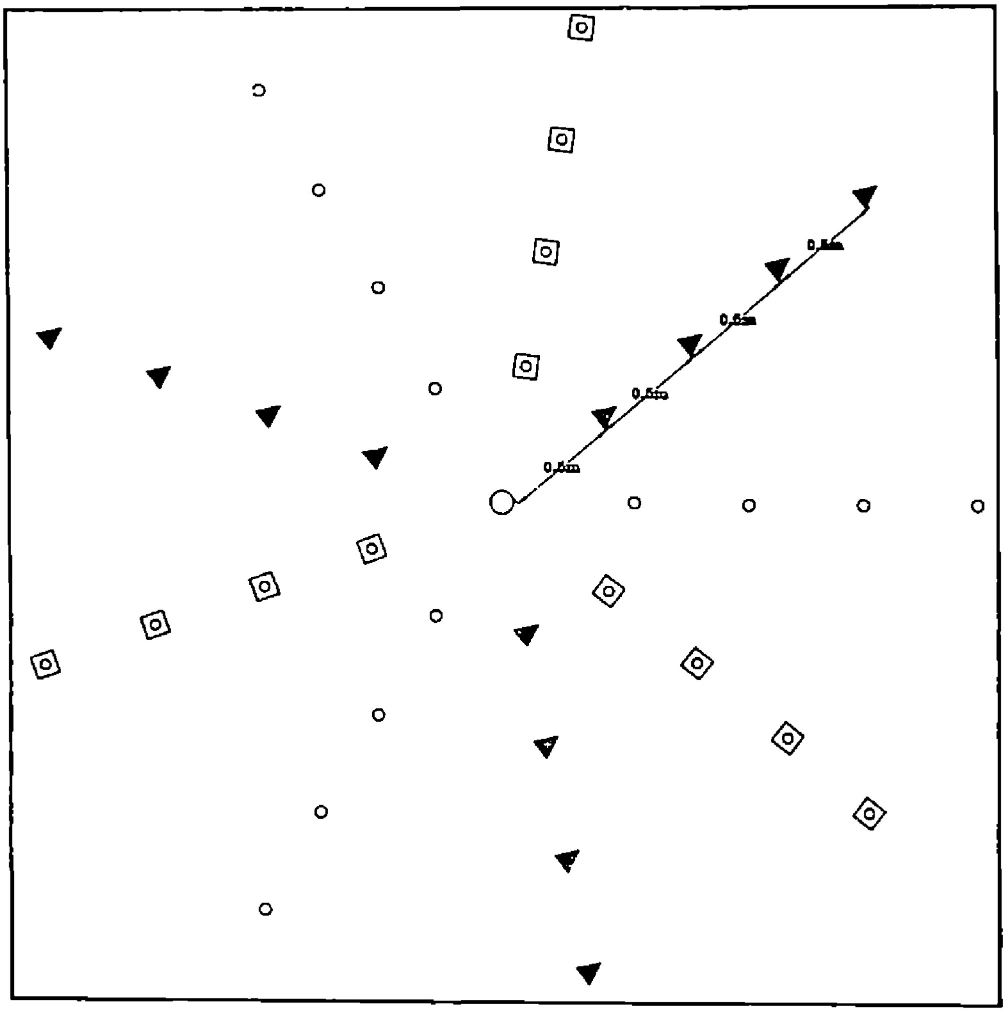
3 7 Characterisation of root interaction

The nature and extent of root interaction among the components of the agrisilviculture system were studied by radio tracer technique involving soil injection of P An experiment involving coconut as the treated plant was laid out for this purpose The objectives included assessing the extent of root competition between coconut and the associated multipurpose tree component besides coconut and kacholam

Coconut palms in the centre of each plot was selected for ^{3}P application so as to ensure least interference with the adjacent experimental units A total of 21 palms (seven treatments each replicated thrice) were selected for this purpose To ensure effective absorption of ^{32}P by the palms whole basin application approach was adopted It involved application of ^{32}P in 36 holes per palm basin corresponding to combinations of four lateral distances (50 100 150 and 200 cm) and three depths (30 60 and 90 cm) Schematic representation of the experimental unit is given in Fig 4 These lateral distances and depths were selected for P application because more than 80% of root activity of coconut lies in a soil cylinder of 2 m radius around the palm and to a depth of 90 cm (Anilkumar and Wahid 1988)

Nine equi spaced holes were drilled to the required depth at each lateral distance as per the treatment protocol using soil auger of 2 5 cm diameter Then PVC tubes were inserted into the holes with 10 15 cm protruding above the soil surface (see Plate 1) Open ends were covered with polythene covers and rubber bands to prevent any possible entry of rainwater into the tubes

F g 4 Layout plan for sotope appl cat on n coconut bas n show ng holes fo nject on of ^{32}P



LEGEND

O COCONUT

Depth of ho es

⊞ 30CM

► 60CM

90CM

PLATE 1 Experimental unit for ^{32}P application in coconut basin showing the access tubes for isotope injection

(per tree)

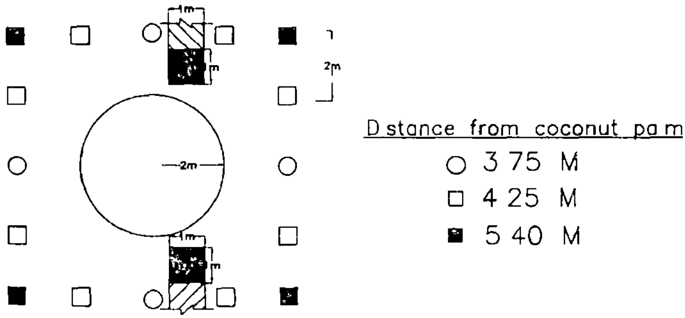
^{32}P solution at the rate of 3 mCi at carrier level of 1000 ppm P was dispensed into the access tubes at the rate of 5 ml per hole on 21st November 1995 using a Lumac dispensette (Wahid *et al* 1988) After dispensing the residual activity remaining inside the access tubes was washed down with a jet of about 15 ml water Carrier in the ^{32}P solution was included to minimise the soil fixation of the radio isotope

3 7 1 Leaf sampling and radioassay

Leaves from the treated coconut palms neighbouring multipurpose trees and kacholam were sampled for radio assay at 15 30 and 45 days after application of ^{32}P For coconut the sixth fully opened leaf was selected and three leaflets from either side of the midrib were sampled from the middle portion following the standard procedure (IAEA 1975) For multipurpose trees the most recently matured leaves were sampled Leaf samples from multipurpose trees at equal distances on either side of the palm were pooled together to obtain composite samples Fig 5a and 5b gives the distribution and lateral distance of sampled trees around the applied coconut palms Most recently matured leaves of kacholam were also sampled from beds on either side of the treated palms (leaves were collected randomly from 1 m^2 area (2 5 3 5 m from coconut) on either sides)

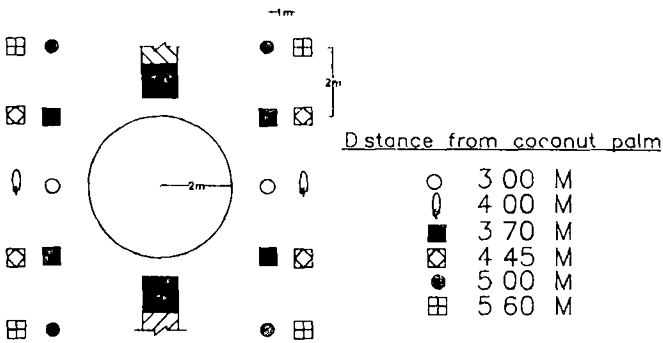
The leaf samples were dried at 70° C and radio assayed for ^{32}P count by Cerenkov counting technique (Wahid *et al* 1985) at the Radio Tracer Laboratory Vellanikkara The method consisted of wet digestion of one gram of dried

Fig 5 Location of multipurpose trees and kacholam leaves sampled for ^{32}P analysis



(a) Single hedge planting

Sampling region for kacholam leaves



(a) Double hedge planting

plant (Leaf) sample using diacid mixture (HNO and $HClO_4$ in 2 1 ratio) The digest was transferred to a counting vial and made upto 20 mL The samples in vials were counted in a Liquid Scintillation Counter (Wallac 1409 Pharmacia Finland) by Cerenkov Counting Technique Count rates were expressed as cpm (counts per minute)

Prior to statistical analysis the cpm values were corrected for background as well as decay and subjected to $\log_{10}(x+1)$ transformation Analysis of variance was performed on foliar P data individually for coconut multipurpose trees and kacholam

3 8 Phytochemical analysis

Duplicate samples of coconut leaves (10th fully opened leaf Gopi 1981) and multipurpose tree foliage (most recently matured leaf) collected after the harvest of kacholam in March 1996 were analysed for nitrogen phosphorus and potassium contents In the case of kacholam foliage (sampled at 90 and 150 days after planting) and rhizome (collected at 90 150 and 210 days after planting) were analysed

The samples were initially oven dried at 70°C ground to pass through a 2 mm sieve and stored in double sealed polythene containers Total nitrogen was estimated following the micro Kjeldahl method Phosphorus and potassium contents were estimated after digesting the samples in a triacid mixture (HNO H SO_4 and $HClO_4$ in the ratio 10 1 3) Phosphorus was determined by the Vanado molybdo phosphoric yellow colour method and potassium by flame photometry (Jackson 1958)

3 8 1 Quality attributes of kacholam

Finely ground samples of dried mature rhizomes were analysed for essential oil and oleoresin contents Twenty gram sample was mixed with ammonium sulphate (non frothing agent) and 250 ml distilled water in a round bottom flask for the extraction of essential oil by distillation in Clevenger apparatus for 4 hours (till there was no further increase in oil level) Essential oil was expressed on percentage basis (volume of oil extracted/?0 x 100)

For oleoresin estimation 10 g finely powdered sample was covered in a filter paper and made as a pouch This was distilled in a soxhlet apparatus with 250 mL petroleum eather (boiling point 60 80° C) as solvent for eight hours The extract was then transferred to a 250 mL flask and petroleum ether evaporated The difference in weight of the flask is recorded as the quantity of oleoresin Percentage oleoresin was calculated (increase in weight of flask (g)/10(g) x 100)

3 9 Soil chemical analysis

Soil samples were collected from the experimental units before (May 1995) and after (March 1996) the kacholam crop Samples were collected from the surface layer (0 15 cm) at six random points in each plot and mixed thoroughly to obtain a composite sample The samples were air dried ground to pass through a 2 mm sieve and stored in double sealed polythene containers Duplicate samples were analysed for pH electrical conductivity organic carbon nitrogen phosphorus and potassium as follows

Soil pH was determined using an aqueous suspension of soil (soil and water in 1 2 ratio) using an Elico pH meter Electrical conductivity of the above suspension was measured using an Elico conductivity bridge Organic carbon was estimated by Walkley and Black method and total nitrogen by micro Kjeldahl method Available phosphorus was extracted using Bray I extractant and the P content estimated calorimetrically using chloro molybdic acid blue colour method with stannous chloride as the reducing agent Available potassium was determined flame photometrically using 1N neutral normal ammonium acetate solution as the extractant (Jackson 1958) All the nutrients were expressed on an oven dry basis

3 10 Statistical analysis

The experimental data pertaining to various observations were analysed following the analysis of variance technique using MSTAT statistical package and programmes developed in BASIC

Results

RESULTS

4 1 Coconut productivity

Mean nut yield of 18 year old (1995 96) coconut palms were not seen affected either by multipurpose trees or its planting geometry (Table 1 and Fig 6) Pre treatment yield of coconut (1991 92) ranged from five to eight nuts/palm annually Two years after planting the multipurpose trees (1993 94) the yield averaged between 20 and 29 nuts/palm year The respective figures for 1995 96 were 36 and 42

4 2 Foliar nutrient concentration of coconut

Nutrient concentrations (N P and K) in the coconut foliage also was not substantially altered during the first four years of the experiment Nitrogen content ranged from 1 73% to 1 90% phosphorus from 0 13% to 0 17% and potassium from 1 28% to 1 46% (Table 2)

4 3 Growth characteristics of multipurpose trees

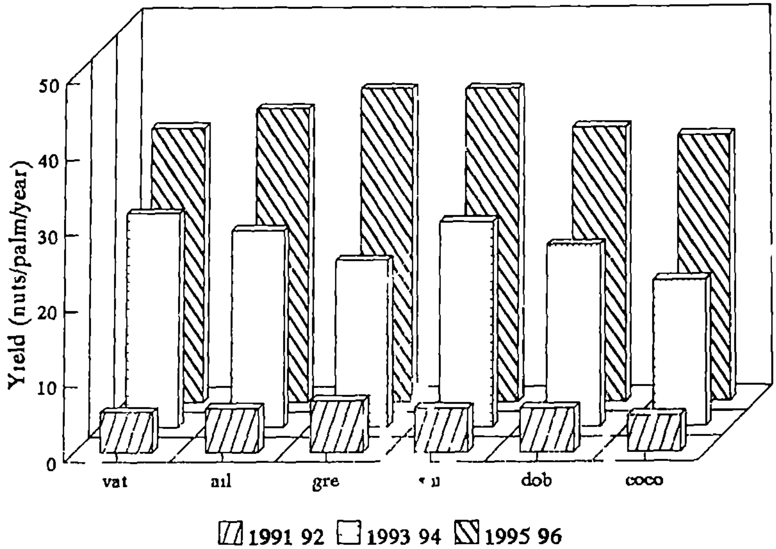
The three multipurpose tree species grown in the agri silvicultural system exhibited marked variations in their growth rates (Table 3) Differences in tree height were significant till April 1994 with *Vateria indica* registering the fastest growth rate followed by *Grevillea robusta* and *Ailanthus triphysa* These differences were

Table 1 Mean nut yield of coconut palms { (x 1) transformed values of two consecutive year means} as affected by multipurpose tree species and their planting geometry

Treatments	1991 92 (Nuts/palm/year)	1993 94 (Nuts/palm/year)	995 96 (Nuts/palm/year)
Species			
1 *Va e a t a*	5 (5 3)	5 4 (?8 ?)	6 1 (?(?)
2 *A lar l tr pl y*	? 6 (6 8)	5 ? ?6 0)	(3 (38 7
3 *G e llea rol s a*	? 8 (6 8)	4 8 (? 0)	6 5 (41 3
F tes	NS	NS	NS
SEm (	0 4078	0 3874	0 3866
Planting geometry			
1 Single row	? 6 (5 8)	5 3 (?7 1	6 ? (41 3)
2 Double row	? 6 5 8)	5 0 (?4 0)	6 1 (36 ?)
F test	NS	NS	NS
SEm (±)	0 3330	0 3163	0 3157
Species vs planting geometry			
F est	NS	NS	NS
SEm ( )	0 5767	0 5478	0 5468
Control (coconut alone)	? 4 (4 8)	4 5 (19 3)	6 0 (?5 0)
Control vs rest			
F tes	NS	NS	NS
SEm ( )	0 5767	0 5478	0 5468

Figures in parentheses indicate r transformed values

Fig.6 Yield of coconut in the agrisilviculture system



vat Vateria indica ail Ailanthus triphysa gre Grevillea robusta
sin Single row dob Double row coco Coconut alone

Table 2 Foliar nutrient concentrations of coconut at 17 years and 8 months of age (March 1996) as affected by species and planting geometry

Treatments	Coconut		
	N (%)	P (%)	K (%)
Species			
1 *Vateria indica*	1 82	0 15	1 46
2 *Ailanthus triphysa*	1 82	0 15	1 30
3 *Grevillea robusta*	1 80	0 14	1 39
F test	NS	NS	NS
SEm ( )	0 0527	0 0052	0 1046
Planting geometry			
1 Single row	1 86	0 16	1 36
2 Double row	1 77	0 14	1 40
F test	NS	NS	NS
SEm ( )	0 0430	0 0043	0 0854
Species vs planting geometry			
F test	NS	NS	NS
SEm (±)	0 0746	0 0074	0 1479
Control (coconut monoculture)	1 85	0 13	1 34
Control vs rest			
F test	NS	NS	NS
SEm ( )	0 0746	0 0074	0 1479

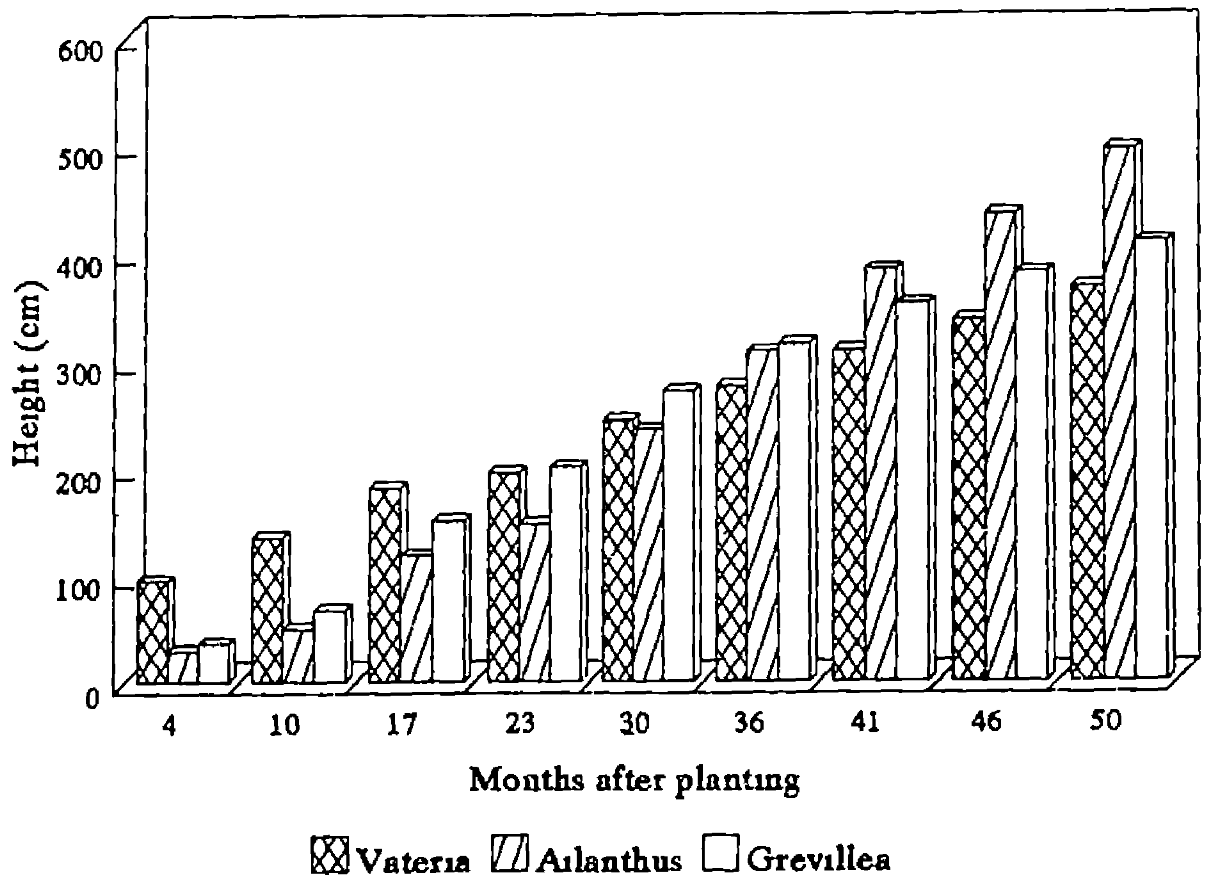
NS Not significant

Table 3 Height of multipurpose trees (cm) at periodic intervals (from September 1992 to July 1996)

Treatments	Spt 92	Mar 93	Oct 93	Apl 94	Nov 94	May 95	Oct 95	Mar 96	Jul 96
Species									
1 *Vateria indica*	93 32	133 29	178 37	192 90	241 67	272 83	306 63	335 17	364 33
2 *Ailanthus triphysa*	28 01	48 96	116 72	145 72	233 33	305 50	381 17	431 83	492 33
3 *Grevillea robusta*	35 10	66 15	148 65	198 75	268 33	313 00	349 67	378 00	406 33
F test	< 0 01	< 0 01	< 0 01	< 0 05	NS	NS	NS	NS	< 0 05
SEm (±)	2 3371	5 1334	7 9579	11 0778	15 0308	18 0805	22 5258	25 3783	26 5130
CD (0 05)	7 36	16 17	25 07	34 90					83 54
Planting geometry									
1 Single row	52 13	83 45	143 78	172 18	236 67	281 56	329 76	370 11	405 33
2 Double row	52 15	82 15	152 05	186 07	258 89	312 67	361 89	393 22	436 67
F test	NS	NS	NS	NS	NS	NS	NS	NS	NS
SEm (±)	1 9082	4 1914	6 4976	9 0450	12 2726	14 7626	18 3923	20 6723	21 6478
Species vs planting geometry									
F test	NS	NS	NS	NS	NS	NS	NS	NS	NS
SEm (±)	3 3051	7 2597	11 2542	15 6663	21 2568	25 5697	31 8563	35 8055	37 4950

NS Not significant

Fig.7 Height of multipurpose trees in a coconut based agrisilvicultural system



however not statistically significant during the period from November 94 to March 96 Nonetheless height difference were significant in July 96 (Fig 7) At this stage height growth followed the order ailanthus > grevillea > vateria Mean annual increment in height growth also followed a similar trend (Table 4) although mean annual increment was highest for vateria upto 17 months after planting Planting geometry did not influence height growth of multipurpose trees Interaction effects were also not significant

Regarding radial growth *Vateria indica* registered the highest basal stem diameter initially (Table 5) However subsequently *A triphysa* recorded significantly higher values (Fig 8) In July 96 ailanthus recorded a value 206% greater than that of vateria

Diameter mean annual increment (Table 6) was also highest for vateria in the early stages of growth but unlike height ailanthus over took other two species from an early stage (17 months onwards) At 50 months after planting ailanthus had a mean annual diameter increment of 2 6 cm yr For the period from 36 to 46 months after planting no statistically significant differences were discernable

Crown diameter stand leaf area index and height to the first crown forming branch at four years and two months of age showed significant variations between the three multipurpose tree species (Table 7) *Vateria indica* had wider crowns as compared to both *Grevillea robusta* and *Ailanthus triphysa* Mean crown diameter of

Table 4 Mean annual increment in height growth (cm yr^{-1}) of multipurpose trees at periodic intervals (from September 1992 to July 1996)

Months after planting / Treatments	4 (Spt 92)	10 (Mar 93)	17 (Oct 93)	23 (Apl 94)	30 (Nov 94)	36 (May 95)	41 (Oct 95)	46 (Mar 96)	50 (Jul 96)
Species									
1 *Vateria indica*	279 95	159 95	125 91	100 64	96 67	90 95	89 75	87 44	87 44
2 *Ailanthus triphysa*	84 04	58 75	82 39	76 03	93 33	101 84	111 56	112 65	118 16
3 *Grevillea robusta*	105 29	79 38	104 93	103 69	107 33	104 33	102 34	98 61	97 52
F test	< 0 01	<0 01	< 0 01	< 0 05	NS	NS	NS	NS	< 0 05
SEm (±)	7 0112	6 1593	5 6169	5 7800	6 0123	6 0271	6 5931	6 6051	6 3631
CD (0 05)	22 09	19 41	17 70	18 21					20 05
Planting geometry									
1 Single row	156 39	100 14	101 49	89 83	94 67	93 85	96 51	96 55	97 28
2 Double row	156 46	98 58	107 33	97 08	103 56	104 22	105 92	102 58	104 80
F test	NS	NS	NS	NS	NS	NS	NS	NS	NS
SEm (±)	5 7246	5 0290	4 5862	4 7194	4 9090	4 9211	5 3832	5 3931	5 1955
Species vs. planting geometry									
F test	NS	NS	NS	NS	NS	NS	NS	NS	NS
SEm (±)	9 9153	8 7106	7 9436	8 1742	8 5027	8 5236	9 3240	9 3411	8 9988

NS Not significant

Table 5 Basal stem diameter (cm) of multipurpose trees at periodic intervals (from September 1992 to July 1996)

Treatments	Spt 92	Mar 93	Oct 93	Apl 94	Nov 94	May 95	Oct 95	Mar 96	Jul 96
Species									
1 *Vateria indica*	1 31	1 45	2 52	2 70	3 19	4 20	4 39	4 70	5 30
2 *Ailanthus triphysa*	0 77	1 28	3 11	3 94	5 74	8 10	8 56	9 40	10 92
3 *Grevillea robusta*	0 50	0 87	2 01	2 27	3 13	4 16	4 35	4 80	5 24
F test	< 0 01	< 0 05	< 0 01	< 0 01	< 0 01	< 0 01	< 0 01	< 0 01	< 0 01
SEm ( )	0 0375	0 1344	0 1103	0 1644	0 2328	0 3241	0 3472	0 3990	0 4475
CD (0 05)	0 12	0 42	0 35	0 52	0 [illegible]3	1 02	1 09	1 26	1 41
Planting geometry									
1 Single row	0 82	1 25	2 49	2 88	3 89	5 37	5 65	6 25	7 14
2 Double row	0 90	1 15	2 60	3 06	4 15	5 60	5 88	6 35	7 17
F test	NS	NS	NS	NS	NS	NS	NS	NS	NS
SEm ( )	0 0307	0 1097	0 0900	0 1342	0 1901	0 2646	0 2835	0 3257	0 3654
Species vs planting geometry									
F test	NS	NS	NS	NS	NS	NS	NS	NS	NS
SEm (±)	0 0531	0 1901	0 1559	0 2324	0 3292	0 4583	0 4910	0 5642	0 6329

NS Not significant

Fig 8 Basal stem diameter of multipurpose trees in a coconut based agrisilvicultural system

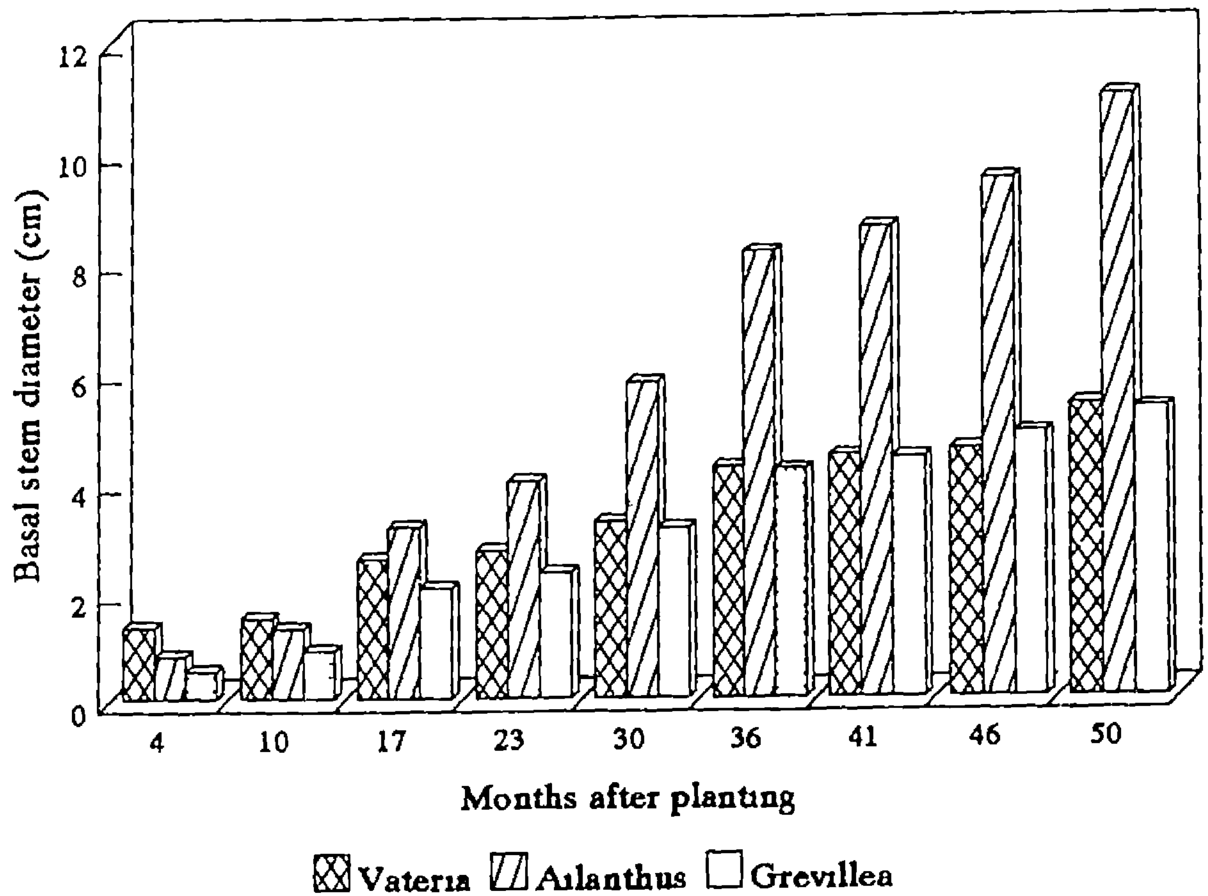


Table 6 Mean annual increment in basal stem diameter growth (cm yr⁻¹) of multipurpose trees at periodic intervals (from September 1992 to July 1996)

Months after planting / Treatments	4 (Spt 92)	10 (Mar 93)	17 (Oct 93)	23 (Apl 94)	30 (Nov 94)	36 (May 95)	41 (Oct 95)	46 (Mar 96)	50 (Jul 96)
Species									
1 *Vateria indica*	3 93	1 74	1 78	1 41	1 28	1 40	1 25	1 22	1 27
2 *Ailanthus triphysa*	2 30	1 53	2 19	2 06	2 30	2 70	2 51	2 45	2 62
3 *Grevillea robusta*	1 51	1 05	1 42	1 19	1 25	1 39	1 27	1 25	1 26
F test	< 0 01	<0 01	< 0 01	< 0 05	NS	NS	NS	NS	< 0 05
SEm (±)	0 1126	0 1615	0 0782	0 0860	0 0929	0 1082	0 1018	0 1042	0 1081
CD (0 05)	0 3546	0 5097	0 2474	0 2698	0 2933	0 3403	0 3203	0 3280	0 3403
Planting geometry									
1 Single row	2 46	1 50	1 76	1 50	1 56	1 79	1 65	1 63	1 71
2 Double row	2 70	1 37	1 84	1 60	1 66	1 87	1 72	1 66	1 72
F test	NS	NS	NS	NS	NS	NS	NS	NS	NS
SEm (±)	0 0920	0 1319	0 0638	0 0702	0 0758	0 0884	0 0831	0 0851	0 0882
Species vs. planting geometry									
F test	NS	NS	NS	NS	NS	NS	NS	NS	NS
SEm (±)	0 1593	0.2284	0 1106	0 1216	0 1314	0 1531	0 1440	0 1474	0 1528

NS Not significant

Table 7 Observations on crown diameter height to the first crown forming branch and stand leaf area index (LAI) of multipurpose trees at 4 years and 2 months of age (August 1996) as affected by species and planting geometry

Treatments	Height to the first crown forming branch (m)	Crown diameter (cm)	Stand LAI
Species			
1 *Vateria indica*	1 38	297 96	6 12
2 *Ailanthus triphysa*	3 77	190 88	7 15
3 *Grevillea robusta*	1 31	212 22	5 24
F test	< 0 01	< 0 05	< 0 01
SEm ( )	0 1218	6 3853	0 2511
CD (0 05)	0 38	20 12	0 77
Planting geometry			
1 Single row	2 08	211 39	6 28
2 Double row	2 23	209 31	6 06
F test	NS	NS	NS
SEm (±)	0 0994	5 2136	0 2050
Species vs planting geometry			
F test	NS	NS	NS
SEm ( )	0 1722	9 0302	0 3550
Control (coconut monoculture)			4 89
Control vs rest			
F test			< 0 01
SEm ( )			0 3550
CD (0 05)			1 09

NS Not significant

the three species were 298 cm 212 cm and 191 cm respectively Regarding height to the first crown forming branch however *A triphysa* showed greater values Ailanthus crowns probably may have originated at a height of about 377 cm whereas that of vateria and grevillea started from 138 and 131 cm respectively Both crown diameter and height to the first crown forming branch was not influenced by planting geometry

Multipurpose trees exhibited significant difference in stand leaf area index Ailanthus recorded the highest leaf area index of 7 15 followed by vateria with 6 12 and grevillea with 5 24 Planting geometry had no marked influence on stand leaf area index (Table 7)

Foliar concentrations of N P and K in different species showed considerable variations Nonetheless planting geometry had no pronounced influence on this parameter (Table 8) Ailanthus showed the highest N concentration of 2 07% followed by grevillea (1 37%) and vateria (1 24%) Phosphorus conten followed the order ailanthus > vateria > grevillea Regarding potassium grevillea exhibited maximum content (0 89%) and vateria the lowest (0 48%)

4 4 Understorey field crop production

4 4 1 Growth attributes of Kacholam

Multipurpose trees in general did not influence tiller number number of leaves and mean plant height of kacholam (Table 9) However comparisons involving

Table 8 Foliar nutrient concentrations of multipurpose trees at 3 years and 9 months of age (March 1996) as affected by species and planting geometry

Treatments	Multipurpose trees		
	N (%)	P (%)	K (%)
Species			
1 *Vateria indica*	1 24	0 10	0 48
2 *Ailanthus triphysa*	2 07	0 14	0 86
3 *Grevillea robusta*	1 37	0 08	0 89
F test	< 0 01	< 0 01	< 0 01
SEm (±)	0 0502	0 0048	0 0564
CD (0 05)	0 1581	0 0129	0 1778
Planting geometry			
1 Single row	1 54	0 10	0 79
2 Double row	1 58	0 11	0 70
F test	NS	NS	NS
SEm (±)	0 0410	0 0033	0 0461
Species vs planting geometry			
F test	NS	NS	NS
SEm ( )	0 0710		0 0798

NS Not significant

PLATE 2 Multipurpose trees and coconut in the agrisilvicultural system

a) *Grevillea robusta* double hedge

b) *Vatena indica* double hedge

PLATE 3 Kacholam n the agr s lv culture system at d fferent stages of growth

a) 90 days after plant ng

b) 150 days after plant ng

control plots with the rest yielded significant differences in respect of tiller number and leaf number per plant Sole crop of kacholam recorded maximum number of tillers per hill at 90 days after planting and was significantly superior to single row planting of both ailanthus and grevillea At 150 days after planting coconut + kacholam combination gave maximum number of tillers It also had the maximum number of leaves (9 0) at 90 days after planting although at 150 days after planting sole crop of kacholam gave the maximum number of leaves (15 3)

Planting geometry of multipurpose trees exerted a profound influence on the growth attributes of kacholam At both the stages of observations (Table 9) the double hedge planting system resulted in greater number of leaves (9 and 12 respectively at 90 and 150 days after planting) Plant height was lower in the sole crop of kacholam (15 77 cm) and greater in the double hedge of ailanthus (18 30 cm) The double hedge planting in general favoured growth attributes of kacholam (Tables 9 and 10)

Leaf area index of kacholam was neither influenced by the tree species nor their planting geometry at 90 days after planting At 150 days after planting however leaf area index was maximum for the sole crop of kacholam though not statistically significant Furthermore the double hedge planting system favoured higher leaf area index in kacholam (Table 9) Plates 3(a) and 3(b) shows kacholam at different stages of growth

Table 9 Biometric observations above ground biomass production (fresh weight and dry weight) and leaf area index of kacholam as influenced by multipurpose trees and planting geometry at different stages of growth

Treatments	90 days after planting					
	No of tiller per hill	No of leaves per hill	Plant height (cm)	Leaf area index	Fresh weight (kg ha)	Dry weight (kg ha)
Species						
1 *Vateria indica*	2 82	8 53	14 45	1 34	7763 67	517 16
2 *Ailanthus triphysa*	2 81	7 98	15 76	1 48	8498 50	537 25
3 *Grevillea robusta*	2 80	8 13	15 04	1 44	8112 07	526 46
F test	NS	NS	NS	NS	NS	NS
SE (±)	0 0987	0 3439	0 5447	0 0932	502 35	41 84
Planting geometry						
1 Single row	2 68	7 63	14 82	1 39	7554 38	512 98
2 Double row	2 91	8 80	15 00	1 45	8495 11	540 93
F test	NS	<0 05	NS	NS	NS	NS
SEm (±)	0 0806	0 2808	0 4448	0 0761	410 16	34 16
CD (0 05)		0 8517				
Species vs planting geometry						
F test	NS	NS	NS	NS	<0 05	NS
SEm (±)	0 1396	0 4863	0 7704	0 1319	710 43	59 17
CD (0 05)					2154 85	
Control						
1 Coconut kacholam	3 07	9 24	13 87	1 37	8344 00	624 41
2 Kacholam sole crop	3 14	9 19	13 82	1 55	10255 00	691 28
F test	NS	NS	NS	NS	NS	NS
SEm ( )	0 1396	0 4863	0 7704	0 1319	710 43	59 17
Control vs rest						
F test	<0 05	<0 05	NS	NS	<0 05	<0 05
SEm ( )	0 1396	0 4863	0 7704	0 1319	710 43	59 17
CD (0 05)	0 4233	1 4751			2154 85	179 46

Contd

Table 9 contd

Treatments	150 days after plant ng					
	No of t llers per h ll	No of leave per l ll	Plant he ght (cm)	Leaf area index	Fresh we ght (kg ha)	Dry weight (kg ha)
Species						
1 *Vater a nd ca*	3 76	1 53	17 75	2 20	11460 67	894 ?2
2 *A lantl s tr ph a*	3 6?	10 9?	17 49	1 98	10355 33	890 20
3 *Gre llea r b ta*	3 71	10 55	16 79	1 99	10371 83	885 12
F te t	NS	NS	NS	NS	NS	NS
SEm ( )	0 2641	0 8186	0 ?769	0 1427	694 54	59 44
CD (0 05)						
Plantin geometry						
1 S ngle ro v	3 53	9 93	16 89	1 85	6947 67	829 62
? Do ble row	3 86	12 07	17 79	2 26	11810 89	950 07
F te t	NS	<0 05	<0 05	<0 05	<0 05	NS
SEm ( )	0 2156	0 6684	0 2261	0 1165	567 09	48 53
CD (0 05)		2 0273	0 6858	0 3534	1720 09	
Species vs planting geometry						
F test	NS	NS	NS	NS	NS	NS
SEm (±)	0 3735	1 1577	0 3516	0 2018	982 23	84 06
Control						
1 Coconut + kacholam	4 16	13 43	16 60	2 14	11644 00	1117 2?
? Kacholam ole crop	3 76	15 26	15 77	2 37	13799 67	1320 22
F test	NS	NS	NS	NS	NS	NS
SEm (±)	0 3735	1 1577	0 3516	0 2018	98? 23	84 06
Control vs rest						
F test	NS	<0 01	<0 01	NS	<0 05	<0 01
SEn ( )	0 3735	1577	0 3516	0 2018	982 23	84 06
CD (0 05)		3 5114	1 1878		2979 28	254 95

Table 10 Combined effects of multipurpose tree species and planting geometry on the number of tillers number of leaves and plant height of kacholam

No. of tillers (90 DAP)

	Vateria	Ailanthus	Grevillea
Single row	2.79	2.61	2.68
Double row	2.85	3.00	2.91

Control

Sole crop of kacholam 3.14
Kacholam + coconut 3.07

CD for interaction 0.4233

No. of leaves (90 DAP)

	Vateria	Ailanthus	Grevillea
Single row	8.26	8.86	7.76
Double row	8.80	9.10	8.50

Control

Sole crop of kacholam 9.19
Kacholam + coconut 9.24

* CD for interaction 1.4751

No. of leaves (150 DAP)

	Vateria	Ailanthus	Grevillea
Single row	10.35	8.94	10.50
Double row	12.71	12.90	10.60

Control

Sole crop of kacholam 15.26
Kacholam + coconut 13.43

** CD for interaction 3.5114

Plant height in cm (150 DAP)

	Vateria	Ailanthus	Grevillea
Single row	17.71	16.68	16.30
Double row	17.79	18.30	17.29

Control

Sole crop of kacholam 15.77
Kacholam + coconut 16.60

** CD for interaction 1.19

DAP days after kacholam planting

Table 11 Combined effects of multipurpose tree species and planting geometry on above ground biomass production of kacholam

Fresh weight (kg ha 1) at 90 DAP

	Vateria	Ailanthus	Grevillea
Single row	7583 33	6616 33	8463 47
Double row	7944 00	9780 67	7760 67

Control

Sole crop of Kacholam 10255 00
Kacholam + coconut 8344 00

* CD for interaction 2154 85

Dry weight (kg ha 1) at 90 DAP

	Vateria	Ailanthus	Grevillea
Single row	530 10	464 61	544 23
Double row	504 22	609 90	508 68

Control

Sole crop of Kacholam 691 28
Kacholam + coconut 624 41

* CD for interaction 179 46

Fresh weight (kg ha 1) at 150 DAP

	Vateria	Ailanthus	Grevillea
Single row	11121 67	7899 67	9921 67
Double row	11799 67	12811 00	10822 00

Control

Sole crop of Kacholam 13799 61
Kacholam + coconut 11644 00

* CD for interaction 2979 284

Dry weight (kg ha^{1}) at 150 DAP

	Vateria	Ailanthus	Grevillea
Single row	873 95	726 63	888 29
Double row	914 49	1053 76	881 95

Control

Sole crop of Kacholam 1320 217
Kacholam + coconut 1117 223

** CD for interaction 254 95

DAP days after kacholam planting

4 4 2 Above ground biomass production of kacholam

Comparisons involving sole crop of kacholam with intercropped plots showed substantial variability in total above ground biomass production (Table 9) At 90 days after planting fresh weight of sole crop (10255 kg ha) was significantly higher than single row of ailanthus double row of grevillea and both the planting geometries of vateria (Table 11) Dry weight also followed a similar trend Species planting geometry interaction was not significant

At 150 days after planting also sole crop of kacholam registered the highest above ground biomass production of 13800 kg ha and 1320 kg ha fresh weight and dry weight respectively Ailanthus single row resulted in the lowest fresh weight yield of 7900 kg ha for the above ground portions While comparing planting geometry of multipurpose trees double hedge system of planting was found to give better yield as compared to single hedge planting

4 4 3 Below ground biomass production of kacholam

Treatment means showed discernible differences only between inter cropped and sole cropped situations at 150 days after planting (Table 12 and Fig 9) At this stage sole crop of kacholam gave significantly higher yield (fresh weight 12589 kg ha) as compared to all other treatments except for kacholam + coconut and ailanthus double hedge planting They were statistically at par Neither tree species nor their planting geometries showed any marked difference in respect of yield (Table 12 and 13)

Table 12 Below ground biomass production (kg ha) of kacholam as influenced by the multipurpose trees and planting geometry at different stages of growth

Treatments	90 days after planting		150 days after planting		210 days after planting	
	Fresh weight	Dry weight	Fresh weight	Dry weight	Fresh weight	Dry weight
Species						
1 *Vateria indica*	5333 00	575 97	7855 17	1525.23	4316 42	1492 12
2 *Ailanthus triphysa*	6041 33	704 82	8405 17	1575 50	4058 00	1425 44
3 *Grevillea robusta*	5663 83	631 12	8449 50	1618 78	4624 50	1658 74
F test	NS	NS	NS	NS	NS	NS
SEm (±)	422 20	44 34	751 95	164 18	561 08	131 29
Planting geometry						
1 Single row	5605 22	609 68	7955 11	1487.22	4243 94	1476 77
2 Double row	5753 56	664 92	8518 11	1659 12	4422 00	1640 76
F test	NS	NS	NS	NS	NS	NS
SEm (±)	344 72	36 20	613 97	134 06	458 12	107 20
Species vs planting geometry						
F test	NS	NS	NS	NS	NS	NS
SEm (±)	597 08	62 71	1063 42	232 19	793 48	185 68

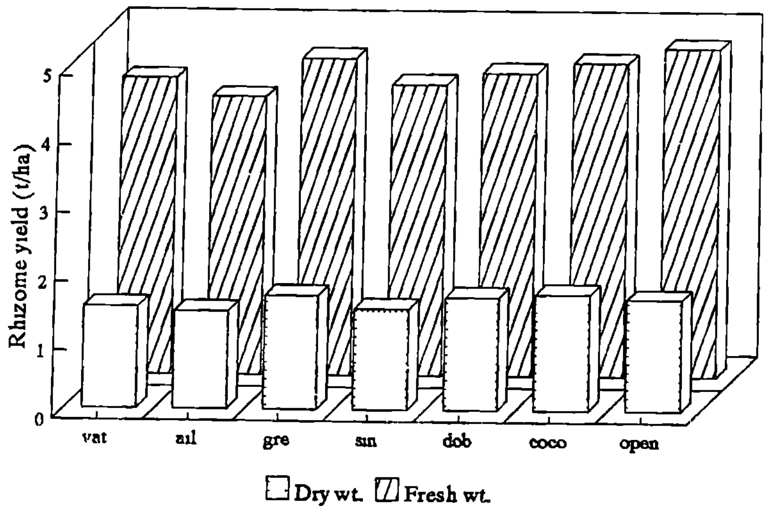
Contd

Tal le 12 cont d

Control						
1 Coco u kacholar	57[illegible]7 87	685 41	[illegible]	1887 94	4566 33	1695 91
2 Kacholam sole crop	7307 00	775 81	12588 67	2237 81	4788 67	1619 13
F es	NS	NS	NS	NS	NS	NS
SEm (±)	597 08	62 7	1063 42	232 19	793 48	185 68
Control vs rest						
F tes	NS	NS	<0 01	<0 01	NS	NS
Sem (±)	597 08	62 71	1063 42	232 19	793 48	185 68
CD (0 05)			3225 54	704 27		

NS Not s gnif can

Fig 9 Yield of kacholam grown in the agrisilvicultural system involving coconut and multipurpose trees



vat Vateria indica ail Ailanthus triphysa gre Grevillea robusta
sin Single row dob- Double row coco Coconut alone

Table 13 Combined effects of multipurpose tree species and planting geometry on rhizome yield

Fresh weight (kg ha ^{1}) at 150 DAP

	Vateria	*Ailanthus*	*Grevillea*
Single row	7944 00	7044 00	8877 33
Double row	7766 33	9766 33	8021 67

Control

Sole crop of kacholam	12588 67
Kacholam + coconut	11222 00
**CD for interaction	3225 54

Dry weight (kg ha ^{1}) at 150 DAP

	Vateria	*Ailanthus*	*Grevillea*
Single row	1570 49	1319 29	1571 87
Double row	1479 97	1831 71	1665 69

Control

Sole crop of kacholam	2237 81
Kacholam + coconut	1887 94
**CD for interaction	704 27

DAP days after kacholam planting

Kacholam sole crop also recorded the highest rhizome dry weight (2238 kg ha) It was significantly higher than vateria double hedge and ailanthus single hedge treatments All other treatments were statistically at par Planting geometry had no influence on biomass production in kacholam (Table 12)

Final rhizome yield of kacholam was not influenced by the experimental variables in any substantial manner However maximum fresh weight (5788 kg ha) and dry weight (1753 kg ha) were recorded for sole crop of kacholam and grevillea plots (1753 kg ha) respectively (Table 12 and 13)

Vateria plots and sole crop of kacholam resulted in the highest number of rhizomes (2 92) and length of rhizome (3 55 cm) respectively (Table 14)

4 4 4 Quality attributes of kacholam rhizome

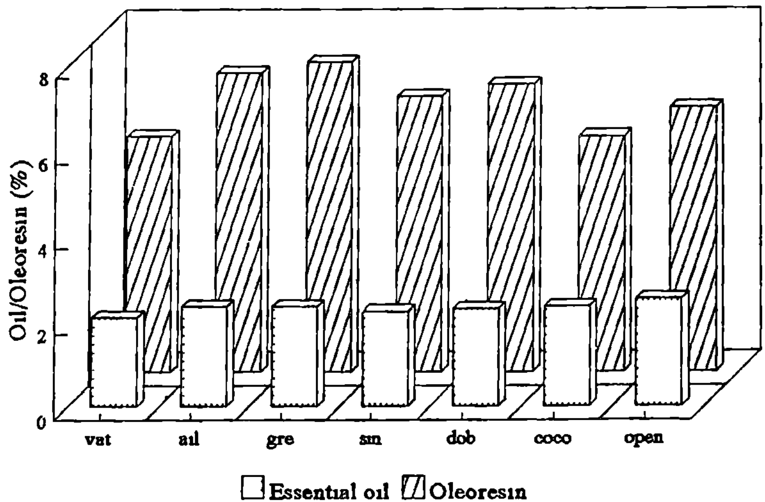
Essential oil content of dry kacholam rhizomes ranged from 2 0% to 2 5% (Table 14) But the differences were not statistically significant Oleoresin content of kacholam however was significantly influenced by the multipurpose tree species Vateria plots recorded maximum oleoresin content (7 25%) and grevillea the lowest (5 58%) Planting geometry did not affect either the essential oil or oleoresin contents significantly (Table 14 and Fig 10)

Table 14 Number of rhizomes per plant rhizome length and quality attributes of kacholam rhizomes at final harvest (210 days after planting)

Treatments	No of rhizome per plant	Length of rhizome per plant (cm)	Essential oil content (%)	Oleoresin content (%)
Species				
1 *Vateria indica*	2 92	3 43	2 08	5 58
2 *Ailanthus triphysa*	2 76	3 32	2 33	7 00
3 *Grevillea robusta*	2 70	3 22	2 33	7 25
F test	NS	NS	NS	<0 05
SEm (±)	0 1378	0 1602	0 1583	0 4551
CD (0 05)				1 3803
Planting geometry				
1 Single row	2 66	3 25	2 22	6 44
2 Double row	2 93	3 40	2 28	6 78
F test	NS	NS	NS	NS
SEm ( )	0 1125	0 1308	0 1298	0 3716
Species vs planting geometry				
F test	NS	NS	NS	NS
SEm (+)	0 1948	0 2265	0 2238	0 6436
Control				
1 Coconut + kacholam	2 74	3 30	2 33	5 50
2 Kacholam sole crop	2 91	3 55	2 50	6 17
F test	NS	NS	NS	NS
SEm (±)	0 1948	0 2265	0 2238	0 6436
Control vs rest				
F test	NS	NS	NS	NS
Sem ( )	0 1948	0 2265	0 2238	0 6436

NS Not significant

Fig 10 Quality of kacholam grown in the agrisilvicultural system involving coconut and multipurpose trees



vat Vateria indica ail Ailanthus triphysa gre Grevillea robusta
sin Single row dob Double row coco Coconut alone

4 4 5 Tissue nutrient levels of kacholam

4 4 5 1 Above ground portions

Foliar nitrogen content of kacholam did not manifest any major changes either with respect to the time after planting and/or the experimental variables (Table 15) It varied from 1 85 to 1 99% Regarding phosphorus comparisons involving sole crop with the intercropped plots yielded significant differences at both the stages of observations Intercropping in general favoured higher phosphorus levels in kacholam leaves Sole crop recorded the lowest value of 0 18% at 150 days after planting Higher phosphorus content was observed in the double row planting system of vateria (Table 16) Interaction between species and planting geometry was not significant

Potassium content of kacholam leaves did not show much seasonal variations (Table 15) Although at 90 days after planting multipurpose species and planting geometry did not influence foliar potassium content their interaction effects were significant Double row of ailanthus gave the highest K content (5 73%) Comparisons involving sole crop and rest were also statistically significant at latter stages of observations Sole crop of kacholam recorded the lowest content of potassium (4 37%) Profound variations in potassium content owing to multipurpose tree species was observed at 150 days after planting Sole crop of kacholam gave lowest potassium content of 2 17% significantly lower than all other treatments Species planting geometry interactions were also significant Intercropping in general and vateria in particular favoured higher concentration of K in the kacholam foliage (Table 15 and 16)

Table 15 Foliar nutrient content of kacholam plants at different stages of growth as influenced by multipurpose trees and planting geometry

Treatments	90 days after planting			150 days after planting		
	N (%)	P (%)	K (%)	N (%)	P (%)	K (%)
Species						
1 *Vateria indica*	1 92	0 36	5 34	1 91	0 35	5 50
2 *Ailanthus triphysa*	1 86	0 37	5 24	1 91	0 38	5 10
3 *Grevillea robusta*	1 93	0 35	4 90	1 94	0 36	4 77
F test	NS	NS	NS	NS	NS	< 0 05
SEm (±)	0 0256	0 0193	0 1253	0 0494	0 0264	0 1818
CD (0 05)						0 5514
Planting geometry						
1 Single row	1 91	0 36	5 09	1 88	0 34	5 07
2 Double row	1 91	0 37	5 23	1 95	0 38	5 18
F test	NS	NS	NS	NS	NS	NS
SEm (±)	0 0209	0 0158	0 1023	0 0404	0 0216	0 1484
CD (0 05)						
Species vs. planting geometry						
F test	NS	NS	< 0 01	NS	NS	NS
SEm (±)	0 0362	0 0273	0 1772	0 0699	0 0374	0 2571
CD (0 05)			0 5374			

Contd

Table 15 contd

Control						
1 Coconu + kacholam	1 88	0 35	4 71	1 85	0 32	3 85
2 Kacholam alone	1 94	0 27	4 35	1 99	0 18	2 17
F test	NS	NS	NS	NS	< 0 05	< 0 01
SEm (±)	0 0362	0 0273	0 1772	0 0699	0 0374	0 2571
CD (0 05)					0 1134	0 7798
Control vs. rest						
F test	NS	< 0 05	< 0 01	NS	< 0 01	< 0 01
SEm (±)	0 0362	0 0273	0 1772	0 0699	0 0374	0 2571
CD (0 05)		0 0829	0 5374		0 1134	0 7798

NS Not significant

Table 16 Combined effects of multipurpose tree species and planting geometry on the foliar nutrient content of kacholam

P% at 90 DAP

	Vateria	*Ailanthus*	*Grevillea*
Single row	0 33	0 38	0 36
Double row	0 39	0 36	0 35

Control

Sole crop of Kacholam 0 27
Kacholam + coconut 3 07

* CD for interaction 0 0829

K% at 90 DAP

	Vateria	*Ailanthus*	*Grevillea*
Single row	5 29	4 75	5 23
Double row	5 38	5 73	4 57

Control

Sole crop of Kacholam 9 19
Kacholam + coconut 9 24

**CD for interaction 0 5374

P% at 150 DAP

	Vateria	*Ailanthus*	*Grevillea*
Single row	0 28	0 38	0 36
Double row	0 42	0 37	0 35

Control

Sole crop of Kacholam 0 18
Kacholam + coconut 0 32

** CD for interaction 0 1134

K% at 150 DAP

	Vateria	*Ailanthus*	*Grevillea*
Single row	5 58	5 05	4 57
Double row	5 42	5 15	4 97

Control

Sole crop of Kacholam 2 17
Kacholam + coconut 3 85

** CD for interaction 0 7798

DAP days after kacholam planting

4 4 5 2 Below ground portions

Nitrogen content of kacholam rhizomes increased with age of plants Initially till about 150 days after planting the rhizome nitrogen concentration was in the range of 0 71 to 0 80% of the dry weight It however increased to about 1 4% at the time of harvesting Experimental variables did not influence this parameter in a significant manner (Table 17) except for the sole crop vs intercropped situations at 150 days after planting Foliar nitrogen levels were significantly lower in all inter cropping situations evaluated

Phosphorus content of rhizomes did not show any perceptible seasonal variations Regarding the experimental variables double hedge system of planting was superior to that of single hedge (Table 17) The species vs planting geometry interaction was significant with vateria double hedge system registering the highest value (Table 18)

With regard to seasonal variation potassium levels in kacholam rhizomes followed a divergent trend from that of nitrogen Potassium concentration peaked during the initial stages (90 days after planting) indicating a subsequent decline (Table 17) In general intercropped kacholam absorbed higher quantities of potassium than sole crop This however was found to be dependent on the planting geometry of the multipurpose tree component Though the effect of species was not significant species planting geometry interaction was significant (Table 18) Single and double rows of vateria recorded the lowest (1 24%) and highest potassium contents (1 68%) respectively

Table 17 Nutrient content (N P K) of kacholam rhizome as influenced by mutipurpose trees and planting geometry at diferent stages of growth

Treatments	90 days after planting			150 days after planting			210 Days after planting		
	N (%)	P (%)	K (%)	N (%)	P (%)	K (%)	N (%)	P (%)	K (%)
Species									
1 *Vateria indica*	0 75	0 25	3 01	0 79	0 23	1 34	1 56	0 23	1 46
2 *Ailanthus triphysa*	0 74	0 25	3 00	0 78	0 22	1 56	1 36	0 26	1 56
3 *Grevillea robusta*	0 75	0 26	2 92	0 77	0 22	1 30	1 36	0 25	1 48
F test	NS	NS	NS	NS	NS	NS	NS	NS	NS
SEm (±)	0 0967	0 0152	0 2144	0 0673	0 0135	0 0711	0 0621	0 0090	0 0540
CD (0 05)									
Planting geometry									
1 Single row	0 76	0 26	3 09	0 76	0 23	1 44	1 44	0 22	1 41
2 Double row	0 73	0 25	2 87	0 80	0 22	1 37	1 41	0 27	1 58
F test	NS	NS	NS	NS	NS	NS	NS	< 0 01	< 0 05
SEm (±)	0 0790	0 0124	0 1751	0 0549	0 0110	0 0580	0 0507	0 0073	0 0441
CD (0 05)								0 0222	0 1337
Species vs. planting geometry									
F test	NS	NS	NS	NS	NS	NS	NS	< 0 01	< 0 05
SEm (±)	0 1368	0 0215	0 3032	0 0952	0 0191	0 1005	0 0879	0 0127	0 0763
CD (0 05)								0 0385	0 2316

Contd

Table 17 contd

Control									
1 Coconut + kacholam	0 78	0 26	3 39	0 71	0 22	1 38	1 39	0 26	1 61
2 Kacholam alone	0 77	0 24	3 13	0 85	0 17	1 07	1 34	0 23	1 41
F test	NS	NS	NS	< 0 05	NS	< 0 05	NS	NS	NS
SEm (±)	0 1368	0 0215	0 3032	0 0952	0 0191	0 1005	0 0879	0 0127	0 0763
CD (0 05)				0 1281		0 3049			
Control vs. rest									
F test	NS	NS	NS	NS	NS	< 0 05	NS	NS	NS
SEm (±)	0 1368	0 0215	0 3032	0 0952	0 0191	0 1005	0 0879	0 0127	0 0763
CD (0 05)						0 3049			

NS Not significant

Table 18 Combined effects of multipurpose tree species and planting geometry on rhizome nutrient contents

K% at 150 DAP

	Vateria	*Ailanthus*	*Grevillea*
Single row	1 28	1 65	1 38
Double row	1 40	1 47	1 23

Control

Sole crop of kacholam 1 07
Kacholam + coconut 1 38

**CD for interaction 0 3049

P% at 210 DAP

	Vateria	*Ailanthus*	*Grevillea*
Single row	0 18	0 25	0 24
Double row	0 28	0 27	0 26

Control

Sole crop of kacholam 0 23
Kacholam + coconut 0 26

**CD for interaction 0 0385

K% at 210 DAP

	Vateria	*Ailanthus*	*Grevillea*
Single row	1 24	1 61	1 39
Double row	1 68	1 51	1 56

Control

Sole crop of kacholam 1 41
Kacholam + coconut 1 61

** CD for interaction 0 2316

DAP days after kacholam planting

4 5 Canopy light interception

The proportion of incoming solar radiation intercepted by the multipurpose tree crowns ranged from 55% in coconut monoculture to 82 5% in ailanthus double row Coconut monoculture intercepted the lowest amount of incoming solar radiation (Table 19) Among the three multipurpose tree species interception was highest for ailanthus at both heights whereas lowest interception was recorded for vateria at 0 5 m height (74%) and for grevillea at 1 5 m height (72%) Among the two planting geometries double hedge system consistently intercepted more light However their interactions were not significant (Tables 19 and 20 Fig 11 and 12)

4 6 Root interactions

4 6 1 Foliar P recovery by coconut

In general ^{2}P uptake by coconut palms increased from 15 to 30 days after application and then decreased (Table 21) Although comparisons involving coconut monoculture and the intercrop plots did not yield statistically significant differences multipurpose tree species exerted a profound influence in this respect Grevillea plots showed consistently higher uptake of the radio label and ailanthus the lowest value As regards the planting geometry the differences were significant only at 30 days after application of labelled phosphorus Nevertheless single row planting system of multipurpose trees resulted in greater absorption of applied ^{2}P by coconut at all stages of observations Interaction effects were also not statistically significant

Table 19 Percentage light interception by tree canopy as affected by different multipurpose trees and planting geometries

Treatments	0 5 m height (%)	1 5 m height (%)
Species		
1 *Vateria indica*	73 86	74 09
2 *Ailanthus triphysa*	81 92	77 85
3 *Grevillea robusta*	76 63	71 55
F test	< 0 05	NS
SEm ( )	1 8896	1 8668
CD (0 05)	5 82	
Planting geometry		
1 Single row	75 81	73 32
2 Double row	79 13	75 67
F test	NS	NS
SEm ( )	1 5428	1 5242
Species vs planting geometry		
F test	NS	NS
SEm ( )	2 6723	2 6401
Control (coconut monoculture)	55 08	54 80
Control vs rest		
F test	< 0 01	< 0 01
SEm ( )	2 6723	2 6401
CD (0 05)	8 23	8 14

NS Not significant

Table 20 Combined effects of multipurpose tree species and planting geometry on percentage light interception by tree canopy in the agrisilviculture system

0 5 m height

	Vateria	*Ailanthus*	*Grevillea*
Single row	72 01	81 28	74 15
Double row	75 71	82 55	79 11

Control

Coconut monoculture 55 08

**CD for interaction 8 23

1 5 m height

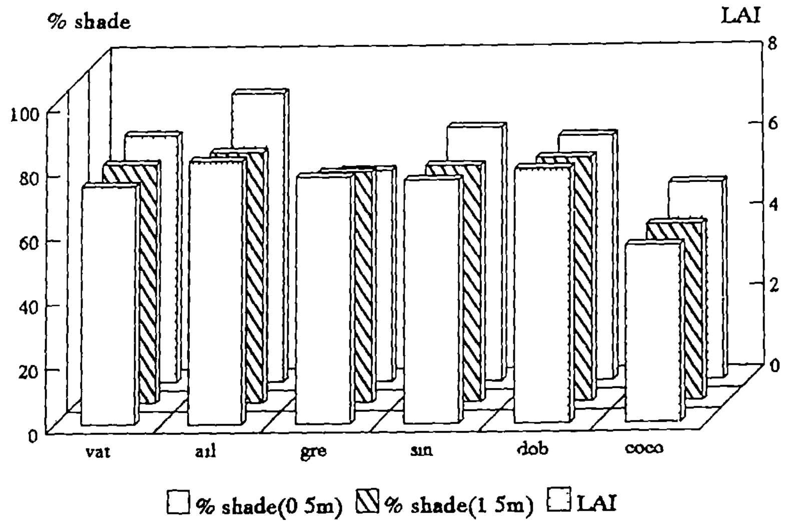
	Vateria	*Ailanthus*	*Grevillea*
Single row	72 55	77 22	70 20
Double row	75 62	78 48	72 89

Control

Coconut monoculture 54 80

**CD for interaction 8 14

Fig 11 Leaf area ındex and lıght ınterception in the agrisilvıcultural system



vat Vaterıa ındıca ail Aılanthus trıphysa gre Grevıllea robusta
sın Sıngle row dob- Double row coco Coconut alone

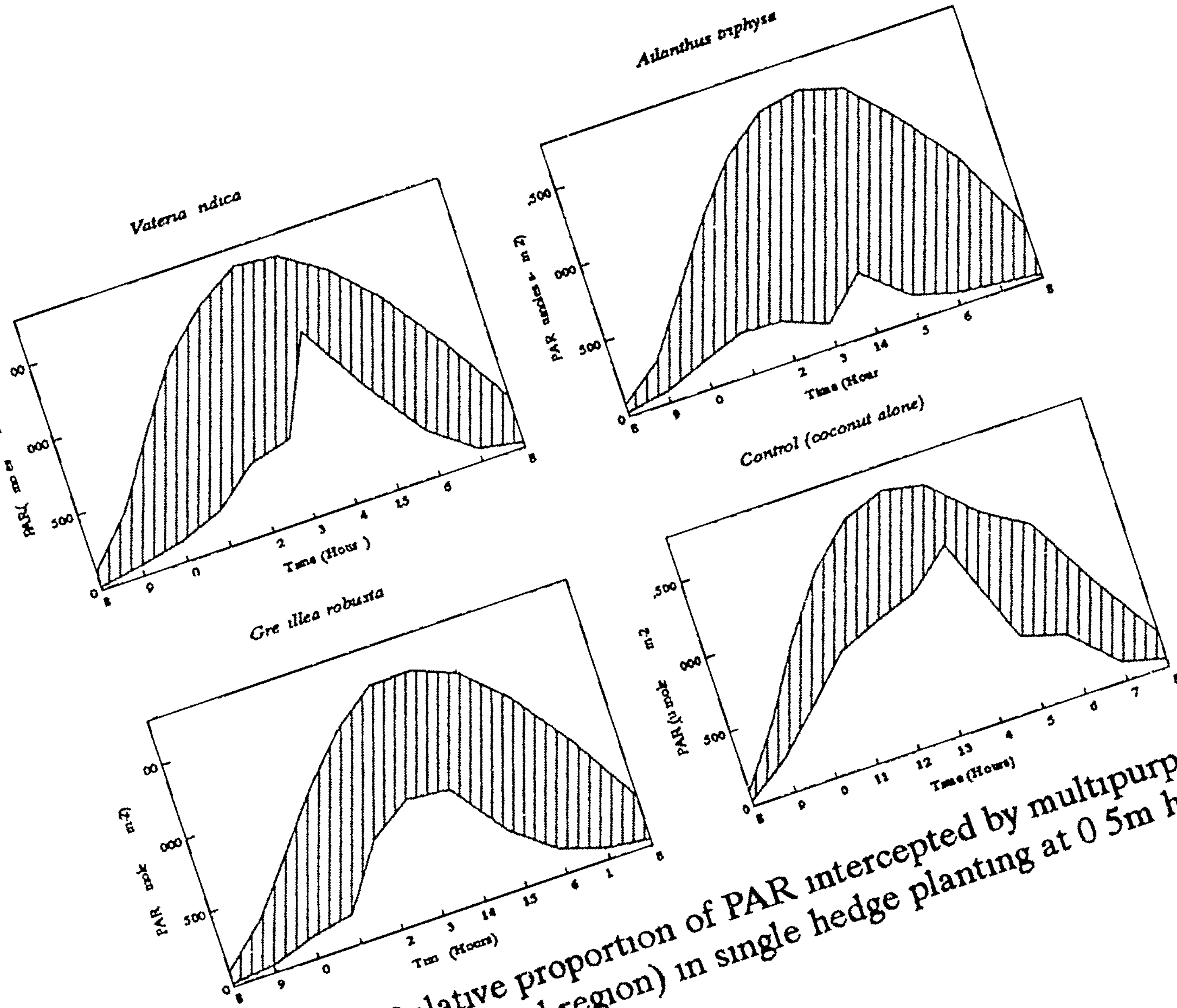


Fig 12a Relative proportion of PAR intercepted by multipurpose tree canopy (shaded region) in single hedge planting at 0 5m height

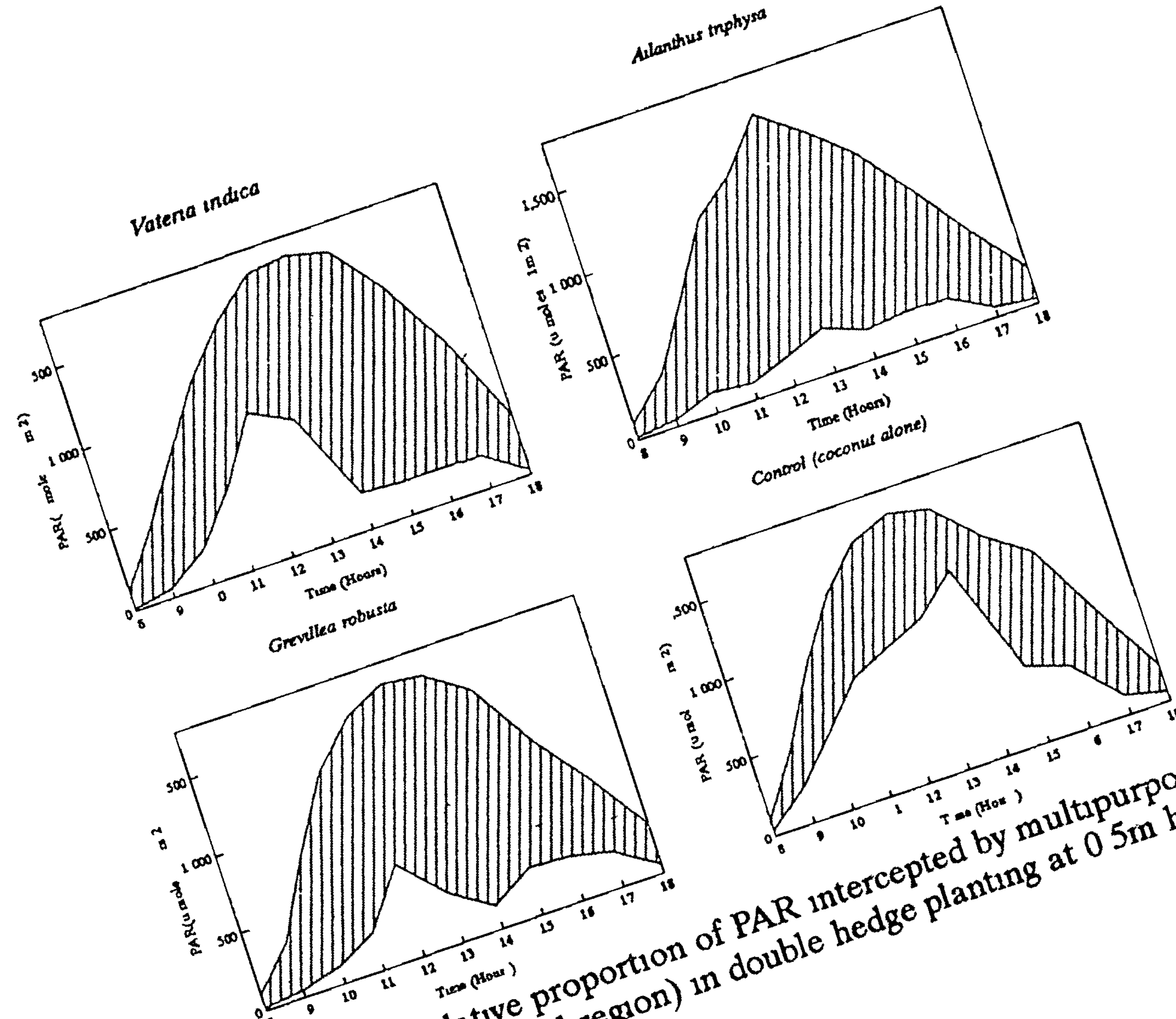


Fig 12b Relative proportion of PAR intercepted by multipurpose tree canopy (shaded region) in double hedge planting at 0 5m height

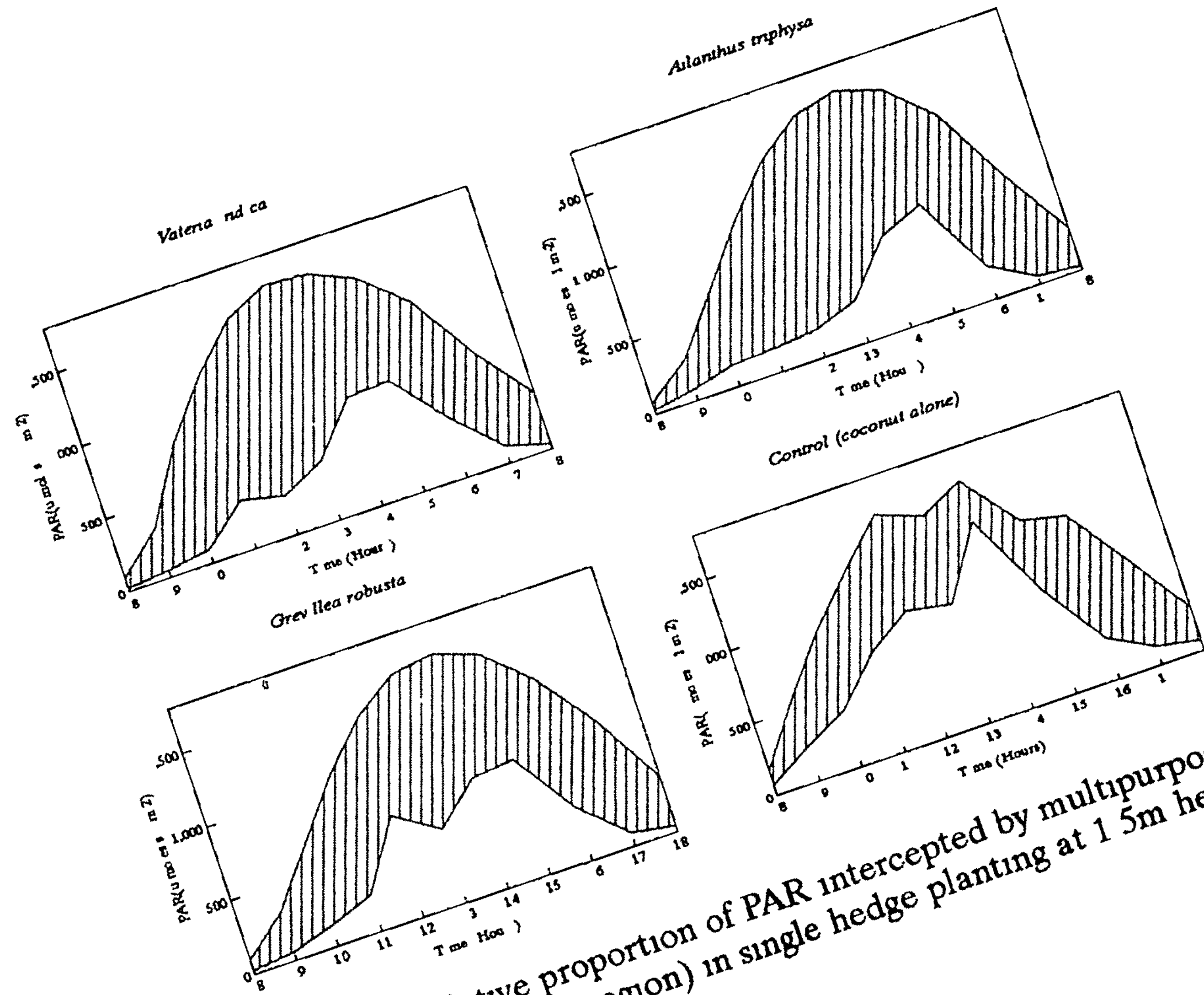


Fig 12c Relative proportion of PAR intercepted by multipurpose tree canopy (shaded region) in single hedge planting at 1 5m height

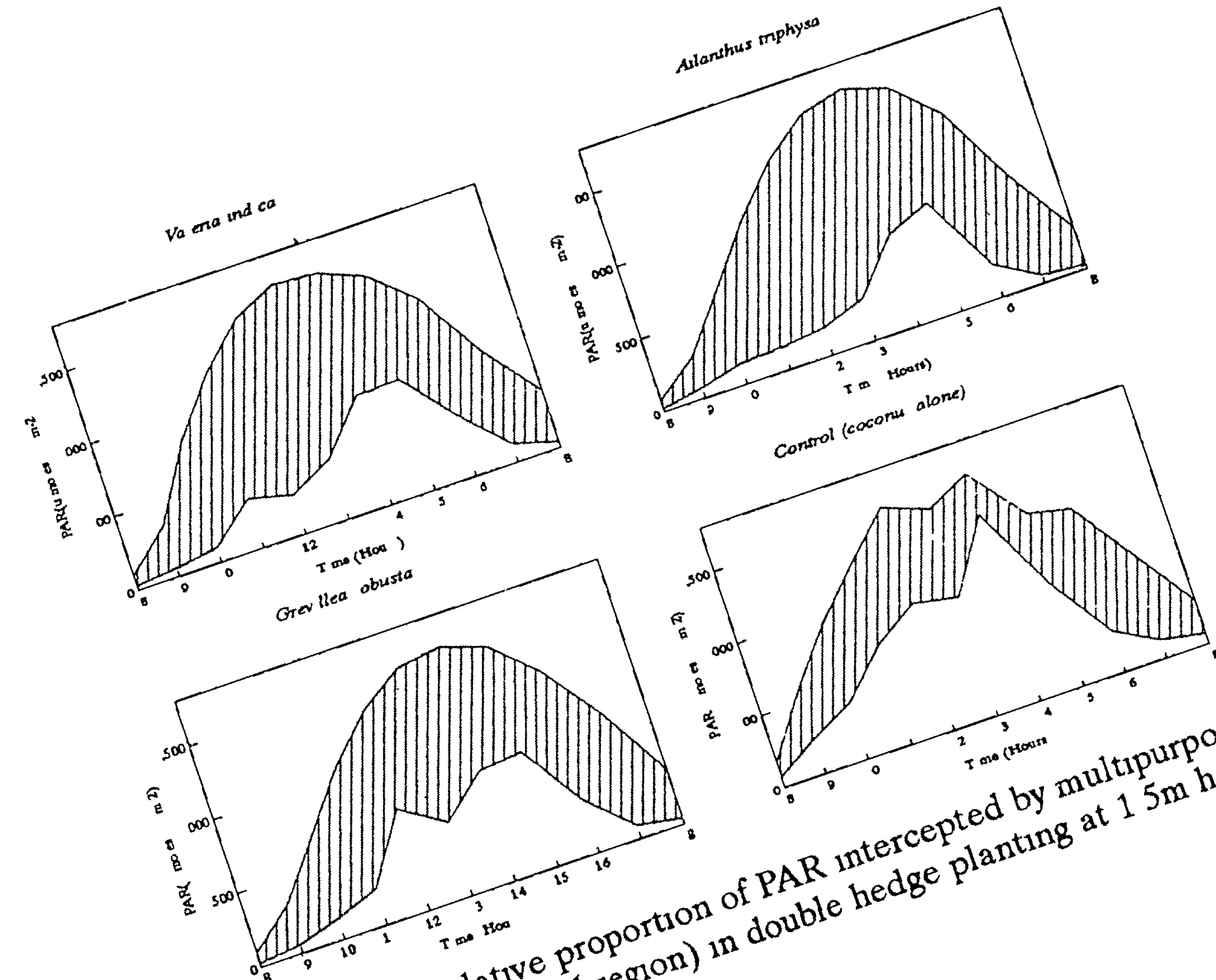


Fig 12d Relative proportion of PAR intercepted by multipurpose tree canopy (shaded region) in double hedge planting at 1 5m height

Table 21 ^{32}P uptake (cpm) by coconut as affected by multipurpose trees and planting geometry {$\log_{10}(x+1)$ transformed values}

Treatments	15 days after application	30 days after application	45 days after application
Species			
1 *Vateria indica*	1 75 (56 23)	2 14 (138 04)	1 90 (79 43)
2 *Ailanthus triphysa*	1 71 (51 29)	2 06 (114 82)	1 85 (70 79)
3 *Grevillea robusta*	2 12 (131 83)	2 39 (245 47)	2 12 (131 83)
F test	<0 05	<0 01	<0 05
SEm (±)	0 0873	0 0623	0 0691
CD (0 05)	0 2689	0 1918	0 2128
Planting geometry			
1 Single row	1 97 (93 33)	2 28 (190 55)	2 01 (102 33)
2 Double row	1 75 (55 23)	2 11 (128 82)	1 91 (81 28)
F test	NS	<0 05	NS
SEm (±)	0 0712	0 0508	0 0564
CD (0 05)		0 1506	
Species vs plant geometry			
F test	NS	NS	NS
SEm (±)	0 1234	0 0880	0 0977
Control (without multipurpose trees)	1 94 (87 1)	2 25 (177 83)	2 11 (128 82)
Control vs rest			
F test	NS	NS	NS
SEm (±)	0 1234	0 0880	0 0977
CD (0 05)	0 3802	0 2713	0 3009

NS Not significant

Figures in parenthesis indicate retransformed values

4 6 2 Foliar ^{32}P recovery by multipurpose trees

Data presented in Table 22 clearly suggest that the multipurpose trees neighbouring the treated coconut palm absorbed a substantial portion of the radio label Species influences were pronounced in this respect (at 45 days after application) Vateria recorded higher foliar ^{32}P activity at this stage although initially ailanthus showed greater ^{3} P uptake

Planting geometry and the combined effects of species and planting geometry were also significant Single row planting (with 16 sampled trees) had greater recovery as compared to double row (with 20 sampled trees) initially However the trend was reversed subsequently Among the combinations single row of grevillea and double row of ailanthus exhibited higher absorption while double row of grevillea accounted for the lowest figure at 15 days after application (Table 23)

At 45 days after application double row planting system showed greater ^{32}P recovery as compared to single row planting Among the different treatment combinations double row of vateria and ailanthus exhibited higher absorption of ^{32}P (Table 23)

4 6 3 Foliar recovery of ^{32}P by neighbouring multipurpose trees as a function of distance from the treated coconut palm

P recovery by the neighbourhood trees did not show any consistent pattern especially for the double row planting system In the single row planting system a

Table 22 ^{32}P recovery (cpm) by multipurpose trees (sum of the ^{32}P counts from all trees* surrounding the coconut basin [log $_0$(x+1) transformed values])

Treatments	15 days after appl cat on	30 days after application	45 days after appl cat on
Species			
1 *Vateria indica*	2 07 (117 49)	2 54 (346 74)	1 60 (9 81)
2 *Ailanthus tripl ysa*	2 09 (123 03)	2 70 (501 19)	? 44 (279 42)
3 *Grevillea robusta*	1 91 (81 28)	2 46 (288 40)	2 26 (181 97)
F test	NS	NS	<0 01
SEm (±)	0 0884	0 1382	0 2072
CD (0 05)			0 6529
Planting geometry			
1 S ngle row	2 16 (144 54)	2 56 (366 08)	1 58 (38 02)
2 Double row	1 89 (77 62)	2 57 (371 54)	2 63 (426 58)
F test	<0 05	NS	<0 01
SEm (±)	0 0722	0 1128	0 1691
CD (0 05)	0 2275		0 5328
Species vs plant geometry			
F test	<0 01	NS	<0 01
SEm (±)	0 1250	0 1954	0 2930
CD (0 05)	0 3939		0 9232

* Fol ar P act v y of multipurpose trees n each plot s worked out as the sum of activ ties for all trees sampled (In s ngle row 16 trees and in double row 20 trees)

D fference in the number s due to sampl ng density (See Fig 3)

F gures n parenthes s nd cate retransformed values

Table 23 Combined effects of multipurpose tree species and planting geometry on foliage ^{32}P activity of multipurpose tree (log_{10} (x+1) transformed values (cpm) with retransformed values in parentheses

^{32}P activity of multipurpose tree foliage at 15 days after application

	Vateria	*Ailanthus*	*Grevillea*
Single row	2 287 (192 64)	1 763 (56 94)	2 424 (264 46)
Double row	1 845 (68 98)	2 424 (264 46)	1 385 (23 27)

** CD for interaction 0 3939

^{32}P activity of multipurpose tree foliage at 45 days after application

	Vateria	*Ailanthus*	*Grevillea*
Single row	0 422 (1 64)	2 088 (121 46)	2 217 (163 82)
Double row	2 783 (605 74)	2 786 (609 94)	2 310 (203 17)

** CD for interaction 0 9232

total of 16 trees adjacent to applied coconut was grouped into three sampling units based on its distance from the base of coconut (3 75 m to 5 40 m) In the case of double row planting a total of 20 trees adjacent to applied palm was grouped into six sampling groups based on its distance from the palm (3 0 m to 5 6 m) The comparisons however did not result in any predictable pattern (Table 24)

4 6 4 Foliar ^{32}P recovery by kacholam

Recovery of the ^{32}P label by intercropped kacholam was strongly influenced by the multipurpose tree component at 15 days after application (Table 25) Grevillea favoured greater uptake of ^{32}P by kacholam just as it stimulated ^{32}P recovery by the coconut palms However the results at later stages of observation were inconsistent and also not statistically significant

Regarding planting geometry of multipurpose trees the double row system favoured higher uptake of ^{32}P by the herbaceous crop component with significantly higher values at 45 days after application Furthermore multipurpose tree species vs planting geometry interaction was significant at 15 days after application (Table 26) While the double row planting system resulted in greater foliar ^{32}P activity of kacholam with grevillea and ailanthus it was the single row planting system that favoured higher recovery of ^{32}P in kacholam when grown in association with vateria (Table 26) Differences between sole crop of kacholam and the rest were not statistically significant

Table 24 Recovery of soil applied ^{32}P (in coconut basin) by multipurpose trees at different lateral distances from the treated coconut palm ($\log_0 (x+1)$ transformed values with percentage of total in parentheses

	15 day after application	30 days after application	45 days after application
Vateria indica			
Single row			
S (3 75 m)	47 33 (24 17)	221 60 (64 39)	5 81 (100 00)
S_2 (4 35 m)	3 25 (1 66)	56 96 (16 55)	
S (5 40 m)	145 28 (74 18)	65 60 (19 06)	
Total	195 86	344 16	5 81
Ailanthus triphysa			
Single row			
S (3 75 m)	28 36 (58 53)	98 78 (21 27)	108 67 (59 90)
S (4 35 m)		261 07 (56 49)	18 59 (10 25)
S (5 40 m)	20 09 (41 47)	102 80 (22 24)	54 17 (29 86)
Total	48 45	462 15	181 43
Grevillea robusta			
Single row			
S (3 75 m)	33 07 (17 93)	44 57 (9 29)	78 36 (47 45)
S (4 35 m)	151 36 (82 07)	414 16 (86 36)	55 39 (33 54)
S (5 40 m)		20 81 (4 34)	31 39 (19 01)
Total	184 43	479 55	165 13
Vateria indica			
Double row			
S (3 00 m)		154 72 (42 38)	39 66 (5 98)
S (4 00 m)	4 87 (9 40)	15 82 (4 33)	31 87 (4 80)
S (3 70 m)	25 06 (48 38)	9 75 (2 67)	592 00 (89 22)
S (4 45 m)		84 60 (23 17)	
S (5 00 m)		56 52 (15 48)	
S_6 (5 60 m)	21 87 (42 22)	43 71 (11 97)	
Total	51 80	365 18	663 53

Contd

Table 24 contd

Ailanthus triphysa			
Double row			
S (3 00 m)	4 21 (2 28)	169 17 (23 29)	159 50 (20 52)
S (4 00 m)		29 00 (3 99)	28 57 (3 68)
S (3 70 m)	1 63 (0 88)	98 68 (13 59)	39 43 (5 07)
S (4 45 m)	11 67 (6 33)	293 91 (40 46)	506 53 (65 18)
S (5 00 m)	73 47 (39 87)	50 03 (6 89)	35 40 (4 56)
S (5 60 m)	93 29 (50 63)	85 56 (11 78)	7 69 (0 99)
Total	184 27	726 35	777 12
Grevillea robusta			
Double row			
S (3 00 m)	4 13 (17 04)	8 72 (2 61)	22 10 (10 65)
S (4 00 m)		17 55 (5 25	41 57 (20 03)
S_3 (3 70 m)		27 52 (8 23)	14 83 (7 15)
S (4 45 m)	5 03 (20 76)	92 75 (27 72)	9 11 (4 39)
S (5 00 m)	15 07 (62 20)	47 89 (14 39)	64 39 (31 03)
S (5 60 m)		140 13 (41 88)	55 33 (26 66)
Total	24 23	334 56	207 51

S to S nd ca e d a ce of the tree fro ba e of tl e coconut

Table 25 Recovery of ^{32}P (cpm) applied in the coconut basin by the kacholam as affected by multipurpose trees and planting geometry (log $_0$ (x+1) transformed values}

Treatments	15 days after application	30 days after application	45 days after application
Species			
1 *Vateria indica*	0 79 (6 17)	1 48 (30 20)	1 34 (21 88)
2 *Ailanthus triphysa*	1 21 (6 22)	1 60 (39 81)	0 77 (5 89)
3 *Grevillea robusta*	1 69 (48 97)	1 52 (33 11)	0 97 (9 33)
F test	<0 01	NS	NS
SEm ( )	0 1314	0 0549	0 653
CD (0 05)	0 4047		
Planting geometry			
1 Single row	1 34 (21 88)	1 50 (31 62)	0 66 (4 57)
2 Double row	1 12 (13 18)	1 57 (37 15)	1 40 (25 12)
F test	NS	NS	<0 01
SEm ( )	0 1073	0 0448	0 1350
CD (0 05)			0 4159
Species vs plant geometry			
F test	<0 01)	NS	NS
SEm (±)	0 1858	0 0776	0 2338
CD (0 05)	0 5724		
Control (without multipurpose trees)	1 28 (19 05)	1 48 (30 20)	1 39 (24 55)
Control vs rest			
F test	NS	NS	NS
SEm (±)	0 1858	0 0776	0 2338

NS Not significant

Figures in parentheses indicate retransformed values

Table 26 Combined effects of multipurpose tree species and planting geometry on foliage ^{32}P activity of kacholam ($\log_{10}(x+1)$ transformed values with retransformed values in parentheses

Foliar ^{32}P activity in kacholam at 15 days after application

	Vateria	*Ailanthus*	*Grevillea*
Single row	1 30 (18 95)	1 15 (13 13)	1 56 (35 31)
Double row	0 29 (0 95)	1 26 (17 20)	1 81 (63 57)

Control

Coconut + Kacholam 1 28(18 05)

**CD for interaction 0 57

4 6 5 Coconut root count

Coconut roots exhibited remarkable propensity to forage from the kacholam beds However the experimental variables did not reveal any statistically significant variations in this respect except for the higher order roots and species planting geometry interactions for the first order roots at 3 25 m away from the base of the coconut palm (Table 27 and 28)

At a distance of 3 25 m from the palm (corresponding to 1 00 m in the bed from the end facing coconut palm) double row planting of ailanthus had a higher number of first order roots (Table 28) As regards to the higher order roots ailanthus resulted in higher activity of roots in kacholam beds and vateria the lowest

4 7 Soil chemical characteristics

A comparison of the initial (pre kacholam) physico chemical properties of the soil between the control plots (kacholam sole crop) and the rest revealed marked variations in respect of soil potassium and pH (Table 29 and 30) Intercropped plots in general recorded higher levels of soil potassium Soil pH also was lower in the sole crop plots

Soil analysis after the harvest of kacholam crop revealed marginally lower soil nitrogen levels in the intercropped plots (Table 31) Soil potassium level continued to register higher values in the intercropped plots Regarding the multipurpose tree species grevillea plots recorded significantly higher soil organic carbon content Similarly double row planting system resulted in significantly higher soil phosphorus content

Table 27 Density of coconut roots on kacholam beds as influenced by multipurpose trees and planting geometry (log_{10} x+1) transformed value of number of roots per 100 m^2)

Treatments	2.5 m from the base of coconut		3.25 m from the base of coconut	
	First order roots Dia (>0.5 cm)	Higher order roots Dia (<0.5 cm)	First order roots Dia (>0.5 cm)	Higher order roots Dia (<0.5 cm)
Species				
1 *Vateria indica*	0.34 (1.19)	0.71 (4.13)	0.31 (1.04)	0.65 (3.47)
2 *Ailanthus triphysa*	0.42 (1.63)	0.70 (4.01)	0.42 (1.63)	0.75 (4.62)
3 *Grevillea robusta*	0.38 (1.40)	0.70 (4.01)	0.41 (1.57)	0.70 (4.01)
F test	NS	NS	<0.05	NS
SEm (±)	0.0383	0.0467	0.0288	0.0375
CD (0.05)			0.0874	
Planting geometry				
1 Single row	0.42 (1.63)	0.71 (4.13)	0.42 (1.63)	0.68 (3.79)
2 Double row	0.34 (1.19)	0.70 (4.01)	0.35 (1.29)	0.72 (4.25)
F test	NS	NS	NS	NS
SEm (±)	0.0313	0.0381	0.0235	0.0306
Species vs planting geometry				
F test	NS	NS	NS	<0.01
SEm (±)	0.0542	0.0660	0.0408	0.0530
CD (0.05)				0.1607

Contd

Table 27 contd

Controls				
1 Coconut + kacholam	0 36 (1 29)	0 62 (3 17)	0 28 (0 91)	0 69 (3 90)
2 Coconut monoculture	0 33 (1 14	0 54 (2 47)	0 30 (1 04)	0 58 (2 80)
F test	NS	NS	NS	NS
SEm (±)	0 0542	0 0660	0 0408	0 0530
Control vs rest				
F test	NS	NS	<0 05	NS
SEm (±)	0 0542	0 0660	0 0408	0 0530
CD (0 05)			0 1237	

Figures in parentheses indicate retransformed values
NS Not significant

Table 28 Combined effects of multipurpose tree species and planting geometry on coconut root density on kacholam beds $\log_{0} x+1$ transformed value of number of roots per 100 m^2 with retransformed values in parentheses

No of first order roots (>0 5 cm) at 3 25 m from the palm

	Vateria	*Ailanthus*	*Grevillea*
Single row	0 35 (1 24)	0 47 (1 95)	0 43 (1 69)
Double row	0 28 (0 91)	0 37 (1 34)	0 40 (1 51)

Control

Coconut and kacholam	0 28(0 91)
Coconut without agrisilviculture	0 03(1 00)
**CD for interaction	0 0408

No of higher order roots (<0 5 cm) at 3 25 m from the palm

	Vateria	*Ailanthus*	*Grevillea*
Single row	0 69 (3 90)	0 60 (2 98)	0 74 (4 50)
Double row	0 62 (3 17)	0 89 (6 76)	0 66 (3 57)

Control

Coconut and kacholam	0 69(3 90)
Coconut without agrisilviculture	0 582(2 80)
**CD for interaction	0 1607

Values in parentheses indicate retransformed values

Table 29 Soil chemical properties as influenced by multipurpose trees and planting geometry before kacholam cultivation (May 1995)

Treatment	OC (%)	N (%)	P(ppm)	K(ppm)	pH	EC
Species						
1 *Vateria indica*	2.07	0.17	17.37	115.11	5.31	100.40
2 *Ailanthus triphysa*	1.94	0.17	15.92	136.98	5.44	102.43
3 *Grevillea robusta*	2.16	0.18	14.50	126.11	5.47	103.78
F test	NS	NS	< 0.05	NS	NS	NS
SEm (±)	0.1002	0.0148	0.6027	10.8960	0.0525	9.0110
CD (0.05)			1.8442			
Planting geometry						
1 Single row	2.05	0.17	15.28	123.35	5.45	104.27
2 Double row	2.07	0.17	16.58	126.78	5.37	100.14
F test	NS	NS	NS	NS	NS	NS
SEm (±)	0.0819	0.0121	0.4921	8.8967	0.0429	7.3575
Species vs planting geometry						
F test	NS	NS	NS	NS	NS	NS
SEm (±)	0.1418	0.0209	0.8523	15.4095	0.0742	12.7435
Control						
1 Coconut + kacholam	2.20	0.20	15.83	110.42	5.32	88.70
2 Kacholam sole crop	2.29	0.20	14.33	59.37	5.19	92.90
F test	NS	NS	NS	< 0.05	NS	NS
SEm (±)	0.1418	0.0209	0.8523	15.4095	0.0742	12.7435
CD (0.05)				46.74		
Control vs rest						
F test	NS	NS	NS	< 0.01	< 0.05	NS
SEm (±)	0.1418	0.0209	0.8523	15.4095	0.0742	12.7435
CD (0.05)				46.74	0.2252	

NS Not significant

Table 30 Combined effects of multipurpose tree species and planting geometry on soil chemical properties

K(ppm) before cultivation

	Vateria	*Ailanthus*	*Grevillea*
Single row	97 92	136 46	141 67
Double row	132 29	137 50	110 54

Control

Sole crop of kacholam 59 37
Kacholam + coconut 110 42

** CD for interaction 46 74

pH (before cultivation)

	Vateria	*Ailanthus*	*Grevillea*
Single row	5 37	5 53	5 44
Double row	5 26	5 36	5 49

Control

Sole crop of kacholam 5 19
Kacholam + coconut 5 32

* CD for interaction 0 2252

N(%) after cultivation

	Vateria	*Ailanthus*	*Grevillea*
Single row	0 18	0 18	0 17
Double row	0 15	0 17	0 18

Control

Sole crop of kacholam 0 20
Kacholam + coconut 0 19

* CD for interaction 0 0360

K(ppm) after cultivation

	Vateria	*Ailanthus*	*Grevillea*
Single row	86 67	121 67	90 83
Double row	105 83	109 17	78 33

Control

Sole crop of kacholam 48 33
Kacholam + coconut 99 17

**CD for interaction 36 79

Table 31 Soil chemical properties as influenced by multipurpose trees and planting geometry after kacholam cultivation (March 1996)

Treatments	OC (%)	N (%)	P(ppm)	K(ppm)	pH	EC
Species						
1 *Vateria indica*	1 43	0 17	14 53	101 25	5 43	60 07
2 *Ailanthus triphysa*	1 60	0 18	13 82	115 42	5 51	74 65
3 *Grevillea robusta*	1 94	0 18	13 07	84 58	5 43	79 65
F test	<0 05	NS	NS	NS	NS	NS
SEm (±)	0 1183	0 0084	0 6539	8 5764	0 0361	6 5648
CD (0 05)	0 3587					
Planting geometry						
1 Single row	1 62	0 18	12 80	103 06	5 48	75 53
2 Double row	1 70	0 17	14 81	97 78	5 44	67 38
F test	NS	NS	<0 01	NS	NS	NS
SEm (±)	0 0966	0 0069	0 5339	7 0026	0 0295	5 3601
CD (0 05)			1 6195			
Species vs planting geometry						
F test	NS	NS	NS	NS	NS	NS
SEm (±)	0 1672	0 0119	0 9248	12 1289	0 0510	9 2840
Control						
1 Coconut + kacholam	1 58	0 19	12 80	99 17	5 52	81 70
2 Kacholam sole crop	1 75	0 20	14 81	48 33	5 33	83 27
F test	NS	NS	NS	<0 01	<0 05	NS
SEm (±)	0 1672	0 0119	0 9248	12 1289	0 0510	9 2840
CD (0 05)				36 79	0 1548	
Control vs rest						
F test	NS	<0 05	NS	<0 01	NS	NS
SEm (±)	0 1672	0 0119	0 9248	12 1289	0 0510	9 2840
CD (0 05)		0 0360		36 79		

NS Not significant

Discussion

DISCUSSION

5 1 Growth and productivity of coconut

Data on nut yield (Table 1 and Fig 6) indicate that coconut productivity is not adversely affected by planting multipurpose trees in the interspaces until about 50 months of age More importantly a pronounced increase in nut yield also was observed in the last few years starting from 1991 92 It may be seen that the palms started bearing in 1991 and presumably they are yet to reach yield stabilization Hence the increase in yield observed at this stage cannot be attributed to a positive influence of the multipurpose trees However if the observed yield advantages persist over a longer period of time then it can probably be related to such a multipurpose tree effect

Furthermore a longer period of time may be necessary for the multipurpose trees to manifest any possible negative influences in this regard Admittedly the onset of interspecific competition is a function of crown and root architecture which in turn are dependent on the age of trees During the initial stages when the trees are relatively small they probably grow at their potential (without competition Oliver 1980) The age at which competitive interaction begins is a function of the initial stocking level and the growth rates of individual trees The latter of course is dependent on species site quality and interaction with subordinate vegetation (Long and Smith 1984)

The multipurpose trees in the present study are only four years old Furthermore their crown sizes are relatively small (Table 7) As such they are yet to interact competitively with the coconut palms Lack of statistically significant differences in light interception by the multipurpose trees at 1 5 m above ground (Table 19 and Fig 12) also imply that the multipurpose trees are not competing with coconut palms for light until about four years of age Moreover being 18 years old the palm crowns are held substantially higher than the multipurpose tree crowns (Plate 2a and 2b) However with the development of larger crowns their emergence above the palm crowns and with the onset of root competition the multipurpose trees may probably affect coconut productivity adversely

Data on foliar nutrient concentration (Table 2) and ^{3} P recovery (Table 21) also reveal that there is no marked reduction in the nutrient uptake of coconut palms on account of planting multipurpose trees in the interspaces It is however too early to make any firm conclusions Stage of stand development is a major factor determining the nature of inter specific competition Dhyani *et al.* (1990) reported that inter specific root competition is minimal during initial years of the growth It intensifies at later stages of tree growth (Roy and Gill 1991b) Complementary effects of multipurpose trees on coconut yield also have been reported For instance coconut yield increased due to intercropping clove and cocoa (Anilkumar and Pillai 1988) Kumar (1994) also observed better yield for coconut intercropped with *Ailanthus triphysa* as compared to non intercropped plots Incorporation of *Leucaena leucocephala* loppings gave a substantial increase in coconut production (Liyanage *et al* 1993)

5 2 Growth of multipurpose trees

The three multipurpose species (*Vateria indica Ailanthus triphysa* and *Grevillea robusta*) when grown in the coconut interspaces exhibited profound variability in their growth rates (Tables 3 and 5 Figs 7 and 8) Data on mean annual increment also showed wide variations (Tables 4 and 6) Vateria exhibited the highest mean annual increment in height and basal stem diameter during early stages It however recorded the lowest growth rate subsequently (two years of age) On the other hand ailanthus with lowest height growth upto 30 months emerged as the tallest species after about 40 months Crown diameter and stand leaf area index also showed corresponding variations (Table 7)

Variations in growth characteristics between the species probably mirror genetic variability inherent in them Vateria being a pronounced shade bearer grows well under an overstorey of semi evergreen forests The coconut based cropping systems may simulate the forest influences to some extent Under exposed situations however vateria is found to have relatively lower growth rates (FRI 1986) In contrast ailanthus a pronounced light demander (Troup 1921) possibly can be adversely affected by shading in a coconut grove although no strong evidences were forthcoming from the present study in support of this contention

Relatively higher values of mean annual increment in height and basal stem diameter (118 2 and 2 62 cm yr respectively) were observed in the present study in comparison to previous reports (72 0 to 85 0 cm yr for height and 1 28 to 1 60 cm yr for dbh at 48 months of age under monocultural situations Thomas 1996) Microsite improvements and/or the micro environmental changes characteristic of intercropping situations may provide a plausible explanation for this differential growth rates observed Presumably these micro-environmental modifications may reduce the incidence of two major insect pests of ailanthus (*Atteva fabriciella* Lepidoptera Yponameutidae and *Eligma narcissus* Lepidoptera Noctuidae Varma 1986) Admittedly in the previously referred study (Thomas 1996) incidence of these insect pests have adversely affected tree growth He reported a pest incidence score of 1 44 (in a scale of 0 to 9) based on visual observations on intensity of defoliation and growth retardation It is therefore hypothesised that though ailanthus is a light demander it s performance under intercropping situations may be better owing to reduced pest incidence probably engineered by microclimatic shifts

On good soils with suitable climate an annual increment of 2 m in height and 2 cm in dbh has been reported for grevillea in the first five years (Harwood and Getahun 1990) However in tropical soils with medium to high rainfall height increment may be of the order of about one meter per annum (Harwood and Getahun 1990) Jama *et al* (1989) reported a maximum height of 6 1 m for grevillea in 6 years with an average annual increment of 90 cm whereas in Orissa it recorded a height growth of 93 188 220 360 520 630 and 850 cm at the end of first seven years (ICAR 1992)

The planting geometries did not exert any discernible influence on tree growth presumably due to the lack of intra specific competition The situation may however undergo a drastic change as the trees increase in size and their requirement for site resources Eventually crown class differentiation may set in and some of the individuals may become suppressed and some others dominant (Long and Smith 1984)

As regards to the leaf nutrient status the three multipurpose trees exhibited considerable variations (Table 8) Ailanthus with its fast growing nature had higher quantities of nitrogen and phosphorus in the foliage Potassium content was also higher but comparable with that of grevillea Except for phosphorus vateria exhibited th lowest concentrations of nutrients among the three species Lack of variation in nutrient content with regard to planting geometry provides further evidence for the lack of inter specific competition between coconut and the multi purpose trees

5 3 Growth and yield of kacholam

5 3 1 Growth attributes

Overall the sole crop (open grown) of kacholam recorded higher values than the intercrop for most biometric observations (Table 9) Kacholam intercropped in coconut plantations (without multipurpose trees) and the open grown crop were significantly superior to the twin tree (coconut and multipurpose trees) intercropping systems Implicit in this superior performance of the kacholam crop under sole crop and/or coconut alone situations is probably its lack of shade tolerance or at best moderate degree of shade tolerance Reports of moderate levels of shade tolerance have been published on other rhizomatous crops For instance turmeric recorded increased plant height reduced tillering (Jayachandran *et al* 1992) and increased number of leaves (Paul 1992) under moderate levels of shade (25 to 50 %) Varghese (1989) also reported an increase in plant height decrease in number of tillers and number of leaves in turmeric with increasing shade intensity In an agrisilviculture system ginger grown under different planting densities of ailanthus recorded higher number of tillers tiller height number of leaves and leaf area index as compared to open grown plants (Thomas 1996) implying its preference to moderate levels of shade (25 to 50 %)

5 3 2 Yield and its components

Open grown kacholam crop has consistently out yielded other treatments at all stages of observation It was however closely followed by the coconut + kacholam combination Interplanting multipurpose trees in the coconut plantations had a pronounced depressing effect on below ground biomass production of the associated kacholam crop at 150 days after planting (Tables 9 and 12) This again suggests the moderately shade tolerant nature of the crop Various yield components (Table 14) also followed a similar trend

On the whole kacholam can tolerate shade upto about 55% of the light intensity in open albeit higher yields were obtained in the open Coconut crowns intercepted about 55% of total incoming solar radiation (Table 19) If light interception exceeds this limit it may lead to lower yields (Fig 13) However upto 30% light intensity no appreciable yield reduction was observed

Other workers also reported similar results In an ailanthus ginger agrisilviculture experiment ginger recorded higher above and below ground biomass production under shaded conditions with 42% more dry rhizome under 46-48% shade as compared to open grown plants (Thomas 1996) Maximum yield for ginger and turmeric were recorded at 25% and 50% shade intensity respectively (Bai 1981)

Below ground drymatter accumulation as a function of time followed a curvilinear trend (Table 12) with maximum fresh and dry weights occurring at about 150 days after planting Beyond this stage fresh weight and dry weight decreased Similar trends were reported in ginger also (Ravisankar and Muthuswamy 1986) The magnitude of such reduction in weight was higher in the sole crop which is intriguing

5 3 3 Rhizome quality

Quality attributes of rhizome was not significantly altered by the experimental variables (Table 14) Nonetheless the oil content of rhizome was modestly lower under the tree canopy than in the open

Latha (1994) also reported that oil yield in kacholam was independent on shade In ginger oil and oleoresin content were unaffected by the

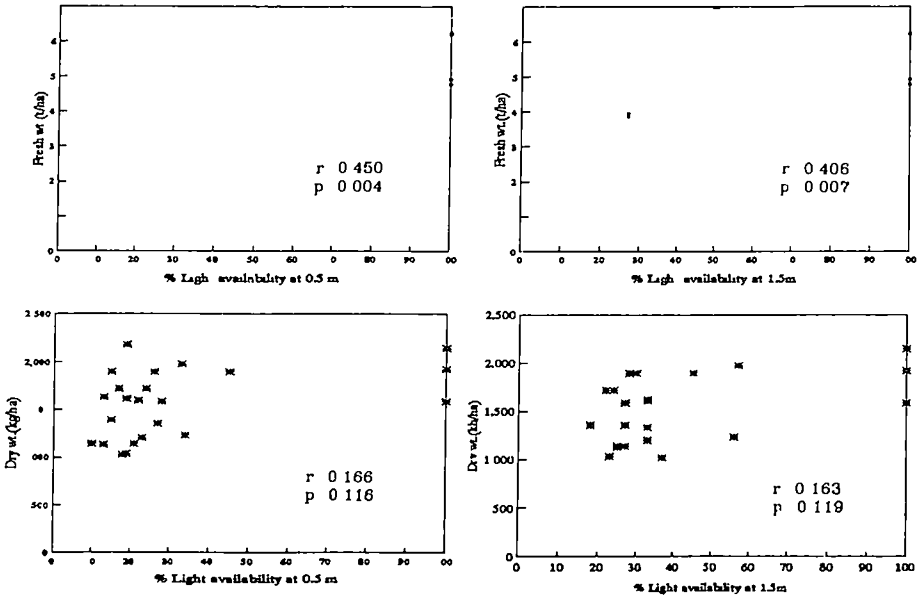


Fig 13 Relationship between kacholam yield and light availability under the canopy in the agrisilviculture system

canopy (Thomas 1996) Percentage of essential oil is primarily dependent on variety maturity and environmental conditions under which the crop is grown (Nybe 1978 Ravishankar and Muthuswamy 1986 Jaswal *et al* 1993) Shade level *perse* have only a modest influence on this parameter

Pillai and Warriar (1962) reported 2 87% of essential oil in open grown kacholam Panicker *et al* (1926) reported 2 4 to 3 88% of volatile oil from dry rhizomes of kacholam Compared to these values the present figures (2 08 2 50%) are relatively lower

5 4 Tissue nutrient content of kacholam

Foliar phosphorus and potassium contents of kacholam were significantly higher when grown in association with coconut and multipurpose trees (Table 15) In ginger and turmer c Bai (1981) observed an increase in N P and K content with increasing intensities of shade In the case of ginger grown under ailanthus canopy nutrient content was found to be more for open grown plants in the early stages whereas towards maturity plants grown under shaded conditions exhibited higher nutrient contents (Thomas 1996) This probably indicates a dynamic relationship between stage of crop growth/sampling and soil nutrient availability

Enrichment of the surface horizons of soil through nutrient pumping is an important indirect benefit of multipurpose trees (Nair 1993) In the present study soil nutrient analysis revealed significantly higher contents of P and K in soils under multipurpose trees (Table 29) This increase in soil nutrients may be responsible for the higher nutrient uptake by kacholam grown under multipurpose trees

5 5 Canopy light interception

Light availability (photosynthetically active radiation) near the ground surface (0 5 m above) ranged from 18% (ailanthus + coconut) to 45% (coconut alone) of that in the open (Table 19 and Fig 12) Implicit in this marked reduction in understorey light availability is that interplanting multipurpose trees in the coconut plantation may intercept a substantial portion of the incoming solar radiation about 72 to 82% depending on the nature of the tree crowns Planting geometry had no pronounced influence in this respect Presumably the present light infiltration pattern may change as the trees advance in their age and as the tree crowns expand

Regarding coconut pure plantations light infiltration studies in different situations of age height spacing and canopy characteristics of palms revealed that upto a height of 6 4 m corresponding to an age of 9 years there is reduction in light infiltration with increase in palm height However beyond this stage a reversal of this trend occurs owing to a reduction in effective canopy size (Abraham 1993)

In agroforestry systems the amount of light available at the ground level depends primarily on the nature of the tree species their spacing/planting geometry and age (Payne 1985 Mathew *et al* 1992) Perhaps crown characteristics (density leaf arrangement etc) are more important than the quantitative spread of crown

In the present study ailanthus intercepted more light despite its lower crown width (Table 7) Moreover vateria having larger crowns intercepted relatively lower proportion of photosynthetically active radiation Ailanthus crowns inspite of the narrow appearance is denser This is exemplified by the high leaf area index (7 15) of ailanthus (Table 7) Kellomaki *et al* (1985) also reported that crown shape had only a small influence on interception of solar radiation and that a dense regularly spaced stand of trees with tall narrow symmetrical crown was most efficient in attenuating incoming light Thomas (1996) reported a leaf area index of 2 71 and light interception of 46 to 51% for a four year old ailanthus stand with 1600 trees per hectare

As regards to crown characteristics Agetsuma (1989) found that leaf density and leaf angle had positive curvilinear relationships with understorey light intensity Sampson and Smith (1993) simulated the effects of changing canopy architecture on light infiltration and found that the order of importance on light penetration was leaf area index foliage aggregation average leaf inclination angle and vertical distribution of foliage

Integration of multipurpose trees in coconut plantations although desirable from the so l fertility and wood production point of view may impose restrictions on nature of intercrops to be grown in the interspaces Shade tolerant crop species/varieties are ideally suited for such situations Kacholam being a moderately shade tolerant crop can be grown without any drastic yield reduction although its productivity may be better under full sunlight situations Other crops such as ginger (Thomas 1996) and turmeric (Bai 1981) are also worth trying in view of their shade relationships

In the case of shade intolerant crop species/ varieties biomass production is probably a function of the photosynthetically active radiation (Hazra and Tripathi 1986) Consequently their productivity may be lower under agrisilviculture systems However the available solar energy is more efficiently used in agrisilviculture owing to the vertical stratification of vegetative components (Payne 1985) Fundamental advantage of this system is the partitioning of incoming solar radiation between the two or more strata and consequently more efficient light utilization in comparison to monocultural situations

5 6 Changes in soil fertility

Three to four years of tree growth has brought about only modest changes in soil physico-chemical properties which is not surprising (Table 29 and 31) While the tree component exerted a negative influence on soil nitrogen its effect on available potassium was more positive with ailanthus registering the highest values In general fast growing trees are expected to remove a substantial quantity of nutrients through root uptake especially during the initial stages of growth which may be recycled subsequently (Nair 1993)

Enrichment of surface layers by nutrient pumping by trees also has been widely reported in agroforestry systems (Ong *et al* 1991b Huxley 1984 Nair 1984 1993 Young 1987) Liyanage *et al* (1993) reported substantial improvements in soil organic carbon content water holding capacity and bulk density (lower) by planting *Leucaena leucocephala* under coconut and incorporating the tree loppings According to Harwood and Getahun (1990) roots of grevillea penetrate deep into the soil far below the zone utilized by agricultural crops and recycles nutrients from these layers back into surface However no predictable pattern emerged from the present study presumably because of the relatively young age of the stand

A modest increase in soil pH was observed in the multipurpose tree intercropped plots There was a concomitant reduction in soil organic matter content and nitrogen levels too Although reports abound in literature on improved soil organic matter status under agroforestry (Nair 1985 Agarwal *et al* 1976 Liyanage *et al* 1993) the present results show a divergent trend The underlying mechanisms for improved soil organic matter status are enhanced carbon fixation and its transfer through the litter and fine root decomposition routes (Young 1989) Decrease in soil organic matter content observed in the present study can however be explained based on the lower magnitude of litter and fine root production in young stands of multipurpose trees (3 4 years) and/or the faster organic matter turn over on account of intercultural operations It is nevertheless premature at this stage to make any firm conclusions in this respect

5 7 Root level interactions

5 7 1 Root activity of coconut

To assess the extent of root competition between coconut palms and the interplanted multipurpose trees ^{32}P soil injection technique was employed It involved applying P at specified depths and lateral distances in the coconut basin followed by the quantification of radio activity absorbed by the treated and surrounding plants In a well managed coconut garden almost 80% of the active roots are believed to be confined to a radius of 2 m around the palm (Anilkumar and Wahid 1988) Hence all the ^{32}P injection holes were within this zone Furthermore as the experiment was conducted during north east monsoon season when soil moisture was not limiting the extent of ^{3} P absorption may reflect root activity pattern for fine root activity of many tree species have been reported to be highest during rainy season (Srivasthava *et al* 1986) It may thus indicate the extent of root competition between coconut and the interplanted multipurpose trees

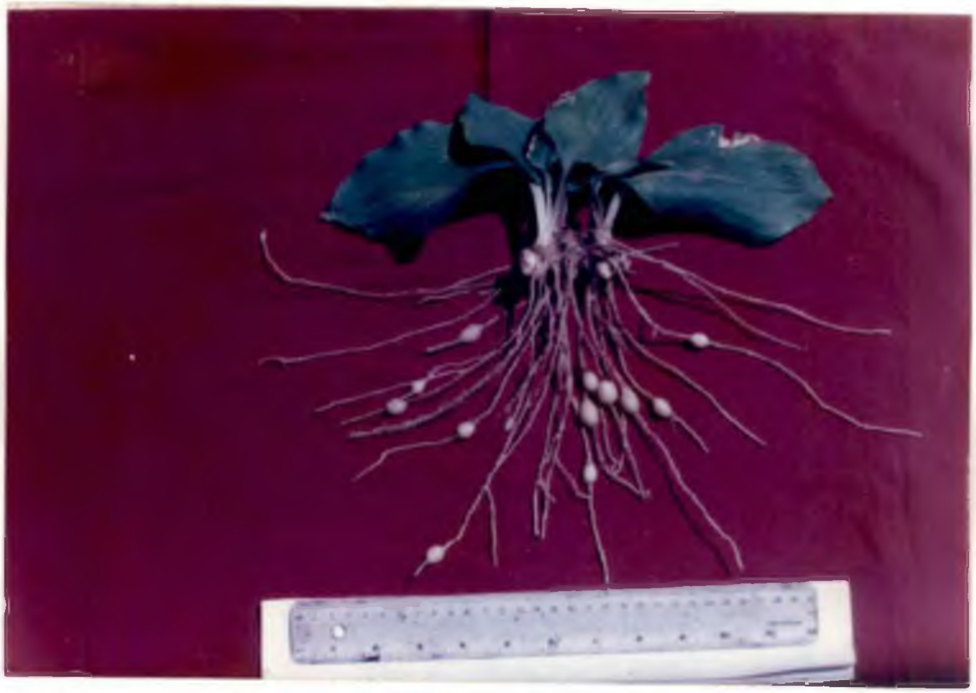
Foliar ^{32}P recovery by coconut increased initially and then decreased over time (Table 21) Earlier reports contain similar observations on cashew and cacao (Wahid *et al* 1989a 1989b) acacia casuarina ailanthus and leucaena (George *et al* 1996) and *Artocarpus hirsutus* (Jamaludheen *et al* 1997) Inter planting of multipurpose tree did not affect the recovery of ^{3} P in coconut foliage although the tree species exhibited considerable variations in this respect Implicit in this lack of difference between coconut monoculture vs multipurpose tree intercropped plots is probably the non competitive nature of root nteraction between coconut and interplanted multipurpose trees until about four years of age of multipurpose trees

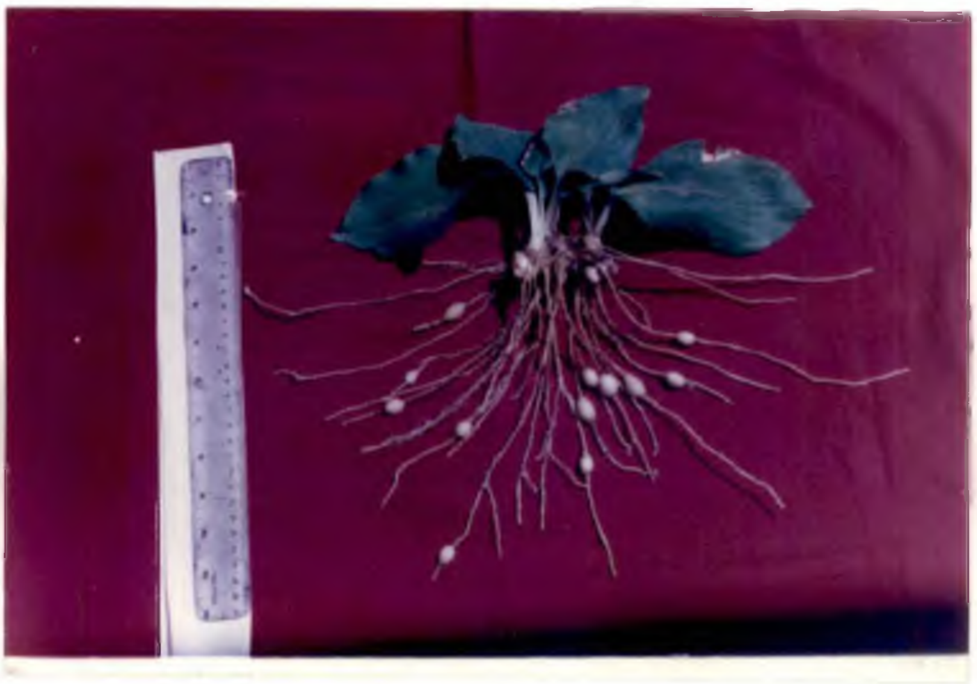
The significant variations in ^{2}p recovery of coconut as a funct on of multipurpose trees despite lack of overall differences between coconut monoculture and coconut + multipurpose tree system imply differences in root distribution pattern of the multipurpose trees Presumably multipurpose tree roots may have strayed into the coconut basin for capturing ^{2}P (Tables 22 and 23) Both ailanthus and vateria exhibited a potential depressing effect on ^{2}P uptake by coconut However grevillea exerted an apparent stimulating effect which is intriguing Interspecific competition between coconut and the mult purpose trees may ncrease as the trees grow further The complementary effects of grevillea roots also can be confirmed only with further studies

Surprisingly kacholam plants grown on raised (25 cm) beds (Fig 3) at a minimum distance of 25 cm from the perimeter of the coconut basins (2 m radius) exh b ted substant al P act vity in the fol age (Table 25) Cons der ng the depth of ^{2}P application (30 60 and 90 cm below groun l level) and the maximum spread of kacholam roots (25 30 cm Plates 4 and 5) it is unlikely that their roots can directly al so l tl e P ıpı l d n c con t bas ı (K chol m leaves for ^{2}P analys s were collected randomlv from one square meter area nearer (2 5 3 5 m from coconut) to the palm bas n from beds on either side of the treated palm) Nonetheless kacholam

PLATE 4 Root distribution of kacholam in the bed

PLATE 5a & 5b Root spread of kacho am plants





exhibited reasonably high levels of foliar P activity Presence or absence of multipurpose trees or their planting geometry had only a negligible influence on this parameter

Implicit in the absorption of basin (coconut) applied ^{32}P by the relatively shallow rooted kacholam plants is the possibility of the coconut roots feeding from the kacholam beds It is hypothesised that such roots may also release leach out and/or exude mineral and organic materials including ^{2}P absorbed from elsewhere into the kacholam rhizosphere Absorption of the mineral and organic materials so released into the rhizosphere may provide a plausible explanation for the recovery of ^{32}P in kacholam leaves Perhaps this may be a case of indirect feeding of roots through current transfer of nutrients between the effective rhizospheres of two associated crops

There are several reports documenting such transfer of mineral and organic nutrients between trees and/or plants through root grafting (Kozlowski and Cooley 1961 Kramer and Kozlowski 1979) Transfer of substances may also occur among closely spaced tree roots even in the absence of root grafting Woods and Brock (1964) found radioactive isotopes injected into stumps of one species from other adjacent species to which they were not directly connected Root exudation and subsequent uptake of minerals by other trees as well as transfer by mycorrhiza forming fungi and rhizospheric organisms has been suggested by Smith (1976) Release of allelopathic chemical by leaching excretion exudation volatilisation and decay either directly or by microbial activ ty is also documented in literature (Went and Westergaard 1949 Bevage 1968 Lerner and Evenari 1961 Rice 1974)

The question of coconut roots entering into the kacholam beds was addressed through excavating these beds at different distances from the coconut basin (2 5 and 3 25 m from coconut palm Plate 6) immediately after the harvest of the kacholam crop (February 1996) Data presented in Table 27 and Plate 6 clearly suggest that a large number of first order and other higher order coconut roots were present on these beds although previously they were devoid of such roots Earlier studies however have reported that over 74 per cent of roots in coconut is limited to 2 meter radius (Kushwah *et al* 1973) The possibility of rest of the roots reaching larger distances cannot be ruled out Anilkumar and Wahid (1988) also found that though 80% of active roots of coconut were confined within an area of 2 m radius about 9% of roots were encountered in the range of 2 0 to 3 0 m Furthermore root activity pattern of coconut is highly dependent on inter cultivation and manuring practices Good soil working and manuring for kacholam cultivation might have facilitated greater lateral spread of coconut roots Kacholam beds on account of better fertility (with fertilization and green manure application) and probably with higher moisture availability too would have thus stimulated higher root spread of coconut Yet another plausible explanation for this rather strange phenomenon is the probable interlinking of coconut and kacholam root through micorrhizal connections This however needs to be confirmed with more detailed studies

5 7 2 Root activity of multipurpose trees

Data on ^{32}P recovery of multipurpose trees surrounding the treated coconut palms showed that they absorb considerable quantities of the label from coconut

PLATE 6 Coconut roots n kacholam beds

a) at 2 5 m from the coconut palm

b) at 3 25 m from the coconut palm

basins (Table 22) In the initial stages of observation (15 and 30 days after application) the differences were not statistically significant However the sampling at 45 days after application showed substantial variations Ailanthus and grevillea absorbed higher quantities of ^{32}P than vateria although the coconut ^{32}P recovery data (Table 21) showed a different trend Absorption of radio label by the multipurpose trees as a function of lateral distance from treated coconut palm (Table 24) did not reveal any consistent or predictable pattern Nonetheless ^{32}P uptake of multipurpose trees was higher at a closer range

The remarkable ^{2}P recovery by multipurpose trees signifies root interference between multipurpose trees and coconut It can be explained by either the straying of their roots into the coconut basin for capturing site resources and/or cross nutrition between multipurpose trees and coconut roots (current transfer of nutrients between the effective rhizosphere regions of two crops as explained earlier) Although interlocking of tree roots through root grafts and/or micorrhizal connections are well entrenched in the literature (Kozlowski and Cooley 1961 Kramer and Kozlowski 1979) evidence for current transfer is scarce Therefore more experimentation is necessary to substantiate this

Root systems of multipurpose trees can also be expected to traverse into the interspaces and kacholam beds But in the present study tree roots were hardly detected in these beds This is probably due to the deep rooted nature of the trees However in an adverse situation (hard pan etc) chances of tree roots emerging to the surface layers to share available site resources cannot be over ruled Further studies involving fertilization of intercrops are perhaps necessary to characterise this

Summary

SUMMARY AND CONCLUSIONS

Agrisilviculture is an important branch of agroforestry which deals with integrated intensive land use systems involving fast growing multipurpose tree species and field crops on the same land management unit Such land use systems are considered useful in the Kerala context where population pressure is high land resources are limited and demands for wood and wood products are growing continuously Although several forms of agrisilviculture and other agroforestry systems are *in vogue* in the traditional holdings of Kerala hardly any research has been done to characterise their productivity compatibility of trees and field crop components and other aspects related to resource sharing

Coconut based agrisilviculture is probably the most important land use system in this respect in Kerala Owing to the wider spacing unique crown and root architecture coconut plantations are ideally suited for interplanting a wide variety of field medicinal and/or horticultural crops It may include multipurpose trees also However little is known about their functional dynamics

Hence an experimental set up involving coconut (*Cocos nucifera* L) three multipurpose trees (Ailanthus *Ailanthus triphysa* (Dennst) Alston Silver oak *Grevillea robusta* A Cunn and Vellapine *Vateria indica* L) and a medicinal herb plant (Kacholam *Kaempferia galanga* L) has been established at Vellanikkara Objectives of the study included evaluating coconut productivity as affected by the multipurpose trees in the interspaces assessing the performance of multipurpose tree in coconut based agrisilviculture systems evaluating the productivity of intercropped kacholam in the coconut multipurpose tree system and characterising the above and below ground resource partitioning in a typical multi species system

Salient results are summarised below

1 Interplanting multipurpose trees in an 18 year old coconut plantation did not adversely affect the nut yield of coconut until about 4 years after planting the multipurpose trees in the interspaces Inter specific competition between coconut and the multipurpose tree components perhaps is limited owing to the juvenile nature of the multipurpose trees

2 Vateria ailanthus and grevillea exhibited marked variability in their growth pattern Vateria recorded highest tree height and basal stem diameter in the early stages perhaps due to its shade loving nature However ailanthus a light demanding species recorded substantially higher values at later stages of observation

3 The difference in planting geometry did not alter the growth of multipurpose trees presumably due to the lack of difference in plant population density between the two treatments (single row and double row systems of planting)

4 Growth characteristics of kacholam was adversely affected by both multipurpose trees and their planting geometries Higher number of tillers number of leaves and leaf area index were observed in the sole crop of kacholam although the differences were negligible between this and coconut (alone) intercropping system

5 Above ground biomass production was more for sole crop however rhizome yield was not significantly affected by the multipurpose tree component of the system Fresh and dry rhizome yield were comparable for all plots

6 Rhizome quality attributes (essential oil and oleoresin) were also not significantly altered by the multipurpose trees and their planting geometry

7 Nutrient content of kacholam foliage and rhizome exhibited seasonal variations but no predictable pattern was obvious

8 Interception of incoming solar radiation was strongly influenced by multipurpose tree species Coconut monoculture with lighter canopy intercepted about 55% of incoming solar radiation whereas ailanthus interplanted in coconut owing to a more dense canopy intercepted as much as 82% of the total solar radiation (in the open)

9 Photosynthetically active radiation (PAR) available under the canopy ranged from 18 25% and 22 45% of that in the open at 50 and 150 cm height above ground level respectively

10 ^{32}P uptake by coconut was not adversely affected by multipurpose trees However the rate of absorption of the radio label varied between the multipurpose trees species Planting geometry had no significant effect in this respect

11 Multipurpose trees absorbed considerable quantities of ^{32}P applied in the coconut basin implying the intrusion of multipurpose tree roots into the coconut rhizosphere However such absorption by multipurpose trees is probably not large enough to cause any significant reduction in ^{32}P recovery by coconut as the multipurpose trees were only 3 year and 6 months old (at the time of P application)

12 Kacholam planted on raised beds in the interspaces (at a minimum lateral distance of 2 5 m from the coconut palm) was found to have substantial ^{32}P activity in their leaves Leaching/exudation of organic and mineral compounds by coconut roots scavenging the kacholam beds and its subsequent absorption by kacholam may provide a plausible explantation for this Maximum lateral spread of kacholam plants was found to be 25 30 cm and depth 20 25 cm

13 Profuse number of coconut roots were detected in the kacholam beds Favourable soil conditions created by intercropping is probably the reason for this proliferation of coconut roots on kacholam beds

14 Three to four years of tree growth has not perceptibly changed the soil physico-chemical properties Cultivation of kacholam however has resulted in a marginal reduction in the nutrient status of soil

FUTURE LINE OF WORK

The interaction between multipurpose trees and coconut is at present non competitive primarily due to the juvenile nature of the trees With further growth the nature of interaction between coconut and multipurpose trees may become competitive Further the impact of multipurpose trees on the productivity of coconut palms will be manifested only after a longer period of time Hence it is essential to continue the present experiment for few more years to evaluate the performance of both the components in future

The yield of kacholam also may decrease with higher spread of tree crown and subsequent reduction in light infiltration The stage upto which kacholam can be grown under the system without yield reduction can be found only with further investigation

Thee root interaction between coconut and kacholam observed in the kacholam beds is another area which require further evaluation Radio tracer technique with coconut and kacholam as treated plants can reveal the exact nature of root interaction between the two species

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