TECHNO ECONOMIC STUDY ON INTERCROPPING MEDICINAL PLANTS IN OIL PALM PLANTATIONS

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DECLARATION

I hereby declare that this thesis entitled "**Techno economic study on intercropping medicinal plants in oil palm plantations**" is a *bonafide* record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associate ship, fellowship or other similar title, of any other university or society.

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CERTIFICATE

Certified that this thesis entitled "**Techno economic study on intercropping medicinal plants in oil palm plantations**" is a record of research work done independently by Smt. P.C. Jessykutty under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associate ship, fellowship to her.

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ml	-	Millilitre
cm	-	Centimetre
m	-	Metre
%	-	Per cent
mg	-	Milligramme
g	-	Gramme
kg	-	Kilogramme
t	-	Tonnes
cv	-	Cultivar
N	-	Nitrogen
P	-	Phosphorus
K	-	Potassium
M	-	Mulch
Pn	-	Net photosynthesis
ha^{-1}	-	Per hectare
g	-	Microgram
s	-	Second
@	-	At the rate of
B:C ratio	-	Benefit : Cost ratio
DMP	-	Dry matter production
CGR	-	Crop growth rate
RGR	-	Relative growth rate
NAR	-	Net assimilation rate
LAD	-	Leaf area duration
LAI	-	Leaf area index
SLW	-	Specific leaf weight
PPFD	-	Photosynthetic photon flux density
NVEE	-	Non-volatile ether extract
HI	-	Harvest index
DAP	-	Days after planting
RBD	-	Randomised block design
m	-	Micrometre

INTRODUCTION

1. INTRODUCTION

Oil palm is unique among the commercial oil yielding crops because of their superior yields in terms of oil and immense potential in the domestic market. In India, large scale commercial plantations of oil palm have been established in Kerala by the Oil Palm India Limited (3645.64 ha in Kollam District) (OPIL, 1996). It is the most rapidly expanding plantation crop in the tropics and now the technology mission on oil seeds and pulses has envisaged a massive area expansion programme to cover 85,000 ha, mostly in Andhra Pradesh, Karnataka and Tamil Nadu. The kari lands of Kerala have also been identified by the technology mission for the profitable cultivation of oil palm, than coconut (Rethinam, 1998). It is also envisaged to develop small oil palm gardens in the farmers' field (Oil Palm Development Programme, OPDP) and the setting up of processing units.

Oil palm is a crop having a gestation period of three to four years. The recommended spacing is 9 x 9 m in the triangular system of planting and the number of plants per ha is 143. In majority of the oil palm growing countries, it is grown as a monocrop. This practice is most inefficient in utilizing the most limited resources like land and water. Effective land utilization assumes greater significance with ever-increasing pressure on land due to population growth, and other related human activities. In the case of small and marginal farmers, monocropping fails to ensure stable income. In order to be competitive, the farmers have to aim at increased productivity at reduced cost of production with the quality of the commodity the consumer wants, and sustained profit, from a unit area of land. This is possible through crop diversification, by adopting inter/ mixed/ multistoried cropping and mixed farming system. This gives a guarantee that the farmer gets assured income from one crop or the other. Also, a multispecies cropping system is conducive for generating multiple sources of food, medicine, fodder, income and employment for the practicing farm households. This ultimately helps to improve the socio- economic status of thousands of small and marginal farmers spread over the major producing areas.

An analysis of the scope of an oil palm based intercropping system reveals that, species that thrive under full sunlight can not be included, because at maturity the oil palm canopy greatly attenuates the amount of sunlight falling on the ground. However, under this canopy, shade tolerant species can be satisfactorily grown.

The agroclimatic conditions in our country provide an ideal habitat for the natural growth of a variety of medicinal plants, majority of which occur as understorey in forests. In fact, India harbours the richest biodiversity, wherein more than 9500 plant species are identified and documented as medicinal plants, which have importance in pharmaceutical industry. However, due to unscrupulous collection without replacement and change in ecological factors, many of the valuable species are either extinct or at the verge of extinction. About eighty per cent of the population in developing countries relies on the traditional medicines, mostly the plant drugs, for their health care, as per the assessment of the World Health Organization (WHO). Besides, these herbs are used as raw material for more than 25 per cent of drugs of modern medicine. This is because of the fact that the medicines derived from the herbs are non-narcotic and have no side effects. Internationally medicinal herbs are traded for more than Rs. 6000 million per year and the growth in the trade is estimated to be more than 7 per cent annually. The Indian share in the global trade is negligible when compared to many countries including China, although potential exists (Sivaraman *et al.*, 2002). Therefore, it is imperative to harness the potential and capitalize the opportunities of increasing demand for medicinal plants globally. This situation points to the domestication and cultivation of medicinal plants on a large scale. Many workers have stressed the importance of incorporating medicinal plants in the different cropping systems involving food and cash crops (Gautam, 1984). Therefore medicinal plants will be the ideal choice for an oil palm based farming system, because majority of them are shade tolerant and also tolerant to various pests and diseases, their cultivation is less labour intensive compared to other cash crops and majority are unpalatable to cattle(cattle grazing is a serious problem in vast unprotected plantations). Moreover, the natural habitat of the medicinal plants and the available microclimate under the oil palm canopy are more or less identical, making it a compatible crop combination. With this background, the present research work was undertaken with the following objectives.

1. To identify the medicinal plant sp. which can be economically grown in the interspaces of young, medium and mature oil palms, by conducting growth and economic analyses.

2. To analyse the morphological, physiological and biochemical characters associated with the shade tolerance of the selected species.

3. To standardize the optimum spacing for the selected species as intercrop in oil palm plantations, as a part of developing package of practices for the potential crops.

Overall aim of the research programme is to achieve the twin objectives of conservation and sustainable utilization of medicinal plants as well as available natural resources.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Intercropping is a useful technique for overcoming the supply and productivity constraints imposed by the long gestation lags of plantation crops. Intercropping is not a new concept, but a continued old technique of intensive farming that has persisted in many areas of the world as a method to maximize land productivity per unit area per unit time. The practice is commonly observed in areas of high rain fall in the tropics where temperature and moisture are favorable throughout the year for crop production. Oil palm based intensive cropping system is an approach to have efficient utilisation of land, water, and light resources available in the oil palm plantations. Past studies have suggested that the filtered light available in the oil palm plantations can sustain many crops. Thus land, water and light could be efficiently utilized. This approach enhances the return per unit area, thus enhances the income of the farmer utilizing the available resources. Success of the farming system will largely depend on the selection of the crops and their management practices. The present study is aimed to evolve a medicinal plant based farming system for oil palm plantations. The results of experiments conducted in different regions of the world on crop mixing in oil palm and other plantation crops with medicinal plants and other crops, effect of shade on the growth, yield and quality of crops and the influence of plant density on the growth, yield and quality of medicinal and other crops have been collected and compiled together in this review, to amply justify the reasons for undertaking the present study.

2.1 INTERCROPPING IN OIL PALM PLANTATIONS

Oil palm being a perennial crop is grown for many years by utilizing the natural resources like light, water and nutrients only to a very limited extent due to the peculiarity of its rooting pattern and canopy structure. Therefore, there is scope for exploiting the unutilized natural resources in an oil palm plantation so that the economic return from a unit area of holding can be enhanced.

Early experiments in Malaysia to study the effect of inter row vegetation on growth and yield of oil palm showed the desirability of natural vegetation as against bare ground conditions (Lucy, 1940). The prospect of obtaining a return from the inter row area in one form or another during the immature period of palms has been examined in Malaysia and elsewhere from very early times (Blencowe, 1969). The requirements for successful intercropping in the oil palm plantations have been described by Turner and Gillbanks (1974).

2.1.1 Canopy Structure and Light Interception in Oil Palm

At maturity, the oil palm canopy greatly attenuates the amount of light falling on the ground. Whilst data on the amount of sunlight reaching the ground under various stages of development are not available, it is unlikely that it is restricted to less than 7.6 per cent of the total incoming radiation. Therefore, plant species that thrive under full sunlight cannot grow, but shade tolerant species can thrive satisfactorily (Broughton, 1977). It has been observed that many medicinal plant species like *Solanum incanum*, *Hemidesmus indicus*, *Strobilanthes sp.* etc are growing as weeds in mature oil palm plantations and their growth is comparable to that in open condition

(Sunitha *et al.,* 1995). Studies conducted by Sarada (2000) in Kulathupuzha oil palm estate showed that many traditionally valued medicinal and aromatic crops are often found as voluntary plants under the oil palm. Corley (1973) explained that oil palm canopy closure starts at four years and canopies reach a constant size by 9 -10 years. The percentage of light intensity below canopy is a function of LAI: Log l = - 0.44 L, where l is light intensity below the canopy and L is leaf area index. Although the leaf area will become constant by 9 -10 years of age, by 20 years the change of leaf lets horizontal angle increases from 20 degrees to probably 40 – 60 degrees. When the leaf let angle becomes vertical, a part of the incident solar radiation to passes through the canopy and falls on the ground.

In a study conducted in Malaysia, to estimate oil palm age classes from spectral land sat TM wave bands by Ibrahim *et al.,* (2000), six types of oil palm plantation spectral response were identified. Their study revealed that, (1) at 1 to 3 years , the oil palm canopy LAI development increases rapidly and at the same time, under layer vegetation decreases, i.e. as the crown diameter increases ,(2) the LAI expands gradually until 8 years old, (3)the LAI reaches a constant at 9 to 10 years old depending on the genotype and the oil palm management practices, (4) the leaf let angles are believed to increase up to 60 ^{0} (starting at 20 years of age) and allow more light penetration to understorey vegetation and soil, (5) after 21 years , the understorey vegetation is believed to increase rapidly and constant understorey vegetation is achieved depending on oil palm plantation management practices.

A study conducted by Suresh and Rethinam (2000) to assess the amount of inter space available during the juvenile phase (1 – 3 years) of oil palm for growing intercrops indicated that the average canopy area was 13.19 m^2 and 6.15 m^2 in the well and poorly managed gardens during the first year. The canopy area was 47.86 m^2 and 65.58 m^2 in the well-maintained and 19.62 m^2 and 36.30 m^2 in the poorly managed gardens during the second and third year respectively. The inter space left would be 8112.90 m^2 3561.20 m^2 and 907.30 m^2 for one hectare, during the first, second and third year respectively. The results indicated that inter crops can be grown successfully in oil palm plantations till the end of second year under good management conditions.

2.1.2 Rooting Pattern and Utilization of Land in Oil Palm

A spacing of 9 m in the triangular system is recommended for oil palm (143 plants ha^{-1}) for optimum production. Oil palm, like other monocots, has a typical adventitious root system. It has relatively shallow root system with most of the active roots found in the upper 30 cm of the soil (Gray, 1969).

In a mature oil palm, the total quantity of absorbing roots extends a radial distance of 3.5 – 4.5 m. But the highest root activity is on the surface, within 100 cm lateral distance from the palm and beyond 300 cm there is a decrease in root activity (IAEA, 1975).

Omoti and Atuga (1983) studied on root activity of 15 year old oil palm using p^{32} and concluded that P uptake was the greatest at a distance of 50 cm from the trunk and at 15 cm depth.

Dufrene (1989) reported that 96 per cent of primary and secondary roots and 49 per cent of tertiary and quaternaries were found on top 40 cm layer of soil.

So in a mature plantation an area of about 4 m width in the inter rows are photo synthetically unexploited and this gap can be filled by plants that can utilize this area for bioconversion in to effective products.

2.1.3 Crops Chosen for Oil Palm Based Inter Cropping System

Striking benefits from intercropping have been obtained in experiments with oil palms in West Africa by cultivating yams, maize, cow pea and okra (Sparnaiij, 1957).

Kowal and Tinker (1959) reported that intercropping resulted in a general, but not very large, depletion of soil nutrients compared with the plots under natural and leguminous covers.

In the immature years of an oil palm plantation, the common practice in estates in Malaysia is to plant and maintain leguminous cover crops as a soil cover in the palm inter row areas, since leguminous covers are beneficial to the oil palm as compared to other intercrops such as grasses (Gray and Hew, 1968).

In Indonesia, experiments have indicated that intercropping with food crops and patchouli if properly carried out, did not have adverse effect on young rubber and oil palm plantings (Soepadyo and Tan, 1968; Tan, 1969).

In an intercropping experiment in oil palm with *Amranthus cruentus* Wainwright (1994) reported that the biomass of the intercropped plants was considerably less than that of the control (open) plants. He also reported that the biomass of the intercropped plants increased with distance from tree, and the biomass was not reduced relative to the controls at light levels > 58 per cent of total PAR.

Under West African conditions, when cocoa was under planted in mature oil palms which had achieved a maximum canopy formation, there was no significant difference in oil palm yield. On the other hand cocoa, seedling growth and yield were significantly better under the oil palm (Amoah *et al.*, 1995).

Salako *et al.*, (1995) recommended the owners of small scale oil palm plantations at Okamu in Nigeria, to maximize land use and profit by intercropping oil palm with *Xanthosoma sagittifolium* during the first five years of palm establishment or when a shade tolerant crop is required as an intercrop within the five years. They also reported that the oil palm yield in intercropped plots was comparable to the expected average yield in the area.

From an intercropping experiment in oil palm, with soya been, maize and cocoyam, Erhabor and Filson (1999) reported that intercropping depressed the sex ratio in oil palm by 6 to17 per cent. They also reported that by intercropping the soil organic matter declined from 10 - 51 per cent, and total N decline was 50 - 70 per cent whereas P level increased up to 71 per cent and exchangeable K declined from 32 – 62 per cent. According to them the observed decline in N and K could be due to crop removal and leaching. However they observed that intercropping was shown to encourage the maximization of land use, stability in yield and profit.

In India no recent published results are available about the intercropping of food and other cash crops in the inter rows of oil palm. However, the results of some trials conducted at farmer's fields under Indian conditions are available. In these trials more than 20 intercrops were tested particularly in Andhra Pradesh and Karnataka. The list of intercrops included fruits (banana, watermelon), oil seeds (gingelly, groundnut, sunflower) ornamentals (jasmine, tuberose, crossandra), vegetables (cabbage, cauliflower, chillies, cucurbits, tomato) and other crops (cotton, tobacco, turmeric, ragi, mulberry). The net income could be above Rs. 4000 per year depending upon the crops grown (SDH, 1996).

The data collected from a study on the farming systems in Southern Nigeria revealed that intercropping was the dominant cropping system, with cassava, yam and maize as the principal arable crops, while cocoa, kola nut, oil palm, rubber, cashew, banana / plantain and citrus were the main permanent crops (Ndaeyo *et al.*, 2001).

From an experiment to study the influence of companion food crops viz. soya bean, maize and cocoyam on the root distribution pattern of young oil palm, Erhabor *et al.*, (2002) concluded that intercrops played magnificent roles in nutrient cycling, erosion and weed control, water conservation and maintenance of favorable soil physical properties in addition to reducing the risk of crop failure.

2.2 MEDICINAL PLANTS AS INTERCROP

Medicinal plants in general have a short history of cultivation, since leaving aside a few, most of the requirements of these plants are met from wild sources. The increasing demand for medicinal plants and depleting forest resources points to the urgent need for domestication of many of the commercially important medicinal and aromatic plants. In Kerala where the cropping intensity is very high, there is limited scope for mono cropping of medicinal plants, however, there is ample scope to introduce them as an intercrop in majority of the plantations which occupy about 47 per cent of the total cropped area in the state.

2.2.1 Medicinal Plants as Intercrop in Plantations

An evaluation of the agro forestry systems in China showed that traditional medicinal plants are the common intercrops with various tree sp. like *Populus* sp. Cunninghamia etc. especially after their canopy closure (Kumar, 1987).

In Kerala, preliminary studies on intercropping medicinal plants in coconut and rubber plantations were conducted by Kerala Agricultural University and Rubber Research Institute of India. Twenty four medicinal plant species were identified as potential intercrops in rubber during the immaturity period .Among the plants *Adhatoda beddomei, Plumbago rosea, Holostemma annulare, Kaempferia galanga and Kaempferia rotunda* were reported to come up well under deep shade (RR II,1989).

Higher LAI, CGR, NAR, total dry matter production, growth and yield of arrowroot were reported by Muraleedharan (1990), when grown as an intercrop in areca nut garden compared to open space.

Preliminary trials on intercropping 12 species of medicinal plants in coconut plantations and their biomass analysis revealed encouraging results as to the possibility of growing them as intercrops in 8 - 20 year old coconut plantations, where no other intercrops are usually recommended (Nair *et al.*, 1991).

Further studies in this line revealed that yield of officinal part and phyto constituents were influenced by age of coconut palms which has a role in determining light infiltration. The crop species responded differently to inter cropping situations. In fifteen year old coconut plantations, growing Plumbago showed no significant difference in yield and plumbagin content as compared to pure crop while Kacholam showed better response under open conditions. The adaptability and performance of five commercial medicinal plants for intercropping were studied by growing them in 20 year old coconut plantation with light infiltration ranging from 27 to 35 percent. The test species *Kaempferia galanga, Plumbago rosea, Asparagus racemosus* , *Adhatoda beddomei* and *Holostemma adokodian* showed no significant yield differences under the two cropping situations (pure crop and inter crop) and hence suitable for inter cropping in coconut garden. Kacholam, Plumbago, and Asparagus were better suited for intercropping as indicated by higher yield and benefit cost ratio as intercrop. Holostemma recorded slightly higher benefit cost ratio for pure crop and hence to be preferred for pure cropping. Cultivation of Adhatoda for roots alone is not a profitable venture and leaves should also find a market demand. Based on cost benefit analysis, the most preferable crop is Plumbago, followed by Kacholam, Holostemma and Asparagus. Plumbagin, the therapeutic principle of Plumbago showed less difference between pure crop and inter crop whereas vasicine, the major phytoconstituent of Adhatoda and volatile oil and oleoresin, the flavour principles in Kacholam were slightly high for the pure crop. Total saponins, the therapeutic principle in Asparagus, soluble and insoluble sugar and total free amino acids were high in intercrop. Asparagus showed high soluble sugar content due to presence of steroidal sapogenin having sugar moiety. Holostemma also showed high soluble and insoluble sugar for the intercrop. In spite of these variations, certain accessions showed high potential for accumulation of active principle at higher rate in inter cropping system. This indicates the scope for recommending such accessions as intercrop without compromise on yield and quality. Anatomical features revealed that the test species responded similar to sun plants with thick cuticle; cells closely packed with less inter cellular space, more chloroplastids and well developed vascular system. When grown as pure crop these features were modified similar to sciophytes, with thin cuticle, cells loosely packed, less chloroplastids and poorly developed vascular system. When grown as inter crop Kacholam leaf sections exhibited cranz anatomy with the bundle sheath cells containing large quantity of chloroplast. Physiological features like chlorophyll a, b, a + b, stomatal distribution, canopy diameter/ height ratio and anatomical features of any one species covered in the study totally agree with that of sciophytes. Hence physiological features can not be considered as prediction index of shade tolerance (Kurian *et al.*, 2000).

Raghavan (1992) catalogued the medicinal plants seen naturally in the Vellanikkara rubber estate and reported favorable growth of *Hemidesmus indicus* and *Curculigo orchioides* under the dense canopy of rubber.

Intercropping in coconut with patchouli and thippali was attempted at AICRP on M & AP. Intercropping trials on patchouli showed that it grows well under partially shaded condition and the type Singapore registered the highest yield of 152.18 kg ha $^{-1}$ under 50 per cent shade. In thippali maximum spike yield was from Cheema thippali (430.60 kg ha $^{-1}$) followed by Pattambi (355.20 kg ha^{-1}) when intercropped in irrigated coconut garden (AICRP, 1992).

Rajagopal *et al.*, (1992) conducted intercropping studies in coconut with five medicinal plants viz. *Andrographis paniculata, Coleus vetiveroides. Kaempferia galanga, Maranta arundinaceae and Sida retusa*. These were grown under different shade intensities viz. full shade (60 – 90 per cent), partial shade (30 – 60 per cent) and open (0 – 30 per cent). In all species, the yield was found to be high under full/ partial shade of coconut. The economics of intercropping these medicinal plant species in coconut garden was worked out and they reported that maximum additional income was obtained by growing *Coleus vetiveroides* followed by *Maranta arundinaceae*.

Increased litter production was reported in mint and Cympopogon intercropped eucalyptus plantation, compared with pure stands at all ages by Mohsin *et al.*, (1996).

The survival varied considerably when four medicinal plant species viz. *Rauvolfia serpentina, Curcuma aromatica, Chlorophytum arundinaceum,* and *Curculigo orchioides* were grown under tree plantation in Madhya Pradesh. Highest survival was noticed in *Curculigo orchioides* and the lowest was in *R. serpentina*. The best survival and yields were under *Eucalyptus tereticornis, Acacia auriculiformis* and *Leucaena leucocephala* and the poorest under *Melia azadirach* and *Pongamia pinnata* (Chadhar and Sharma, 1996).

In an investigation to evaluate the performance of Kacholam (*Kaempferia galangal L.*) in a 30-year-old coconut garden, Maheswarappa *et al.*, (1998 b) reported that growth and rhizome yield were higher when it was grown as an intercrop compared with as a sole crop. The essential oil and oleoresin contents were also higher in inter cropped rhizomes.

In an intercropping experiment of rubber with medicinal yam and pigeon pea, the latex yield was not affected by intercropping, whereas the yields of medicinal yam and pigeon peas were decreased under intercropping (Singh *et al.*, 1998).

The economic benefit of intercropping tea with *Ginkgo biloba*, a Chinese medicinal plant was reported by Lei (1998).

For developing new strategies for rain forest conservation canopy farming concept could open up the rich canopy potential for ecologically sound utilization of a variety of forest products, both wood and non-wood, thus creating an economic motivation for the total protection of rain forests. The use of select, small products, such as medicinal species and ornamental plants, can offer economic as well as ecological advantages. For example, the low biomass of such products can be paired to high added market value at the same time that their extraction from the forest is least disruptive. (Verhoeven and Beckers, 1999).

Forest as a complex ecosystem, along with a series of significant functions, is a potential source for the exploitation of various miscellaneous products like medicinal plants, which are classified in the category of raw materials of special significance. In order to avoid the unfavorable effects of depletion of natural resources, special attention should be devoted to plantations with medicinal plants (Obratov-Petković and Dukić, 2000).

2.2.2 Medicinal Plant as Intercrop with Other Crops

Successful intercropping of apple orchards with chamomile (*Matricaria sp.*) has been reported by Vaigi and Graf (1971).

Valeriana wallichi could be successfully grown as an inter crop in apple orchards in the Himalayas (Gupta and Sha, 1981).

Inter cropping with *Asparagus racemosus* was found to be effective in reducing soil and root population of root knot nematode (*Meloidogyne javanica*) in grapevine (var.*perlette*) (Baghel and Gupta, 1996).

Potential growth of medicinal plants *Coptis japonica* and *Epimedium grandiflorum* within forest stands had been reported by Saitoh (1989).

Experiments conducted in Egypt to evaluate the competitive relationships of three medicinal crops viz. star anise (*Illicium verum*) caraway (*Carum carvi*) and coriander (*Coriandrum sativum*) intercropped with faba beans showed that intercropping reduced yields of all crops compared with monoculture (Kamel *et al.*, 1992).

Intercropping with *Gentiana scabra* increased maize yields by 10 per cent as reported by Shumei *et al.*, (1995).

The technique of inter planting cotton with *Pinellia ternate*, a traditional Chinese medicinal plant, has been reported by Xiang and Yeng, (1995).

In a study to evaluate the growth of American ginseng (*Panax quinquefolius*) under the radiata pine (*Pinus radiata*) canopy, Follett (1997) reported that only 28 per cent of plants survived during the first year.

Medicinal spice crops intercropped with geranium showed greater yield advantages in terms of main crop equivalent yield of essential oil compared with that of geranium monoculture. The quality of geranium essential oil, in terms of its major constituent citronellol, was not affected by intercropping (Ram and Kumar, 1998).

An experiment conducted in Japan to study the effect of intercropping medicinal plants for suppressing soil – borne plant diseases revealed that intercropping *Geranium pratense* with potatoes, decreased common scab disease incidence (Ushiki *et al.*, 1998).

Rathore *et al.*, (1999) reported growing of isabagol (*Plantago ovata*) with sugarcane crop in Madhya Pradesh.

2.3 CROP RESPONSES TO SHADE

Solar radiation is one of the primary factors governing the ultimate yield of any crop. The growth, yield and quality of crops are influenced by shade at various stages of growth and development. Differential response to shade has been noticed in various crops.

2.3.1 Morphological Characters

2.3.1.1 Plant Height

Soya bean under 70 per cent shade grow much better than those in the light (Allen, 1975). Tarila *et al.,* (1977) reported that high intensity of light reduced plant height in cowpea. George (1982) observed an increase in plant height due to shading in ground nut. Positive influence of shade on plant height was reported in cassava (Ramanujam *et al.,*, 1984; Sreekumari *et al.,* 1988), in broad bean (Xia, 1987), and in colocasia (Prameela, 1990). In ginger an increasing trend in plant height with increasing shade intensity was reported by Ancy, 1992; Beena, 1992; Babu, 1993 and Sreekala, 1999.

In a trial to study the effect of shade on growth contributing characters and factors in relation to yield of tomato, it was observed that the only vegetative parameter affected by shade was plant height, which increased with increasing amount of shade (Sharma and Tiwari, 1993).

Studies conducted in Brazil on the effect of organic manure on biomass production of quebra-pedra (*Phyllanthus stipulatus*), where the roots and whole plants are used as a popular remedy to reduce uric acid in the blood and to facilitate the elimination of kidney stones, revealed that total plant biomass was similar in sun and shade, but plant height was greater in shade than in sun (Filho *et al.*, 1997).

In onion tallest plants were observed in 25 per cent PAR treatment and smallest plants were observed under full sun light (Miah, *et al.*, 1998).

Ginger plants grown as intercrop in areca nut plantation were significantly taller than those under open conditions when measured 200 days after planting and had significantly lower number of functional leaves and tillers per clump. (Hedge *et al.*, 2000)

In mint species grown as intercrop in sugarcane under sub-tropical climate of north Indian plains, increased plant height and decreased leaf :stem (L:S) ratio and leaf area index (LAI) were observed under intercropping, compared to the respective sole crop treatments (Singh *et al.*, 2002).

2.3.1.2 Number of Leaves

Sannamarappa and Shankar (1988) reported no significant variation in leaf number in turmeric due to intercropping with arecanut. Sreekumari, *et al.*, (1988) reported that in cassava, leaf number decreased while leaf size and longevity increased when grown under shade in a coconut garden. Varghese (1989) observed a decrease in the number of leaves with shading in ginger and turmeric. In ginger maximum leaf production was observed under 25 per cent shade (Ancy, 1992; Babu, 1993). A study carried out in relation to the raising of crops grown for their leaves in agro forestry systems, where senna (*Cassia angustifolia*) plants were subjected to shaded conditions, revealed that, shade increased plant height, number of nodes, mean internodal length and various growth attributes. Leaf growth also increased in terms of number, expansion (leaf area) and dry matter accumulation. The promotional effect was most marked at 25 per cent shade, and the impact of further increase in the shade level (to 50per cent) was marginal. *C. angustifolia* would, therefore, be suitable for growing in agro forestry systems (Vyas and Nein, 1999).

2.3.1.3 Leaf Area

The response of low- light stress generally includes an increase in plant leaf area to maximize light interception and changes in physiological processes to enhance the efficiency of carbon utilization.

Bai (1981) reported that leaf area was not influenced by different intensities of shade in ginger, turmeric and coleus. But increased leaf area under reduced light intensity in ginger was reported by Ravisankar and Muthuswamy (1988), Ancy (1992) and George (1992). In ginger minimum leaf area was noticed in plants grown under open condition (Sreekala, 1999).

In forage grasses, responses to reduced light (shade) include larger leaves with fewer mesophyll cells and stomata per unit leaf area, more intercellular air space, higher leaf area ratio (LAR), and reduced specific leaf weight (SLW) (Allard, *et al.,* 1991; Kephart, *et al.,* 1992). The increased leaf area is the result of longer leaves because of an increased duration of leaf elongation (Allard, *et al.,* 1991). Sanderson and Nelson (1995) showed that reducing light in a step wise manner resulted in longer leaves with a larger area and lower SLW, a greater leaf elongation rate and reduced dry matter deposition in high yield per tiller and low yield per tiller genotypes of tall fescue. Increasing light at graded levels reversed these responses. The greater leaf elongation rate at low light was due to a longer zone of cell elongation in the leaf blade meristem. The data indicated that the longitudinal growth rate and spatial distribution of growth in leaf blades of tall fescue were nearly quantitatively reversible with increases or decreases of light, similar to the photosynthetic and specific leaf area responses of annual rye grass to alternate low and high light (Prioul, *et al.,* 1980).

In a study to find the effect of light intensity and quality on the growth and quality of Korean ginseng (*Panax ginseng* C.A. Mayer), plants were planted at two densities and two shade levels. As plant density increased the leaf area per plant decreased but the LAI increased. The optimum LAI under the two shade treatments was 2.4 and 2.7 respectively (Cheon *et al.,* 1991)

In *Ilex paraguariensis* plants total leaf area was the greatest in plants growing under shade. The specific leaf weight of leaves from pruned and non pruned plants growing in full sun was 97.98 per cent and 43.33 per cent respectively of that of shaded leaves (Rey, 1990).

An investigation of three tree species in controlled growth experiments showed that leaf area was the most significantly affected factor between species grown in sun and 40 per cent shade conditions (Netshiluvhi,. 1999).

2.3.1.4 Number of Branches/ Tillers

In Arizona leather flower, *Clematis hirsutissima* var. *arizonica*, a geographically rare species, at natural light levels lower than 40 per cent, plants had significantly lower stem production, seed production, and photosynthetic rates than plants growing at higher light levels (Maschinski *et al.*, 1997). Decrease in the number of tillers with increasing levels of shade in turmeric was reported by Susan (1989) and Jayachandran *et al.*, (1992).However, in colocasia there was no significant reduction in tiller production with respect to increasing levels of shade (Prameela, 1990). According to Aclan and Quisumbing (1976) in ginger, tillering was not affected by shade.

In a study to find out the effect of shade on bark yield component of cinnamon intercropped with rubber, Pathiratna and Perera (1998) reported that the number of shoots /bush and mature shoot length were the highest in plants under 21 per cent light.

Goulet *et al.*, (2000) reported that phenotypic plasticity enables tree saplings to change their morphology according to their environment to grow towards a better light microhabitat .The results of their study to evaluate the effects of position and light availability on shoot growth within the crowns of under storey saplings of sugar maple (*Acer saccharum*) and yellow birch (*Betula alleghaniensis*), revealed that there is a clear branch position effect on shoot growth in the crown for yellow birch saplings, and that, it is partly related to the presence of two types of shoots. Dead branches were located at the bottom of the crown of sugar maple saplings; they were smaller in size, had wider angles and had lower indexes of vigor than live branches found nearby.

In an investigation to study the effect of shade on the growth of *Enicostemma littorale*, a medicinal plant well known for its diuretic and anti diabetic properties, Sharma *et al.*, (1994) reported that vegetative growth (height), FW, DW and leaf and branch number were enhanced in the shade compared with plants grown in full sun, but reproductive growth (flower number) was reduced by shade.

2.3.1.5 ***Root Characters***

The effect of different light conditions on germination and seedling growth was investigated in four forest tree species-*Bridelia retusa, Holarrhena antidysenterica [H. pubescens], Lagerstroemia parviflora* and *Wrightia tinctoria*. Root and shoot length were maximum under semi-shady conditions in *B. retusa* and *H. antidysenterica* while in *L. parviflora* and *W. tinctoria* they were maximum in full sunlight. Root: shoot ratio was the highest under shady conditions in *H. antidysenterica, L. parviflora* and *W. tinctoria*, but in full sunlight in *B. retusa* (Chaturvedi and Bajpai, 1999).

2.3.2 Anatomical Characters

2.3.2.1 Leaf Thickness

In *Achyranthes aspera* L., sun adapted plants had thicker leaves and chloroplast, total protein and RNA contents were higher. Higher $^{14}CO_2$ incorporation, leaf area ,total chlorophyll content, surface area of the stomatal apparatus, leaf protein content and total phenol, reducing sugar and total amino acid contents of chloroplasts were observed in shade- adapted plants (Vora *et al* ., 1989).

In a comparison of wild and cultivated *Camellia ptilophylla* plants growing in shaded or open situation Wang *et al.,* (1993) reported that cultivated plants were usually shrubby and had more and smaller leaves than wild plants, which were usually small trees. Leaf thickness and proportion of palisade tissues in leaves did not differ significantly between wild and cultivated plants in shaded situations but in open situations the leaves of cultivated plants were thicker and had more stomata.

A foliar anatomical study of five species of medicinal plants viz. *Adhatoda beddomei, A.vascica, Alpinia galanga, Plumbago rosea,* and *Strobilanthes heyneanus* grown as intercrop in rubber plantations under direct sun light and 70 per cent shade revealed that a significant decrease in leaf thickness was observed under shade which could be attributed a decrease in intercellular space and cell number in palisade layer (Neerakkal *et al.,* 2001).

2.3.2.2 Stomatal Density

In *Impatiens flanaganae*, an endangered South African medicinal plant, an increase in stomatal abnormalities was noticed in leaves of plants grown under high light intensities. These abnormalities included degradation of guard cells, super imposed and juxtaposed contiguous stomata, stomata with persistent intervening walls, cytoplasmic connections, single guard cells, guard cells without pores and persistent stomatal cells. In view of this increase in abnormalities under higher light intensities, it was concluded that removal of forest canopy may threaten the survival of this species (Lall and Bhat, 1996).

A study carried out to investigate the degree of leaf wetness and its capacity to retain water droplets in relation to leaf morphological characteristics of *Valleriana jatamansi* grown under open and shade habitats revealed that leaves developed in open habitats had less wettability but higher capacity to retain water droplets and more number of stomata than those in shade habitats. (Pandey and Nagar, 2002)

2.3.3 Physiological Attributes

2.3.3.1 Dry Matter Production (DM)

When *Panax quinquefolium* plants were grown under a black poly propylene shade canopy there was rapid stem growth and dry matter production during the early season of growth (Bailey and Stathers, 1991).

Light levels influenced both dry matter production and allocation in *Amaranthus cruentus*. For plants grown shaded conditions, total DM was 70 and 22 per cent less in *A. cruentus* and *Solanum nigrum* respectively compared with plant grown in full sunlight. The DM reproductive allocation was 79 and 42 per cent less in *A. cruentus* and *S. nigrum* respectively grown in the shade compared with those grown in full sun light (Sattin *et al.,* 1992).

The effects of shade and soil temperature on growth of jarrah (*Eucalyptus marginata*) seedlings were studied in Perth, Australia, in greenhouse experiments. Plant dry weight and that of all plant parts declined in response to shade, as did root/shoot ratio. Plant leaf area was less in unshaded plants than in plants grown in shade, and specific leaf area increased with shade. Unshaded seedlings had a greater light-saturated rate of photosynthesis, a higher light compensation point and a higher light saturation point than seedlings grown in 70per cent shade. The relation between plant dry weight and leaf dry weight was independent of shading, whereas the relation between plant dry weight and plant leaf area was dependent on shading. Therefore, leaf dry weight may be a better predictor of biomass production than leaf area in forest stands where shade is likely to affect growth significantly (Stoneman and Dell, 1993).

In *Datura stramonium,* biomass partitioning within the plant reduced the per cent of dry matter accumulated in reproductive organs, leading to a marked decrease in the harvest index, due to shading. Shading also caused species dependent delay in the onset of the flowering and the ripening stages (Benvenuti *et al.,* 1994).

In a study to find out the effect of light availability and photosynthesis of *Pseudotsuga menziesii* seedlings grown in the open and in the forest under storey, Chen and Klinka (1997) reported that, on a leaf area basis, dark respiration rate of under storey–grown branches was lower and net photosynthetic rates were higher, than those of open grown branches exposed to low PPFD (photosynthetic photon flux density). When measurements were expressed on a leaf dry mass basis , there was no difference in dark respiration rates between under storey branches and open–grown branches , but net photosynthetic rates of under storey branches were equal to or higher than those of open grown branches at all PPFDs (Chen and Klinka, 1997).

Wheat grain yield, dry matter yield, leaf area index, spikes/m, grains/spike and test weight were reduced under the tree canopy compared with crops growing in the open (Nandal *et al.,* 1999).

Research conducted on *Aloe vera*, a traditional medicinal plant, to investigate the effects of light on growth, carbon allocation, and the concentrations of organic solutes, including soluble carbohydrates and aloin, revealed that plants grown under full sun produced more numerous and larger axillary shoots, resulting in twice the total dry mass than those grown under partial shade. The dry mass of the plants grown under deep shade was 8.6 per cent that of plants grown under full sun. Partial shade increased the number and length of leaves produced on the primary shoot, but leaf dry mass was still reduced to 66 per cent of that in full sun. Partial and deep shade reduced root dry mass to 28 and 13 per cent, respectively, of that under full sun. Limitation in light availability primarily affected total dry mass production and allocation, without substantial effects on either primary or secondary carbon metabolites (Paez *et al.,* 2000).

In *Trema micrantha* total biomass decreased with decreasing irradiance, reflecting reductions in dry mass of leaves, stems and roots. In response to shading, allocation of biomass to leaves increased, while allocation of biomass to roots decreased. Specific leaf area, leaf area ratio and leaf mass ratio increased with decreasing irradiance (Valio, 2001).

2.3.3.2 Leaf Area Index (LAI)

The effect of light (full sun or partial shade) on the growth of *B. lupulina* an ornamental and medicinal shrub was investigated over 2 years. The acclimation responses of *B. lupulina* to the lower light regime included an increase in leaf area ratio and a decrease in specific leaf weight. A decrease in root: shoot ratio was also observed (Páez *et al.*, 1998).

2.3.3.3 Crop Growth Rate (CGR)

Ramadasan and Satheesan (1980) reported highest crop growth rate with three turmeric cultivars grown in open compared to shaded condition.

The maximum individual CGR recorded in the study conducted by Whiley (1980) in Ginger was 39.78 g m^{-2} day^{-1} .

Ramanujam and Jose (1984) found that the CGR of Cassava grown under shade was reduced significantly when compared to those plants grown under normal light.

The crop growth rate was found to be maximum under 25 per cent shade at growth phases (90-135 DAP and 135 – 180 DAP) followed by that under 50 per cent shade and open condition in ginger (Ancy, 1992).

Babu (1993) observed significantly superior crop growth rate under 25 per cent shade in ginger

2.3.3.4 Relative Growth Rate (RGR)

Both absolute biomass gain and relative growth rate (RGR) had significant positive correlations with water potential, stomatal conductance and leaf carbon content but were not correlated with leaf nitrogen content or leaf phosphorous content. Multiple regression analysis identified water potential and stomatal conductance as the factors which contributed most to the observed variation of absolute biomass gain and RGR (Costa and Rozana, 2000).

Effects of artificial shading on growth of *Trema micrantha* (Ulmaceae) seedlings revealed that shading for 60 days had no effect on survival, but it influenced all growth parameters measured. Decreases in relative growth rate were caused by reductions in net assimilation rate rather than leaf area ratio (Valio, 2001).

2.3.3.5 Net Assimilation Rate (NAR)

In chickpea, NAR decreased with decreasing light intensities (Pandey *et al.*, 1980).

Ramadasan and Satheesan (1980) observed high NAR in turmeric cultivars grown under open condition compared to shade. Ramanujam and Jose (1984) also observed similar response in cassava.

Ancy (1992) observed higher NAR under 25 and 50 per cent shade levels and a drastic decrease in NAR in heavy shade, in ginger.

2.3.3.6 Specific leaf weight (SLW)

In Rhododendron hybrid Pink Ruffles, shoot: root ratio and specific leaf weight were proportional to light level (Andersen *et al.*, 1991).

Reduced height and specific leaf weight in beans was reported by Newman *et al.*, (1997) when it was grown as an intercrop in Paulownia plantations in China.

The effect of conventional shading (light transmittance rate of 3 per cent) and polyethylene net shading (light transmittance rate of 10 per cent) on the growth (leaf area, specific leaf weight, leaf and stem dry weight (DW)) of *P. ginseng* [*P. pseudoginseng*], under ridge cultivation in Korea Republic, was investigated in 2-, 4- and 6-year-old plants. In 4-year-old plants, leaf area, stem and leaf DW decreased with increasing intensity of shade under conventional shading; little difference was observed under net shading. These trends were more obvious in 6-year-old plants (Lee, 1997).

Studies on the effects of shading on photosynthesis and leaf yields of ginkgo showed that with increase in shading intensity, the following indexes decreased: fresh weight per leaf area, net photosynthetic rate, light saturation point and the dried leaf weight per seedling (Xiang *et al.*, 2000).

2.3.3.7 Harvest Index

Shading of *D. stramonium* led to a greater decrease in seed production and, consequently, in the harvest index than in the other species examined (Benvenuti, *et al.*, 1994).

A moderate light intensity (60 lx) resulted in the highest biomass production and harvest index (2.137) in *Urginea indica* (Pal and Gupta 1991).

2.3.3.8 Stomatal Conductance

Leaf physiology and plant growth of Rhododendron hybrid Pink Ruffles were compared under conditions of 100 per cent sun and under polyethylene shade cloth with specifications of 69 per cent, 47 per cent and 29 per cent light transmittance. Net CO_2 assimilation (A) and stomatal conductance to water vapour (g_s) were often reduced for plants in the 100 per cent sun regime, although few differences existed among the 69 per cent, 47 per cent and 29per cent sun treatments. Stomatal conductance was very sensitive to leaf to air vapour pressure deficits (VPD) (Andersen *et al.*, 1991).

In *Photinia x fraseri* stomatal conductance was often inversely related to light level (Norcini *et al.,* 1991).

Controls on leaf stomatal conductance imposed by soil water availability and foliage acclimatization to long-term integrated irradiance were studied over 2 yr (1995-96) in a natural mixed deciduous stand composed of shade-intolerant *Populus tremula* (a dominant species in the overstorey) and shade-tolerant *Tilia cordata* in the lower canopy, in Järvselja forest in Estonia. Positive relationships between maximum stomatal conductance and seasonal integrated average daily quantum flux density (Q_{int}, mol m^{-2} d^{-1}, measured at 18 canopy locations over a whole growing season) were observed in both species; the slope of this relationship declined with increasing soil water limitations. There were negative correlations between Q_{int} and leaf water and osmotic potentials, and stomatal conductance reached in conditions of severe water stress were relatively lower in the upper than in the lower canopy in both species. Across the whole set of data, there was a negative correlation between minimum daily leaf water potential and stomatal conductance, because both variables covaried with irradiance. When the covariation with light was accounted for by a multiple linear regression analysis, minimum leaf water potential had no significant effect on stomatal aperture. Instead, stomatal conductance correlated positively with soil water potential in both species (Niinemets *et al.,* 1999).

Transpiration from sunlit and shaded fractions of a maize (Zea mays L m^{-2}.) canopy was estimated using a modified Penman-Monteith energy balance equation. Estimated values were validated by a heat pulse system, which measured stem sap flow, and by a weighing lysimeter. A relationship between incident radiation and leaf stomatal conductance for critical levels of leaf water potential was used to estimate transpiration. Computed transpiration of the shaded canopy ranged from 27 to 45 per cent of the total transpiration when fluctuations in atmospheric demand and the level of water stress were taken into account. Hourly and daily estimates of transpiration showed agreement with lysimeter and heat pulse measurements on the well-watered plots. For the water-limited plots the precision of the estimate decreased due to difficulties in simulating the canopy stomatal conductance (Santos *et al.,* 1999).

A study was conducted at the Lower Hantana University, to examine the variation of leaf stomatal conductance (g_l) and leaf water potential (Ψ) in selected forest tree species under varying levels of natural shade, quantify the relationship between g_l and Ψ, and determine the environmental and plant factors that determine g_l. Nine forest tree species (*Alstonia macrophylla, Macaranga peltata, Acronychia pedunculata, Tectona grandis, Terminalia catappa, Swietenia macrophylla, Filicium decipiens, Mesua ferrea* and *Semicarpus nigro-viridis*), which included both pioneer and climax forms, growing under different levels of natural shade, namely open, medium shade and full shade, were used for measurements. Total leaf conductance (g_l) varied significantly with tree species and shade levels. The highest g_l were observed in Semicarpus and Terminalia , i.e. 92 and 78 mmol $m^{-2}s^{-1}$, respectively. The rest of the species had significantly lower g_l values, which ranged from 34-44 mmol $m^{-2}s^{-1}$. When averaged across tree species, g_l was significantly greater under open conditions as compared to medium and full shade. Ψ also varied significantly with tree species and shade levels. Swietenia and Filicium showed the lowest Ψ values. There was a positive relationship between Ψ and g_l under all three shade levels. However, the relationship was strongest (r^2=0.764) under open conditions and became weaker with increasing shade (r^2=0.531 and 0.363 under medium and full shade, respectively). Under open conditions, 58 per cent of the overall variation of g_l was explained by Ψ. This decreased to 28 per cent under medium shade. Under full shade, 93 per cent of the variation of g_l was explained by leaf temperature and light intensity. Stomatal density did not have a significant correlation with g_l despite showing significant variation with tree species and shade levels (Costa *et al.,* 2000)

A field study conducted in Utah, USA, to examine the demographic effects of associating *Cryptantha flava* with shrubs revealed that shading did not reduce stomatal conductance proportionally to photosynthesis, which led to decreased water use efficiency for plants under shrub. (Forseth *et al.,* 2001)

In Citrus, mid day leaf temperatures and leaf - to - air vapour pressure differences were reduced by shading, resulting in increased stomatal conductance and photosynthetic activity of shaded leaves compared to sunlit leaves (Jifon and Syvertsen, 2001).

Morphological characteristics and responses of gas exchanges to light intensity were examined in a typical vernal species, *Erythronium japonicum,* grown (i) on the floor of a deciduous broad-leaved *Quercus mongolica* forest (one of its native habitats, the *Q. mongolica* stand); (ii) bare land left undisturbed for 9 years after forest clearing (the bare stand); and (iii) in a sun crop, soyabean, grown for 110 days in an experimental field and for 17 days in pots, in order to evaluate the adaptability of the photosynthetic process of this vernal species to its shady native habitats. The daytime solar radiation, air and leaf temperatures and leaf-air vapour pressure difference (VPD) were significantly higher at the bare stand than at the *Q. mongolica* stand. When environmental factors observed at the *Q. mongolica* and bare stands were reproduced in an assimilation chamber, leaf temperatures of *E. japonicum* plants increased markedly with increased radiation, whereas those of soyabean plants differed little from the respective air temperatures. The photosynthetic and transpiration rates and stomatal conductance in the former plants placed under conditions at the *Q. mongolica* stand increased with radiation and reached respective steady state values at maximum radiation at the site; whereas, under the conditions at the bare stand, they also increased and reached respective steady state values, but then continuously decreased to be lower than the respective value at the *Q. mongolica* stand. However, both rates and the conductance in the soyabean plants under both conditions increased significantly with radiation and reached much higher respective values at the respective maximum radiations (Sawada *et al.*, 2002).

2.3.3.9 Water Potential

Increasing salinity and irradiance reduced leaf water potential ($\Psi\omega$), osmotic potential ($\Psi\pi$) and turgor potential ($\Psi\tau$) in strawberry. There was an interaction between salinity and irradiance on $\Psi\tau$ with the lowest $\Psi\tau$ recorded for the unshaded leaves (Awang and Atherton,1994).

In *Encelia farinosa* , a common C_3 sub-shrub in arid regions of southwestern USA, dark respiration decreased with decreasing leaf water potential (Ψ_l) in sun plants, but remained unchanged in shade plants; day respiration was little affected by PPFD for both sun and shade plants. Stomatal conductance (g_s) was similar for sun and shade plants under high soil-moisture conditions, but was higher in sun plants as Ψ_l decreased; for all data considered together, changes in the leaf-air vapour pressure difference accounted for 71 per cent of the variation in g_s (Zhang HeHui *et al.,* 1995).

Shade-tolerant species that coexist in the forest understorey exhibit differences in leaf lifespan that have been associated with variation in physiological traits. Water relations of understorey species with widely divergent leaf lifespan differ in response to drought. The predawn leaf water potential declined to -2.8 and -3.6 MPa during the dry season in *Hybanthus prunifolius and Psychotria horizontalis,* respectively, two species with short leaf lifespans, but remained above -1.3 MPa in two species with long leaf lifespans, *Swartzia simplex* and *Ouratea lucens.* The midday leaf water potential dropped as low as -3.4 and -4.5 MPa for *H. prunifolius* and *P. horizontalis,* respectively. The osmotic potential of *H. prunifolius and P. horizontalis* and another species with short leaf lifespan, *Alseis blackiana*, decreased early in the dry season, a period during which all three had substantially negative predawn water potential. In contrast, the osmotic potential of *S. simplex, O. lucens, and Licania platypus,* a third species with long leaf lifespan, declined late in the dry season. (Tobin *et al.*, 1999)

2.3.3.10 Photosynthetically Active Radiation (PAR)

The photosynthetic activity of grapevine leaves (Sangiovese/ Kober 5BB) was evaluated under field conditions on mature vines grown under photosynthetically active radiation (PAR) rates of 100, 60 or 30 per cent sunlight. In comparison with unshaded vines at flowering and veraison, the leaves of shade-grown vines (60 per cent and 30 per cent sunlight) showed significantly lower values of Pn_{sat} (saturated rate of net photosynthesis) and dark respiration (R_d), and lower light compensation (PAR_c) and light saturation points (PAR_{sat}), whereas the apparent quantum yield of CO_2 assimilation (ϕ_i) was significantly higher. At phenological stages, the diurnal patterns of Pn (net photosynthesis), stomatal conductance to H_2O vapour (g_s) and leaf water potential (Ψ) were positively correlated with PAR. The growth habit of shade-grown vines also changed to a more open canopy, which increased the PAR trapping efficiency. It was concluded that vine leaves should receive approx. 700-900 micro $molm^{-2}s^{-1}$ of PAR for the greater part of the day during the entire crop cycle so that yield and berry quality were maintained (Cartechini and Palliotti, 1995).

In Norway spruce (*Picea abies*) at the saturating photosynthetically active photon flux density (PPFD), the maximum rate of CO_2 uptake (P_{Nmax}) of exposed shoots (E-shoots) was 1.7 times that of the shaded shoots (S-shoots). The apparent quantum yield (α) of E-shoots was 0.9 times that of the S-shoots.

A lower ability to use excess energy at high PPFD in photosynthesis was observed in the S-layer. The CO_2- and PPFD-saturated rate of CO_2 uptake (P_{Nsat}) of the E-shoots was 1.12 times and the carboxylation efficiency (τ) 1.6 times that of the S-shoots. In addition to the irradiation conditions and thus limitation by low J_a, the important limitation of photosynthesis in shade needles was due to carboxylation. This limitation of photosynthesis was accompanied by lower stomatal conductance (Sprtová ane Marek, 1999).

An experiment conducted in Pune, Maharashtra, India, to study the reflected photosynthetically active radiation (PAR) under sorghum-based intercropping system revealed that generally, RPARs values were highest during the initial stages of crop growth due to less leaf area index (LAI). Generally, RPAR increased with the increase in crop age up to 42 DAS due to the increase in LA and LAI. RPAR values increased significantly in sole sorghum and pigeon pea than in groundnut 112 DAS. This was due to the dense canopy and small size of groundnut leaves (Singh *et al.,* b 2002).

2.3.4 Biochemical Attributes

2.3.4.1 Chlorophyll (a, b and total)

In intercropping study to find the effect of shade on photosynthesis and plant morphology of Stokes aster, it was observed that high light plants were least efficient due to a vertical leaf orientation. As environment light intensity (LI) declined, plants had more chlorophyll per unit DW, a higher chl b: chl a ratio, less leaf DW, less leaf area, and a lower root: shoot ratio (Callan, and Kennedy, 1995).

In *Camptotheca acuminata* shaded leaves displayed significantly higher chlorophyll fluorescence than the non-shaded leaves.

Leaves of shade-grown grape vines had higher contents of chlorophyll (Cartechini and Palliotti, 1995).

2.3.4.2 Starch

In grape vine modifications that occurred under shading were associated with decreases in leaf DW, leaf soluble carbohydrates and starch content, vine yield, total soluble solids in the berries, total leaf area per vine and number of axillary shoots per cane (Cartechini and Palliotti, 1995).

2.3.5 Yield

In *Malwa verticillata* growth and yields were reduced by shading (KiCheol *et al.,* 1995).

Appropriate tree shade can promote the photosynthetic rate of tea plants and thus increase tea yields (Jianhui and RongnNan, 1998).

Ginseng (*Panax ginseng* C.A. Meyer) were grown under different shades levels of shading provided by straw or polyethylene nets. Shading with a poly ethylene net giving light transmittance rate of 10 per cent gave the highest root yield which was 40 per cent higher than the yield obtained with straw shading. (Cheon *et al.,* 1991)

In *Cinchona ledgeriana* grown in Darjeeling, data on the comparative growth, and bark and quinine yields of plants grown with or without shade of *Alnus nepalensis*, showed that shade increased all this parameters (Nandi and Chatterjee, 1991).

In a study to find out the radiation stress on therapeutic yield and biomass production in *Nerium oleander* and *Urginea indica*, the highest biomass production, harvest index and therapeutic yield in *N. oleander* and therapeutic yield of *U.indica* were obtained at radiation stress (120 lx). A moderate light intensity (60 lx) resulted in the highest biomass production and harvest index in *U.indica* (Pal and Gupta, 1991).

In a study to find out the effect of shade on yield of *Aralia continentalis* Kitag, a medicinally valuable herb found in far east Russia, Ostrogradskii and Chernyshev (1992) reported that plants growing in the open produced significantly greater amounts of above- and below- ground parts than plants growing in the shade of oak trees. In the first and second year in plants in the open the above-ground mass was greater than that below ground but in the third year the opposite was true.

Trials conducted in Janseong to determine the effect of 20 to 95 per cent shading on leaf and flowering characteristics, and bulb production of *Lycoris radiate*, a herbaceous medicinal plant, revealed that increased shading delayed flowering and shortened its duration. Bulb yield was the highest within 35 per cent shade and the lowest with 95 per cent shade (Choi *et al.*, 1991).

In a field of tea, shoot population density and yield were the highest in unshaded plants, indicating that shoot population was the most important component in determining yield. Plants growing in *Grevillea robusta* shade had the lowest shoot DW and yield. *G. robusta* significantly and persistently depressed tea yield, even when shade was reduced by lopping (Othieno and Ng'etich, 1992).

In *Datura stramonium* decrease in seed production under shading was reported by Benvenuti *et al.*, (1994). They opined that this might be due to a decrease in the number of roots per plant.

Pineapple intercropped with *Alnus nepalensis* recorded the lowest flowering percentage, fruit weight and fruit yield compared with plants intercropped with Acacia. Although pineapple can tolerate high amount of shade, the shade cast by Alnus was excessive (77 to 83 per cent of light was intercepted) and hence adversely affected fruit yield and quality (Dhyani *et al.*, 1995).

Both fresh and dry yields of onion were the highest under full sunlight (Miah *et al.*, 1998). Under natural shade in the coconut plantation there was a 32 per cent increase in rhizome yield in ginger (Jayachandran *et al.*, 1998).

Wheat grain dry matter yield, leaf area index were reduced under the tree canopy compared with crops grown in the open (Nandal *et al.*, 1999).

Per plant yield of ginger under areca nut plantation was significantly higher when compared open conditions (Hedge *et al.*, 2000).

Shade tree cover of 23-38 per cent had a positive effect on yield of coffee plants but production may decrease under shade cover by more than 50 per cent (Soto-Pinto *et al.*, 2000).

Grain yield and biological yield of wheat were decreased below tree canopies while higher harvest index and yield attributes were observed in treatments below tree canopies compared to control (Kiran and Agnihotri, 2001).

2.3.6 Quality

In *A. korupensis*, a rainforest liana of limited distribution in the Cameroon, which contains michellamine B, a novel isoquinoline alkaloid with antiviral activity against the AIDS virus studies indicated that the leaf litter, obtained from underneath canopy vines, contained significant amounts of michellamine B (Thomas *et al.,* 1994).

Nutritive value of the oat fodder grown under trees was better than that in the open field (more crude protein and minerals and less crude fibre, and neutral and acid detergent fibre (Nandal and Bisla,1995).

Boldo (*Peumus boldus* Mol) leaves grown in the shade had higher essential oil (2.9per cent) and alkaloid (0.12per cent) contents than those in full sunlight (1.8 and 0.07per cent, respectively) (Vogel *et al.,* 1996).

Shade-grown *Aloe arborescence* and *A. saponaria* contained less anthocyanins and carotenoids than those grown in the field; shade- and field-grown *A. vera* contained similar amounts of these compounds. The proline, protein and polyamine contents of *A. arborescence* and *A. saponaria* decreased in the shade; those of *A. vera* were similar in the field and in the shade (Lee *et al.,* 1996).

The proportion of coumarins in green and red leaves of *Justicia pectoralis* var. *stenophylla* was compared for plants grown in the sun or shade. In red leaves, which contain carotenoids and anthocyanins, the amount of total coumarins was greater than in green leaves grown in the sun or shade. Red leaves, which developed in the shade, contained less 4-methylumbelliferone and more 1, 2-benzopyrone than those grown in sunlight. For medicinal purposes, the use of plants with predominantly red leaves grown under strong sunlight was recommended (Barros *et al.,* 1997).

Tree shade can improve the quality of tea leaves by increasing concentration of amino acid and caffeine and carotenoids (JianHui and RongnNan, 1998).

Genetic resources of the medicinal and vegetable plant *Centella asiatica*, collected from different parts of India, were screened for their herb and asiaticoside yields under different levels of shading, under subtropical field conditions of Indo-Gangetic plains at Lucknow. 50 per cent shading of plants resulted in higher yields of herbage and asiaticoside. Thirteen out of the 16 accessions studied had shading requirements for high yields of fresh and dry herb and asiaticoside. The accession CaShT, from Meghalaya, was identified as very high herbage and asiaticoside yielding but requiring shading of about 50 per cent. On the other hand, accessions CaBp and CaCl from Orissa and West Bengal, respectively, gave high herb and asiaticoside yields under full light. It was concluded that triterpenoid saponin rich *C. asiatica* for high yields could be cultivated in the field under shade or full light by selecting the genotype adapted to the respective growth conditions (Shalini *et al.,* 2000)

The effects of different agrotechniques (e.g. shading, harvesting date, soil pH) on the chemical composition and quality of the drug from *Desmodium* *gangeticum* plants grown on sodic soil (pH 8.6-10) were investigated. The roots were extracted with ethanol or 50 per cent ethanol: water. The leaves were analysed for ash, protein, carotenoid (provitamin-A), vitamin C, tannins, phenolics, anthocyanins, sugars, nitrate and oxalate. The total ethanol and 50 per cent ethanol: water extracts showed that the shaded plants produced higher amounts (4.91per cent and 14.27per cent, respectively) of total extract compared to the plants grown in the open (2.89per cent and 11.23per cent, respectively). Similarly, the wild plants collected from shade treatment also had 5.17 per cent and 11.97 per cent total ethanol and 50per cent ethanol: water extractives, respectively, compared with the plants grown in the open (4.46 per cent and 10.20 per cent, respectively) (Prakash *et al.*, 2001).

In a study to find out the effect of shading on growth, hook yield and alkaloid content in *Uncaria rhynchophylla,* Kawazoe *et al.* (1989) reported that plant growth rate and hook yield were higher when the plants were grown under 40 per cent shade but alkaloid contents in the hooks (per cent FW) increased with the degree of shade. It was concluded that 40 per cent shade was the optimum for alkaloid yield.

Annual fluctuations of starch, soluble sugars nitrogen, proteins, lipids and energy contents of storage substances were determined and compared in sun and shade leaves from *Arbutus unedo,Olea europaea* (olive*),Pstacia lentiscus* and *Quercus coccifera* collected from plants growing near Athens by Meletiou-Christou (1994). Sun leaves of *P.lentscus* and *Q.coccifera* contained higher amount of starch than shade leaves; in *A.unedo* and *O.europea* reciprocal results were obtained. The seasonal trends of soluble sugar content differed among species. Sun leaves contained higher amounts of protein and lower amounts of soluble nitrogen than shade leaves. The total lipid content was greater in sun leaves than in shade leaves of *P.lentiscus* and *Q.coccifera*, whereas shade leaves of *A.unedo* and *O.europaea* contained higher amounts of total lipids at the beginning of the growing season. They assumed that these variations in accumulation, in sun and shade leaves represent a species –specific response.

Results of a study on concentrations and diversities of plant secondary compounds in the canopy and understorey in four tree species, *Aucoumea klaineana, Marquesia excelsa, Paraberlinia bifoliolata, and Xylopia hypolampra* from a tropical rain forest in Gabon, suggested that surveys for biologically active molecules (i.e. new drugs or pesticides) should emphasize the canopy (Downum *et al.,* 2001).

In a study to find out the effects of temperature, shade, and nitrogen application on the growth and accumulation of bioactive compounds in cultivars of *Plantago lanceolata* L revealed that plants grown under shading treatment were lower in number of leaves per plant, top dry matter weights and top dry matter contents, although they were higher in plant height. The contents of aucubin and acteoside were extremely lower in plants grown in the shade. It was apparent that shade represses the growth and accumulation of aucubin and acteoside in the cultivars of *P. lanceolata* (Tamura, 2001).

2.4 PLANT DENSITY

In a study to find out the effect of sett size, plant population and organic manures on growth components of arrowroot (*Maranta arundinacea* L.) grown as intercrop in coconut garden showed that plant density did influence yield. At a lower plant density (111 thousand/ha), plants were taller, with more leaves and a higher leaf area than those grown at a higher plant density (166 thousand/ha) (Maheswarappa *et al.*, 1998).

2.5 ECONOMICS OF INTERCROPPING

From a study of yield advantageous in agro forestry systems in China, it was concluded that the managed agro forestry systems were advantageous compared with the control monocultures of trees or arable crops, even though the relative yields of intercrops were > 1. It was suggested that the relative yield and land equivalent ratio could be increased by substituting the high light demanding crops with the shade tolerant crops as tree shade increased (WenDing and QiFen, 1999).

Intercropping with banana improved fractional interception and radiation-use efficiency of immature rubber plantations. Intercropping provided an important means of raising not only productivity and land-use efficiency of smallholder rubber lands, but also income generation during the unproductive immature phase of the rubber tree (Rodrigo *et al.*, 2001).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

To study the adaptability and performance of ten selected medicinal plant species as intercrops in young, medium and mature oil palm plantations, field experiments were conducted at Kulathupuzha oil palm estate during the period from October 1999 to September 2002. The study also envisaged, to standardize optimum spacing for the most suitable medicinal plant species as intercrop in oil palm plantations of different age groups and to analyse its shade tolerance mechanism. The materials used and the methods adopted in the experiments are detailed hereunder. The experiments were conducted in two phases.

PHASE I EXPERIMENT

In the phase I experiment, 10 species of medicinal plants were screened for adaptability and shade tolerance under three shade situations viz., in the inter rows of oil palms of age groups, below five years (young), between five and eleven years (medium) and above eleven years (mature) and in the adjacent open area by conducting growth and yield analyses.

PHASE II EXPERIMENT

In the phase II experiment it was envisaged to select promising species based on the performance of the screening trial and to grow this under different levels of spacing to find out the optimum spacing under different shade situations and to analyse the shade tolerance mechanism of the selected species. In the present experiment, Kacholam was selected for the phase II studies.

3.1. EXPERIMENTAL SITE

Kulathupuzha oil palm estate is situated 9° 5' N latitude and 76° 8' E longitude, 100 – 300 m above mean sea level. The oil palm estate at Kulathupuzha covers a total area of 390 ha. It comprises of trees belonging to three categories, young, medium and mature.

Palms are spaced at 9 m in the triangular planting system and the variety planted is Tenera (Dura x Pisifera). The experimental site is a partially shaded oil palm plantation having palms of age group ranging between 4 and 15 years.

3.1.1 Climate

The climate of the experimental site is humid tropical. Mean temperature during the experimental period ranged between 29.4° C – 21.7° C. Average rainfall during the experimental period is given in Table 1.

Table 1. Average rainfall per month during the cropping period (cm)

Month	2000-01	2001-02	2002-03
September	9.39	9.83	8.98
October	9.57	9.27	9.92
November	11.98	12.86	14.76
December	10.61	8.60	-
January	10.60	1.10	-
February	1.30	1.12	-
March	6.90	12.60	-
April	8.70	14.60	-
May	13.20	7.31	-
June	9.11	8.26	-
July	12.49	9.45	-
August	10.36	7.75	

Fig. 1 Rainfall data during the cropping period

3.1. 2 Soil

The soil in the selected field belongs to Palode Soil Series, which are tentatively classified under clayey skeletal, mixed isohyperthermic Typic kandihumults. The soil is well drained with depth more than 100 cm and is developed from gnessic material. Soil is dark grayish brown to strong brown with gravelly loam to gravelly clay texture.

3.1. 3 Cropping History of the Experimental Site

The inter spaces are densely covered by numerous weed species. No cultivation operation and intercropping is being practiced in this area prior to the commencement of the experiment.

3.2 PHASE I EXPERIMENT – SCREENING TRIAL OF MEDICINAL PLANTS

3.2.1 Design and Lay Out

The experiment was laid out in split plot design with three replications.

Main plot Treatments – 4 shade levels

Table 2. Description of the shade level

Sl. No	Stage	Description	Illustration
1	Young	< 5 years	(Plate 1)
2	Medium	5 to 11 years	(Plate 2)
3	Mature	> 11 years	(Plate 3)

Plate 1. Young oil palm plantation

Plate 2. Medium oil palm plantation

Plate 3. Mature oil palm plantation

Table 3. Treatment details - Main plot

Sl. No	Treatments	Notations
1.	Open	S_0
2.	Palms below 5 years (young)	S_1
3.	Palms between 5 & 11 years (medium)	S_2
4.	Palms above 11 years (mature)	S_3

Sub plot Treatments – 10 medicinal plant species (plate 4) viz.,

***Adhatoda beddomei* (Malabar nut)** – (Vernacular name - Chittadalodakam), a small shrub known for its bronchodialatory and antispasmodic properties. Roots are the officinal part; leaves are also used for medicinal purpose.

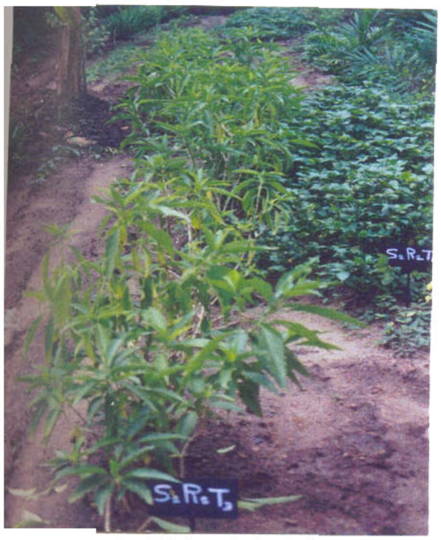
***Alpinia calcarata* (Lesser galangal)** – (Vernacular name – Chittaratha), a perennial herb with fleshy rhizome which has diuretic, carminative and expectorant properties.

***Asparagus racemosus* (Asparagus)** - (Vernacular name - Sathavari), a perennial woody climber with numerous fleshy roots used as a rejuvenative and restorative tonic and galactagogue.

***Coleus zeylanicus* (Hribera)** - (Vernacular name – Iruveli), stems and roots are used for digestive and urinary disorders.

***Kaempferia galanga* (Galanga)** - (Vernacular name – Kacholam), a herbaceous rhizomatous plant, essential oil of rhizome is widely used in perfumery, as a condiment and folk medicine.

Plate 4. Medicinal plant species selected for the study



A. Chittadalodakam

B. Chittaratha

C. Chunda

D. Iruveli

E. Karimkurinji

Medicinal plant species selected for the study

F. Kacholam

G. Koduveli

H. Patchouli

I. Sathavari

J. Thippali

Plumbago rosea **(Rosy leadwort)** - (Vernacular name – Chethikoduveli), an attractive erect rambling shrub with long tuberous roots which is an esteemed remedy for leucoderma and other skin diseases.

Pogostemon patchouli **(Patchouli)** - (Vernacular name – Patchouli), a herbaceous perennial plant, herbage oil of which is widely used in perfumery and pharmaceutical industries.

Piper longum **(Long pepper)** - (Vernacular name – Thippali), a rambling herb the roots and spikes are widely used in respiratory diseases.

Solanum incanum **(Medicinal solanum)** - (Vernacular name – Chunda), a spiny under shrub roots of which are widely used in ayurvedic medicines.

Strobilanthes haenianus **(Medicinal strobilanthes)** - (Vernacular name – Karimkurinji), a perennial shrub, dried roots and stem are used against neurological disorders, glandular swellings and rheumatism.

Table 4. Treatment details - Sub plot

Sl. No	Treatments	Notations
1	*Adhatoda beddomei*	T_1
2	*Alpinia calcarata*	T_2
3	*Solanum incanum*	T_3
4	*Coleus zeylanicus*	T_4
5	*Kaempferia galanga*	T_5
6	*Strobilanthes haenianus*	T_6
7	*Plumbago rosea*	T_7
8	*Pogostemon patchouli*	T_8
9	*Asparagus racemosus*	T_9
10	*Piper longum*	T_{10}

Replications - 3

Number of plants per replication - 50

3. 2. 2 Nursery

Cuttings of Chittadalodakam, Iruveli, Koduveli, Patchouli, Thippali and Karimkurinji were rooted in the polythene bags filled with potting mixture. Seeds of Chunda and Sathavari were planted in polythene bags to get uniform seedlings. Rhizome pieces of Chittaratha and Kacholam were planted in poly bags to get uniform planting material.

3.2. 3 Main Field Preparation and Planting

Raised beds of 23.7 m length and 5.6 m width were taken in the inter rows of oil palm leaving 2.5 m from the base of the palms. Spacing of 50 x 15 cm was given commonly to all plants.

3.2.3.1 Application of Manures and Fertilizers

No manures and fertilizers were applied to the plants

3.2.3.2 Irrigation

The plants were grown under rain fed condition. However, life saving irrigation was given to the plants during the initial months of planting.

3.2. 3.3 Weeding

Periodical weeding was done and the plots were kept weed free.

3.2.4 Sampling

Destructive random sampling was done at monthly intervals, starting from one month after planting of the crop, for taking different observations. At each sampling a total of one hundred and twenty plants were harvested and observation on growth parameters were taken from these plants. Each plant sample was partitioned into stem, leaves and roots and dried in a hot air oven at $70^{0} - 80^{0}$ C to estimate the dry matter accumulation and its distribution.

3.2.5 Observations

3.2.5.1 Morphological Parameters

3.2.5.1.1 Plant Height

The height of the plant was measured from the base of the plant to the tip of the tallest branch and was expressed in centimetre.

3.2.5.1.2 Number of Tillers / Branches

Total number of tillers per plant was counted and recorded in the case of Chittaratha and Kacholam. For other treatments the total number of primary and secondary branches per plant was recorded

3.2.5.1.3 Number of Leaves

The number of fully opened leaves per plant was counted and recorded.

3.2.5.1.4 Leaf Area

The length and maximum breadth of five leaves from the sample plant was measured at monthly intervals and the leaf area in cm^2 was estimated based on the length and breadth method.

Table 5. Regression equation for computing leaf area

Sl.No.	Species	Regression equation	R^2
1	Chittadalodakam	$Y = 10.4539 + 0.0288\ X$	0.9832
2	Chittaratha	$Y = 34.11391 + 0.0114\ X$	0.8872
3	Chunda	$Y = 15.33097 + 0.0339\ X$	0.9885
4	Iruveli	$Y = 11.97851 + 0.0696\ X$	0.9745
5	Kacholam	$Y = 8.948437 + 0.0489\ X$	0.9422
6	Karimkurinji	$Y = 4.783947 + 0.0510\ X$	0.9413
7	Koduveli	$Y = 11.16466 + 0.0440\ X$	0.9829
8	Patchouli	$Y = 19.62526 + 0.0383\ X$	0.9852
9	Thippali	$Y = 13.0082 + 0.0574\ X$	0.8457

Y = leaf area, X = product of length and breadth

3.2.5.1.5 Number of Roots

The root of sample plants was removed carefully, washed and the number of primary and secondary roots were counted and recorded.

3.2.5.1.6 Root Length

Maximum length of root was measured and mean expressed in centimetre (cm).

3.2.5.2 Physiological Characters

3.2.5.2.1 Dry Matter Production

Stems, leaves and roots of the uprooted sample plants were dried to a constant temperature at 70° – 80° C in a hot air oven. The sum of the dry weight of the component parts gave total dry matter production and expressed as g plant $^{-1}$.

3.2.5.2.2 Leaf Area Index

Leaf area index was computed using the following relationship (Williams, 1946).

$$\text{LAI} = \frac{\text{Leaf area of the plant (cm}^2\text{)}}{\text{Area of the land covered by the plant (cm}^2\text{)}}$$

3.2.5.2.3 Net Assimilation Rate

Net assimilation rate (NAR) refers to the change in dry weight of the plant per unit leaf area per unit time. The procedure given by Watson (1958) modified by Buttery (1970) was used for calculating NAR and expressed in g m^{-2} day^{-1}.

$$\text{NAR} = \frac{W_2 - W_1}{(t_2 - t_1)\ \dfrac{(A_1 + A_2)}{2}}$$

where W1 and W_2 are the total dry weight of plant (g) at time t_1 and t_2 respectively. A_1 and A_2 are leaf area indices at time intervals (days) t_1 and t_2 respectively.

3.2.5.2.4 *Crop Growth Rate*

It is the absolute growth rate per unit of ground or the rate of increase in dry weight per unit ground area. Crop growth rate (CGR) was worked out using the formula of Watson (1958) and expressed as g m^{-2} day^{-1}

$$C\,G\,R = N\,AR \times LAI$$

3.2.5.2.5 *Relative Growth Rate*

Relative growth rate (RGR) is the rate of increase in dry weight per unit time expressed as gm^{-2} day^{-1}. Relative growth rate was calculated as per the method of Blackman (1919).

$$R\,G\,R = \frac{\log_e W_2 - \log_e W_1}{(t_2 - t_1)}$$

where W_1 and W_2 are total dry weight per plant at time t_1 and t_2 respectively.

3.2.5.2.6 *Absolute Growth Rate*

This gives an idea of daily growth rate. AGR was worked out by the formula suggested by Briggs *et al.* (1920) and expressed as g day^{-1}

$$A\,G\,R = \frac{(W_2 - W_1)}{(t_2 - t_1)}$$

where W_1 and W_2 are total dry weight per plant at time t_1 and t_2 respectively.

3.2.5.2.7 *Photosynthetically Active Radiation*

Photosynthetically active radiation (PAR) in the interspaces of oil palms was measured using the steady state porometer (T) and expressed in μ mol m^{-2} s^{-1}.

3.2.5.3 Yield

From the four shade situations, three plants each per replication were selected randomly and uprooted carefully for estimating the yield. Chunda was harvested six months after planting, Kacholam, Iruveli and Patchouli after seven months, while Koduveli, Karimkurinji, Chittaratha, Chittadalodakam, Thippali and Sathavari were harvested eighteen months after planting for estimating the yield. Medicinal plant population in the open condition and under the intercropped situation were worked out separately for computing the yield ha^{-1}.

3.2.5.4 Harvest Index

Harvest Index (HI) was calculated at final harvest as follows

$$HI = \frac{Y\ econ.}{Y\ biol.}$$

where, Y econ. = dry weight of officinal part, Y biol. = total dry weight of plant

3.2.6 Soil Analysis

The soil analysis was done to find out the content of organic carbon. available nitrogen, phosphorous and potassium before and after the experiment. Composite soil samples were used for estimating the available nutrients present in the soil at the time of laying out of the experiment. Soil samples were collected from individual plots after the harvest of the crop, dried in shade, sieved through 2 mm sieve and analysed. Available N was estimated by alkaline permanganate method (Subbiah and Asija, 1956), available P by Bray method (Jackson, 1973) and available K by neutral normal ammonium acetate method (Jackson, 1973).

3.2.7 Statistical Analysis

The data of the screening trial were analyzed by the analysis of variance for split plot design. Critical differences (CD) at 5 per cent level of significance were provided wherever the effects were found to be significant.

3.2.8 Economic Analysis

Economics of cultivation was worked out for the screening trial after taking into account the cost of cultivation of the ten medicinal plant species and their prevailing market price. In computing the cost involved, different variable cost items like planting materials and labour charges were considered at the prevailing market rate during 2000 – 2001 and 2001 – 2002.

The net income and benefit cost ratio was calculated as follows

Net income (Rs. ha^{-1}) = Gross income – Total expenditure

Benefit cost ratio = Total income / Total expenditure

3.3 PHASE II EXPERIMENT - STANDARDIZATION OF OPTIMUM SPACING FOR KACHOLAM AND STUDY OF SHADE TOLERANT MECHANISM

Based on the results of growth analysis and economic analysis Kacholam was selected as the most suitable medicinal plant species for intercropping in oil palm plantations.

3.3.1 Design and Lay Out of the Experiment

Design – 4 x 3 Factorial R B D

Treatments

1. Three shade situation + open
2. Three levels of spacing

Table 6. Treatment details of phase II experiment

Treatments	Details	Notations	No. of plants per plot
Levels of shade	Open	S_0	-
	Young - palms below 5 years	S_1	-
	Medium -palms between 5 & 11 years	S_2	-
	Mature - palms above 11years	S_3	-
Levels of spacing	20 x 10 cm	D_1	30
	20 x 15 cm	D_2	21
	20 x 20 cm	D_3	15
Control	Clean weeding	-	-

Treatment combinations

Table 7. Treatment combinations in phase II experiment

$S_0 D_1$	$S_2 D_1$
$S_0 D_2$	$S_2 D_2$
$S_0 D_3$	$S_2 D_3$
$S_1 D_1$	$S_3 D_1$
$S_1 D_2$	$S_3 D_2$
$S_1 D_3$	$S_3 D_3$

3.3.2 Main Field Preparation and Planting

Raised beds 5.5m length and 1.2 m width were taken in the oil palm inter rows leaving 2.5 m from the base of the palms.

3.3.3 Sampling

Random sampling was done at 60, 120 and 180 days after planting and the observations on various growth parameters were recorded.

Final harvest was done seven months after planting.

3.3.4 Observations

3.3.4.1 Morphological Parameters

Morphological parameters like number of tillers, number of leaves, leaf area, leaf dry weight, number of roots , length of roots , weight of roots , thickness of rhizome , fresh and dry weight of rhizome and harvest index were recorded as in the case of phase I experiment.

3.3.4.2 Physiological Characters

3.3.4.2.1 Leaf Area Index

As in the case of phase I experiment.

3.3.4.2.2 Specific Leaf Weight

Specific leaf weight was assessed by dividing the individual leaf dry weights by corresponding leaf area and is expressed as $g\ cm^{-2}$

3.3.4.2.3 Stomatal Conductance

Stomatal conductance was measured using the steady state porometer and expressed as $\mu\ mol\ m^{-2}\ s^{-1}$

3.3.4.2.4 Photosynthetically Active Radiation on Leaf Surface

Photosynthetically active radiation on leaf surface was measured using the Steady state porometer (T) and expressed as $\mu\ mol\ m^{-2}\ s^{-1}$

3.3.4.3 Biochemical Analysis

3.3.4.3.1 Chlorophyll Content (%)

The chlorophyll content was estimated by following method prescribed by Starnes and Hadley (1965). A representative sample of 25 mg was weighed and the leaf tissues were then ground with 10 ml of 80 per cent acetone using a pestle and mortar. The OD value of the extract was measured at 663, 665, and 480 nm using 80 per cent acetone as the blank in the spectrophotometer.The amount of pigments was calculated using the formulae and expressed in mg of pigments g^{-1} of fresh leaf.

Total chlorophyll = (20.2 (OD at 645) + 8.01 (OD at 663) xv / (w x 1000)m g ^{1}

Chlorophyll a = (12.7 (OD at 663) - 2.69 (OD at 645) xv / (w x 1000) mg g^{-1}

Chlorophyll b = (22.9 (OD at 645) - 4.68 (OD at 663) xv / (w x 1000) mg g^{-1}

3.3.4.3.2 Volatile Oil (%)

The content of volatile oil was estimated by Clevenger distillation method AOAC., 1975) and expressed as percentage (v/w) on dry weight basis.

3.3.4.3.3 Oleoresin (%)

Oleoresin was estimated by Soxhlet distillation method (AOAC., 1975) and expressed as percentage on dry weight basis.

3.3 4.3.4 Starch (%)

Starch content was analyzed using copper reduction method suggested by AOAC., (1975) and expressed as percentage on dry weight basis.

3.3.4.3.5 Ash (%)

The ash content estimated by using muffle furnace by ashing the plant sample and expressed as percentage on dry weight basis.

3.3.4.4 Yield

Rhizome weight of three plants from each treatment after sun drying recorded and the average worked out and expressed as g plant $^{-1}$. Plant population at different spacings both in the open area and in intercropped situation worked out and used for computing the yield ha^{-1}.

3.3.5 Yield of Oil Palm

The yield of oil palm (number of bunches and bunch weight in kg of six palms surrounding each plot) at the experimental site was recorded before and after the experiment. The yield of clean weeded palms in each treatment was also taken for comparison.

3.3.6 Statistical Analysis

The data of the spacing trial was analyzed by the analysis of variance for factorial RBD. Critical differences (CD) at 5 per cent level of significance were provided wherever the effects were found to be significant.

3.3.7 Economic Analysis

Economics of cultivation worked out for the spacing trial after taking in to account the cost of cultivation of Kacholam and their prevailing market price. In computing the cost involved, different variable cost items like planting materials and labour charges were considered at prevailing market rate during 2000 – 2001 and 2001 – 2002.

The net income and benefit cost ratio was calculated as follows:

$$\text{Net income (Rs ha}^{-1}\text{)} = \text{Gross income} - \text{Total expenditure}$$

$$\text{Benefit cost ratio} = \text{Total income} \;/\; \text{Total expenditure}$$

RESULTS

4. RESULTS

4.1 PHASE I EXPERIMENT

The results of the screening trial of ten selected medicinal plants under the shade of oil palm of different age groups are presented below:

4.1.1 Growth Characters

4.1.1.1 Plant Height

The influence of different shade levels under the oil palm canopy on the height of the medicinal plant species is described in the following pages.

Growth Stage, Month 1

Effect of shade on plant height was not significant (Table I, Appendix) .

The species differed significantly in their plant height and Karimkurinji recorded higher value (26.54 cm) (Table 8).

Shade x species interaction was also significant (Table 9.1). Under open condition Sathavari and Karimkurinji recorded higher values (19.00 and 17.23 cm respectively). Among young, medium and mature palm canopy also Karimkurinji was significantly taller (28.00, 37.93 and 23.00 cm respectively).

Regarding height of species under different shade situations the data showed that Chittadalodakam was significantly taller under young oil palm canopy (14.33 cm) which was on par with those under other situations (11.67, 11.4 and 10.67 cm under open, medium and mature condition respectively). Chittaratha recorded the highest value under mature palms (22.4 cm) which was on par with open (14.00 cm) and under medium palms (13.00 cm). Chunda was the tallest under medium palms (18.67 cm) which was on par with other shade situations. Iruveli produced highest value under mature palms (20.30 cm) which was on par with those under other situations. Karimkurinji registered the tallest plants under medium oil palms (37.93 cm) which was on par with young oil palm canopy (28.00 cm). In the case of Koduveli, higher plant height was under medium palms (15.33 cm) which was on par with those under other situations.

Table 8: **Mean plant height of medicinal plant species for oil palm shade conditions at different stages of plant growth, cm**

Treatment	Growth stage - month																	
Shade conditions	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Open	13.19	15.93	20.22	24.10	26.16	28.42	27.62	33.33	40.84	41.62	45.53	48.87	52.28	56.01	59.67	66.68	70.07	72.86
Young	15.85	19.87	22.99	26.64	28.84	33.47	31.78	35.40	44.72	47.62	52.07	61.44	67.26	72.83	75.77	80.83	86.59	90.74
Medium	17.24	21.85	27.79	32.76	33.12	39.37	41.88	44.19	48.44	48.27	50.56	55.24	61.64	65.34	67.05	71.19	72.42	75.29
Mature	14.79	16.83	19.41	23.09	26.03	28.01	28.28	26.42	29.21	30.73	31.59	35.68	35.67	39.07	43.05	47.65	47.98	49.17
CD 0.05	**N.S.**	**N.S.**	**3.276**	**4.747**	**N.S.**	**2.874**	**3.188**	**4.322**	**2.822**	**3.533**	**5.706**	**7.865**	**4.016**	**8.370**	**3.786**	**9.490**	**9.242**	**5.409**
Species																		
Chittadalodakam	12.02	14.22	16.18	17.72	19.76	22.31	24.21	28.01	32.21	35.68	40.38	46.15	52.53	58.83	60.43	64.03	65.92	67.24
Chittaratha	14.89	13.17	14.98	19.11	18.76	20.84	23.86	22.58	37.20	31.51	33.73	43.22	42.24	41.01	38.28	43.38	46.52	55.83
Chunda	15.74	25.58	33.92	39.83	45.17	50.79	Crop harvested											
Iruveli	16.03	18.83	18.89	20.76	20.98	21.62	24.26	Crop harvested										
Karimkurinji	26.54	31.75	32.28	34.11	34.26	36.52	37.50	37.28	41.53	43.03	43.71	46.08	48.55	52.24	56.85	61.16	63.07	64.28
Koduveli	14.35	17.82	20.42	21.98	23.92	26.50	27.43	28.33	31.09	32.82	33.37	34.79	36.64	38.43	39.45	40.93	42.21	40.81
Patchouli	10.37	13.10	18.22	25.97	30.88	36.87	40.71	Crop harvested										
Sathavari	15.53	18.46	17.93	27.39	39.36	49.63	54.60	61.94	66.99	72.43	78.71	87.40	95.13	103.27	113.33	123.07	123.90	125.10
Thippali	11.93	14.65	20.63	22.96	23.77	25.78	26.56	30.87	35.82	36.89	39.73	44.21	50.19	56.08	59.98	66.97	73.98	78.83
C D 0. 05	**4.759**	**4.272**	**3.877**	**7.326**	**6.920**	**4.954**	**5.358**	**3.429**	**5.447**	**6.107**	**7.140**	**5.991**	**5.629**	**5.253**	**7.896**	**6.931**	**7.767**	**6.535**

Patchouli reported higher plant height under mature palms (11.77 cm) and Sathavari under open condition (19.00 cm). In these plants, height was on par under the four situations. Thippali recorded higher plant height under young oil palm canopy (17.87 cm) which was on par with those under medium and mature palms (15.17 cm and 9.2 cm).

Growth Stage, Month 2

Effect of shade on plant height was not significant (Table I, Appendix) .

The data given in Table I Appendix showed that the interspecies variation in plant height was highly significant and Karimkurinji (31.75 cm) recorded the highest value (Table 8).

Shade x species interaction was also highly significant (Table 9.2). Chunda recorded highest value under open condition (26.33 cm) which was on par with Sathavari (22.00 cm) and Koduveli (20.33 cm). Under young oil palm canopy, medium and mature oil palms, Karimkurinji excelled with 38.33, 41.33 and 30.33 cm respectively.

Regarding species performance under different shade levels, plant height under the four shade situations was on par in Chittadalodakam, Chittaratha, Chunda, Iruveli, Koduveli, Patchouli and Sathavari. However, Chittadalodakam registered higher plant height under open (16.90 cm), Chittaratha, under medium palms (19.67 cm), Chunda under young oil palm canopy (28.33 cm), Iruveli under medium palms (24.80 cm) Karimkurinji under medium palms (41.33 cm), Koduveli under open (20.33 cm) Patchouli under mature palms (16.17 cm) and Sathavari under young oil palm (22.67 cm). Thippali recorded the highest plant height was under medium palms (22.83 cm) which was on par with those under young oil palm canopy (21.03 cm).

Growth Stage, Month 3

Shade significantly influenced this character (Table I, Appendix) and significantly higher plant height was reported from medicinal plant species grown under medium palms. Interspecies variation was also highly significant with Chunda recording the highest plant height (33.92 cm) which was on par with Karimkurinji (32.28 cm) (Table 8).

Table 9.1: Mean plant height showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, cm -month 1

Shade conditions	Chittadalodakam	Chittaratha	Chunda	Iruveli	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	11.67	14.00	14.30	13.33	17.23	14.33	9.33	19.00	5.50
Young	14.33	10.17	16.33	12.00	28.00	14.00	9.33	10.63	17.87
Medium	11.40	13.00	18.67	18.47	37.93	15.33	11.03	14.17	15.17
Mature	10.67	22.40	13.67	20.30	23.00	13.73	11.77	18.33	9.20

CD_1 (0.05) 9.519 CD_2 (0.05) 10.11

Table 9.2: Mean plant height showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, cm -month 2

Shade conditions	Chittadalodakam	Chittaratha	Chunda	Iruveli	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	16.90	11.00	26.33	14.67	17.00	20.33	9.83	22.00	5.33
Young	16.00	10.83	28.33	12.17	38.33	17.33	12.10	22.67	21.03
Medium	12.60	19.67	26.00	24.80	41.33	17.93	14.30	17.17	22.83
Mature	11.37	11.17	21.67	23.67	30.33	15.67	16.17	22.00	9.40

CD1 (0.05) 8.544 CD2 (0.05) 12.70

CD 1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

Shade x species interaction also varied significantly (Table 9.3). Chunda and Sathavari were significantly taller under open condition (35.00 and 29.00 cm respectively). Under young oil palm, Karimkurinji and Chunda recorded the highest value (39.00 and 35.00 cm). Under medium and mature palms, Karimkurinji was significantly superior (41.87 and 32.33 cm respectively).

Regarding individual species performance, Chittadalodakam produced the highest height under young oil palm (19.33 cm), Chunda under medium palms (36.00 cm), Koduveli under open condition (22.33 cm) and Sathavari under open condition (29.00 cm). The height of these species was on par under the four shade situations. Chittaratha recorded higher height under medium palms (20.00 cm) which was on par with those under mature and young oil palm (14.00 and 13.93 cm respectively). Iruveli recorded higher height under medium palms (25.57 cm) which was on par with those under mature palms (24.33 cm). Karimkurinji performed well under medium palms (41.87 cm) and this was on par with those under young oil palm (39.00 cm). Patchouli had the highest height under medium palms (23.23 cm) which was on par with those under mature palms (22.33 cm). Thippali had higher height under medium palms (32.63 cm) which as on par with young oil palm (27.80 cm).

Growth Stage, Month 4

Shade had significant influence on plant height (Table I, Appendix) as indicated by the significantly superior plant height under medium palms.

Interspecies difference in plant height was also highly significant. Chunda recorded the highest plant height of 39.83 cm, which was on par with Karimkurinji (34.11 cm) (Table 8).

Shade x species interaction was also significant (Table 9.4). Chunda and Sathavari were taller under open condition (41.67 and 34.67 cm respectively). Under young oil palm canopy the Chunda, Karimkurinji, Thippali and Sathavari recorded higher values and were on par (44.00, 40.33, 33.06 and 31.10 cm respectively). Under medium palms, Karimkurinji recorded the highest value of 41.10 cm, which was on par with Thippali (33.86 cm), Chunda (35.00 cm),

Table 9.3: Mean plant height showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, cm -month 3

Shade conditions	Chittadalodakam	Chittaratha	Chunda	Iruveli	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	18.67	12.00	35.00	12.33	15.90	22.33	13.47	29.00	13.30
Young	19.33	13.93	35.00	13.33	39.00	19.33	15.83	23.33	27.80
Medium	14.43	20.00	36.00	25.57	41.87	22.00	23.23	24.37	32.63
Mature	12.27	14.00	29.67	24.33	32.33	18.00	22.33	25.00	8.77

CD1 (0. 05) 7.753 CD2 (0. 05) 7.99

Table 9.4: Mean plant height showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, cm -month 4

Shade conditions	Chittadalodakam	Chittaratha	Chunda	Iruveli	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	22.67	23.00	41.67	12.00	20.23	24.00	15.67	34.67	12.90
Young	19.00	15.00	44.00	15.67	40.33	20.17	21.43	31.10	33.06
Medium	16.40	21.53	35.00	29.13	41.10	24.83	31.80	31.13	33.86
Mature	12.80	16.90	38.67	26.23	34.67	18.90	34.97	32.67	12.00

CD1 (0. 05) 14.653 CD2 (0. 05) 14.58

CD 1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

Patchouli (31.80 cm) and Sathavari (31.13 cm). Under mature palms also, Chunda recorded the highest height (38.67 cm) which was on par with Patchouli (34.97 cm), Sathavari (32.67 cm) and Karimkurinji (34.67 cm).

Regarding intershade species performance, Chittadalodakam, Chittaratha, Chunda, Koduveli and Sathavari performed equally well with regard to plant height under the four situations. However, Chittadalodakam, Chittaratha and Sathavari were taller under open condition (22.67 cm, 23.00 cm and 34.67 cm). Chunda recorded higher values under young oil palm canopy (44.00 cm) and Koduveli under medium palms (24.83 cm). Iruveli recorded higher plant height under medium palms (29.13 cm) which was on par with mature and young oil palm canopy (26.23 and 15.67 cm respectively). Karimkurinji also recorded superior plant height under medium palms (41.10 cm) which was on par with young oil palm canopy and mature palms (40.33 and 34.67 cm respectively). Patchouli recorded the highest values under mature oil palm canopy (34.97 cm) which was on par with medium and young oil palm canopy (31.80 and 21.43 cm respectively). Thippali had the highest height under medium palms (33.86 cm) and was on par with young oil palm canopy (33.06 cm).

Growth Stage, Month 5

The data suggested that the influence of shade on plant height was not significant (Table I, Appendix). The species differed significantly with regard to their plant height and higher plant height was for Chunda (45.17 cm) (Table 8).

Shade x species interaction was also significant (Table 9.5). Chunda and Sathavari recorded significantly higher values under open condition (50.67 and 38.33 cm respectively). Under young oil palm canopy also, Chunda excelled with a plant height of 56.33 cm while under medium and mature palms Karimkurinji, Chunda, Patchouli and Sathavari recorded significantly higher values.

With reference to individual species performance, Chittadalodakam, Chittaratha, Koduveli and Sathavari showed no inter shade variation. However, Chittadalodakam recorded higher plant height under open (27.03 cm), Chittaratha under medium palms (22.00 cm), Koduveli under open (25.33 cm) and Sathavari under mature palms (42.30 cm). Chunda recorded the highest plant height under young oil palm (56.33 cm) which was on par with those under open (50.67 cm). Iruveli had the highest plant height under medium palms (29.63 cm) and was on par with those under mature palms (27.30 cm) and open condition (15.33 cm). Karimkurinji recorded significantly superior height under the three shade situations (43.90, 41.67 and 36.00 cm under medium, young and mature oil palm canopy respectively). Patchouli was significantly taller under mature palms (42.37 cm) which was on par with medium palms (38.17 cm). Thippali recorded higher plant height under young oil palm canopy (33.23 cm) and was on par with those under medium palms (33.10 cm).

Growth Stage, Month 6

Shade significantly influenced plant height (Table I, Appendix) and plants grown under medium palms recorded higher values. Species variation was also highly significant with Chunda recording the highest height of 50.79 cm. This was on par with Sathavari (49.63 cm) (Table 8).

Shade x species interaction effect was significant (Table 9.6). Chunda and Sathavari were significantly taller under open condition (55.80 and 40.67 cm respectively). Under young oil palm canopy, Chunda recorded the highest value of 68.00 cm. Under medium oil palms, values for Sathavari, Chunda, Patchouli and Karimkurinji were on par (52.30, 44.43, 43.40 and 43.90 cm) respectively. Under mature palms, Sathavari recorded significantly the highest height (55.97 cm).

Regarding the performance of individual medicinal plant species under different levels of shade, Chittadalodakam recorded significantly superior plant height under open condition (31.67 cm) which was on par with those under young oil palm canopy (22.33 cm). On the other hand, Chittaratha was significantly taller under medium palms (26.33 cm) which was on par with those under open condition (21.00 cm) and under mature palms (20.03 cm).

Table 9.5: Mean plant height showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, cm -month 5

Shade conditions	Chittadalodakam	Chittaratha	Chunda	Iruveli	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	27.03	19.33	50.67	15.33	15.47	25.33	16.23	38.33	17.73
Young	19.67	15.67	56.33	11.67	41.67	21.67	26.73	32.97	33.23
Medium	17.80	22.00	34.67	29.63	43.90	25.00	38.17	33.80	33.10
Mature	14.53	18.03	39.00	27.30	36.00	23.67	42.37	42.3.	11.00

CD1 (0. 05) 13.840 CD2 (0. 05) 14.62

Table 9.6: Mean plant height showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, cm -month 6

Shade conditions	Chittadalodakam	Chittaratha	Chunda	Iruveli	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	31.67	21.00	55.80	11.67	17.17	28.67	18.40	40.67	20.73
Young	22.33	16.00	68.00	16.00	45.33	24.33	36.83	49.57	32.80
Medium	19.43	26.33	44.43	31.23	43.90	25.67	43.40	52.30	37.63
Mature	15.80	20.03	34.93	27.57	39.67	27.33	48.83	55.97	11.90

CD1 (0. 05) 9.908 CD2 (0. 05) 9.76

CD 1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

Chunda recorded the highest value under young oil palm (68.00 cm) while Iruveli had the highest height when grown under medium palms (31.23 cm) and was on par with mature palms (27.57 cm). Karimkurinji recorded the highest plant height under the three shade situations (45.33, 43.9 and 39.67 cm under young, medium and mature oil palm canopy respectively) and were on par. In the case of Koduveli, higher value was recorded by plants under open condition (28.67 cm) which was on par with other treatments. Patchouli under mature palms recorded the highest value (48.83 cm) which was on par with those under medium palms (43.40 cm). Sathavari also exhibited the same pattern with the highest value under mature palms (55.97 cm) and was on par with those under medium (52.30 cm) and young oil palm (49.57 cm). Thippali recorded the highest value when grown under medium palms (37.63 cm) and was on par with those under young oil palm canopy (32.80 cm).

Growth Stage, Month 7

Plant height varied significantly with shade condition (Table I, Appendix) and significantly higher values were recorded from species grown under medium palms. Interspecies variation was also highly significant and Sathavari was the tallest among all the species (54.60 cm) (Table 8).

Shade x species interaction also significantly influenced this trait (Table 9.7). Under open condition, Sathavari recorded higher plant height (52.33 cm) while, under young oil palm canopy it was Karimkurinji that performed well (45.67 cm). However, its height was on par with Sathavari (44.27 cm) and Patchouli (41.70 cm). Under medium palms, again, Sathavari was significantly taller (90.80 cm), while under mature palms, Patchouli, Karimkurinji and Koduveli exhibited higher values (46.77, 42.00 and 32.33 cm respectively).

Regarding inter shade variation among the ten species, Chittadalodakam was the tallest under open condition (33.47 cm) and Chittaratha under medium palms (36.5 cm). In the case of Iruveli, the highest value was under medium palms (31.67 cm) which was on par with mature palms (28.53 cm). Karimkurinji recorded superior plant height under young oil palm canopy, medium and mature palms (45.67, 44.83 and 42.00 cm respectively) and these were on par. In Koduveli, the data under the four shade situations were on par. However higher plant height was under mature palms (32.33 cm). Patchouli recorded the highest value under mature palms (46.77 cm) which was on par with medium (46.17 cm) and young oil palm canopy (41.70 cm). Sathavari was the tallest under medium palms (90.80 cm). Thippali recorded significantly highest value under medium, young oil palm canopy and under open condition (35.80, 33.37 and 29.93 cm respectively).

Growth Stage, Month 8

Shade conditions significantly influenced plant height (Table I, Appendix) and significantly superior values were recorded by species grown under medium palms. Species variation in plant height was also highly significant with Sathavari producing the tallest plants of 61.94 cm (Table 8).

Shade x species interaction was also significant (Table 9.8). Under open, young and medium oil palm, Sathavari excelled with values of 60.67 cm, 60.63 cm and 96.80 cm respectively. However, under mature palms Karimkurinji excelled with a height of 41.00 cm.

With regard to individual species performance, Chittadalodakam produced significantly taller plants under open condition (36.57 cm), Chittaratha under medium palms (29.67 cm), which was on par with those under open (22.67 cm) and mature palms (21.30 cm), Karimkurinji under young, medium and mature oil palm canopy (46.33, 43.60 and 41.00 cm respectively), Koduveli under mature, medium and young oil palm canopy (33.00, 28.00 and 27.67 cm respectively), and Sathavari and Thippali under medium palms (96.80 cm and 40.40 cm respectively).

Growth Stage, Month 9

Shade significantly influenced plant height (Table I, Appendix). higher plant height was under medium palms. Species variation was also significant and Sathavari was significantly taller (66.99 cm) (Table 8).

Shade x species interaction was not significant (Table 9.9).

Table 9.7: **Mean plant height showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, cm -month 7**

Shade conditions	Chittadalodakam	Chittaratha	Iruveli	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	33.47	22.87	13.67	17.50	23.00	28.20	52.33	29.93
Young	24.27	14.10	23.17	45.67	27.67	41.70	44.27	33.37
Medium	22.53	36.50	31.67	44.83	26.73	46.17	90.80	35.80
Mature	16.57	21.97	28.53	42.00	32.33	46.77	31.00	7.13

CD1 (0. 05) 11.400 CD2 (0. 05) 13.02

Table 9.8: Mean plant height showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, cm -month 8

Shade conditions	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	36.57	22.67	18.20	24.67	60.67	37.23
Young	28.23	16.67	46.33	27.67	60.63	32.87
Medium	26.67	29.67	43.60	28.00	96.80	40.40
Mature	20.57	21.30	41.00	33.00	29.67	12.97

CD1 (0. 05) 8.388 CD2 (0. 05) 8.770

CD 1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

Growth Stage, Month 10

Plant height of the ten species varied significantly with shade conditions (Table I, Appendix) and higher plant height was under medium palms and was on par with those under young oil palm canopy. Species variation was also significant and among the species, Sathavari had the highest plant height (72.43 cm) (Table 8).

Shade x species interaction was also significant (Table 9.10). Under open, young and medium oil palm canopy, Sathavari excelled with a significantly superior plant height of 75.00 cm, 85.43 cm and 94.07 cm respectively. Under mature palms, Karimkurinji recorded the highest height (40.67 cm) which was on par with Koduveli (37.67 cm) Sathavari (35.2 cm) and Chittaratha (31.03 cm).

With reference to the species performance, Chittadalodakam was significantly taller under open condition (48.27 cm), while in Chittaratha the values were on par. However, higher height was under young oil palm canopy (35.00 cm). Karimkurinji registered higher value under young oil palm canopy (51.00 cm) which was on par with those under medium and mature palms (50.30 and 40.67 cm respectively). In Koduveli also, the values were on par. For Sathavari highest value under medium palms (94.07 cm). Thippali also exhibited the same trend with the highest value under medium palms (44.93 cm) and was on par with those under open (44.70 cm) and young oil palm canopy (40.20 cm).

Growth Stage, Month 11

Shade significantly influenced this trait in different species (Table I, Appendix). Higher plant height was recorded from plants under young oil palm canopy, which was on par with those under mature oil palm canopy. Interspecies variation was also significant with Sathavari recording the highest values of 78.71 cm (Table 8).

Shade x species interaction effect was also highly significant (Table 9.11). As in the previous months, Sathavari excelled both under the open and under young and medium oil palm canopy. The respective plant height recorded

Table 9.9: Mean plant height showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, cm -month 9

Shade conditions	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	44.23	26.77	29.77	28.20	72.40	40.84
Young	32.30	39.67	50.67	31.00	72.67	44.72
Medium	31.67	48.03	43.67	31.00	92.73	48.44
Mature	21.03	34.33	42.00	34.17	30.17	29.21

N.S.

Table 9.10: Mean plant height showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, cm -month 10

Shade conditions	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	48.27	25.00	30.13	26.60	75.00	44.70
Young	38.73	35.00	51.00	35.33	85.43	40.20
Medium	33.67	35.00	50.30	31.67	94.07	44.93
Mature	22.07	31.03	40.67	37.67	35.20	17.73

CD1 (0. 05) 12.215 CD2 (0. 05) 12.320

CD 1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

were 82.00 cm, 105.97 cm and 93.43 cm. However, under mature palms, Koduveli recorded significantly highest value (42.67 cm) which was on par with Karimkurinji (41.00 cm), Sathavari (33.43 cm) and Chittaratha (31.27 cm).

Regarding individual species performance, Chittadalodakam registered the highest plant height under open condition (51.50 cm) which was on par with those under young oil palm canopy (48.03 cm). In Chittaratha, values under the four shade situations were on par. However, higher plant height was under medium oil palm canopy (41.67 cm). Same situation was observed in the case of Karimkurinji. Koduveli recorded higher height under mature palms (42.67 cm). Sathavari recorded significantly highest value under young oil palm canopy (105.97 cm) while Thippali had higher plant height under open condition (53.30 cm) which was on par with those under medium (47.33 cm) and young oil palm canopy (42.10 cm).

Growth Stage, Month 12

Shade significantly influenced plant height (Table I, Appendix). Higher plant height was under young oil palm canopy, which was on par with those under medium palms. Species also varied significantly and Sathavari (87.40 cm) showed higher plant height (Table 8).

Shade x species interaction was also highly significant (Table 9.12). The performance of Sathavari was the best under open condition and under young and medium oil palm canopies (88.67, 122.20 and 103.83 respectively). However, under mature palms Koduveli was significantly taller (45.67 cm) which was on par with Karimkurinji (45.33 cm), Chittaratha (39.20 cm) and Sathavari (34.90 cm).

Regarding individual species performance, Chittadalodakam excelled under young oil palm canopy with 58.50 cm plant height. Chittaratha also had the highest value under young oil palm canopy (58.80 cm). On the other hand, Karimkurinji was the best under medium palms (53.73 cm). Koduveli recorded higher plant height under mature palms, (45.67 cm) which was on par with those under young and medium oil palm canopy (34.33 and 33.33 respectively).

Table 9.11 : Mean plant height showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, cm -month 11

Shade conditions	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	51.50	29.33	30.93	26.13	82.00	53.30
Young	48.03	32.67	51.67	32.00	105.97	42.10
Medium	37.00	41.67	51.23	32.67	93.43	47.33
Mature	25.00	31.27	41.00	42.67	33.43	16.20

CD1 (0. 05) 14.280 CD2 (0. 05) 14.200

Table 9.12: Mean plant height showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, cm -month 12

Shade conditions	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	53.70	31.30	33.00	25.83	88.67	60.70
Young	58.50	58.80	52.23	34.33	122.20	42.60
Medium	43.00	43.57	53.73	33.33	103.83	53.97
Mature	29.40	39.20	45.33	45.67	34.90	19.57

CD1 (0. 05) 11.983 CD2 (0. 05) 13.420

CD 1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

Sathavari had the highest value under young oil palm canopy (122.20 cm). Thippali recorded the highest value under open condition (60.70 cm).

Growth Stage, Month 13

Plant height was significantly influenced by shade conditions (Table I, Appendix). higher plant height recorded under young oil palm canopy.

Species variation was also highly significant with Sathavari showing the highest value of 95.13 cm (Table 8).

Shade x species interaction also significantly affected plant height (Table 9.13). Under open, young and medium oil palm canopies, Sathavari recorded the highest value of 95.00 cm, 142.30 cm and 107.33 cm respectively. However, under mature palms Koduveli was superior (48.67 cm) which was on par with Karimkurinji (47.00 cm).

The performance of different species under different shade situation also varied significantly. Chittadalodakam was superior under young oil palm canopy (65.87 cm) and was on par with those under open condition (56.53 cm). The plant height of Chittaratha was the highest under both young and medium palms (55.00 and 48.33 cm) while Karimkurinji was superior under medium, young and mature oil palm canopies (57.23, 56.00 and 47.00 cm respectively). Koduveli recorded the highest value under mature palms (48.67 cm) while Sathavari exhibited higher values under the young oil palm canopy (142.30 cm).

Growth Stage, Month 14

Significant influence of shade on plant height continued (Table I, Appendix) with higher plant height being recorded by plants under young oil palm canopy, which was on par with those under medium palms. Species variation was also significant and Sathavari excelled among the species with a height of 103.27 cm (Table 8).

Significant shade x species interaction effect was also noticed (Table 9.14). As in the previous months, Sathavari showed its superiority with highest

Table 9.13: Mean plant height showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, cm -month 13

Shade conditions	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	56.53	34.00	33.97	25.67	95.00	68.63
Young	65.87	55.00	56.00	35.00	142.30	49.37
Medium	53.87	48.33	57.23	37.33	107.33	65.77
Mature	33.83	31.63	47.00	48.67	35.87	17.00

CD1 (0. 05) 11.258 CD2 (0. 05) 11.010

Table 9.14: Mean plant height showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, cm -month 14

Shade conditions	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	57.37	30.67	34.95	26.70	111.00	75.37
Young	75.60	56.33	57.67	37.00	153.47	56.90
Medium	61.67	45.00	63.00	39.00	111.00	72.37
Mature	40.70	32.07	53.33	51.00	37.60	19.70

CD1 (0. 05) 10.505 CD2 (0. 05) 12.670

CD 1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

values under open (111.00 cm), young oil palm canopy (153.47 cm) and medium palms (111.00 cm). However, under mature palms, Karimkurinji showed its superiority with 53.33 cm plant height, which was on par with Koduveli (51.00 cm).

The performance of Chittadalodakam was significantly superior under young oil palm canopy (75.60 cm). Chittaratha exhibited better performance both under young oil palm canopy and medium palms (56.33 and 45.00 cm), while that of Karimkurinji was under medium, young and mature oil palm canopy (63.00, 57.67 and 53.33 cm respectively). Koduveli performed well under mature palms (51.00 cm) while Sathavari under young oil palm canopy (153.47 cm) and Thippali both under open and medium palms (75.37 cm and 72.37 cm respectively).

Growth Stage, Month 15

The significant positive influence of shade on plant height was continued (Table I, Appendix). Higher plant height was recorded by plants under young oil palm canopy. Significant difference in plant height of different species was observed with Sathavari recording the highest value of 113.33 cm (Table 8).

Shade x species interaction was also highly significant (Table 9.15). The performance of Sathavari was excellent under the first three shade situations (open, young and medium oil palm canopy) with values of 127.33, 164.13 and 115.67 cm respectively. However, under mature palms, Karimkurinji and Koduveli were excellent (63.33 and 53.00 cm respectively).

With regard to the height recorded by the individual species under different shade situations, it was found that Chittadalodakam performed well under young oil palm canopy and medium palms (76.40 and 62.40 cm respectively). Chittaratha excelled under young oil palm canopy alone (51.33 cm). In the case of Karimkurinji, the performance was superior under medium, mature and young oil palm canopy (69.60, 63.33 and 58.33 cm respectively). The plant height of Koduveli was significantly superior under mature palms (53.00 cm) which was on par with those under medium palms (41.33 cm).

Sathavari performed well under young oil palm canopy (164.13 cm) while Thippali had the highest value under medium palms (76.97 cm). This was on par with those under young oil palm canopy (72.07 cm) open condition (68.57 cm).

Growth Stage, Month 16

Shade significantly influenced this character (Table I, Appendix) and higherplant height was recorded under young oil palm canopy. This was on par with those under medium palms. Species difference was also highly significant and Sathavari (123.10 cm) recorded the highest value (Table 8).

Shade x species interaction also significantly influenced plant height (Table 9.16). Under open, young and medium oil palm canopy, Sathavari excelled with a significantly superior value of (147.33, 170.13 and 125.20 cm respectively) while under mature palms, Karimkurinji was superior (75.00 cm).

Regarding the response of different species under different shade situations, Chittadalodakam recorded higher plant height under young oil palm canopy (77.60 cm) which was on par with medium palms (67.60 cm) while Chittaratha performed well under young oil palm canopy only (60.33 cm). Karimkurinji recorded the highest plant height under mature palms (75.00 cm) which was on par with medium and young oil palm canopy (72.33 and 60.67 cm respectively). Koduveli also followed the same trend with higher plant height under mature palms (55.00 cm) which was on par with medium palms (42.00 cm). Sathavari recorded the highest value under young oil palm canopy (170.13 cm). Thippali also exhibited the same pattern with the highest value under young oil palm canopy (84.23 cm) which was on par with medium palms (81.33 cm) and open condition (81.17 cm).

Growth Stage, Month 17

The significant influence of shade on plant height was continued (Table I, Appendix) with higher plant height recorded in plants under young oil palm canopy. Species variation with respect to the values was also highly significant with Sathavari recording a higher value of 123.90 cm (Table 8).

Table 9.15: Mean plant height showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, cm -month 15

Shade conditions	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	58.20	36.67	36.13	31.13	127.33	68.57
Young	76.40	51.33	58.33	32.33	164.13	72.07
Medium	62.40	36.33	69.60	41.33	115.67	76.97
Mature	44.70	28.77	63.33	53.00	46.17	22.33

CD1 (0. 05) 15.792 CD2 (0. 05) 14.890

Table 9.16: Mean plant height showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, cm -month 16

Shade conditions	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	58.90	41.33	36.63	34.73	147.33	81.17
Young	77.60	60.33	60.67	32.00	170.13	84.23
Medium	67.60	38.67	72.33	42.00	125.20	81.33
Mature	51.97	33.20	75.00	55.00	49.60	21.13

CD1 (0. 05) 13.863 CD2 (0. 05) 15.76

CD 1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

Shade x species interaction was also significant (Table 9.17). Under open, young and medium oil palm canopy, Sathavari produced significantly taller plants (149.00, 175.77 and 120.50 cm respectively) as in the previous months. Under mature palms, Karimkurinji was the best (77.33 cm).

Chittadalodakam recorded the highest value under young oil palm canopy (78.87 cm) which was on par with those under medium palms (68.53 cm). Chittaratha also produced the tallest under young oil palm canopy (72.47 cm). Karimkurinji had higher plant height under mature palms (77.33 cm) which was on par with medium and young oil palm canopy (75.00 and 61.67 cm respectively). Koduveli recorded higher plant height under mature palms (56.33 cm) which was on par with those under medium palms (42.67 cm). Sathavari had highest plant height under young oil palm canopy (175.77 cm). Thippali also followed the same trend with 95.77 cm height under young oil palm canopy, which was on par with open (94.00), and medium palms (85.37 cm).

Growth Stage, Month 18

The influence of shade on plant height was highly significant (Table I, Appendix) and higherplant height was recorded under young oil palm canopy. Species also differed significantly with respect to this character and higher height was exhibited by Sathavari (125.10 cm) (Table 8).

However, shade x species interaction was not significant (Table 9.18).

An overview of the results of the influence of four treatments on height of plants revealed the following:

The different shade levels did not significantly alter the height of plants during first, second and fifth months. The plants grown under medium shade were significantly taller during third, fourth, sixth and ninth months. From the tenth month onwards, the plants under young palms overtook those under medium shade and produced higher values. The values under young and medium palms were on par during eleventh and fourteenth to sixteenth month.

Among the ten species studied, Karimkurinji produced significantly taller plants up to the second month. Chunda and Karimkurinji were

Table 9.17: Mean plant height showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, cm -month 17

Shade conditions	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	59.97	44.33	38.27	34.83	149.00	94.00
Young	78.87	72.47	61.67	35.00	175.77	95.77
Medium	68.53	42.43	75.00	42.67	120.50	85.37
Mature	56.30	26.83	77.33	56.33	50.33	20.77

CD 1 (0. 05) 15.534 CD2 (0. 05) 16.870

Table 9.18: Mean plant height showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, cm -month 18

Shade conditions	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	60.13	48.57	39.47	30.23	150.33	97.50
Young	80.07	60.49	62.43	32.33	180.07	95.87
Medium	70.13	50.19	75.20	44.33	121.00	100.53
Mature	58.63	32.78	80.00	56.33	49.00	21.40

N. S.

CD 1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

significantly taller and on par during third and forth month. During fifth month, Chunda was the tallest. From the sixth to eighteenth month, Sathavari consistently recorded taller plants.

Shade levels had no significant influence on plant height of Chittadalodakam upto five months after planting. There after upto eleventh month, taller plants were recorded under open condition. Towards the later periods of crop growth, taller plants were recorded under young and medium palms. In Chittaratha, the influence of shade on plant height was insignificant during second, fourth, fifth, tenth and eleventh month. During the remaining period upto ninth month, significantly taller plants were observed under medium palms. However, towards the later stages of crop growth (from twelfth month onwards) taller plants were observed under young palms. In the case of Chunda, the effect of shade on plant height was not consistent and taller plants were recorded under medium and young palms during first and last month of crop growth. During second and fourth months, the plant heights under the four shade levels were on par. Iruveli recorded significantly taller plants under medium and mature palms. In Karimkurinji, significantly taller plants were noticed under the three shade levels compared to open through out the growth period. The influence of shade on the height of Koduveli plants was insignificant upto tenth month after planting. From eleventh month onwards, taller plants were observed under the deep shade level of medium and mature palms. Shade levels had significant influence on the plant height of Patchouli and significantly taller plants were noticed under medium and mature palms throughout the growth period. In Sathavari, the influence of shade on plant height was insignificant during the first five months after planting. Thereafter significantly taller plants were noticed under medium oil palms while towards the later stages of crop growth (from eleventh month onwards) consistently taller plants were recorded under young palms. Thippali recorded significantly taller plants under young and medium oil palm canopy almost throughout the growth period.

4.1.1.2 Number of Leaves

The effect of different levels oil palm canopy shade on the number of leaves at different growth stages of the selected medicinal plant species is presented below.

Growth Stage, Month 1

Shade exhibited significant influence on the number of leaves produced by the medicinal plant species (Table II, Appendix). Higher leaf number was recorded from species under young oil palm canopy, which was on par with those recorded under medium palms. Plant species also differed significantly and higher leaf number was recorded in Karimkurinji (25.83) (Table 10).

Shade x species interaction was also significant (Table 11.1). Under open condition, Iruveli produced higher number of leaves (15.33) which was on par with Chunda (14.67) and Sathavari (10.00). Under the three shade situations, Karimkurinji produced higher number of leaves (33.00, 39.33 and 25.33 respectively under young, medium and mature oil palm canopy). Under medium palms, leaf production in Sathavari (33.67) was on par with those of Karimkurinji.

Among the ten plants under study, Chittadalodakam produced higher number of leaves under young oil palm canopy (21.33). Chittaratha was the best under medium palms (13.67) and was on par with those under young oil palm canopy (11.33). In Chunda, same trend was noticed (24.00 and 18.00 under medium and young oil palm canopy respectively). In Iruveli higher leaf number was under open condition, (15.33) and the four shade levels did not produce significant influence on the character. In Kacholam, the highest leaf production was noticed under young oil palm canopy (12.00) which was on par with the other three shade conditions. For Karimkurinji significantly superior leaf production was noticed under medium palms (39.33) which were on par with young oil palm canopy (33.00). For Patchouli and Thippali, leaf number was on par under the four shade situations. Patchouli registered the highest value under mature palms (1.67) and Thippali under young oil palm canopy

Table 10 : Mean Leaf number of medicinal plant species under oil palm shade conditions at different stages of plant growth

Treatment	Growth Stage - month																	
Shade conditions	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Open	8.20	12.67	17.23	18.43	21.77	21.69	17.52	23.94	30.83	32.39	36.72	41.22	45.47	49.11	53.94	64.33	70.83	74.78
Young	13.83	28.46	34.20	38.23	42.20	47.70	46.70	61.94	65.17	88.44	98.67	105.83	121.56	132.28	157.56	175.89	169.89	178.06
Medium	13.47	19.77	22.40	25.20	29.10	33.20	32.30	41.11	53.17	56.94	63.22	72.28	85.56	95.33	94.28	98.44	100.94	103.28
Mature	9.53	12.80	16.53	16.93	19.83	19.70	21.78	27.17	32.00	32.89	35.06	41.56	47.50	53.39	58.17	64.22	71.06	74.11
CD 0.05	**3.007**	**6.954**	**6.355**	**11.925**	**10.374**	**7.320**	**3.397**	**3.864**	**8.366**	**19.857**	**8.763**	**16.942**	**9.546**	**12.622**	**8.269**	**11.187**	**10.970**	**7.509**
Species																		
Chittadalodakam	11.33	13.75	16.33	16.58	20.25	23.42	24.75	28.50	32.33	38.17	43.42	50.50	59.00	65.92	67.83	70.50	72.08	73.83
Chittaratha	8.67	11.58	15.50	15.50	19.42	20.83	16.50	26.67	33.92	38.83	42.83	43.42	44.75	50.42	45.83	48.00	37.75	48.75
Chunda	16.75	29.42	39.50	46.17	51.50	53.48	Crop harvested											
Iruveli	12.25	20.75	19.33	14.33	15.50	16.25	18.83	Crop harvested										
Kacholam	8.92	9.67	10.75	12.00	14.83	12.17	7.92	Crop harvested										
Karimkurinji	25.83	57.75	65.33	73.38	83.25	91.58	104.71	114.17	137.17	166.33	188.42	211.33	254.08	287.33	330.50	375.83	393.25	401.17
Koduveli	3.67	4.75	5.42	5.83	6.00	6.67	6.25	7.33	8.08	8.25	8.42	8.50	8.92	9.33	9.67	9.83	9.92	9.92
Patchouli	1.00	7.25	4.33	9.50	2.33	8.08	40.67	Crop harvested										
Sathavari	9.92	15.50	22.42	25.58	30.08	33.50	6.33	42.92	47.33	51.17	53.25	63.17	66.42	67.00	76.33	82.83	88.17	92.50
Thippali	4.25	3.83	7.00	7.92	9.08	9.75	10.17	11.67	12.92	13.25	14.17	14.42	16.50	15.17	15.75	17.33	17.92	19.17
C D 0.05	**3.462**	**9.387**	**8.417**	**11.925**	**15.080**	**13.551**	**15.190**	**5.413**	**2.999**	**20.563**	**11.116**	**12.106**	**10.261**	**11.541**	**10.725**	**7.058**	**9.012**	**5.424**

(5.67). Sathavari produced significantly superior leaf number under medium palms (33.67).

Growth Stage, Month 2

Shade significantly influenced leaf production (Table II, Appendix) and higher leaf number was under young oil palm canopy. Interspecies difference in leaf production was also highly significant and Karimkurinji produced higher number of leaves (57.75) (Table 10).

Shade x species interaction was also highly significant (Table 11.2). Under open condition, Chunda produced higher number of leaves (27.33) which was on par with Iruveli (21.00), Sathavari (15.00), Karimkurinji (10.33), Chittadalodakam (10.00), Kacholam (9.33) and Patchouli (9.00). Under young oil palm canopy, Karimkurinji produced significantly higher number of leaves (128.00). Under medium and mature oil palm also, Karimkurinji recorded the highest leaf number (54.33 and 38.33 respectively).

With regard to the performance of individual crops, the leaf number all species were on par under the different shade levels except Karimkurinji where higher leaf number was noticed under young oil palm canopy (128.00).

Growth Stage, Month 3

Shade significantly influenced the number of leaves produced by different plants (Table II, Appendix). Significantly superior leaf production was recorded under young oil palm canopy. Interspecies difference in leaf production was also highly significant and Karimkurinji produced higher number of leaves (65.33) (Table 10).

Shade x species interaction was also highly significant (Table 11.3). Under open condition, Chunda recorded the highest leaf number (50.00).Under young, medium and mature oil palm canopies, significantly higher leaf number was recorded by Karimkurinji (142.00, 59.33 and 45.67 respectively).

The number of leaves produced under the different shade situations was on par in Chittaratha, Kacholam, Iruveli, Koduveli, Patchouli Sathavari and

Table 11.1: Mean Leaf number showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth - month 1

Shade conditions	Chittadalodakam	Chittaratha	Chunda	Iruveli	Kacholam	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	6.00	4.33	14.67	15.33	7.67	5.67	4.67	0.67	10..	2.67
Young	21.33	11.33	18.00	10.67	12.00	33.00	3.67	1.33	11.33	5.67
Medium	9.33	13.67	24.00	9.67	8.67	39.33	3.67	0.33	33.67	4.33
Mature	8.67	5.33	10.33	13.33	7.33	25.33	2.67	1.67	6.33	4.33

CD1 (0.05) 6.924 CD2 (0.05) 7.202

Table 11.2: Mean Leaf number showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth - month 2

Shade conditions	Chittadalodakam	Chittaratha	Chunda	Iruveli	Kacholam	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	10.00	6.00	27.33	21.00	9.33	10.33	6.67	9.00	15.00	2.00
Young	24.33	15.00	34.33	22.67	12.33	128.00	4.67	0.67	16.00	6.67
Medium	11.00	16.33	33.67	32.67	10.00	54.33	4.33	4.67	16.00	4.67
Mature	9.67	9.00	22.33	6.67	7.00	38.33	3.33	4.67	15.00	2.00

CD1 (0.05) 18.774 CD2 (0.05) 19.072

CD 1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

Thippali. In Chittadalodakam, significantly superior leaf number was noticed under young oil palm canopy (29.33) which was on par with those under open (13.67) and medium oil palm canopy (13.00). In Karimkurinji also, the highest leaf number was recorded under young oil palm canopy (142.00).

Growth Stage, Month 4

Shade significantly influenced this character (Table II, Appendix) . Higher leaf production was noticed under the young oil palm canopy. Interspecies difference in leaf production was also highly significant and Karimkurinji produced higher number of leaves (73.38) (Table 10).

Shade x species interaction was also highly significant (Table 11.4). Under open condition, significantly higher leaf number was recorded by Chunda (57.67). Under young oil palm canopy, Karimkurinji produced significantly higher leaf number (159.67). Under medium oil palm canopy, superior leaf production was recorded by Karimkurinji (62.67) which was on par with Chunda (42.67) and Sathavari (37.67). Under mature oil palm canopy also, Karimkurinji produced the highest leaf number (54.00) which was on par with Chunda (33.33).

Regarding individual species performance, only Karimkurinji responded significantly to shade and higher leaf production was recorded under the young oil palm canopy (159.67). In all other species, the number of leaves produced under all situations was on par.

Growth Stage, Month 5

Shade significantly influenced the number of leaves (Table II, Appendix) and higher leaf number was recorded under young oil palm canopy. Interspecies difference in leaf production was also highly significant and Karimkurinji produced higher number of leaves (83.25) (Table 10).

Shade x species interaction was also highly significant (Table 11.5). Under open condition, significantly superior leaf production was by Chunda (63.00). Under young, medium and mature oil palm canopy, the performance of Karimkurinji was superior (162.33, 79.00 and 69.67 respectively).

Table 11.3: Mean Leaf number showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth - month 3

Shade conditions	Chittadalodakam	Chittaratha	Chunda	Iruveli	Kacholam	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	13.67	14.33	50.00	18.00	9.33	14.33	7.33	9.00	23.67	2.67
Young	29.33	18.00	39.00	22.00	12.00	142.00	5.67	8.33	27.00	8.67
Medium	13.00	20.33	38.67	19.67	11.33	59.33	5.00	1.67	23.33	11.67
Mature	9.30	9.33	30.33	17.67	10.33	45.67	3.67	8.33	15.67	5.00

CD1 (0.05) 16.835 CD2 (0.05) 17.145

Table11.4: Mean Leaf number showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth - month 4

Shade conditions	Chittadalodakam	Chittaratha	Chunda	Iruveli	Kacholam	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	17.00	13.33	57.67	15.00	10.67	8.00	7.67	1.67	20.33	3.00
Young	28.33	21.33	51.00	16.00	14.67	159.67	5.67	4.00	31.33	9.33
Medium	14.00	18.33	42.67	18.33	13.33	62.67	6.00	6.67	37.67	12.33
Mature	7.00	9.00	33.33	8.00	9.33	54.00	4.00	4.67	13.00	7.00

CD1 (0.05) 33.771 CD2 (0.05) 34.106

CD 1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

Regarding individual species performance, during this month also, only Karimkurinji responded significantly to shade. It produced higher number of leaves under young oil palm canopy (162.33) and minimum under the open condition (22.00). In all other species, the number of leaves produced under all situations was on par.

Growth Stage, Month 6

Shade had significant influence on the number of leaves produced by the medicinal plant species (Table II, Appendix) and higher leaf production was recorded under young oil palm canopy. Interspecies difference in leaf production was also highly significant and Karimkurinji produced higher number of leaves (91.58) (Table 10).

Shade x species interaction was also highly significant (Table 11.6). Under open condition, Chunda produced highest number of leaves (52.27) which was on par with Chittadalodakam (28.67) and Karimkurinji (26.00).

Under young, medium and mature oil palm canopy, Karimkurinji produced higher number of leaves (182.00, 88.33 and 70.00 respectively).

With regard to comparison between different shades, only Karimkurinji showed significant response to shade, for which higher leaf production was under young oil palm canopy (182.00) and minimum under open (26.00). In all other species, the number of leaves produced under all situations was on par.

Growth Stage, Month 7

Shade significantly influenced on the number of leaves (Table II, Appendix) and higher leaf number was noticed in plants grown under young oil palm canopy, which was on par with those under medium palms. Interspecies difference in leaf production was also highly significant and Karimkurinji produced higher number of leaves (104.71) (Table 10).

Shade x species interaction was also highly significant (Table 11.7). Under open condition, there was no significant difference among the different plants, except Kacholam and Sathavari, which produced minimum number of leaves. In all the shade situations, Karimkurinji produced significantly higher

Table 11.5 : Mean Leaf number showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth - month 5

Shade conditions	Chittadalodakam	Chittaratha	Chunda	Iruveli	Kacholam	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	23.67	16.67	63.00	17.00	12.67	22.00	8.00	7.00	23.00	5.67
Young	30.00	23.33	61.33	14.33	16.00	162.33	6.00	8.00	38.67	12.00
Medium	16.00	28.00	46.67	19.00	14.67	79.00	5.67	3.67	45.00	13.33
Mature	11.33	9.67	35.00	11.67	16.00	69.67	4.33	0.67	14.67	5.33

CD1 (0.05) 30.161 CD2 (0.05) 30.367

Table 11.6 : Mean Leaf number showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth - month 6

Shade conditions	Chittadalodakam	Chittaratha	Chunda	Iruveli	Kacholam	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	28.67	16.33	52.27	13.33	11.33	26.00	9.67	3.33	18.33	7.67
Young	34.00	26.00	79.00	19.33	12.67	182.00	6.33	0.67	45.67	11.33
Medium	19.00	30.00	52.67	19.67	16.00	88.33	6.00	1.33	55.00	14.00
Mature	12.00	11.00	30.00	12.67	8.67	70.00	4.67	7.00	15.00	6.00

CD1 (0.05) 27.103 CD2 (0.05) 26.690

CD 1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

number of leaves than all other species (193.33, 113.67 and 80.33 under young, medium and mature oil palm canopy respectively).

The number of leaves produced by different medicinal plants under different shade levels was on par except that Karimkurinji produced significantly higher number of leaves under young oil palm canopy (193.33).

Growth Stage, Month 8

The different shade levels significantly influenced the number of leaves produced (Table II, Appendix) and higher leaf number noticed in plants grown under young oil palm canopy. Interspecies difference in leaf production was highly significant and Karimkurinji produced higher number of leaves (114.17) (Table 10).

Shade x species interaction was also highly significant (Table 11.8). The number of leaves produced by different plants under the open condition was on par. However, under the three shade situations Karimkurinji produced significantly higher number of leaves (205.67, 122.33 and 93.33 under young, medium and mature oil palm canopy respectively).

The performance of all species was similar under the different shade levels and in the open except that Karimkurinji and Sathavari recorded higher leaf number under young oil palm canopy (205.67 and 59.33 respectively).

Growth Stage, Month 9

Shade levels significantly influenced the number of leaves produced by the ten selected plants (Table II, Appendix) and the highest leaf number was noticed under the young oil palm canopy. Interspecies difference in leaf production was also highly significant and Karimkurinji produced the highest number of leaves (131.17) (Table 10).

Shade x species interaction was also highly significant (Table 11.9). Under open condition, the leaf number was on par among the different plants except Thippali and Koduveli. Karimkurinji recorded the higher number of

Table 11.7 : Mean Leaf number showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth - month 7

Shade conditions	Chittadalodakam	Chittaratha	Iruveli	Kacholam	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	27.00	11.33	9.67	4.67	31.67	7.33	34.67	2.67	8.67
Young	36.33	24.33	25.00	6.67	193.33	6.33	68.00	9.00	11.33
Medium	22.00	17.33	23.00	9.67	113.67	5.67	26.00	7.33	16.00
Mature	13.67	13.00	17.67	10.67	80.33	5.67	34.00	6.33	4.67

CD1 (0.05) 30.381 CD2 (0.05) 30.895

Table 11.8 : Mean Leaf number showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth - month 8

Shade conditions	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	31.00	22.00	35.33	8.00	37.67	9.67
Young	41.67	44.00	205.67	8.00	59.33	13.00
Medium	25.00	25.33	122.33	6.67	50.00	17.33
Mature	16.33	15.33	93.33	6.67	24.67	6.67

CD1 (0.05) 30.942 CD2 (0.05) 31.175

CD 1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

leaves under all the shade situations (218,185.33 and 105.33 under young, medium and mature palms respectively).

The performance of Chittadalodakam with regard to the number of leaves was significantly superior under young oil palm canopy (46.67) which was on par with those under open and medium palms (38.00 and 29.67 respectively). In Chittaratha and Sathavari also, higher leaf production was under young oil palm canopy (44.33 and 60.67 respectively). Karimkurinji also recorded significantly higher number of leaves under young oil palm canopy (218.00) and lower number in the open condition (40.00). Koduveli and Thippali did not exhibit significant response.

Growth Stage, Month 10

Shade had significant influence on the number of leaves (Table II, Appendix). Significantly superior leaf number was under young oil palm canopy. The number of leaves produced was on par under open condition and mature palms. Interspecies difference in leaf production was also highly significant and Karimkurinji produced higher number of leaves (166.33) (Table 10).

Shade x species interaction was also highly significant (Table 11.10). In all species, number of leaves produced under the open condition was on par. However, under the three shade situations the performance of Karimkurinji was significantly superior when compared to all other species (314.00, 192.33 and 111.67 under young, medium and mature oil palm canopy respectively).

In Chittadalodakam, Koduveli, Sathavari and Thippali the leaf number remained unaltered due to different treatments. In Karimkurinji, significantly higher leaf number was noticed under the young oil palm canopy (314.00). Chittaratha produced the highest number of leaves under the young oil palm canopy (71.67) which was on par with those under open (36.67) and medium (30.33).

Growth Stage, Month 11

Shade levels significantly influenced the number of leaves produced (Table II, Appendix) and superior performance was noticed under the young oil

Table 11.9 : Mean Leaf number showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth - month 9

Shade conditions	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	38.00	39.67	40.00	9.00	46.33	12.00
Young	46.67	44.33	218.00	9.00	60.67	12.33
Medium	29.67	26.67	185.33	7.33	52.33	17.67
Mature	15.00	25.00	105.33	7.00	30.00	9.67

CD1 (0.05) 17.142 CD2 (0.05) 17.694

Table 11.10 : Mean Leaf number showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth - month 10

Shade conditions	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	42.00	36.67	47.33	8.33	46.67	13.33
Young	60.33	71.67	314.00	9.33	61.33	14.00
Medium	31.67	30.33	192.33	7.67	61.00	18.67
Mature	18.67	16.67	111.67	7.67	35.67	7.00

CD1 (0.05) 41.127 CD2 (0.05) 42.353

CD 1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

palm canopy. Interspecies difference in leaf production was also highly significant and Karimkurinji produced higher number of leaves (188.42) (Table 10).

Shade x species interaction was also highly significant (Table 11.11). Under open condition, Sathavari, Karimkurinji, Chittadalodakam and Chittaratha produced higher number of leaves (55.00, 53.00, 46.33 and 38.67 respectively). Lower leaf production was noticed in Koduveli (8.33). However, in all shade situations the performance of Karimkurinji was significantly superior (336.00, 241.33 and 123.33 under young, medium and mature oil palm canopy respectively).

The leaf production in Chittadalodakam, Chittaratha Karimkurinji, Koduveli and Sathavari was significantly superior under the young oil palm canopy (70.33, 84.33, 336.00 and 79.33 respectively). The different treatments did not impose any significant influence on leaf number in Koduveli and Thippali.

Growth Stage, Month 12

Leaf number was significantly influenced by shade levels (Table II, Appendix). Higher leaf production was under the under the young oil palm canopy. Interspecies difference in leaf production was also highly significant and Karimkurinji produced higher number of leaves (211.33) (Table 10).

Shade x species interaction was also highly significant (Table 11.12). Under open condition, higher leaf production was noticed in Sathavari, which was on par with Karimkurinji, Chittadalodakam and Chittaratha (63.67, 63.00, 47.33 and 45.67 respectively). Leaf number in Koduveli and Thippali (8.33 and 19.33) was on par. In all shade situations, Karimkurinji performed well with 363.67, 264.67 and 154.00 leaves respectively.

The performance of Chittadalodakam, Chittaratha and Karimkurinji was significantly superior under the young oil palm canopy (88.33, 75.33 and 363. 67 respectively). The leaf number in Koduveli and Thippali remained unchanged by different treatments. In Sathavari, leaf production was the highest

Table 11.11 : Mean Leaf number showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth - month 11

Shade conditions	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	46.33	38.67	53.00	8.33	55.00	19.00
Young	70.33	84.33	336.00	9.33	79.33	12.67
Medium	35.33	31.00	241.33	7.67	46.33	17.67
Mature	21.67	17.33	123.33	8.33	32.33	7.33

CD1 (0.05) 22.231 CD2 (0.05) 22.059

Table 11.12 : Mean Leaf number showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth - month 12

Shade conditions	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	47.33	45.67	63.00	8.33	63.67	19.33
Young	88.33	75.33	363.67	9.33	84.00	14.33
Medium	41.33	35.33	264.67	7.67	65.33	19.33
Mature	25.00	17.33	154.00	8.67	39.67	4.67

CD1 (0.05) 24.212 CD2 (0.05) 27.737

CD 1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

(84.00.) under young oil palm canopy, which was on par with those under medium (65.33) and open (63.67).

Growth Stage, Month 13

The different shade levels significantly influenced the number of leaves produced by the plants under study (Table II, Appendix). higher leaf production was under young oil palm canopy. Interspecies difference in leaf production was also highly significant and Karimkurinji produced the highest number of leaves (254.08) (Table 10).

Shade x species interaction was also highly significant (Table 11.13). Under open condition, leaf number was the highest in Karimkurinji (75.00) and Sathavari (73.00), and under the three shade situations, significantly higher leaf number was noticed in Karimkurinji (426.33, 341.67 and 173.33 respectively).

Chittadalodakam, Chittaratha, Karimkurinji and Sathavari had significantly higher number of leaves under the young oil palm canopy (103.00, 84.67, 426.33 and 91.00 respectively). However, in Thippali and Koduveli the leaf number was on par under all shade situations.

Growth Stage, Month 14

Shade had significant influence on the number of leaves produced (Table II, Appendix) and the highest leaf production was under the young oil palm canopy. Interspecies difference in leaf production was also highly significant and Karimkurinji registered the highest number of leaves (287.33) (Table 10).

Shade x species interaction was also highly significant (Table 11.14). Karimkurinji produced significantly higher number of leaves in the open as well as three shade situations (99.00, 473.67, 376.67 and 200.00 respectively).

The performance of Chittadalodakam, Chittaratha, Karimkurinji and Sathavari was significantly superior under the young oil palm canopy (114.67, 89.67, 473.67 and 90.33 respectively) Leaf production of Koduveli and Thippali was on par under all shade conditions.

Table 11.13 : Mean Leaf number showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth - month 13

Shade conditions	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	51.33	41.67	75.00	8.33	73.00	21.67
Young	103.00	84.67	426.33	9.33	91.00	15.00
Medium	51.67	33.67	341.67	9.00	57.67	19.67
Mature	30.00	19.00	173.33	9.00	44.00	9.67

CD1 (0.05) 20.523 CD2 (0.05) 20.971

Table 11.14 : Mean Leaf number showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth - month 14

Shade conditions	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	51.67	53.00	99.00	8.67	64.67	17.67
Young	114.67	89.67	473.67	9.67	90.33	15.67
Medium	61.33	39.00	376.67	9.67	65.00	20.33
Mature	36.00	20.00	200.00	9.33	48.00	7.00

CD1 (0.05) 23.082 CD2 (0.05) 24.483

CD 1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

Growth Stage, Month 15

Shade significantly influenced the number of leaves produced (Table II, Appendix). Higher leaf production was noticed under the young oil palm canopy. Interspecies difference in leaf production was also highly significant and Karimkurinji produced higher number of leaves (330.50) (Table 10).

Shade x species interaction was also highly significant (Table 11.15). Leaf production was the highest in Karimkurinji under open condition and under all shade situations (122.33, 592.33, 384.33 and 223.00 respectively).

Similar to previous months, significantly superior leaf number was recorded under the young oil palm canopy by Chittadalodakam, Chittaratha, Karimkurinji and Sathavari (118.00, 90.33, 592.33 and 119.33 respectively). The shade levels did not alter the leaf number in Koduveli and Thippali.

Growth Stage, Month 16

During this period, shade exhibited significant influence on the number of leaves produced by different plants (Table II, Appendix) and significantly superior leaf production was noticed under the young oil palm canopy. Interspecies difference in leaf production was also highly significant and Karimkurinji produced the highest number of leaves (375.83) (Table 10).

Shade x species interaction was also highly significant (Table 11.16). The indication was that the Karimkurinji was superior under all conditions recording 167.33 under open and 696.67, 388.33 and 251.00 respectively under the three shade conditions.

In Chittadalodakam (113.33) Chittaratha (92.67), Karimkurinji (696.67) and Sathavari (124.33) significantly superior leaf production was noticed under young oil palm canopy. The leaf production in Thippali and Koduveli was on par under the three shade levels.

Growth Stage, Month 17

Shade significantly influenced on the number of leaves (Table II, Appendix). Significantly superior leaf production was noticed under the young oil palm canopy. Interspecies difference in leaf production was also highly

Table 11.15 : M Mean Leaf number showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth - month 15

Shade conditions	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	52.33	46.33	122.33	10.00	74.67	18.00
Young	118.00	90.33	592.33	9.33	119.33	16.00
Medium	59.33	25.33	384.33	9.67	66.00	21.00
Mature	41.67	21.33	223.00	9.67	45.33	8.00

CD1 (0.05) 20.451 CD2 (0.05) 21.213

Table 11.16 : Mean Leaf number showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth - month 16

Shade conditions	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	54.33	49.00	167.33	10.67	84.33	20.33
Young	113.33	92.67	696.67	9.00	124.33	19.33
Medium	66.67	28.67	388.33	9.67	75.33	22.00
Mature	47.67	21.67	251.00	10.00	47.33	7.67

CD1 (0.05) 14.117 CD2 (0.05) 16.991

CD 1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

significant and Karimkurinji produced higher number of leaves (393.25) (Table 10).

Shade x species interaction was also highly significant (Table 11.17). Under open condition (190.67) and three shade conditions (696.67, 395.67 and 290.00), Karimkurinji produced the highest number of leaves.

In Chittadalodakam (118.00), Chittaratha (51.33), Karimkurinji (696.67) and Sathavari (121.00), significantly superior leaf production was under the young oil palm canopy. Leaf production under all the shade situations were on par in the case of Thippali and Koduveli.

Growth Stage, Month 18

Shade levels significantly influenced the number of leaves (Table II, Appendix). Significantly superior leaf production was under young oil palm canopy and minimum leaf production was in open and mature oil palm canopy. Interspecies difference in leaf production was also highly significant and Karimkurinji produced higher number of leaves (401.17) (Table 10).

Shade x species interaction was also highly significant (Table 11.18). Both under the open condition and shaded conditions Karimkurinji produced significantly higher number of leaves (200.67, 703.33, 400.67 and 300.00 respectively) and lower leaf production was by Koduveli and Thippali.

Chittadalodakam, Chittaratha, Karimkurinji, Sathavari and Thippali produced significantly higher number of leaves under young oil palm canopy (119.67, 75.33, 703.33, 135.00 and 25.67) while in Koduveli leaf number was on par under the four situations.

An overall assessment of the influence of different shade levels on the leaf production of medicinal plants revealed that significantly higher number of leaves was produced under partial shade of young oil palm canopy.

Among the different species studied, Karimkurinji produced significantly higher number of leaves throughout the growth period. Under open condition, Chunda excelled in leaf number up to sixth month after planting. From sixth to tenth month no significant difference in the different species were noticed. During eleventh, twelfth and thirteenth month, Sathavari,

Table 11.17 : Mean Leaf number showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth - month 17

Shade conditions	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	55.33	50.67	190.67	10.33	97.33	20.67
Young	118.00	51.33	696.67	9.67	121.00	22.67
Medium	66.67	28.33	395.67	9.67	83.67	21.67
Mature	48.33	20.67	290.00	10.00	50.67	6.67

CD1 (0.05) 18.024 CD2 (0.05) 19.705

Table 11.18 : Mean Leaf number showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth - month 18

Shade conditions	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	56.33	62.33	200.67	10.33	97.33	21.67
Young	119.67	75.33	703.33	9.33	135.00	25.67
Medium	66.67	35.00	400.67	10.00	85.33	22.00
Mature	52.67	22.33	300.00	10.00	52.33	7.33

CD1 (0.05) 10.848 CD2 (0.05) 12.379

CD 1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

Karimkurinji, Chittadalodakam and Chittaratha recorded significantly higher number of leaves. From fourteenth month onwards, the leaf number of Karimkurinji was the highest.

Under young, medium and mature oil palm shade condition, however Karimkurinji recorded significantly higher number of leaves throughout the growth period.

Regarding individual plant effect, in Chittadalodakam, the influence of different shade levels on the number of leaves was insignificant upto eight month after planting. However, the situation changed from ninth month onwards and significantly higher number of leaves were recorded under young palms. In Chittaratha also, the influence of shade levels on the number of leaves was not visible upto eight month after planting. Thereafter, significantly higher number of leaves was noticed under young oil palm canopy. In Chunda, Iruveli, Koduveli, Patchouli and Thippali, the different shade trade treatments did not have any influence on the number of leaves produced throughout the crop growth period. In Karimkurinji, significantly higher number of leaves was noticed under the young palms throughout the growth period. In Sathavari, the influence of shade became visible from eighth month after planting and significantly higher number of leaves were noticed under young oil palm canopy.

4.1.1.3 Number of Branches

The effect of shade on number of branches of medicinal plants during the various growth stages are presented below.

Growth Stage, Month 1

The influence of shade on branch production was not significant (Table III, Appendix). The species differed significantly with regard to branch production and the highest branch number was noticed in Chunda (8.50) (Table 12).

Shade x species interaction was significant (Table 13.1). The highest value was noticed in Chunda under open condition as well as under the different shade levels (8.00, 10.33, 8.67 and 7.00 respectively).

Table 12 Mean branch number of medicinal plant species under oil palm shade conditions at different stages of plant growth

Treatment	Growth Stage - month																	
Shade condition	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Open	2.20	3.20	3.60	4.20	4.60	4.67	3.89	4.06	5.17	5.44	5.89	5.80	7.61	7.39	7.78	8.44	8.83	9.78
Young	2.67	4.10	5.40	5.43	6.77	7.07	6.00	7.44	7.22	8.50	9.39	10.61	12.78	13.06	13.17	13.22	13.39	13.78
Medium	2.33	3.23	3.93	4.17	4.60	4.90	4.82	4.05	4.72	5.28	6.06	10.39	8.06	9.44	9.56	9.89	10.83	10.22
Mature	2.00	2.53	2.97	3.07	3.80	4.27	3.44	3.94	4.44	5.33	5.50	6.17	6.33	6.83	7.22	7.61	8.06	8.33
CD 0.05	**N.S**	**0.409**	**0.677**	**0.898**	**0.789**	**0.825**	**0.953**	**0.467**	**0.791**	**0.444**	**1.197**	**N.S**	**1.299**	**1.288**	**1.641**	**2.479**	**1.737**	**2.047**
Species																		
Chittadalodakam	1.17	1.67	1.92	1.83	2.25	2.83	2.75	3.25	3.33	4.75	5.08	5.33	7.33	6.58	7.42	8.17	8.42	8.75
Chittaratha	2.50	3.75	4.08	4.83	4.92	5.58	6.17	6.25	7.00	7.08	7.30	13.75	8.67	8.83	8.92	9.33	10.75	9.92
Chunda	8.50	10.25	10.83	10.75	13.50	12.83	Crop harvested											
Iruveli	1.50	2.58	2.50	2.42	2.58	3.08	2.92	Crop harvested										
Kacholam	1.92	2.33	3.17	4.00	4.25	4.08	4.08	Crop harvested										
Karimkurinji	3.17	5.33	6.92	7.75	9.42	9.92	12.08	13.92	15.50	17.83	20.33	23.67	28.00	31.50	32.08	32.75	33.42	34.58
Koduveli	0.75	1.25	1.50	1.75	1.50	1.83	1.92	2.00	2.17	2.42	2.50	2.42	2.50	2.50	2.58	2.58	2.75	3.25
Patchouli	2.67	4.08	5.08	6.17	6.92	7.67	7.42	Crop harvested										
Sathavari	0.50	0.75	1.33	1.42	1.58	1.67	1.75	1.92	2.58	2.50	2.75	2.50	3.25	3.25	3.25	3.50	3.42	3.67
Thippali	0.33	0.67	2.42	1.25	2.50	2.75	1.75	2.58	1.75	2.25	2.25	1.83	2.42	2.42	2.33	2.42	2.92	3.00
CD 0.05	**0.625**	**1.118**	**0.900**	**1.293**	**1.019**	**1.323**	**0.934**	**0.959**	**0.935**	**0.819**	**0.965**	**6.071**	**0.872**	**1.565**	**1.641**	**1.651**	**1.393**	**1.905**

The response of the individual species under different shade conditions on branch production showed that the values were on par in Chittaratha, Kacholam, Karimkurinji, Koduveli, Patchouli, Sathavari and Thippali. In Chittadalodakam and Chunda, the highest branch number was recorded under young oil palm canopy (2.33 and 10.33) and in Iruveli under open condition (3.33).

Growth Stage, Month 2

Shade significantly affected branch production (Table III, Appendix). higher branch production was noticed under young oil palm canopy. The species differed significantly with regard to branch production and highest branch number was noticed in Chunda (10.25) (Table 12).

Shade x species interaction was significant (Table 13.2). Under open condition, Chunda produced the highest number of branches (11.00). Under young oil palm canopy, Karimkurinji recorded the highest branch number (9.00). Under medium and mature palms, tiller production was the highest in Chittaratha (5.00 and 4.67) which was on par with Patchouli, Karimkurinji, Chunda and Kacholam.

With regard to the performance of individual species under different shade conditions, branch production was on par in Chittadalodakam, Kacholam, Koduveli, Patchouli, Sathavari and Thippali. In Chittaratha the highest tiller number was under medium oil palm canopy (5.00), Chunda under open (11.00) and Iruveli and Karimkurinji under young oil palm canopy (4.67 and 9.00 respectively).

Growth Stage, Month 3

Branch production was significantly influenced by shade levels (Table III, Appendix). Higher branch production was noticed under young oil palm canopy. The species differed significantly with regard to branch production and the highest branch number was noticed in Chunda (10.83) (Table 12).

Shade x species interaction was significant (Table 13.3). Irrespective of the condition under which Chunda was grown, it produced the highest number of branches when compared to other species.

Table 13.1 : Mean branch number showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth - month 1

Shade conditions	Chittadalodakam	Chittaratha	Solanum	Iruveli	Kacholam	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	0.67	2.00	8.00	3.33	2.33	2.67	0.33	2.00	0.67	0.00
Young	2.33	2.67	10.33	2.33	1.67	3.67	0.67	3.00	0.00	0.00
Medium	1.00	3.00	8.67	0.00	1.67	3.33	1.00	3.00	0.67	1.00
Mature	0.67	2.33	7.00	0.33	2.00	3.00	1.00	2.67	0.67	0.33

CD1 (0.05) 12.51 CD2 (0.05) 1.351

Table 13.2 : Mean branch number showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth - month 2

Shade conditions	Chittadalodakam	Chittaratha	Solanum	Iruveli	Kacholam	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	2.00	2.67	11.00	3.33	2.67	5.00	1.33	3.00	0.67	0.33
Young	2.33	2.67	4.10	4.67	2.33	9.00	1.33	5.00	1.00	0.00
Medium	1.33	5.00	3.23	2.33	3.00	3.67	1.33	4.00	0.33	0.33
Mature	1.00	4.67	2.53	0.00	1.33	3.67	1.00	4.33	1.00	2.00

CD1 (0.05) 2.24 CD2 (0.05) 2.158

CD1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

With regard to individual species performance under different shade conditions, branch production was on par in Chittadalodakam, Kacholam, Koduveli, Sathavari and Thippali. In Chittaratha, the highest tiller number was under young oil palm canopy (5.00), Chunda under young oil palm canopy and open (14.00 and 11.67), Iruveli under young oil palm canopy (4.00) and Karimkurinji under young oil palm canopy (10.00).

Growth Stage, Month 4

Shade levels significantly affected branch production (Table III, Appendix). Higher branch production was noticed under young oil palm canopy. The species differed significantly with regard to branch production and the highest branch was number noticed in Chunda (10.75) (Table 12).

Shade x species interaction was significant (Table 13.4). Under open condition and young oil palm canopy, Chunda produced the highest number of branches (12.67, and 15.00). Under medium and mature palms also the values recorded by Chunda were superior (8.67 and 6.67) but was on par with Karimkurinji, Patchouli, and Chittaratha.

With regard to branch number of individual species under different shade conditions, the values were on par in Chittadalodakam, Koduveli, Sathavari and Thippali. In Chittaratha the highest tiller number was recorded under medium oil palm canopy (6.30), Chunda under young oil palm canopy and open (15.00 and 12.67), Iruveli under young oil palm canopy (4.00), Kacholam under medium oil palm canopy (5.00), Karimkurinji under young oil palm canopy (11.00) and Patchouli under young oil palm canopy (8.33).

Growth Stage, Month 5

Comparative evaluation of the influence of shade on branch production showed that the effects were significant (Table III, Appendix). higher branch production was noticed under young oil palm canopy. The species differed significantly with regard to branch production and the highest branch number was noticed in Chunda (13.50) (Table 12).

Shade x species interaction was significant (Table 13.5). Under open condition, Chunda produced the highest number of branches (17.67). Under

Table 13.3 : Mean branch number showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth - month 3

Shade conditions	Chittadalodakam	Chittaratha	Solanum	Iruveli	Kacholam	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	2.00	2.67	11.67	2.33	3.33	6.67	1.67	3.33	1.00	1.33
Young	2.67	5.00	14.00	4.00	3.33	10.00	2.00	8.00	1.33	3.67
Medium	1.67	4.33	10.33	2.33	3.67	7.00	1.33	4.67	1.67	2.33
Mature	1.33	4.33	7.33	1.33	2.33	4.00	1.00	4.33	1.33	2.33

CD1 (0.05) 1.80 CD2 (0.05) 1.832

Table 13.4 Mean branch number showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth - month 4

Shade conditions	Chittadalodakam	Chittaratha	Solanum	Iruveli	Kacholam	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	2.00	4.33	12.67	2.00	4.33	8.33	1.67	4.33	0.67	1.67
Young	2.67	4.00	15.00	4.00	4.67	11.00	2.00	8.33	2.00	0.67
Medium	1.67	6.30	8.67	3.00	5.00	6.33	1.33	6.33	1.67	0.67
Mature	1.00	4.67	6.67	0.67	2.00	5.33	1.75	5.67	1.33	2.00

CD1 (0.05) 2.59 CD2 (0.05) 2.606

CD1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

young, medium and mature palms also, branch number of Chunda (16.67, 10.33 and 9.33) were superior and on par with Karimkurinji.

With regard to number of branches of individual species under different shade conditions, branch production was on par in Chittadalodakam, Koduveli. and Sathavari. In Chittaratha the highest tiller number was recorded under young oil palm canopy (6.33), Chunda under open (17.67), Iruveli, Kacholam, Karimkurinji, Patchouli and Thippali under young oil palm canopy (4.33, 5.33, 14.33, 9.67 and 4.30 respectively).

Growth Stage, Month 6

Shade levels significantly influenced branch production (Table III, Appendix). Higher branch production was noticed under young oil palm canopy. The species differed significantly with regard to branch production and highest branch number was noticed in Chunda (12.83) (Table 12).

Shade x species interaction was significant (Table 13.6). Under open condition, Chunda produced the highest number of branches (13.33). Under young oil palm canopy, Karimkurinji produced the highest number of branches (16.67), which was on par with Chunda (15.67). Under medium and mature palms, Chunda was superior (9.67 and 12.67).

With regard to number of branches of individual species under different shade conditions, the values were on par in Chittadalodakam, Iruveli, Koduveli, Sathavari and Thippali. In Chittaratha, the highest tiller number was observed under young oil palm canopy (8.00), Chunda under young oil palm canopy (15.67), Kacholam under medium oil palm canopy (5.00), Karimkurinji under young oil palm canopy (16.67) and Patchouli under young oil palm canopy (9.33).

Growth Stage, Month 7

Shade significantly affected branch production (Table III, Appendix). higher branch production was noticed under young oil palm canopy. The species differed significantly with regard to branch production and the highest branch number was noticed in Karimkurinji (12.08) (Table 12).

Table 13.5 : Mean branch number showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth - month 5

Shade conditions	Chittadalodakam	Chittaratha	Solanum	Iruveli	Kacholam	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	2.67	3.67	17.67	1.67	4.33	7.33	1.00	4.67	1.00	2.00
Young	3.00	6.33	16.67	4.33	5.33	14.33	2.00	9.67	1.67	4.30
Medium	2.00	4.67	10.33	3.00	4.33	8.67	1.67	7.33	2.00	2.00
Mature	1.33	5.00	9.33	1.33	3.00	7.33	1.33	6.00	1.67	1.67

CD1 (0.05) 2.04 CD2 (0.05) 2.083

Table 13.6 : Mean branch number showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth – month 6

Shade conditions	Chittadalodakam	Chittaratha	Solanum	Iruveli	Kacholam	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	3.33	4.67	13.33	2.33	4.33	8.00	1.67	6.00	1.00	2.00
Young	3.67	8.00	15.67	4.33	4.67	16.67	2.33	9.33	1.67	4.33
Medium	2.67	4.67	9.67	3.33	5.00	8.67	2.00	8.33	2.00	2.67
Mature	1.67	5.00	12.67	2.33	2.33	6.33	1.33	7.00	2.00	2.00

CD1 (0.05) 2.65 CD2 (0.05) 2.639

CD1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

Shade x species interaction was not significant (Table 13.7).

Growth Stage, Month 8

Shade levels significantly affected branch production during this period (Table III, Appendix). higher branch production was noticed under young oil palm canopy. The species differed significantly in this trait and the highest value was recorded by Karimkurinji (13.92) (Table 12).

Shade x species interaction was significant (Table 13.8). Under open condition, Karimkurinji produced the highest number of branches (8.67) which was on par with Chittaratha and Chittadalodakam (6.33 and 4.00 respectively). Under all shade conditions, Karimkurinji produced the highest number of branches (23.67, 12.00 and 11.33).

The number of branches produced by the individual species under different shade conditions was on par in Koduveli and Sathavari. In Chittadalodakam, the highest branch number was recorded under young oil palm canopy (4.33) which was on par with those under open and medium oil palm canopy (4.00 and 2.67). In Chittaratha the highest tiller number was under young oil palm canopy (8.00), which was on par with open (6.33). In Karimkurinji, the highest branch number was observed under young oil palm canopy (23.67) and Thippali under young oil palm canopy (3.67) which was on par with those under open and medium oil palm canopy (2.33 and 3.00).

Growth Stage, Month 9

The number of branches produced by the plants was significantly influenced by shade levels (Table III, Appendix). Higher branch production was noticed under young oil palm canopy. The species differed significantly with regard to branch production and highest branch number was observed in Karimkurinji (15.50) (Table 12).

Shade x species interaction was significant (Table 13.9). Under all situations, Karimkurinji produced the highest number of branches (10.33, 24.67, 12.00 15.00 respectively under open, young, medium and mature oil palm canopy).

Table 13.7 : **Mean branch number showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth - month 7**

Shade conditions	Chittadalodakam	Chittaratha	Iruveli	Kacholam	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	3.00	5.33	2.33	5.00	8.00	1.33	6.33	1.00	2.67
Young	3.67	6.33	4.00	5.33	20.33	2.33	9.00	2.33	0.67
Medium	2.33	7.67	3.67	3.33	11.00	2.00	8.67	2.00	2.67
Mature	2.00	5.33	1.67	2.67	9.00	2.00	5.67	1.67	1.00

N.S

Table 13.8 : Mean branch number showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth - month 8

Shade conditions	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	4.00	6.33	8.67	1.33	1.67	2.33
Young	4.33	8.00	23.67	2.67	2.33	3.67
Medium	2.67	5.33	12.00	2.00	2.00	3.00
Mature	2.00	5.33	11.33	2.00	1.67	1.33

CD1 (0.05) 1.92 CD2 (0.05) 1.810

CD1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

With regard to branch number produced by individual species under different shade conditions, the values were on par in Koduveli and Sathavari. In Chittadalodakam, the highest branch number was recorded under open (5.67) which was on par with those under young oil palm canopy (4.67). In Chittaratha, the highest tiller number was under open (9.00). In Karimkurinji, highest branch number was under young oil palm canopy (24.67) and Thippali under medium oil palm canopy (3.00) which was on par with those under open (2.00).

Growth Stage, Month 10

The different treatments significantly affected branch production of the plants (Table III, Appendix). Higher branch production was noticed under young oil palm canopy. The species differed significantly with regard to branch production and the highest branch number was noticed in Karimkurinji (17.83) (Table 12).

The interaction effect was also significant (Table 13.10). Under all situations, Karimkurinji produced highest number of branches (11.00, 27.67, 14.67 and 18.00 respectively under open, young, medium and mature oil palm canopy).

With regard to the branch number of individual species under different shade conditions, the data recorded were on par in Thippali. In Chittadalodakam, the highest branch number was under open (7.00), which was on par with those under young oil palm canopy (6.00). In Chittaratha, the highest tiller number was under open (9.00) which was on par with those under young oil palm canopy (8.67)). In Karimkurinji the highest branch number was recorded under young oil palm canopy (27.67), Koduveli under young oil palm canopy (3.00) which was on par with those under medium and mature (2.67 and 2.67) and Sathavari under young oil palm canopy (3.67), which was on par with those under medium (2.33).

Growth Stage, Month 11

Branch production was significantly influenced by shade levels (Table III, Appendix). Higher branch production was noticed under young oil palm

Table 13.9 : Mean branch number showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth - month 9

Shade conditions	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	5.67	9.00	10.33	1.67	2.33	2.00
Young	4.67	6.67	24.67	2.67	3.67	1.00
Medium	2.00	7.00	12.00	2.00	2.33	3.00
Mature	1.00	5.33	15.00	2.33	2.00	1.00

CD1 (0.05) 1.87 CD2 (0.05) 1.876

Table 13.10 : Mean branch number showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth - month 10

Shade conditions	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	7.00	9.00	11.00	1.33	2.00	2.33
Young	6.00	8.67	27.67	3.00	3.67	2.00
Medium	3.67	5.33	14.67	2.67	2.33	3.00
Mature	2.33	5.33	18.00	2.67	2.00	1.67

CD1 (0.05) 1.64 CD2 (0.05) 1.559

Critical difference at 5 % level for comparing two species at a fixed shade
Critical difference at 5 % level for comparing two shade for a fixed or different species

canopy. The species differed significantly with regard to this character and the highest value was noticed in Karimkurinji (20.33) (Table 12).

Shade x species interaction was significant (Table 13.11). Under all situations, Karimkurinji produced the highest number of branches (12.33, 32.33, 18.67 and 18.00 respectively under open, young, medium and mature oil palm canopy).

The individual species grown under different shade conditions differed significantly. The values were on par in Koduveli, Sathavari and Thippali. In Chittadalodakam, the highest branch number was recorded under open (7.00) which was on par with young oil palm canopy (7.00). In Chittaratha, the highest tiller number was under open (9.00) which was on par with young oil palm canopy (8.67), while in Karimkurinji the highest branch number was under young oil palm canopy (32.33).

Growth Stage, Month 12

The influence of shade on branch production was not significant (Table III, Appendix). However, the species differed significantly and the highest branch number was registered by Karimkurinji (23.67) (Table 12).

Interaction effect was not significant (Table 13.12).

Growth Stage, Month 13

Shade levels significantly influenced branch production (Table III, Appendix). Higher branch production was noticed under young oil palm canopy. The species differed significantly with regard to branch production and highest branch number was noticed in Karimkurinji (28.00) (Table 12).

The interaction effect was significant (Table 13.13). Under all situations, Karimkurinji produced the highest number of branches (17.33, 45.00, 27.67 and 22.00 respectively under open, young, medium and mature oil palm canopy).

A comparison of branch number of the individual species under different shade conditions revealed that the values were on par in Koduveli, Sathavari and Thippali. In Chittadalodakam, the highest branch number was recorded under young oil palm canopy (10.33), which was on par with those

Table 13.11 : Mean branch number showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth - month 11

Shade conditions	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	7.00	9.00	12.33	1.67	2.67	2.67
Young	7.00	8.67	32.33	3.00	3.33	2.00
Medium	4.00	5.00	18.67	3.00	2.67	3.00
Mature	2.33	6.67	18.00	2.33	2.33	1.33

CD1 (0.05) 1.93 CD2 (0.05) 2.121

Table 13.12 : Mean branch number showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth - month 12

Shade conditions	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	6.33	7.30	15.67	1.67	2.00	2.00
Young	9.00	10.67	37.00	2.00	3.67	1.33
Medium	4.00	29.33	20.67	3.33	2.00	3.00
Mature	2.00	7.67	21.33	2.67	2.33	1.00

N.S

1 Critical difference at 5 % level for comparing two species at a fixed shade
2 Critical difference at 5 % level for comparing two shade for a fixed or different species

under open (10.00). In Chittaratha, the highest tiller number was under young oil palm canopy (12.00). In Karimkurinji also, the highest branch number was observed under young oil palm canopy (45.00).

Growth Stage, Month 14

Shade levels significantly affected branch production (Table III, Appendix). Higher branch production was noticed under young oil palm canopy. The species varied significantly and the highest branch number was observed in Karimkurinji (31.50) (Table 12).

The data on shade x species interaction was significant (Table 13.14). Irrespective of the treatments, Karimkurinji produced the highest number of branches (19.33, 46.00, 36.33 and 24.33 respectively under open, young, medium and mature oil palm canopy).

The individual species grown under different shade conditions differed significantly. The values were on par in Koduveli and Thippali. In Chittadalodakam, the highest branch number was recorded under young oil palm canopy (11.00). In Chittaratha, the highest tiller number was observed under young oil palm canopy (12.00). In Karimkurinji also, the highest branch number was showed under young oil palm canopy (46.00). In Sathavari, the highest branch number was observed under open (5.00), which was on par with those under young oil palm canopy (3.67).

Growth Stage, Month 15

The results furnished in Table III, Appendix indicated significant difference due to treatments. Higher branch production was noticed under young oil palm canopy. The species varied significantly and the highest branch number was noticed in Karimkurinji (32.08) (Table 12).

The data on shade x species interaction was significant (Table 13.15). In all treatments, Karimkurinji produced the highest number of branches (20.33, 45.67, 36.67 and 25.67 respectively under open, young, medium and mature oil palm canopy).

The plants responded differently with shade levels. Branch production was on par in Koduveli, Sathavari and Thippali. In Chittadalodakam, the

Table 13.13 : Mean branch number showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth - month 13

Shade conditions	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	10.00	9.33	17.33	1.67	4.33	3.00
Young	10.33	12.00	45.00	3.00	4.00	2.33
Medium	5.67	7.00	27.67	2.67	2.33	3.00
Mature	3.33	6.33	22.00	2.67	2.33	1.33

CD1 (0.05) 1.74 CD2 (0.05) 2.047

Table 13.14 : Mean branch number showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth - month 14

Shade conditions	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	6.00	9.33	19.33	1.67	5.00	3.00
Young	11.33	12.00	46.00	3.00	3.67	2.33
Medium	5.67	7.00	36.33	2.67	2.00	3.00
Mature	3.33	7.00	24.33	2.67	2.33	1.33

CD1 (0.05) 12.51 3.13 CD2 (0.05) 3.128

CD1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

highest branch number was recorded under young oil palm canopy (11.67). In Chittaratha, the highest tiller number was observed under young oil palm canopy (12.33). In Karimkurinji also, the highest branch number was registered under young oil palm canopy (45.67).

Growth Stage, Month 16

The response of plants to shade on branch production was significant (Table III, Appendix). Higher branch production was noticed under young oil palm canopy. The species differed significantly in this regard and the highest branch number was exhibited by Karimkurinji (32.75) (Table 12).

Shade x species interaction was significant (Table 13.16). As in the previous month, Karimkurinji produced the highest number of branches (22.00, 46.67, 37.00, and 25.33 respectively under open, young, medium and mature oil palm canopy).

The response of individual species in all treatments to shade varied and the values were on par in Koduveli, Sathavari and Thippali. In Chittadalodakam, the highest branch number recorded was under young oil palm canopy (11.33), which was on par with those under open (9.67). In Chittaratha, the highest tiller number was observed under young oil palm canopy (11.33), which was on par with those under mature and open (9.67 and 9.33 respectively). In Karimkurinji, highest branch number was observed under young oil palm canopy (46.67).

Growth Stage, Month 17

Branch production was significantly influenced by shade levels during this stage (Table III, Appendix). higher branch production was noticed under young oil palm canopy. The species showed significant variation in this character and the highest branch number was noticed in Karimkurinji (33.42) (Table 12).

The data indicated that shade x species interaction was significant (Table 13.17). Karimkurinji produced the highest number of branches (22.33, 47.00, 37.33, 27.00 respectively under open, young, medium and mature oil palm canopy) under all situations studied.

Table 13.15 : Mean branch number showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth - month 15

Shade conditions	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	8.00	9.00	20.33	2.00	4.33	3.00
Young	11.67	12.33	45.67	2.67	4.00	2.67
Medium	6.00	6.67	36.67	3.00	2.33	2.67
Mature	4.00	7.67	25.67	2.67	2.33	1.00

CD1 (0.05) 3.28 CD2 (0.05) 3.154

Table 13.16 : Mean branch number showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth - month 16

Shade conditions	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	9.67	9.33	22.00	2.00	5.00	2.67
Young	11.33	11.33	46.67	2.67	4.33	3.00
Medium	7.00	7.00	37.00	3.00	2.67	2.67
Mature	4.67	9.67	25.33	2.67	2.00	1.33

CD1 (0.05) 3.30 CD2 (0.05) 3.887

CD1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

The results on individual species under the different shade situations showed that the values were on par in Chittaratha, Koduveli, Sathavari and Thippali. In Chittadalodakam, the highest branch number was produced under young oil palm canopy (12.00) which was on par with those under open (10.67). In Karimkurinji, the highest branch number was recorded under young oil palm canopy (47.00).

Growth Stage, Month 18

The number of branches per plant was significantly affected by shade levels (Table III, Appendix) . Branch number was the highest under young oil palm canopy. The species also differed significantly and the highest branch number was noticed in Karimkurinji (34.58) (Table 12).

The results indicated that shade x species interaction was significant (Table 13.18). As observed during the previous month Karimkurinji produced the highest number of branches under all situations (24.33, 48.00, 38.00, and 28.00 respectively under open, young, medium and mature oil palm canopy).

The data on branch production of individual plants under the different shade situations indicated that the values were on par in Chittaratha, Koduveli Sathavari. In Chittadalodakam, the highest branch number was recorded under young oil palm canopy (12.33) which was on par with those under open (11.67). In Karimkurinji, the highest branch number was observed under young oil palm canopy (48.00). In Thippali the highest branch number was obtained under open (4.67) which was on par with those under young (3.67) and medium (2.33) oil palm canopies.

An overall assessment of the influence of different shade levels on the number of branches of medicinal plants during the experimental period revealed that the branch number was significantly affected by the shade levels and the highest number was noticed under the young oil palm canopy throughout the growth period except during the first month.

Among the ten species studied, Chunda recorded the highest number of branches during the initial six months. In the succeeding months, Karimkurinji

Table 13.17: Mean branch number showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth - month 17

Shade conditions	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	10.67	9.33	22.33	2.67	4.67	3.33
Young	12.00	10.67	47.00	3.00	4.00	3.67
Medium	6.67	12.33	37.33	2.67	2.67	3.33
Mature	4.33	10.67	27.00	2.67	2.33	1.33

CD1 (0.05) 2.79 CD2 (0.05) 3.069

Table 13.18 : Mean branch number showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth - month 18

Shade conditions	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	11.67	9.67	24.33	3.00	5.33	4.67
Young	12.33	10.33	48.00	4.00	4.33	3.67
Medium	6.33	8.67	38.00	3.33	2.67	2.33
Mature	4.67	11.00	28.00	2.67	2.33	1.33

CD1 (0.05) 3.81 CD2 (0.05) 4.024

Critical difference at 5 % level for comparing two species at a fixed shade
Critical difference at 5 % level for comparing two shade for a fixed or different species

recorded the highest number of branches. Under open condition during the first six months Chunda produced the highest number of branches. Under young, medium and mature palms also, higher number of branches was recorded by Chunda and also by Karimkurinji, Patchouli and Chittaratha upto six months after planting. During the seventh month, the influence of shade on number of branches was not significant and from eighth month onwards, Karimkurinji recorded the highest number of branches consistently under all shade levels.

Regarding individual plant effect the branch number in Chittadalodakam was not influenced by the shade levels up to six months after planting. Thereafter higher number of branches was noticed under open condition and young palms. In Chittaratha, the highest number of branches was recorded under young palms almost throughout the growth period. In Chunda also, the highest branch number was recorded under young palms and open condition throughout the growth period. Iruveli, Karimkurinji and Patchouli also produced higher number of branches under young oil palm canopy almost throughout the growth period. No significant influence of shade on the number of branches in Koduveli, Sathavari and Thippali was noticed during the course of investigation. In Kacholam, tiller number was influenced by shade levels during the later part of crop growth where higher numbers were recorded under medium and young palms.

4.1.1.4 Number of Roots

The effect of oil palm canopy on the number of roots of the ten medicinal plant species are presented below.

Growth Stage, Month 1

Shade did not produce significant influence on the number of roots produced. (Table IV, Appendix). However, the plants differed significantly in this character and highest root number was recorded in Chunda (9.67) which was on par with Chittaratha (9.33), and Kacholam (9.17) (Table 14).

The data on interaction between shade and species showed that these were significantly different (Table 15.10). Under open condition Chunda, Kacholam and Chittadalodakam produced significantly higher number of roots

Table 14 : Mean number of roots of medicinal plant species under oil palm shade conditions at different stages of plant growth

Treatment	Growth Stage month																	
Shade condition	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Open	6.80	8.77	9.67	9.10	10.13	10.43	10.26	11.11	18.00	13.17	14.89	16.67	18.78	18.78	19.44	21.44	22.94	25.56
Young	7.07	9.20	11.10	14.07	14.53	16.50	17.26	17.72	21.00	23.67	23.22	31.89	29.33	30.89	31.11	31.50	31.89	38.00
Medium	7.13	8.70	10.23	12.20	13.17	13.77	14.11	12.94	16.67	17.11	17.22	19.33	20.56	20.22	20.56	21.44	22.28	21.78
Mature	6.57	7.23	8.07	8.00	8.83	9.17	8.82	8.89	9.83	10.06	10.72	12.44	13.11	13.56	16.11	15.78	17.11	19.61
CD 0. 05	**N.S.**	**N.S.**	**N.S.**	**0.637**	**1.356**	**1.929**	**2.646**	**2.910**	**3.864**	**3.735**	**2.610**	**4.660**	**1.759**	**3.520**	**3.014**	**3.356**	**5.056**	**2.911**
Species																		
Chittadalodakam	8.08	9.08	10.08	10.25	10.67	11.50	11.25	11.33	12.83	12.00	12.58	13.08	13.58	12.42	12.50	12.58	12.50	14.25
Chittaratha	9.33	11.00	13.67	15.08	16.33	17.75	15.75	18.42	30.00	25.75	24.08	34.58	28.67	28.83	28.92	27.50	30.33	37.75
Chunda	9.67	11.25	12.83	11.67	12.58	12.42	Crop harvested											
Iruveli	4.67	5.17	5.33	5.33	6.67	7.33	9.67	Crop harvested										
Kacholam	9.17	13.08	14.25	18.33	19.42	20.83	25.42	Crop harvested										
Karimkurinji	6.50	7.58	8.75	9.92	10.00	11.50	11.08	11.67	13.00	13.92	15.33	16.92	19.67	21.50	24.08	26.42	28.67	30.08
Koduveli	3.58	4.33	4.50	4.75	4.83	5.67	5.33	5.17	5.58	6.08	6.58	7.00	7.08	7.50	7.17	7.25	6.92	6.58
Patchouli	5.83	8.42	0.83	2.33	3.33	3.83	14.42	Crop harvested										
Sathavari	7.33	9.25	10.33	12.50	13.92	15.08	5.33	18.92	22.33	24.33	26.67	35.25	36.75	38.83	41.17	42.58	43.42	44.08
Thippali	4.75	5.58	7.08	8.33	8.92	8.75	5.25	10.50	14.50	13.92	13.83	13.67	16.92	16.08	17.00	18.92	19.50	24.67
C D 0. 05	**1.434**	**1.893**	**1.912**	**2.714**	**1.356**	**1.965**	**2.484**	**2.473**	**3.643**	**3.177**	**2.677**	**5.171**	**3.355**	**3.520**	**3.238**	**3.678**	**4.091**	**6.379**

(11.0, 9.67 and 9.0 respectively). Number of roots produced by Thippali, Chittaratha, Iruveli and Sathavari were on par. Under young oil palm canopy, Chunda and Chittaratha produced significantly higher number 12.67 and 10.00 respectively. There was no significant difference in the number of roots produced by Thippali, Karimkurinji, Iruveli, Koduveli and Sathavari. Under medium oil palm canopy, higher rooting was in Kacholam, Chittaratha and Chunda (11.00, 10.33 and 8.67 respectively) and lower in Thippali, Patchouli, Koduveli and Iruveli (7.13, 6.67, 4.67 and 4.33 respectively).Under mature oil palm, Chittaratha produced significantly higher number (12.00) while those of Koduveli (5.67) and Sathavari (3.33) were the lowest.

The number of roots under the different shade situations was on par in Chittadalodakam, Iruveli, Karimkurinji, Koduveli, Patchouli and Thippali. Root production in Chittaratha was the highest under mature palm shade (12.00) which was on par with those under medium (10.33) and young oil palm canopy (10.00). Chunda produced the highest number of roots under young oil palm canopy (12.67) which was on par with those under open (11.00). In Kacholam, higher root production was under the medium oil palm canopy (11.00) which was on par with open (9.67) and young oil palm canopy (8.33). Sathavari produced highest number of roots under medium oil palm canopy (7.33) which was on par with those under young oil palm canopy (4.33).

Growth Stage, Month 2

During the second month of planting also, no significant influence of shade on root numbers (Table IV, Appendix). However, the species differed significantly in this character and the highest root number was recorded in Kacholam (13.08) which was on par with Chunda (11.25) (Table 14).

The interaction effect was significantly different (Table 15.2). Under the open condition, Chunda and Kacholam produced the highest number of roots (15.00 and 14.30) and the lowest number was recorded by Chittaratha (5.33), Iruveli (5.00) and Thippali (3.60). Under young oil palm canopy Kacholam, Chunda, Chittaratha and Sathavari produced significantly higher number of roots (14.00, 13.00, 12.67 and 11.00). Under medium oil palm canopy

Table 15.1 Mean root number showing the interaction effect of oil palm shade conditions x medicinal species at different stages of plant growth- month 1

Shade conditions	Chittadalodakam	Chittaratha	Chunda	Iruveli	Kacholam	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	9.00	5.00	11.00	4.67	9.67	7.33	8.00	7.00	4.00	6.80
Young	8.33	10.00	12.67	5.00	8.33	5.33	5.00	7.67	4.33	7.07
Medium	7.33	10.33	8.67	4.33	11.00	7.33	4.67	6.67	7.33	7.13
Mature	7.67	12.00	6.33	4.67	7.67	6.00	5.67	8.00	3.33	6.57

CD 1 (0.05) 2.868 CD 2 (0.05) 3.037

Table 15.2 : Mean root number showing the interaction effect of oil palm shade conditions x medicinal species at different stages of plant growth- month 2

Shade conditions	Chittadalodakam	Chittaratha	Chunda	Iruveli	Kacholam	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	10.33	5.33	15.00	5.00	14.30	8.00	8.00	9.00	9.00	3.67
Young	9.00	12.67	13.00	5.67	14.00	7.33	3.67	9.33	11.00	6.33
Medium	8.00	13.00	10.00	5.67	14.67	8.67	2.67	8.00	8.00	8.33
Mature	9.00	13.00	7.00	4.33	9.33	6.33	3.00	7.33	9.00	4.00

CD 1 (0.05) 3.788 CD 2 (0.05) 3.846

CD1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

Kacholam and Chittaratha produced higher number of roots (14.67 and 13.00) while under mature oil palm canopy Chittaratha and Kacholam produced the highest number of roots (13.00 and 9.33 respectively).

With regard to the root production of individual species under different situations, the values were on par under all situations in the case of Chittadalodakam, Iruveli, Karimkurinji, Patchouli and Sathavari. Chittaratha produced the highest number of roots under medium oil palm canopy (13.00) which was on par with those under mature (13.00) and young oil palm canopy (12.67). Chunda produced the highest number of roots under open (15.00) which was on par with those under young oil palm canopy (13.00). Root number in Kacholam under medium shade was the highest (14.67) which was on par with those under open (14.30) and young oil palm canopy (14.00). In Koduveli, higher root number was under open condition (8.00) while in Thippali highest recorded root production was observed under medium shade (8.33) which was on par with young oil palm canopy (6.33).

Growth Stage, Month 3

No significant influence of shade on root production was noticed during this stage (Table IV, Appendix). However, the species differed significantly in the number of roots produced and Kacholam was significantly superior (14.25) which was on par with Chittaratha (13.67) (Table 14).

The data on shade x species interaction effect was significant (Table 15.3). Under open condition, Chunda produced significantly the highest number of roots (16.33) and Chittaratha and Patchouli produced minimum. Under young oil palm canopy, root production was the highest in Chittaratha (19.00) and was on par with Kacholam and Chunda (16.00 and 15.33). Under medium oil palm canopy, the highest root number was recorded in Chittaratha (18.30) and Kacholam (16.00). Under mature oil palm canopy, Kacholam, Chittaratha, Patchouli, Chittadalodakam and Sathavari produced significantly highest number (12.67, 12.33, 9.67, 9.67 and 9.33 respectively).

With regard to the root number produced by individual species under different situations, the values were on par under all situations in the case of

Chittadalodakam, Iruveli, Kacholam, Karimkurinji, Koduveli, Thippali and Sathavari. Chittaratha recorded higher root number under young oil palm canopy (19.00) which was on par with those under medium oil palm canopy (18.30). In Chunda, the highest root production was observed under open (16.33) which was on par with young oil palm canopy (15.33). In Patchouli, higher root number was under mature oil palm canopy (9.67) which was on par with those under medium oil palm canopy (9.33).

Growth Stage, Month 4

Shade conditions significantly influenced the number of roots produced by the medicinal plant species (Table IV, Appendix). Higher number of roots was produced under the young oil palm canopy. The species differed significantly in the number of roots produced and highest root production was noticed in Kacholam (18.33) (Table 14).

Shade x species interaction was significant (Table 15.4). Under open condition, root numbers of Chittadalodakam, Sathavari, Chunda, Karimkurinji, Kacholam and Chittaratha were on par. Under young oil palm canopy, Kacholam produced significantly higher number of roots (28.67) while lower number of roots was noticed in Iruveli, Koduveli and Patchouli (7.32, 4.67 and 4.00 respectively). Under medium oil palm canopy, Kacholam and Chittaratha produced higher number (22.67 and 20.67). Under mature oil palm canopy, root number in Kacholam was the highest (12.33), which was on par with Chittaratha, Sathavari, Chittadalodakam, Chunda and Karimkurinji (11.00, 9.67, 9.00, 8.67 and 7.00 respectively).

With regard to the number of roots produced by individual species under different situations, the values were on par in Chittadalodakam, Iruveli, Karimkurinji, Koduveli, Patchouli and Sathavari. Chittaratha produced higher number of roots under medium oil palm canopy (20.67) which was on par with those under young oil palm canopy (20.33). Chunda produced higher number of roots under young oil palm canopy (16.33) which was on par with those under medium oil palm canopy (11.00). In the case of Kacholam, higher root production was under young oil palm canopy (28.67). For

Table 15.3 : Mean root number showing the interaction effect of oil palm shade conditions x medicinal species at different stages of plant growth- month 3

Shade conditions	Chittadalodakam	Chittaratha	Chunda	Iruveli	Kacholam	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	11.33	5.00	16.33	6.33	12.33	8.67	6.67	1.67	11.00	7.33
Young	10.00	19.00	15.33	5.33	16.00	9.67	4.33	2.67	11.67	7.00
Medium	9.33	18.30	12.00	5.00	16.00	10.00	4.00	9.33	9.33	9.00
Mature	9.67	12.33	7.67	4.67	12.67	6.67	3.00	9.67	9.33	5.00

CD 1 (0.05) 3.824 CD 2 (0.05) 4.170

Table 15.4 : Mean root number showing the interaction effect of oil palm shade conditions x medicinal species at different stages of plant growth- month 4

Shade conditions	Chittadalodakam	Chittaratha	Chunda	Iruveli	Kacholam	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	11.67	8.33	10.67	4.00	9.67	10.00	6.00	3.00	11.33	6.67
Young	10.33	20.33	16.33	7.33	28.67	11.67	4.67	4.00	16.00	11.33
Medium	10.00	20.67	11.00	6.33	22.67	11.00	5.33	2.33	13.00	9.67
Mature	9.00	11.00	8.67	3.67	12.33	7.00	3.00	0.00	9.67	5.67

CD 1 (0.05) 5.428 CD 2 (0.05) 5.586

CD1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

Thippali, higher root production was under young oil palm canopy (11.33) which was on par with those under medium (9.67) and open situations (6.67).

Growth Stage, Month 5

The root number was significantly influenced by shade levels (Table IV, Appendix). Higher root production was noticed under young oil palm canopy. The root number of different species also varied significantly and the highest root number was noticed in Kacholam (19.42) (Table 14).

The results furnished in Table 15.5 showed that shade x species interaction was significant. Under open condition, significantly higher root production was noticed in Sathavari, Kacholam, Chittadalodakam, Chunda, Karimkurinji and Thippali (13.00, 12.33, 11.67, 11.00, 10.00 and 9.00 respectively). Under young oil palm canopy, higher root production was noticed in Kacholam (23.67) which was on par with Chittaratha (22.00). Under medium oil palm canopy also, Kacholam produced significantly higher number of roots (27.67) while under mature oil palm canopy, in addition to Kacholam (14.00), significantly higher root production was recorded by Chittaratha (12.30), Chunda (11.00) and Sathavari (10.30) and these were on par.

The number of roots produced by individual species under different situations showed that Chittadalodakam, Karimkurinji and Koduveli were on par. Chittaratha produced the highest number of roots under medium oil palm canopy (23.00) which was on par with those under young oil palm canopy (22.00). Chunda produced the highest root number under young oil palm canopy (19.00). Iruveli also recorded the highest root number under young oil palm canopy (9.00) which was on par with those under medium oil palm canopy (8.00). Kacholam produced highest root number under medium oil palm canopy (27.67) which was on par with those under young palms (23.67). Patchouli produced the highest root number under young oil palm canopy (6.00). Sathavari also produced the highest number of roots under young oil palm canopy (18.00) which was on par with those under medium oil palm canopy (14.30). Thippali recorded higher root number under young oil palm canopy (10.67) which was on par with plants under medium (10.67) and open situation (9.00).

Growth Stage, Month 6

During this month, the influence of shade on number of roots was significant (Table IV, Appendix). Significantly higher root number was noticed under young oil palm canopy and minimum number under mature oil palm canopy. The species differed significantly and the highest root number was noticed in Kacholam (20.83) (Table 14).

The interaction between shade and species was significant (Table 15.6). Under open condition, Sathavari (15.00), Chittadalodakam (12.33) and Karimkurinji (12.00) produced higher number of roots while the lowest number was noticed in Patchouli (3.37) which was on par with Iruveli (5.33). Under young oil palm canopy, Kacholam, Thippali and Chittaratha produced significantly higher number of roots (30.00, 27.33 and 27.30 respectively) while, lower number was produced by Iruveli, Patchouli and Koduveli (9.67, 6.67 and 6.33 respectively). Under medium oil palm canopy, Kacholam produced the highest number of roots (30.67) and lower values recorded by Iruveli (6.67), Koduveli (4.33) and Patchouli (3.33). Under mature oil palm canopy, Kacholam, Chunda, Thippali and Chittaratha produced significantly higher number of roots (12.00, 11.67, 11.33 and 11.33 respectively). Lower number was noticed in Koduveli (3.33) and Patchouli (2.00).

Individual species responded differently under different situations and number of roots produced under all situations was on par in Chittadalodakam. Chittaratha produced the highest number of roots under young oil palm canopy (27.30) which was on par with plants under medium oil palm canopy (24.30). Chunda produced the highest root number under young oil palm canopy (19.00). In Iruveli, the highest root number was recorded under young oil palm canopy (9.67), which was on par with plants under mature (7.67) and medium palms (6.67). Kacholam recorded the highest root number under medium oil palm canopy (30.67) which was on par with plants under young oil palm canopy (30.00). In Karimkurinji, higher root number was under young oil palm

Table 15.5 : Mean root number showing the interaction effect of oil palm shade conditions x medicinal species at different stages of plant growth- month 5

Shade conditions	Chittadalodakam	Chittaratha	Chunda	Iruveli	Kacholam	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	11.67	8.00	11.00	6.00	12.33	10.00	7.33	3.00	13.00	9.00
Young	11.33	22.00	19.00	9.00	23.67	11.00	4.67	6.00	18.00	10.67
Medium	10.67	23.00	9.33	8.00	27.67	11.33	4.00	2.67	14.30	10.67
Mature	9.00	12.30	11.00	3.67	14.00	7.67	3.33	1.67	10.30	5.33

CD 1 (0.05) 4.329 CD 2 (0.05) 4.317

Table 15.6: Mean root number showing the interaction effect of oil palm shade conditions x medicinal species at different stages of plant growth- month 6

Shade conditions	Chittadalodakam	Chittaratha	Chunda	Iruveli	Kacholam	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	12.33	8.00	9.67	5.33	10.67	12.00	8.67	3.33	15.00	8.00
Young	12.00	27.30	19.00	9.67	30.00	13.00	6.33	6.67	20.00	27.33
Medium	12.00	24.30	9.33	6.67	30.67	13.00	4.33	3.33	14.67	24.33
Mature	9.67	11.33	11.67	7.67	12.00	8.00	3.33	2.00	10.67	11.33

CD 1 (0.05) 3.930 CD 2 (0.05) 4.184

CD1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

canopy (13.00) which was on par with medium (13.00) and open (12.00). Koduveli produced the highest root number under open condition (8.67). Patchouli produced the highest root number under young oil palm canopy (6.67) which was on par with open (3.33) and medium (3.33). In Sathavari, higher root number was noticed under young oil palm canopy (20.00). In Thippali also, the highest root number was recorded under young oil palm canopy (27.33) which was on par with plants grown under medium palm (24.33).

Growth Stage, Month 7

The significant effect of shade on root production was continued during this month (Table IV, Appendix). The highest root number was recorded under young oil palm canopy and the lowest under mature shade condition, which was on par with open. The species differed significantly and the highest root number was noticed in Kacholam (25.42) (Table 14).

Shade x species interaction effect was significant (Table 15.7). Under open condition Kacholam, Patchouli, Chittadalodakam and Chittaratha produced significantly higher number of roots (13.33, 13.33, 11.67 and 10.26 respectively) and the lowest number was recorded in Sathavari (2.67) which was on par with Thippali (7.33), Koduveli (7.00) and Iruveli (6.67). Under young oil palm canopy Kacholam produced significantly superior number of roots (41.00) while comparatively poor performance was noticed in Sathavari (1.67) which was on par with Thippali (5.33) and Koduveli (5.67). Under medium oil palm shade condition also, Kacholam excelled with 33.67 roots. Koduveli (5.00) showed poor root number, which was on par with Thippali (5.67) and Sathavari (6.00). Under mature palm shade condition, Kacholam, Patchouli and Chittadalodakam produced significantly higher number of roots (13.67, 12.67 and 10.67 respectively) while comparatively lower root production was noticed in Sathavari (1.00) which was on par with Thippali (2.67) and Koduveli (3.67).

The root number of individual species under different situations showed that the values were on par in Chittadalodakam, Karimkurinji, Koduveli, Patchouli, Sathavari and Thippali. However, in Iruveli higher root number was noticed under medium palm (15.00). In Kacholam, higher number of roots was recorded under the young oil palm canopy (41.00).

Growth Stage, Month 8

The influence of shade on root number was significant during this month (Table IV, Appendix). higher number of roots was recorded under the young oil palm canopy and minimum under mature palm. The species differed significantly and the highest root production was noticed in Sathavari (18.92) which was on par with Chittaratha (18.42) (Table 14).

Shade x species interaction effect was significant (Table 15.8). Under open condition, Sathavari produced significantly superior number of roots (15.67) which was on par with Chittadalodakam (12.00) and Thippali (11.33). Under young oil palm canopy, Chittaratha produced higher number of roots (32.67) which was on par with Sathavari (29.00). Under medium palm also, the same trend was noticed in Sathavari (19.67) and Chittaratha (19.00). Under mature palm, root production in Chittaratha (12.33) was the highest and was on par with Sathavari (11.33), Chittadalodakam (10.33) and Karimkurinji (9.00).

The number of roots produced by individual species under all situations was on par in the case of Chittadalodakam, Karimkurinji and Koduveli. In Chittaratha and Sathavari, higher root number was noticed under young oil palm canopy (32.67 and 29.00 respectively). In Thippali, the highest root number was recorded under young oil palm canopy (13.00) which was on par with open (11.33) and medium palm (11.00).

Growth Stage, Month 9

The significant influence of shade on root number was continued during this month (Table IV, Appendix). Higher root number was noticed under young oil palm canopy, which was on par with open condition. The lowest root production was recorded under mature palm. The species differed significantly and the highest root production was noticed in Chittaratha (30.00) (Table 14).

The results furnished in Table 15.9 showed that shade x species interaction effect was significant. Under open condition Chittaratha produced

Table 15.7 : Mean root number showing the interaction effect of oil palm shade conditions x medicinal species at different stages of plant growth- month 7

Shade conditions	Chittadalodakam	Chittaratha	Iruveli	Kacholam	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	11.67	10.26	6.67	13.33	12.00	7.00	13.33	2.67	7.33
Young	13.00	17.26	9.00	41.00	12.00	5.67	17.33	1.67	5.33
Medium	9.67	14.11	15.00	33.67	12.00	5.00	14.33	6.00	5.67
Mature	10.67	8.82	8.00	13.67	8.33	3.67	12.67	1.00	2.67

CD 1 (0.05) 4.967 CD 2 (0.05) 5.361

Table 15.8 : Mean root number showing the interaction effect of oil palm shade conditions x medicinal species at different stages of plant growth- month 8

Shade conditions	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	12.00	9.67	10.33	7.67	15.67	11.33
Young	12.33	32.67	14.33	5.00	29.00	13.00
Medium	10.67	19.00	13.00	4.33	19.67	11.00
Mature	10.33	12.33	9.00	3.67	11.33	6.67

CD 1 (0.05) 4.945 CD 2 (0.05) 5.352

CD1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

significantly higher number of roots (49.00) when compared to other species. Under young oil palm canopy also, higher root number was recorded by Chittaratha (36.33) which was on par with Sathavari (36.33). Koduveli recorded minimum number of roots under young oil palm canopy during this month (5.67).

Chittaratha, Sathavari, Thippali and Karimkurinji produced higher root number and these were on par under medium and mature palm.

The data on number of roots produced by individual species under all situations showed that the values were on par in Chittadalodakam and Koduveli. In Chittaratha, higher root number was recorded under open condition (49.00) and the lowest under mature oil palm canopy (11.33). Karimkurinji produced significantly higher number of roots under medium and young oil palm canopy (17.67 and 14.33) and under open (10.67). In Sathavari, higher root production was noticed under young oil palm canopy (36.33). For Thippali higher root production was noticed under medium palm shade (20.00) which was on par with those under young oil palm canopy (19.00).

Growth Stage, Month 10

The root number was significantly influenced by shade levels (Table IV, Appendix). higher root number was recorded under young oil palm canopy. Number of roots under open and mature palm canopy was on par. The species differed significantly and the highest root number was noticed in Chittaratha (25.75) which was on par with Sathavari (24.33) (Table 14).

The data furnished in Table 15.10 showed that shade x species interaction was significant. Under open condition, Sathavari produced higher number of roots (19.00) which was on par with Chittaratha (18.67). Under young oil palm canopy, Chittaratha produced higher number of roots (47.67) while Koduveli produced minimum (6.00). Under medium oil palm canopy, Chittaratha and Sathavari recorded higher number of roots (24.67) which was on par with Karimkurinji (18.67). Under mature oil palm canopy, root number in Sathavari (14.67) Chittaratha (12.00) Chittadalodakam (10.33), Karimkurinji (10.00) and Thippali (8.67) were higher and on par.

Table 15.9: **Mean root number showing the interaction effect of oil palm shade conditions x medicinal species at different stages of plant growth- month 9**

Shade conditions	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	13.00	49.00	10.67	8.33	17.67	9.33
Young	14.33	36.33	14.33	5.67	36.33	19.00
Medium	12.67	23.33	17.67	4.33	22.00	20.00
Mature	11.33	11.33	9.33	4.00	13.33	9.67

CD 1 (0.05) 7.287 CD 2 (0.05) 7.669

Table 15.10 : Mean root number showing the interaction effect of oil palm shade conditions x medicinal species at different stages of plant growth- month 10

Shade conditions	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	12.33	18.67	11.00	8.00	19.00	10.00
Young	13.33	47.67	16.00	6.00	39.00	20.00
Medium	12.00	24.67	18.67	5.67	24.67	17.00
Mature	10.33	12.00	10.00	4.67	14.67	8.67

CD 1 (0.05) 6.354 CD 2 (0.05) 6.875

CD1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

The individual species recorded significant variation in root number under different situations. The number of roots was on par in Chittadalodakam and Koduveli. Chittaratha produced higher number of roots under the young oil palm canopy (47.67). Same trend was noticed in Sathavari also where higher values were observed under young oil palm canopy (39.00). Both Karimkurinji and Thippali produced higher roots under young and medium shade and in both, root number under open was on par with those under mature palm.

Growth Stage, Month 11

Shade level significantly influenced the number of roots produced (Table IV, Appendix). higher root number was recorded under the young oil palm. The ten species differed significantly and the highest root number was observed in Sathavari (26.67) which was on par with Chittaratha (24.08) (Table 14).

The data on shade x species interaction was significant (Table 15.11). Under open condition, Chittaratha produced higher number of roots (26.67). Under young oil palm canopy, Sathavari produced the highest number of roots (43.00) while Koduveli produced the lowest number (6.67). Under medium palm shade, both Sathavari and Chittaratha produced significantly higher number of roots (25.67 and 24.33 respectively) while Koduveli (6.67) recorded the lowest number. Under mature palm shade condition, also Sathavari produced higher number of roots (17.33).

The individual species behaved differently under the four situations. In Chittadalodakam and Koduveli, the values recorded were on par. In the case of Chittaratha, higher root production was under young oil palm canopy (35.00) and the lowest under mature shade canopy (10.33). In Karimkurinji, higher root production was recorded under medium oil palm canopy (20.00) which was on par with those under young oil palm canopy (18.00). In Sathavari, higher root production was registered under young oil palm canopy, (43.00) and the values under open and mature palms were on par.

***Table 15.11 :* Mean root number showing the interaction effect of oil palm shade conditions x medicinal species at different stages of plant growth- month 11**

Shade conditions	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	12.33	26.67	12.33	7.67	20.67	9.67
Young	14.33	35.00	18.00	6.67	43.00	22.33
Medium	12.33	24.33	20.00	6.67	25.67	14.33
Mature	11.33	10.33	11.00	5.33	17.33	9.00

CD 1 (0.05) 5.355 CD 2 (0.05) 5.526

Table 15.12 : Mean root number showing the interaction effect of oil palm shade conditions x medicinal species at different stages of plant growth- month 12

Shade conditions	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	12.67	31.00	13.67	8.00	21.67	13.00
Young	15.67	64.33	20.00	6.67	69.67	15.00
Medium	12.33	28.67	20.00	7.67	29.67	17.67
Mature	11.67	14.33	14.00	5.67	20.00	9.00

CD 1 (0.05) 10.342 CD 2 (0.05) 10.501

CD1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

In the case of Thippali, higher root number was seen under young oil palm canopy (22.33).

Growth Stage, Month 12

The influence of shade was significant during this month also (Table IV, Appendix). Significantly higher root number was noticed under young oil palm. The species differed significantly and the highest root number was recorded by Sathavari (35.25) which was on par with Chittaratha (34.58) (Table 14).

The data suggested that shade x species interaction was also significant (Table 15.12). Under open condition, Chittaratha produced higher number of roots (31.00) which was on par with Sathavari (21.67). Under young oil palm canopy, Sathavari produced higher number of roots (69.67) which was on par with Chittaratha (64.33). Under medium palm shade, Sathavari, Chittaratha and Karimkurinji recorded significantly higher number of roots (29.67,28.67 and 20.00 respectively), while under mature palm, in addition to the above three crops, Chittadalodakam also produced significantly higher number (20.00,14.33,14.00 and 11.67 respectively).

The number of roots did not vary significantly in Chittadalodakam, Karimkurinji, Koduveli, Sathavari and Thippali. However, in Chittaratha, the effect was significant and it recorded the highest number of roots under young palms and lower under mature palm shade (14.33).

Growth Stage, Month 13

The root number was significantly affected by shade levels (Table IV, Appendix). The plants grown under the young oil palm, recorded higher root number and minimum under the mature palm. The species showed significant difference in root number and the highest number was recorded by Sathavari (36.75) which was on par with Chittaratha (28.67) (Table 14).

The data suggested that shade x species interaction was also significant (Table 15.13). Under open condition, Chittaratha produced the highest number of roots (33.67) and lower values were recorded by Chittadalodakam and Koduveli (14.33 and 8.00) which were on par. Under young oil palm, Sathavari produced the highest number of roots (67.67) and the lowest number was recorded by Koduveli (8.33). Under medium palm, both Sathavari and Chittaratha produced significantly higher number of roots (32.00 and 27.67 respectively) and Chittadalodakam and Koduveli produced lower values (12.33 and 6.67). Under mature palm, Sathavari and Karimkurinji produced significantly higher number of roots (22.33 and 17.00).

The results on number of roots of individual species under different situations showed that these were on par in Chittadalodakam and Koduveli. In Chittaratha, higher root production was obtained under young oil palm and open condition (39.67 and 33.67) and lower under mature palm. In Karimkurinji, higher root number was noticed under the young oil palm canopy (23.67) which was on par with those under medium palm shade (22.00). Sathavari recorded higher root number under young oil palm canopy (67.67) while Thippali recorded the highest root number under medium and young oil palm (22.67 and 20.33 respectively).

Growth Stage, Month 14

Shade significantly influenced the number of roots produced during this month (Table IV, Appendix) and significantly higher root production was recorded under young oil palm canopy. The species varied significantly and the highest root production was noticed in Sathavari (38.83) (Table 14).

The results furnished in Table 15.14 indicated that shade x species interaction was significant. Chittaratha and Sathavari produced higher number of roots under the open condition (30.67 and 25.33). Under young oil palm, Sathavari produced higher number of roots (72.67) while under medium shade Sathavari and Chittaratha produced the highest number (33.67 and 27.00). Under mature palm, Sathavari and Karimkurinji recorded the highest number (23.67 and 19.00 respectively).

The treatments significantly influenced root number of the individual species studied. The number of roots produced was on par in Chittadalodakam and Koduveli. In Chittaratha, higher root production was noticed under the young oil palm canopy (44.33) and lower under mature palm (13.33). In the case of Karimkurinji, significantly higher number of roots was produced under

Table 15.13 : Mean root number showing the interaction effect of oil palm shade conditions x medicinal species at different stages of plant growth- month 13

Shade conditions	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	14.33	33.67	16.00	8.00	25.00	15.67
Young	16.33	39.67	23.67	8.33	67.67	20.33
Medium	12.33	27.67	22.00	6.67	32.00	22.67
Mature	11.33	13.67	17.00	5.33	22.33	9.00

CD 1 (0.05) 6.710 CD 2 (0.05) 6.366

Table 15.14 : Mean root number showing the interaction effect of oil palm shade conditions x medicinal species at different stages of plant growth- month 14

Shade conditions	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	12.67	30.67	18.00	8.00	25.33	18.00
Young	13.33	44.33	26.00	9.00	72.67	20.00
Medium	12.67	27.00	23.00	6.67	33.67	18.33
Mature	11.00	13.33	19.00	6.33	23.67	8.00

CD 1 (0.05) 6.828 CD 2 (0.05) 7.137

CD1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

the three shade conditions (26.00, 23.00 and 19.00 under young, medium and mature oil palm canopy respectively) while the lowest root number was recorded under the open condition (18.00). In the case of Sathavari, higher root production was recorded under the young palm (72.67) and the lowest under mature palm (23.67) which was on par with open (25.33). In Thippali the lowest number was produced under the mature palm shade condition (8.00). In the other three shade conditions, the number of roots produced was on par.

Growth Stage, Month 15

During this month, the shade levels significantly affected the root number (Table IV, Appendix) and significantly higher root production was recorded under young oil palm canopy. The species differed significantly and the highest root values noticed in Sathavari (41.17) (Table 14).

The data revealed that shade x species interaction was also significant (Table 15.15). Under the open condition, Chittaratha and Sathavari produced significantly higher number of roots (30.33 and 28.00 respectively) while minimum number was reported in Koduveli (8.33) which was on par with Chittadalodakam (12.00).Under the young oil palm canopy, Sathavari produced significantly the highest number of roots (74.00) while Chittadalodakam and Koduveli produced lower number of roots (13.00 and 7.67). Under medium shade condition, Sathavari recorded the highest number of roots (34.33) and lower number by Chittadalodakam and Koduveli (13.67 and 6.67). Under mature shade in addition to Sathavari, Karimkurinji also recorded significantly higher number of roots (28.33 and 23.00), while Chittadalodakam, Thippali and Koduveli produced significantly lower number (11.33, 9.00 and 6.00 respectively).

The root number of individual species under four levels of shade also differed significantly and the values recorded under all situations was on par in Chittadalodakam and Koduveli. Chittaratha produced the highest number of roots under young oil palm (40.33) and lower under mature palm shade (19.00). Karimkurinji produced higher number of roots under young and medium oil palm canopy (29.67 and 24.00), while root production under mature shade condition (23.00) was on par with those under open condition (19.67). Sathavari produced higher number of roots under young oil palm canopy (74.00) The number of roots under medium and mature palm shade condition was on par with open (34.33, 28.33 and 28.00 respectively). In the case of Thippali significantly higher number was recorded under the young and medium oil palm canopy and open condition (22.00, 18.67 and 18.33) while comparatively poor root production was recorded under mature (9.00).

Growth Stage, Month 1 6

The influence of shade on root number was significant (Table IV, Appendix). The root number was the highest under young oil palm canopy. The species differed significantly and the highest root number was noticed in Sathavari (42.58) (Table 14).

The data showed that shade x species interaction was also significant (Table 15.16). Under open condition Chittaratha, Sathavari and Thippali produced higher number of roots (31.33, 28.67 and 26.00 respectively). Under young and medium oil palm canopies, Sathavari produced the highest number of roots (78.00, 34.67 respectively). The performance of Chittadalodakam and Koduveli was poor under the above three conditions. Under mature palm, both Sathavari and Karimkurinji recorded the highest number of roots (29.67 and 23.67 respectively) while the performance of Chittadalodakam, Thippali and Koduveli was poor under this shade level also (11.33, 8.77 and 7.33 respectively).

With regard to the root number produced by individual species under different situations, the values were on par in Chittadalodakam and Koduveli. Chittaratha produced the highest number of roots under young palms, which was on par with those under open (36.33 and 31.33 respectively). Karimkurinji and Sathavari produced the highest number of roots under the young oil palm canopy (34.67 and 78.00 respectively) while root number in Thippali under open, young and medium oil palm canopies were on par (26.00, 21.33 and 19.67 respectively).

Table 15.15 : Mean root number showing the interaction effect of oil palm shade conditions x medicinal species at different stages of plant growth- month 15

Shade conditions	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	12.00	30.33	19.67	8.33	28.00	18.33
Young	13.00	40.33	29.67	7.67	74.00	22.00
Medium	13.67	26.00	24.00	6.67	34.33	18.67
Mature	11.33	19.00	23.00	6.00	28.33	9.00

CD 1 (0.05) 6.477 CD 2 (0.05) 6.619

Table 15.16: Mean root number showing the interaction effect of oil palm shade conditions x medicinal species at different stages of plant growth- month 16

Shade conditions	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	12.33	31.33	22.00	8.33	28.67	26.00
Young	12.00	36.33	34.67	6.67	78.00	21.33
Medium	14.67	27.00	26.00	6.67	34.67	19.67
Mature	11.33	15.33	23.00	7.33	29.00	8.67

CD 1 (0.05) 7.357 CD 2 (0.05) 7.488

CD1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

Growth Stage, Month 17

Shade levels significantly influenced the number of roots produced by the species studied (Table IV, Appendix) and significantly higher root production was recorded under young oil palm canopy. The species showed significant difference and the highest root production was noticed in Sathavari (43.42) (Table 14).

The data furnished in Table 15.17 suggested that the interaction effect was also significant. Under open condition, higher root production was for Chittaratha (34.67), Sathavari (30.67) and Thippali (28.33). Under young oil palm canopy, Sathavari produced higher number of roots (78.33). Under medium and mature Sathavari, Karimkurinji and Chittaratha recorded the highest number of roots. Chittadalodakam and Koduveli registered minimum number of roots under all the situations.

A comparison of the root number produced by the individual species under different situations, suggested that the values were on par in Chittadalodakam and Koduveli. Karimkurinji and Sathavari recorded the highest number of roots under the young oil palm canopy 38.33 and 78.33 respectively. In Chittaratha and Thippali, higher root number was noticed under open, young and medium oil palm canopies and the lowest number was recorded under mature shade condition.

Growth Stage, Month 18

The data on number of roots furnished in Table IV, Appendix suggested that the character was significantly influenced by shade levels. As in the previous months, higher root production was noticed under the young oil palm canopy and the lowest under the mature palm. The species also differed significantly and the highest root number was noticed in Sathavari (44.08) (Table 14).

Shade x species interaction effect was significant (Table 15.18). Under open condition, Chittaratha produced the highest number of roots (47.33). Under young oil palm canopy, Sathavari recorded the highest number of roots

(79.67) and under medium and mature palm shade, in addition to Sathavari, Karimkurinji and Chittaratha recorded higher values.

With regard to the root number produced by individual species under different situations, the values obtained under all situations were on par in Chittadalodakam and Koduveli. Sathavari produced higher number of roots under the young oil palm canopy (79.67) while under the other three conditions root number was on par. Chittaratha produced higher number of roots under young oil palm (48.33) which was on par with open (47.33). In Karimkurinji higher root, production was recorded under young oil palm (40.00) which was on par with medium shade (30.00). In Thippali, higher number of roots was recorded under young oil palm canopy (37.00) which was on par with open (32.00).

During the course of investigation, it was noticed that the influence of shade levels on the number of roots was not visible during the first three months. However, during the rest of the period consistently higher root number was recorded under young palms.

Out the ten medicinal plants studied Kacholam recorded significantly higher number of roots till its harvest after seven months. From eighth month onwards, Sathavari and Chittaratha recorded significantly higher number of roots up to thirteenth month after planting. Thereafter Sathavari outnumbered all other species in the number of roots produced.

During the first three months, under open condition, Chunda and Kacholam recorded higher number of roots. Thereafter Sathavari, Karimkurinji and Chittadalodakam joined the group. However, from ninth month onwards throughout growth stage Chittaratha and Sathavari recorded significantly higher number of roots under open condition. Under young and medium palms Kacholam, Sathavari and Chittaratha recorded significantly higher number of roots. Under mature palms during the early growth stages Chittaratha, Kacholam, Chittadalodakam, Sathavari and Patchouli recorded significantly higher number of roots. However towards the later stages of crop growth, i.e.,

Table 15.17 : Mean root number showing the interaction effect of oil palm shade conditions x medicinal species at different stages of plant growth- month 17

Shade conditions	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	12.33	34.67	24.00	7.67	30.67	28.33
Young	11.33	36.33	38.33	7.00	78.33	20.00
Medium	15.00	28.33	28.67	6.33	35.00	20.33
Mature	11.33	22.00	23.67	6.67	29.67	9.33

CD 1 (0.05) 8.181 CD 2 (0.05) 8.986

Table 15.18: Mean root number showing the interaction effect of oil palm shade conditions x medicinal species at different stages of plant growth- month 18

Shade conditions	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	12.33	47.33	25.00	6.00	30.67	32.00
Young	16.33	48.33	40.00	6.67	79.67	37.00
Medium	15.67	20.67	30.00	8.33	35.33	20.67
Mature	12.67	34.67	25.33	5.33	30.67	9.00

CD 1 (0.05) 12.757 CD 2 (0.05) 11.993

CD1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

from eighth month after planting, significantly higher root number was recorded by Chittaratha, Sathavari and Karimkurinji.

Shade had no significant influence on the number of roots produced throughout the growth period in the case of Chittadalodakam and Koduveli. In the case of Chittaratha, plants grown under young and medium palms produce higher number of roots upto six months after planting. Thereafter plants under young palms produced significantly higher number of roots throughout the growth period. In Chunda, the highest root number was noticed under open condition as well as young palms upto three months after planting. From fourth to sixth month, higher number of roots were recorded under young palms. The influence of shade on root number of Iruveli was non significant upto fourth month after planting. However, from fifth month onwards, the influence of shade became pronounced and higher root number was recorded from plants under young and medium oil palm canopy. In Kacholam, higher number of roots was recorded from plants under young and medium oil palm canopy compared to open. Root number was not significantly affected by shade levels in Karimkurinji upto eighth month after planting. However, from ninth month onwards significantly higher number of roots were recorded from plants under young and medium palms. In Patchouli, the effect of shade levels on root number was not pronounced except during the third, fifth and sixth month, where significantly higher number of roots was recorded from plants under the different oil palm canopy shade levels. The influence of shade levels on root number of Sathavari plants became pronounced by fifth month after planting. From this period onwards consistently higher number of roots were noticed in plants grown under young oil palm canopy. The influence of shade levels on the root number of Thippali was highly variable throughout the growth stage. However significantly higher number of roots was noticed in plants grown under young and medium palms.

4.1.1.5 Length of Roots

The influence various shade levels on root length of medicinal plant species during different growth stages are presented below.

Table 16: Mean root length of medicinal plant species for oil palm shade conditions at different stages of plant growth, cm

Treatment	Growth Stage - month																	
Shade condition	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Open	9.31	12.51	12.18	12.29	14.38	14.37	12.77	15.28	15.71	16.25	17.02	17.49	18.81	19.96	20.67	22.08	22.53	22.57
Young	10.09	12.48	13.63	15.23	15.75	16.08	15.90	16.66	24.91	20.52	22.26	22.63	26.82	29.43	30.01	32.31	33.33	33.32
Medium	12.60	12.34	13.99	15.87	15.99	16.57	16.40	19.71	21.22	21.32	22.48	23.38	24.64	26.15	25.73	27.47	26.65	27.41
Mature	10.82	11.03	11.13	11.90	12.84	13.16	14.76	14.38	16.02	17.47	17.60	17.62	18.94	20.46	21.05	21.62	22.14	22.42
CD 0. 05	**N. S**	**0.974**	**1.993**	**2.304**	**1.562**	**1.129**	**2.415**	**1.745**	**N.S.**	**1.550**	**1.768**	**3.227**	**1.677**	**3.810**	**N.S**	**4.221**	**1.260**	**1.961**
Species																		
Chittadalodakam	7.24	8.53	8.99	9.81	10.21	10.60	11.55	11.81	13.07	14.07	15.85	17.74	19.86	21.69	23.38	24.73	25.83	26.08
Chittaratha	12.68	14.78	15.59	14.93	16.10	18.70	17.15	18.86	27.23	19.81	20.85	16.98	22.70	23.83	22.00	24.67	21.62	21.78
Chunda	13.00	15.75	16.75	18.25	20.50	18.73	Crop harvested											
Iruveli	11.35	11.23	11.46	12.63	12.42	11.23	13.54	Crop harvested										
Kacholam	11.21	10.02	11.13	11.38	14.73	14.07	13.28	Crop harvested										
Karimkurinji	12.82	15.60	16.38	17.82	19.23	20.58	22.32	23.72	25.68	26.53	27.84	29.53	31.80	34.35	37.59	40.85	43.36	44.48
Koduveli	11.04	13.26	13.88	14.62	14.83	15.42	14.69	15.76	17.57	18.64	19.83	21.33	20.97	22.53	21.07	22.26	20.97	21.77
Patchouli	9.21	0.75	1.87	3.09	4.18	4.48	15.25	Crop harvested										
Sathavari	8.07	10.20	10.79	11.40	12.33	12.52	4.18	15.09	17.58	17.96	18.71	19.66	21.23	22.69	24.16	25.06	25.90	26.70
Thippali	10.43	10.78	10.52	14.29	12.88	14.11	12.66	13.80	15.64	16.33	15.96	16.43	17.26	18.89	18.00	17.64	19.30	17.76
C D 0. 05	**2.211**	**2.484**	**2.003**	**3.331**	**2.458**	**2.141**	**3.014**	**1.827**	**10.010**	**1.999**	**1.769**	**2.605**	**2.523**	**2.784**	**3.092**	**3.142**	**3.208**	**2.674**

Growth Stage, Month 1

The influence of shade on root length was not significant (Table V, Appendix). The species differed significantly and the highest root length was noticed in Chunda (13.00) which was on par with Karimkurinji (12.82), Chittaratha (12.68), Iruveli (11.35) and Koduveli (11.04) (Table 16).

Shade x species interaction was, however, not significant (Table 17.1).

Growth Stage, Month 2

The influence of shade on root length was significant (Table V, Appendix) and higher root length was observed under open condition, which was on par with those under young and medium oil palm canopies. The species showed significant difference and the highest root length was noticed in Chunda (15.75) which was on par with Karimkurinji (15.60), Chittaratha (14.78) and Koduveli (13.26) (Table 16).

The data showed that shade x species interaction was significant (Table 17.2). Under open condition Koduveli and Chunda recorded higher root length of 23.37 and 21.00 cm respectively. Under young oil palm canopy, Chunda and Chittaratha recorded 18.00 and 17.17 cm respectively. Under medium oil palm canopy, Karimkurinji, Chittaratha and Iruveli recorded significantly longer roots (18.70, 14.80 and 14.33 cm respectively). Under mature oil palm canopy, Karimkurinji recorded the highest length of 22.33 cm.

With regard to the length of roots of individual species under different shade situations, the values were on par in Chittadalodakam, Chittaratha, Patchouli, Sathavari and Thippali. In Chunda, roots were longer under the open condition (21.00 cm) which was on par with young oil palm canopy (18.00 cm). For Iruveli higher root length was under the medium oil palm canopy (14.33 cm) which was on par with those under young oil palm canopy (12.67 cm). Karimkurinji recorded the longest roots under mature oil palm canopy (22.33 cm) which was on par with those under medium oil palm canopy (18.70 cm). Koduveli produced the highest root length under the open condition (23.37 cm).

Table 17.1: Mean root length showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, cm - month 1

Shade condition	Chittadalodakam	Chittaratha	Chunda	Iruveli	Kacholam	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	6.33	11.53	16.00	11.00	11.83	7.73	7.17	9.43	6.77	5.33
Young	8.00	9.80	16.00	7.33	10.33	9.90	12.33	8.33	9.50	9.33
Medium	7.93	16.50	10.00	15.30	10.03	17.50	11.67	9.40	9.67	17.97
Mature	6.70	12.90	10.00	11.77	12.63	16.13	13.00	9.67	6.33	9.10

N.S

Table 17.2: Mean root length showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, cm - month 2

Shade condition	Chittadalodakam	Chittaratha	Chunda	Iruveli	Kacholam	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	7.70	14.67	21.00	8.67	10.17	9.37	23.37	0.53	9.00	10.67
Young	9.67	17.17	18.00	12.67	10.43	12.00	12.00	0.83	9.67	11.67
Medium	8.67	14.80	13.00	14.33	12.13	18.70	8.00	0.73	8.67	11.00
Mature	8.07	12.50	11.00	9.27	7.33	22.33	9.67	0.87	8.07	9.80

CD 1 (0.05) 4.969 CD 2 (0.05) 4.808

CD1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

Growth Stage, Month 3

Shade significantly influenced length of roots of the medicinal plant species studied (Table V, Appendix). higher root length was under medium palm, which was on par with those under young oil palm. The species differed significantly and the longest root was observed in Chunda (16.75) which was on par with Karimkurinji (16.38) and Chittaratha (15.59) (Table 16).

The results given in Table 17.3 showed that shade x species interaction was significant. Under open condition, Koduveli and Chunda recorded longer roots of 19.83 and 16.67 cm respectively. Under young oil palm, Chunda recorded the highest root length of 21.67 cm. Under medium palms, Karimkurinji, Chittaratha, Chunda and Iruveli produced significantly longer roots (19.27, 18.33, 17.67 and 15.67 respectively). Under mature palm, Karimkurinji recorded the highest root length (22.33 cm).

With regard to the individual species under different shade situations, the data suggested that the values were on par in Chittadalodakam, Patchouli and Sathavari. Chittaratha recorded higher root length under medium palm (18.33) which was on par with those under young palms (15.00) and open (15.00 cm). Iruveli had higher root length under medium oil palm canopy (15.67 cm) which was on par with those under young oil palm canopy (13.33 cm). Kacholam recorded the longest roots under open condition (13.17 cm) which was on par with medium (12.37 cm) and young oil palm canopy (10.17 cm) shade. Karimkurinji recorded the longest roots under mature palms (22.33 cm) which was on par with medium palms (19.27 cm). Koduveli registered higher root length under open (19.83 cm) which was on par with root length under young oil palm (13.67 cm). Thippali recorded higher root length under young oil palm canopy (13.67).

Growth Stage, Month 4

The significant effect of shade on root length was continued during this month (Table V, Appendix). Higher root length was under medium oil palm canopy, which was on par with those under young palms. The species differed

Table 17.3 : **Mean root length showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, cm - month 3**

Shade condition	Chittadalodakam	Chittaratha	Chunda	Iruveli	Kacholam	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	8.97	15.00	16.67	9.00	13.17	10.30	19.83	1.20	8.50	9.13
Young	10.00	15.00	21.67	13.33	10.17	13.60	13.67	2.73	12.50	13.67
Medium	9.00	18.33	17.67	15.67	12.37	19.27	13.00	1.53	12.30	10.77
Mature	8.00	14.03	11.00	7.83	8.80	22.33	9.00	2.00	9.83	8.50

CD 1 (0.05) 4.007 CD 2 (0.05) 4.276

Table 17.4 : **Mean root length showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, cm - month 4**

Shade condition	Chittadalodakam	Chittaratha	Chunda	Iruveli	Kacholam	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	9.87	14.67	17.33	11.33	10.17	10.60	17.97	1.73	9.43	9.77
Young	10.67	14.33	23.33	13.83	14.50	15.13	13.67	4.13	12.67	20.03
Medium	10.00	18.50	20.33	15.83	10.17	21.20	17.17	4.50	13.33	17.67
Mature	13.33	12.23	12.00	9.53	10.70	24.30	9.67	2.00	10.17	9.70

CD1 0.05 6.662 CD 2 (0.05) 6.712

CD1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

significantly and the highest root length was noticed in Chunda (18.25) which was on par with Karimkurinji (17.82) (Table 16).

It was found that shade x species interaction was also significant (Table 17.4). Under open condition, Koduveli, Chunda and Chittaratha recorded significantly longer roots (17.97, 17.33 and 14.67 cm respectively). Under young palms, Chunda and Thippali recorded the highest root length of 23.33 and 20.03 respectively. Under medium palms, Karimkurinji, Chunda, Chittaratha, Thippali, Koduveli and Iruveli recorded the longest roots of 21.20, 20.33, 18.50, 17.67 and 17.17 and 15.83 respectively. Under mature palms, Karimkurinji recorded the highest root length of 24.30 cm.

The response of shade on root length of individual species under different shade situations suggested that it was on par in Chittaratha, Iruveli, Kacholam, Patchouli and Sathavari. Chunda recorded the longest roots under young palms (23.33 cm), which was on par with medium palms and open (20.33 and 17.33 cm). Karimkurinji recorded the highest root length under mature palms (24.30 cm) that was on par with those under medium palms (21.20 cm). Koduveli recorded the highest root length under open (17.97 cm) which was on par with medium and young palms (17.17 and 13.67 cm respectively). Thippali recorded the longest roots under young palms (20.03 cm), which was on par with those under medium palms (17.67 cm).

Growth Stage, Month 5

The effect of shade on length of roots was significant (Table V, Appendix). The longest root lengths were recorded under medium palms, which was on par with those under young palms. The species differed markedly and the longest roots were recorded by Chunda (20.50 cm), which was on par with Karimkurinji (19.23 cm) (Table 16).

The data given in Table 17.5 suggested that shade x species interaction was significant. Under open condition, Koduveli and Chunda registered the longest roots length of 21.83 and 21.33 cm respectively. Under young palms, Chunda registered the highest root length of 27.33 cm. Under medium and mature oil palm canopies, Karimkurinji recorded longer roots of 23.67 and 24.67 cm respectively.

The results on the response of individual species root length under different shade situations indicated that Chittadalodakam, Chittaratha, Patchouli and Sathavari produced no pronounced effect due to shade levels. Chunda recorded the longest roots under young oil palm (27.33 cm). Karimkurinji recorded the highest root length under mature palm (24.67 cm), which was on par with medium palms (23.67 cm). Koduveli recorded the highest root length under open (21.83 cm). Thippali registered the longest roots under young palms (16.37 cm) which was on par with those under medium palms (14.60 cm).

Growth Stage, Month 6

It was found that the influence of shade on length of root was significant (Table V, Appendix). The longest roots were produced under medium palms, which was on par with those under young palms. The species differed markedly and the highest value was noticed in Karimkurinji (20.58 cm), which was on par with Chunda (18.73 cm) and Chittaratha (18.70 cm) (Table 16).

The results furnished in Table 17.6 indicated that shade x species interaction was also significant. Under open condition, Koduveli recorded the longest roots (25.13 cm). Under young palms, Chunda registered the highest value (28.00 cm). Under medium palms, Chittaratha recorded the longest roots (25.00 cm) while under mature palms, Karimkurinji produced longest roots (25.00 cm).

The individual species showed difference in their response to shade. The root length of Chittadalodakam, Iruveli and Sathavari did not differ significantly. Chittaratha produced the highest root length under medium palms (25.00 cm). Chunda recorded higher root length under young palms (28.00), which was on par with open (18.33). Kacholam recorded the longest root length under medium palms (17.13), which was on par with those under young palms (15.33 cm). Karimkurinji recorded the highest root length under mature palms (25.00 cm), which was on par with those under medium palms (24.87 cm).

Table 17.5 : Mean root length showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, cm - month 5

Shade condition	Chittadalodakam	Chittaratha	Chunda	Iruveli	Kacholam	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	10.03	15.67	21.33	12.00	16.77	12.10	21.83	2.40	9.90	11.73
Young	11.00	15.33	27.33	12.50	14.57	16.50	13.33	6.30	14.30	16.37
Medium	10.33	17.67	18.33	15.33	16.90	23.67	13.50	5.30	14.23	14.60
Mature	9.47	15.73	15.00	9.83	10.70	24.67	10.67	2.67	10.87	8.80

CD1 0.05 4.916 CD 2 (0.05) 4.908

Table 17.6 : Mean root length showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, cm - month 6

Shade condition	Chittadalodakam	Chittaratha	Chunda	Iruveli	Kacholam	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	10.50	18.00	18.33	10.67	12.33	14.87	25.13	2.73	10.57	10.57
Young	12.00	15.67	28.00	11.13	15.33	17.57	13.00	7.07	13.57	17.43
Medium	10.33	25.00	13.90	12.70	17.13	24.87	13.20	5.77	14.57	18.20
Mature	9.57	16.17	14.67	10.43	11.47	25.00	10.33	2.33	11.37	10.23

CD 1 (0.05) 4.282 CD 2 (0.05) 4.209

CD1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

Koduveli recorded the longest roots under open (25.13 cm). In Patchouli, the highest value was recorded under young palms (7.07) which was on par with those under medium palm (5.73). In the case of Thippali, also the highest root length was under medium oil palm canopy (18.20 cm) which was on par with those under young palms (17.43 cm).

Growth Stage, Month 7

Shade significantly influenced root length during this month (Table V, Appendix). Higher root length was noticed under medium palms, which was on par with those under young palms. The ten species showed significant difference with regard to this character. Karimkurinji produced significantly superior root length (22.32 cm) (Table 16).

The data given in Table 17.7 indicated that shade x species interaction was not significant.

Growth Stage, Month 8

The effect of shade on root length was significant (Table V, Appendix). The species grown under medium oil palms recorded longer roots. Species differences with regard to root length were also significant. Karimkurinji recorded the longest roots of 23.72 cm (Table 16).

The interaction effect between shade and species was significant (Table 17.8). In the open condition, Koduveli recorded significantly longest roots (23.17 cm), which was on par with Chittaratha (19.67 cm). Under young palms, roots of Karimkurinji and Thippali were longer and were on par (21.33 and 18.30 cm respectively). Among medium and mature palms, Karimkurinji recorded the highest value of 31.67 cm and 26.67 cm respectively.

The length of roots of individual species varied significantly. The different shade level did not alter root length of Chittadalodakam. Chittaratha recorded significantly longer roots, when grown under medium palms (25.00 cm). Karimkurinji also recorded the longest roots when grown under medium palms (31.67 cm). Koduveli recorded the longest roots under open condition (23.17 cm). Sathavari produced the longest roots under medium palms (17.40 cm), which was on par with those under young and mature palms (16.30 and

Table 17.7 : Mean root length showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, cm - month 7

Shade condition	Chittadalodakam	Chittaratha	Iruveli	Kacholam	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	11.77	16.33	12.67	10.00	15.03	13.77	13.50	1.23	10.60
Young	12.67	15.60	11.77	14.90	20.23	17.33	18.13	5.63	16.87
Medium	12.00	19.10	15.37	12.83	27.67	15.53	16.03	5.03	14.03
Mature	9.77	17.57	14.37	15.40	26.33	12.13	13.33	4.83	9.13

N.S

Table 17.8 : Mean root length showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, cm - month 8

Shade condition	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	11.83	19.67	15.20	23.17	11.50	10.30
Young	12.33	16.67	21.33	15.00	16.30	18.30
Medium	12.33	25.00	31.67	13.37	17.40	18.50
Mature	10.73	14.10	26.67	11.50	15.17	8.10

CD 1 (0.05) 3.654 CD 2 (0.05) 3.754

CD1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

15.17 cm respectively). Thippali recorded superior root length under medium palms (18.50 cm) which was on par with those under young palms (18.30 cm).

Growth Stage, Month 9

The influence of shade on length of roots was not significant (Table V, Appendix). However, the species differed significantly in their root length. Chittaratha recorded higher root length (27. 23 cm), which was on par with the root lengths of Karimkurinji (25.68), Koduveli (17.57) and Sathavari (17.58 cm) (Table 16).

The effect of shade x species interaction was also not significant (Table 17.9).

Growth Stage, Month 10

Length of roots was significantly influenced by shade levels (Table V, Appendix). Plants grown under medium palms produced the longest roots, which were on par with those under young palms. Species difference with regard to root length was also significant. Among the species, Karimkurinji recorded the longest roots of 26.53 cm (Table 16).

Table 17.10 showed that shade x species interaction was also highly significant. Koduveli produced the longest roots (24.10 cm) under open and Karimkurinji under the three shade situations (26.90, 33.07 and 30.33 cm respectively). Under young palms, Sathavari also produced longer roots (23.23 cm) which was on par with Chittaratha (20.00 cm).

The individual species recorded significant difference in root length under different shade situations. The length of roots of Chittadalodakam and Chittaratha was on par under all shade situations. Karimkurinji recorded the highest root length under medium palms (33.07 cm), which was on par with those under mature palms (30.33 cm). Koduveli recorded the longest roots under open condition (24.10 cm) and its root length under the different treatments was on par. Sathavari produced the longest roots under young palms (23.23 cm) which was on par with those under medium palms (19.43 cm).

Table 17.9 : Mean root length showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, cm - month 9

Shade condition	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	12.33	17.60	15.30	25.03	12.63	11.33
Young	13.67	48.40	24.60	19.00	22.47	21.33
Medium	13.77	26.47	33.17	14.03	19.80	20.07
Mature	12.53	16.43	29.67	12.20	15.43	9.83

N.S

Table 17.10: Mean root length showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, cm - month 10

Shade condition	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	12.67	18.67	15.83	24.10	13.33	12.90
Young	15.67	20.00	26.90	17.67	23.23	19.63
Medium	15.13	21.33	33.07	17.67	19.43	21.27
Mature	12.80	19.23	30.33	15.13	15.83	11.50

CD 1 (0.05) 3.998 CD 2 (0.05) 3.961

CD1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

Thippali produced longest roots under medium palms (21.27 cm), which was on par with those under young palms (19.63 cm).

Growth Stage, Month 11

Influence of shade on root length was highly significant (Table V, Appendix). Taller roots were recorded under medium palms and these were on par with those under young palm. The species also differed significantly and Karimkurinji recorded the longest roots of 27.84 cm (Table 16).

Shade x species interaction was also highly significant (Table 17.11). Under open condition, Koduveli continued to produce longer roots of 22.90 cm, which was on par with Chittaratha (20.33 cm). Under the three shade conditions, Karimkurinji excelled with root lengths of 29.30, 34.23 and 31.00 cm under young, medium and mature palms respectively.

The length of roots produced by the individual species under different shade situations also differed. Chittadalodakam recorded the longest roots of 18.33 cm under young oil palm canopy, which was on par with those under medium palms and open (16.37 and 15.07 respectively). Chittaratha recorded higher value of 24 cm under young palms, which was on par with those under medium palms (21.67 cm). Karimkurinji recorded the longest roots under medium palms (34.23 cm) and was on par with those under mature palms (31.00 cm). Koduveli produced significantly longer roots (22.90 cm) under open condition and was on par with those under medium and young palms (20.80 and 19.67 cm respectively). Sathavari produced the longest roots under young palms (25.07 cm) while Thippali had the longest roots under medium palms (21.67 cm).

Growth Stage, Month 1 2

The influence of shade on root length was significant (Table V, Appendix). Significantly superior root length was recorded from species under medium palms, which was on par with young oil palm canopy. Species also differed significantly with regard to their root length and Karimkurinji (29.53 cm) recorded higher root length (Table 16).

Table 17.11: Mean root length showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, cm - month 11

Shade condition	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	15.07	20.33	16.83	22.90	13.67	13.33
Young	18.33	24.00	29.30	19.67	25.07	17.17
Medium	16.37	21.67	34.23	20.80	20.13	21.67
Mature	13.63	17.40	31.00	15.93	15.97	11.67

CD 1 (0.05) 3.537 CD 2 (0.05) 3.790

Table 17.12 : Mean root length showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, cm - month 12

Shade condition	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	17.13	19.40	18.20	23.77	14.07	12.40
Young	20.00	17.50	32.33	20.33	26.73	18.87
Medium	18.60	16.47	35.90	23.67	21.43	24.20
Mature	15.23	14.57	31.67	17.57	16.40	10.27

CD 1 (0.05) 5.211 CD 2 (0.05) 5.727

CD1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

Shade x species interaction was also significant (Table 17.12), with Koduveli and Chittaratha performing well under the open condition (23.77 and 19.40 cm root lengths respectively). Under the three shade situations, Karimkurinji recorded significantly superior root length of 32.30, 35.90 and 31.67 cm respectively.

Regarding the species performance under different shades, Chittadalodakam and Chittaratha recorded significantly superior root length under all shade levels. Karimkurinji recorded highest root length under medium palms (35.90 cm) which was on par with mature and young oil palm canopy (31.67 and 32.33 cm). Sathavari recorded superior root length under young oil palm canopy (26.73 cm) which was on par with medium palms (21.43 cm) while Thippali produced superior root length under medium palms (24.20 cm) which was on par with young oil palm canopy (18.87 cm).

Growth Stage, Month 13

During this month also, shade had significantly influenced root length (Table V, Appendix) and significantly higher values were recorded under young palms. Species also showed significant difference and the highest values were recorded by Karimkurinji (31.80 cm) (Table 16).

The data on interaction between shade and species was also significant (Table 17.13). Under open condition, Koduveli recorded the highest value (24.27 cm) which was on par with Chittaratha (21.33 cm). Under the three shade situations, Karimkurinji recorded significantly longer roots (37.53, 37.97 and 32.67 cm respectively).

Regarding the response of different species under different shade situations, Chittadalodakam was significantly superior under young oil palm canopy (22.67 cm) which was on par with those under medium palms (21.40 cm) and open condition (18.73 cm). Chittaratha also recorded significantly longer roots under young palms (27.00 cm) which was on par with those under medium palms (23.33 cm). In Karimkurinji, root length was the highest under medium palms (37.97 cm) and was on par with those under young and mature palms (37.53 and 32.67 cm respectively). Koduveli performed well under open condition recording a root length of 24.27 cm which was on par with those under young and medium palms (23.33 and 20.23 cm respectively). Sathavari recorded significantly longer roots under the young palms (31.07 cm) while Thippali recorded higher values under medium palms (23.67 cm) which was on par with those under young palms (19.33 cm).

Growth Stage, Month 14

The influence of shade on length of roots was significant during this period (Table V, Appendix) and the longest root was recorded from species grown under young oil palm canopy. Species difference was also significant with Karimkurinji recording significantly longest root of 34.35 cm (Table 16).

Shade x species interaction was also highly significant (Table 17.14) and under open condition, Koduveli recorded higher root length (24.13 cm) which was on par with Chittaratha (21.67 cm), Karimkurinji (20.60 cm) and Chittadalodakam (19.60 cm). Under the three shade situations, like previous months Karimkurinji recorded significantly longer roots (41.43, 41.03 and 34.33 cm respectively).

Comparative examination of root number recorded by the different species showed that Chittadalodakam produced higher root length under young oil palm canopy (25.33 cm) which was on par with those under medium palms (23.43 cm) and under open (19.60 cm). Chittaratha recorded significantly longer roots under young palms (28.67 cm) which was on par with those under medium palms (23.33 cm). Karimkurinji produced longest roots under young palms (41.43 cm) which was on par with those under medium palms (41.03 cm). Koduveli produced significantly higher values under young palms (26.33 cm) which was on par with open condition (24.13 cm) and under medium palms (20.33 cm). Sathavari recorded superior values when grown under young palms (34.90 cm) while Thippali produced the longest roots under medium palms (27.13 cm).

Growth Stage, Month 15

The data presented in (Table V, Appendix) showed that the influence of shade on root length was not significant.

Table 17.13 : Mean root length showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, cm - month 13

Shade condition	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	18.73	21.33	19.03	24.27	15.13	14.37
Young	22.67	27.00	37.53	23.33	31.07	19.33
Medium	21.40	23.33	37.97	20.23	21.23	23.67
Mature	16.63	19.17	32.67	16.03	17.47	11.67

CD1 0.05 5.046 CD 2 (0.05) 4.894

Table 17.14 : Mean root length showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, cm - month 14

Shade condition	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	19.60	21.67	20.60	24.13	16.37	17.37
Young	25.33	28.67	41.43	26.33	34.90	19.93
Medium	23.43	23.33	41.03	20.33	21.63	27.13
Mature	18.40	21.67	34.33	19.33	17.87	11.13

CD1 0.05 5.570 CD 2 (0.05) 6.329

CD1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

Species differed significantly with regard to root length and higher root length was recorded in Karimkurinji (40.90 cm) (Table 16).

Shade x species interaction was also significant (Table 17.15) and under open condition, Koduveli recorded significantly longer roots (24.93 cm) which was on par with Karimkurinji (22.43 cm), Chittadalodakam (22.03 cm) and Chittaratha (21.67 cm). However, under the three shade situations Karimkurinji performed well recording root lengths of 47.83, 44.10 and 36.00 cm respectively.

Analysis of the results on root lengths recorded by the ten species showed that Chittadalodakam recorded significantly longer roots under young oil palm canopy (27.67 cm) which was on par with those under medium palms (24.17 cm) and open condition (22.03 cm). Chittaratha produced the highest value under medium oil palm canopy (22.33 cm) which was on par with those under other conditions. In the case of Karimkurinji, significantly longer roots were noticed under young palms (47.83 cm) and it was on par with plants grown under medium palms (44.10 cm). Koduveli had the highest value under open condition (24.93 cm) but was on par with the plants under young (22.67 cm) and mature palms (18.97 cm). Sathavari produced the longest roots when grown under young palms (38.40 cm) while Thippali had the longest roots under medium palms (23.17 cm) and this was on par with those under young palms (21.47 cm).

Growth Stage, Month 16

During this month, shade levels significantly influenced length of roots of medicinal plant species (Table V, Appendix) and plants grown under young palms recorded higher root length. Species also differed significantly with Karimkurinji recording a higher root length of 40.85 cm (Table 16).

The data showed that shade x species interaction was also significantly different (Table 17.16) with Koduveli, Karimkurinji, Chittadalodakam, Chittaratha and Thippali recording higher values under open condition (24.87, 24.33, 23.73, 21.33 and 20.80 cm respectively). Karimkurinji alone was

Table 17.15 : Mean root length showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, cm - month 15

Shade condition	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	22.03	21.67	22.43	24.93	17.10	15.87
Young	27.67	22.00	47.83	22.67	38.40	21.47
Medium	24.17	22.33	44.10	17.70	22.93	23.17
Mature	19.63	22.00	36.00	18.97	18.20	11.50

CD 1 (0.05) 6.184 CD 2 (0.05) 6.048

Table 17.16 : Mean root length showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, cm - month 16

Shade condition	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	23.73	21.33	24.30	24.87	17.40	20.80
Young	29.00	31.67	54.60	21.33	41.20	16.07
Medium	24.53	26.67	46.80	20.80	23.10	22.87
Mature	21.67	19.00	37.67	22.03	18.50	10.83

CD 1 (0.05) 6.285 CD 2 (0.05) 7.095

CD1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

superior under the shade conditions (54.60, 46.80 and 37.67 cm long roots under young, medium and mature palms respectively).

A critical analysis of the variation among the species in respect of root length indicated that Chittadalodakam was superior under young oil palm canopy (29.00 cm) and this was on par with those under medium palms (24.53 cm) and under open condition (23.73 cm). Chittaratha produced the highest root length under young oil palm canopy (31.67 cm) which was on par with those under medium palms (26.67 cm). Karimkurinji also produced longer roots under young palms (54.60 cm). The root length of Koduveli was significantly higher under open (24.87 cm) which was on par with other shade conditions (22.03, 21.33 and 20.80 cm under mature, young and medium palms respectively). Sathavari recorded longer roots when grown under young palms (41.20 cm), Thippali recorded superior values under medium palms (22.87 cm) which was on par with those under open and young palms (20.80 and 16.07 cm respectively).

Growth Stage, Month 17

The length of roots was significantly affected by shade levels (Table V, Appendix). Higher root length was recorded from medicinal plants grown under young palms. The response of different species to shade was also highly significant with Karimkurinji recording significantly longer roots of 43.36 cm (Table 16).

The results showed that shade x species interaction also significantly influenced root length (Table 17.17). Karimkurinji (27.33 cm), Chittadalodakam (24.57 cm), Chittaratha (23.00 cm) and Koduveli (22.83 cm) produced significantly longer roots under open condition. However, when these were grown under young, medium and mature palms, Karimkurinji alone recorded significantly longer roots of 59.47, 47.30 and 39.33 cm respectively.

The data on the root length of individual species suggested that Chittadalodakam was significantly superior under young oil palm canopy (29.67 cm), medium palms (25.33 cm) and open condition (24.57 cm). On the contrary, Chittaratha recorded longer roots under all shade conditions.

Karimkurinji recorded significantly longer roots under young palms (59.47 cm) while Koduveli was uniformly superior under all conditions. Sathavari recorded significantly superior values under young palms (43.30 cm) while Thippali produced higher root length under medium palms (24.53 cm). This was on par with those under young palms (22.53 cm) and open condition (18.90 cm).

Growth Stage, Month 18

During this month, the influence of shade on root length was highly significant (Table V, Appendix) with species growing under young palms recording higher root length. Species also differed significantly with Karimkurinji recording the highest root length of 44.48 cm (Table 16).

The data indicated significant shade x species interaction also (Table 17.18) and under open condition, Karimkurinji and Chittadalodakam produced significantly higher values (28.00 and 25.27 cm respectively). Under the three shade conditions, Karimkurinji had the longest root length (60.20, 48.03 and 41.67 cm respectively).

The data given in Table 17.18 also revealed that the length of roots produced by Chittadalodakam was superior under young palms (30.33), medium palms (25.60 cm) and under open condition (25.27 cm). Same was the case with Chittaratha with a root length of 24.53, 22.80 and 21.67 cm under young, medium and open condition respectively. Karimkurinji recorded significantly superior values when grown among young palms (60.20 cm) while Koduveli recorded the highest value under medium palms (25.60 cm), mature palms (20.80 cm) and under open condition (20.67 cm). The root length of Sathavari, as in the previous months, was the highest under young palms (44.80 cm) while that of Thippali was the highest under open condition (20. 70 cm). This was on par with the plants under open (20.03 cm) and medium palms (18.73 cm).

An overall assessment of the influence of different shade levels on the root length of the medicinal plant species revealed that significantly higher root

Table 17.17: Mean root length showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, cm - month 17

Shade condition	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	24.57	23.00	27.33	22.83	18.53	18.90
Young	29.67	24.00	59.47	21.00	43.30	22.53
Medium	25.33	19.80	47.30	19.77	23.17	24.53
Mature	23.73	19.67	39.33	20.27	18.60	11.23

CD1 0.05 6.416 CD 2 (0.05) 5.987

Table 17.18: Mean root length showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, cm - month 18

Shade condition	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	25.27	21.67	28.00	20.67	19.10	20.70
Young	30.33	24.53	60.20	20.00	44.80	20.03
Medium	25.60	22.80	48.03	25.60	23.70	18.73
Mature	23.13	18.13	41.67	20.80	19.20	11.57

CD1(0.05) 5.349 CD 2 (0.05) 5.252

CD1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

length was recorded from plants grown under young and medium palms through out the growth stage except during the first, ninth and fifteenth months after planting.

Among the ten medicinal plant species studied, Chunda, Karimkurinji and Chittaratha excelled in their root length upto ninth month after planting. From tenth month onwards, the longest roots were recorded from Karimkurinji alone. Under open condition significantly longer roots were recorded by Koduveli, Chunda and Chittaratha upto thirteenth month after planting. From fourteenth month onwards in addition to these crops, Chittadalodakam and Karimkurinji also produced longer roots. Under young oil palm canopy, Chunda produced significantly longer roots throughout its growth stage. From eighth month onwards, Karimkurinji excelled producing the longest roots during the rest of the crop growth period. Under the deep shaded condition of the medium and mature palms, Karimkurinji excelled producing the longest roots throughout the growth stage. However, under medium palms, superior performance was exhibited by Chunda, Chittaratha and Iruveli upto fourth month after planting.

Regarding individual plant effect, root length in Chittadalodakam was not affected by the different shade levels upto twelfth month after planting. Thereafter significantly longer roots were produced by plants grown under open condition and young and medium palms. In Chittaratha, the influence of shade became visible only during the third, sixth, eighth, eleventh, thirteenth, fourteenth, sixteenth and eighteenth month after planting, where significantly longer roots were recorded from plants under young and medium palms. Root length of Chunda was significantly higher under open and young palms throughout the growth stage except during the first month after planting. Kacholam plants produced significantly longer roots under young and medium palms, almost throughout the growth period. Karimkurinji produced significantly longer roots under the medium and mature palms upto thirteenth month after planting. Thereafter significantly longer roots were observed under young palms. The influence of shade levels on the root length of Koduveli was not significant and it produced significantly longer roots under open condition almost throughout the growth stage. In Patchouli, the roots lengths under different shade levels were on par throughout the growth stage except during the first and sixth months where significantly longer roots were recorded under young and medium palms. In Sathavari, the influence of shade levels became pronounced by tenth month after planting. From this stage onwards, significantly longer roots were registered from plants under young oil palm canopy. Thippali produced significantly longer roots under young and medium palms almost throughout the growth period.

4.1.2 Physiological parameters

4.1.2.1 Dry matter production

The influence of four shade levels on the dry matter production of medicinal plants during the different growth stages are presented below.

Growth Stage, Month 1

The results indicated that the influence of shade on dry matter production was not significant (Table VI, Appendix) . However, the species differed significantly and the highest dry matter content was noticed in Chittaratha (20.62 g), which significantly differed from other species tried.

The interaction effect between shade x species was significant (Table 19.1). higher dry matter accumulation was recorded in Chittaratha (20.24 g) which was on par with Chittadalodakam (20.22 g) in the open condition. The dry matter accumulation recorded in other species grown in the open condition was on par. Under the young oil palm canopy also the same trend was noticed, where Chittaratha recorded 20.40g and Chittadalodakam 19.57g. Dry matter accumulation in all other species except Karimkurinji was on par. Under the medium palms Chittadalodakam, Chittaratha and Karimkurinji also produced significantly higher dry matter content (15.76, 12.80 and 13.30 g respectively). The dry matter accumulation of all other species except Karimkurinji was on par. Under mature palms Chittaratha and Chittadalodakam produced

Table 18: Mean dry matter production of medicinal plant species under oil palm shade conditions at different stages of plant growth, g plant $^{-1}$

Treatment	Growth stage - month																	
Shade Condition	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Open	6.79	8.58	9.69	12.78	14.17	16.98	19.85	21.80	25.98	29.90	30.35	30.96	38.73	38.58	39.19	47.44	48.76	51.40
Young	7.08	8.99	11.00	14.35	16.31	20.33	23.24	25.97	29.27	36.80	39.26	42.14	51.91	52.33	53.91	90.18	58.15	65.02
Medium	6.03	8.04	9.62	13.22	14.60	16.83	20.39	20.71	23.17	27.93	29.29	36.26	37.99	39.61	40.90	47.21	49.16	50.05
Mature	7.14	7.15	8.47	11.31	12.89	14.58	18.04	17.48	19.61	21.82	23.21	25.38	30.96	33.75	38.22	43.28	42.48	44.65
CD 0.05	**N.S**	**N.S**	**1.233**	**1.981**	**1.567**	**1.602**	**N.S**	**3.160**	**3.217**	**4.180**	**4.641**	**N.S**	**1.623**	**3.818**	**3.503**	**N.S**	**5.946**	**5.315**
Species																		
Chittadalodakam	17.92	20.37	22.74	28.19	29.86	32.56	38.18	39.96	45.44	51.36	55.29	59.53	72.15	71.72	72.78	83.19	83.98	90.99
Chittaratha	20.62	21.28	21.88	30.04	28.14	34.47	40.87	43.23	50.00	59.97	60.14	66.88	74.51	75.22	78.33	130.91	80.56	90.26
Chunda	4.46	7.20	10.31	12.18	15.07	17.56	Crop harvested											
Iruveli	2.81	4.31	5.12	6.08	7.20	8.41	10.83	Crop harvested										
Kacholam	2.51	3.71	7.30	12.37	19.77	26.46	30.91	Crop harvested										
Karimkurinji	9.94	12.46	13.35	17.45	17.83	19.58	23.35	24.00	27.09	33.40	35.64	38.67	48.88	53.52	59.65	72.81	76.77	79.11
Koduveli	4.03	5.04	5.47	6.95	7.35	8.41	9.59	9.71	10.62	12.92	13.42	14.06	16.42	17.29	17.13	19.44	19.44	18.57
Patchouli	2.13	3.62	5.95	9.12	2.02	6.02	19.77	Crop harvested										
Sathavari	2.44	3.11	3.62	5.19	5.80	6.34	7.57	9.19	10.69	13.30	14.47	18.45	21.84	22.97	24.64	28.49	29.23	29.75
Thippali	0.74	0.80	1.25	1.58	1.87	1.96	2.38	2.84	3.20	3.72	4.22	4.52	5.62	5.69	5.94	7.32	7.84	7.98
CD 0.05	**2.276**	**2.480**	**1.432**	**3.119**	**2.306**	**1.842**	**3.505**	**3.334**	**3.779**	**5.274**	**3.000**	**11.186**	**5.704**	**4.872**	**4.936**	**48.868**	**5.071**	**5.619**

CD 0.05 - Critical difference at 5 % level N. S - Non significant

significantly higher dry matter (29.04 and 16.12 g) and dry matter production in all other species except Karimkurinji was on par.

With regard to dry matter production by individual species under different situations, the values were on par in all medicinal plant species except Chittaratha. In Chittaratha, the highest dry matter accumulation was noticed under the mature palms (29.04 g) and the lowest under medium palms (12.80 g).

Growth Stage, Month 2

The influence of shade on dry matter accumulation was not significant during this month (Table VI, Appendix). However, the species differed significantly in dry matter production and the highest dry matter content was noticed in Chittaratha (21.28 g), which was on par with Chittadalodakam (20.37 g) (Table 18).

The data indicated that shade x species interaction was not significant (Table 19.2).

Growth Stage, Month 3

The dry matter production of medicinal plant species was significantly affected by shade (Table VI, Appendix) and higher dry matter production was noted under the young oil palm canopy condition. The species differed significantly and higher value was noticed in Chittadalodakam (22.74 g), which was on par with Chittaratha (21.88 g) (Table 18).

The results presented in Table 19.3 pointed out that shade x species interaction effect was significant (Table 19.3). Significantly higher values were recorded by Chittadalodakam (26.76 g) under open condition. Under the young, medium and mature oil palm canopies, significantly higher dry matter accumulation was noted in Chittaratha (25.52, 21.81 and 21.26 g) and Chittadalodakam (24.18, 20.06 and 19.97 g). The lowest values were recorded by Thippali (1.42, 1.76 and 0.72 g) respectively.

With regard to the dry matter production by individual species performance under different situations, the values were on par under the different situations, in all medicinal plant species except Chittaratha.

Table 19 .1: **Mean dry matter production showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, g - month 1**

Shade condition	Chittadalodakam	Chittaratha	Chunda	Iruveli	Kacholam	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	20.22	20.24	4.60	3.10	2.41	7.70	3.59	2.79	2.60	0.62
Young	19.57	20.40	5.17	2.72	3.20	9.88	4.87	1.85	2.20	0.92
Medium	15.76	12.80	5.08	2.40	2.35	13.30	3.68	1.87	2.29	0.80
Mature	16.12	29.04	2.98	3.04	2.07	8.86	3.98	2.02	2.69	0.62

CD1 (0.05) 4.552 CD2 (0.05) 5.162

Table 19 .2: **Mean dry matter production showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, g - month 2**

Shade condition	Chittadalodakam	Chittaratha	Chunda	Iruveli	Kacholam	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	24.31	20.22	8.37	4.46	3.97	8.09	7.90	4.57	3.36	0.61
Young	21.32	23.76	7.86	4.08	4.39	15.61	5.19	3.45	3.12	1.12
Medium	17.25	21.48	7.69	4.66	3.74	15.12	3.50	3.10	2.79	1.02
Mature	18.60	19.65	4.87	4.04	2.74	11.04	3.55	3.37	3.19	0.44

N.S

CD1 Critical difference at 5 % level for comparing two species at a fixed shade
CD2 Critical difference at 5 % level for comparing two shade for a fixed or different species

Chittaratha recorded the highest dry matter accumulation under the young oil palm canopy (25.52 g).

Growth Stage, Month 4

Shade levels significantly affected the dry matter production of medicinal plant species (Table VI, Appendix) , and the highest dry matter production was noted under the young oil palm canopy condition. The species differed significantly and the highest dry matter content was noticed in Chittaratha (30.04 g), which was on par with Chittadalodakam (28.19 g) (Table 18).

The data showed that shade x species interaction was however not significant (Table 19.4).

Growth Stage, Month 5

The dry matter production of medicinal plant species was significantly influenced by shade (Table VI, Appendix). The highest dry matter production was recorded under the young oil palms and the lowest under mature palms. The species differed significantly and the highest dry matter content was noticed in Chittadalodakam (29.86 g) which was on par with Chittaratha (28.14 g). (Table 18)

Shade x species interaction was also significant (Table 19.5). Under open condition Chittadalodakam produced significantly higher (36.06 g) dry matter compared to all other species and the lowest accumulation was recorded in Thippali (1.96 g) and Patchouli (1.17 g). Under young oil palms also Chittadalodakam showed significantly higher value (32.03 g) and the observations in Sathavari (6.30g) Iruveli (6.13 g) Patchouli (3.57 g) and Thippali (2.29 g) were on par. Under medium palms, both Chittaratha (30.80) and Chittadalodakam (27.96) excelled in this character and the lowest value was for Thippali (2.28 g) and Patchouli (1.37 g). Under mature palms, dry matter production in Chittaratha (28.93 g) was significantly superior while that of Patchouli (1.95 g) and Thippali (0.94 g) was lower.

Table 19 .3: Mean dry matter production showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, g - month 3

Shade condition	Chittadalodakam	Chittaratha	Chunda	Iruveli	Kacholam	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	26.76	18.92	12.15	4.72	6.81	8.26	7.41	6.49	4.29	1.09
Young	24.18	25.52	10.89	5.11	9.87	17.26	5.99	6.42	3.44	1.42
Medium	20.06	21.81	11.17	5.17	6.31	16.01	4.64	5.82	3.43	1.76
Mature	19.97	21.26	7.02	5.47	6.21	11.85	3.84	5.06	3.33	0.72

CD1 (0.05) 2.864 CD2 (0.05) 2.975

Table 19 .4 : Mean dry matter production showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, g - month 4

Shade condition	Chittadalodakam	Chittaratha	Chunda	Iruveli	Kacholam	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	34.35	29.63	12.37	4.94	10.55	12.03	8.70	8.72	5.24	1.28
Young	29.59	31.42	14.43	6.44	14.45	22.78	7.59	9.37	5.55	1.84
Medium	26.09	30.08	12.37	6.73	13.48	19.69	6.79	8.99	5.93	2.06
Mature	22.71	29.03	9.55	6.21	10.99	15.31	4.74	9.39	4.04	1.14

N.S

CD1 Critical difference at 5 % level for comparing two species at a fixed shade
CD2 Critical difference at 5 % level for comparing two shade for a fixed or different species

With regard to drymatter production of individual species under different situations, the values were on par in Chittaratha, Iruveli, Koduveli, Patchouli, Sathavari and Thippali. In Chittadalodakam, dry matter accumulation under open condition and young oil palm canopy was on par (36.06 and 32.03 g respectively). In Chunda the same trend was noticed and dry matter contents were 19.60 and 15.48 g respectively. In the case of Kacholam significantly higher dry matter accumulation was noticed under young oil palm canopy (25.95 g). In Karimkurinji the highest dry matter accumulation was noticed under the young and medium oil palm canopy (22.84 and 21.15 g respectively), and the lowest under the open condition (10.81 g).

Growth Stage, Month 6

Shade levels significantly affected the dry matter production of medicinal plant species (Table VI, Appendix) and the highest value was recorded under the young palms and lowest under mature palms. The species differed significantly and the highest dry matter content was noticed in Chittaratha (34.47 g) which was on par with Chittadalodakam (32.56 g) (Table 18).

The data indicated that shade x species interaction was significant (Table 19.6). Under open condition Chittadalodakam excelled by producing 39.31 g dry matter while lower values were recorded by Patchouli (4.78 g) and Thippali (2.27 g). Under the young palms Chittaratha produced significantly higher dry matter content of 40.93 g while lower value was recorded for Thippali (2.20 g). Under medium palms, both Chittaratha and Chittadalodakam excelled producing 32.08 and 31.29 g respectively while Patchouli (5.08) and Thippali (2.38 g) recorded lower values. Under mature palms, also, Chittaratha recorded the highest value of 30.99 g and Sathavari (4.57 g) and Thippali (0.99 g) recorded lower values.

With regard dry matter production of individual species recorded under different situations, Iruveli, Patchouli, Sathavari and Thippali were on par. Chittadalodakam accumulated the highest dry matter under the open condition (39.31g), and the lowest under mature palms (25.17 g). In

Table 19 .5 : Mean dry matter production showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, g - month 5

Shade condition	Chittadalodakam	Chittaratha	Chunda	Iruveli	Kacholam	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	36.06	26.31	15.48	7.16	16.88	10.81	9.89	1.17	5.96	1.96
Young	32.03	26.53	19.60	6.13	25.95	22.84	7.87	3.57	6.30	2.29
Medium	27.96	30.80	13.16	7.97	18.73	21.15	6.00	1.37	6.52	2.28
Mature	23.38	28.93	12.05	7.56	17.53	16.53	5.63	1.95	4.41	0.94

CD1 (0.05) 4.613 CD2 (0.05) 4.638

Table 19 .6 : Mean dry matter production showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, g - month 6

Shade condition	Chittadalodakam	Chittaratha	Chunda	Iruveli	Kacholam	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	39.31	33.89	16.40	6.27	26.15	12.57	11.50	4.78	6.68	2.27
Young	34.49	40.93	24.40	9.04	31.51	25.62	9.66	8.37	7.06	2.20
Medium	31.29	32.08	16.52	9.26	25.90	22.41	6.31	5.08	7.06	2.38
Mature	25.17	30.99	12.93	9.06	22.30	17.75	6.16	5.86	4.57	0.99

CD1 (0.05) 3.683 CD2 (0.05) 3.832

CD1 Critical difference at 5 % level for comparing two species at a fixed shade
CD2 Critical difference at 5 % level for comparing two shade for a fixed or different species

Chittaratha, higher dry matter accumulation was noticed under the young oil palm canopy (40.93 g), and dry matter accumulation under other two shade situations and open were on par. Chunda and Kacholam also showed high dry matter accumulation under the young palms (24.40 g and 31.51 g respectively). In Karimkurinji higher accumulation was noticed under the young palms (25.62 g) which was on par with those under medium oil palm canopy (22.41 g) whereas in Koduveli higher dry matter accumulation was observed under open condition (11.50 g) which was on par with those under young palms (9.66 g).

Growth Stage, Month 7

The results furnished in Table VI Appendix indicated that the influence of shade on dry matter accumulation was not significant. The species differed significantly and higher dry matter accumulation was noticed in Chittaratha (40.87 g) which was on par with Chittadalodakam (38.18 g) (Table 18).

The interaction effect of shade x species differed significantly (Table 19.7). Under open condition, Chittadalodakam and Chittaratha produced significantly higher dry matter content (44.81g and 39.53 g respectively) whereas lower values were observed in Iruveli (7.64 g) Sathavari (6.86 g) and Thippali (3.28 g) which was on par. Under young palms both Chittadalodakam and Chittaratha was superior, producing 43.60 and 41.68 g dry matter respectively. Under this condition, Sathavari (8.92 g) and Thippali (2.52 g) recorded lower values. Under medium oil palm canopy, Chittaratha produced significantly higher dry matter content of 48.56 g and lower values were recorded by Sathavari (8.93 g), Koduveli (7.96 g) and Thippali (2.83 g). Under mature palms both Chittaratha and Chittadalodakam produced significantly higher dry matter content (33.72 g and 32.09 g respectively) and Sathavari (5.56 g) and Thippali (0.87 g) recorded lower values.

The data on dry matter production individual crops under different shade situations revealed that, only Chittadalodakam and Chittaratha responded differently. In the case of Chittadalodakam, significantly higher dry matter

Table 19 .7: Mean dry matter production showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, g - month 7

Shade condition	Chittadalodakam	Chittaratha	Iruveli	Kacholam	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	44.81	39.53	7.64	29.57	14.97	10.77	21.25	6.86	3.28
Young	43.60	41.68	13.44	34.96	29.71	11.33	22.98	8.92	2.52
Medium	32.19	48.56	11.49	28.13	26.65	7.96	16.79	8.93	2.83
Mature	32.09	33.72	10.76	30.97	22.05	8.31	18.04	5.56	0.87

CD1 (0.05) 7.701 CD2 (0.05) 7.741

Table 19 .8: Mean dry matter production showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, g - month 8

Shade condition	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	47.07	45.20	14.18	11.70	8.70	3.90
Young	43.67	54.91	31.95	10.89	11.82	2.60
Medium	36.22	39.22	27.24	7.76	10.33	3.46
Mature	32.88	33.58	22.64	8.50	5.91	1.38

CD1 (0.05) 6.668 CD2 (0.05) 6.840

CD1 Critical difference at 5 % level for comparing two species at a fixed shade
CD2 Critical difference at 5 % level for comparing two shade for a fixed or different species

accumulation was noted under open (44.81 g) and young palms (43.60 g). In Chittaratha, the highest accumulation was observed under the medium oil palm canopy (48.56 g) which was on par with that in young palms (41.68 g).

Growth Stage, Month 8

Influence of shade on dry matter accumulation was significant during this month (Table VI, Appendix). The highest dry matter accumulation was recorded under the young palms and lower under mature oil palm canopy. The species differed significantly and the highest value was noticed in Chittaratha (43.23 g) (Table 18).

Table 19.8 gives the data on shade x species interaction effect. It was found that the treatment effects were significant during the month. Under open condition, highest dry matter production was noted in Chittadalodakam (47.07 g) and Chittaratha (45.20 g). Under the young palms, Chittaratha produced significantly higher dry matter of 54.91 g whereas Thippali produced the lowest value of 2.60 g. Under medium palms, Chittaratha and Chittadalodakam were on par with 39.22 g and 36.22 g respectively. Lower values were observed in Koduveli (7.76 g) and Thippali (3.46 g) which were on par. Under mature palms also both Chittaratha and Chittadalodakam excelled producing 33.58 g and 32.88 g dry matter respectively while comparatively lower values were recorded by Sathavari (5.91g) and Thippali (1.38 g).

There was significant difference in the dry matter accumulation of individual species under different shade situations during this month. In the case of Chittadalodakam, higher accumulation was observed under the open condition (47.07 g) which was on par with that in young oil palm canopy (43.67g). In Chittaratha, higher dry matter content was recorded under young palms (54.91g). In Karimkurinji higher dry matter accumulation was noticed under young and medium palms. (31.95 and 27.24 g respectively). In Koduveli, Sathavari and Thippali the different shade levels did not influence dry matter accumulation and the values were on par.

Growth Stage, Month 9

During the ninth month also, the influence of shade on dry matter accumulation was continued (Table VI, Appendix). The highest value was recorded under the young palms and the lowest under mature palms. The species differed significantly and the highest value was in Chittaratha (50.00 g) (Table 18).

Shade x species interaction was also significant (Table 19.9). Under open condition, Chittaratha and Chittadalodakam produced significantly higher dry matter content of 57.15 g and 53.03 g respectively and the lowest by Sathavari and Thippali (9.96 and 4.46 g respectively). Under young palms the highest dry matter production recorded by Chittaratha (61.79 g) and minimum by Thippali (2.79 g). Under medium palms, Chittadalodakam and Chittaratha excelled producing 42.86 and 40.12 g dry matter respectively whereas Koduveli and Thippali were inferior. Under mature palms also Chittaratha and Chittadalodakam produced higher dry matter (40.93 g and 35.40 g) and lower values were by Koduveli (8.95 g) Sathavari (6.94 g) and Thippali (1.82 g), which were on par.

There was significant difference in the dry matter accumulation of individual species under different shade situations during this month. In the case of Chittadalodakam, the highest accumulation was recorded under open condition (53.03 g) which was on par with that in young oil palm canopy (50.49 g). Dry matter accumulation under medium and mature oil palm canopy was on par. In Chittaratha, higher dry matter content was noted under young palms (61.79 g) which was on par with open (57.15 g). No significant difference was noticed under medium and mature palm canopies. In Karimkurinji higher dry matter accumulation was noticed under young and medium oil palm canopy (33.78 and 32.67 g respectively) and the value under open condition (18.30 g) was on par with mature oil palm canopy (23.61 g). In Koduveli the highest value was noted under open condition (12.99 g) which was on par with young oil palm canopy (12.26 g) and no significant difference for dry matter content was noticed under medium and mature oil palm canopy. In Sathavari the highest dry matter content was recorded under young and medium oil palm canopy(14.5 g and 11.34 g) and no significant difference was noticed under open and mature oil palm canopy. In the case of Thippali, comparatively lower values were recorded under all condition and the highest dry matter accumulation was recorded under open and medium oil palm canopy (4.46 g and 3.73 g respectively).

Growth Stage, Month 10

During the tenth month, the shade levels significantly affected the dry matter accumulation (Table VI, Appendix). The highest value was recorded under young palms and the lowest under mature oil palm canopy. The species differed significantly and the highest value was noticed in Chittaratha (59.97 g) (Table 18).

The data suggested significant effect of interaction between shade and species (Table 19.10). Under open condition, significantly superior dry matter production was noticed in Chittaratha (65.60 g) and Chittadalodakam (60.66 g) and the lowest in Koduveli, Sathavari and Thippali. Under young palms, Chittaratha produced highest dry matter of 81.92 g and Thippali the lowest (3.61g). Under medium palms, Chittaratha, Chittadalodakam and Karimkurinji produced significantly superior values (49.14 g, 48.27 g and 40.84 g respectively). Lower values were recorded by Sathavari, Koduveli and Thippali (14.50, 10.65 and 4.16 g respectively and these were on par. Under mature oil palm canopy, Chittaratha and Chittadalodakam produced significantly superior dry matter content of 43.23 g and 38.29 g, while the lowest value was recorded in Koduveli, Sathavari and Thippali.

Regarding the dry matter production of individual crops under different shade situation, the highest dry matter production was recorded by Chittadalodakam under open (60.66 g) which was on par with that under young palms (58.22 g). In Chittaratha, the highest dry matter production was recorded under young oil palm canopy (81.92 g). In Karimkurinji, higher dry matter production was observed under young oil palm canopy (43.87 g) which was on

Table 19 .9: Mean dry matter production showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, g - month 9

Shade condition	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	53.03	57.15	18.30	12.99	9.96	4.46
Young	50.49	61.79	33.78	12.26	14.50	2.79
Medium	42.86	40.12	32.67	8.27	11.34	3.73
Mature	35.40	40.93	23.61	8.95	6.94	1.82

CD1 (0.05) 7.558 CD2 (0.05) 7.595

Table 19.10 : Mean dry matter production showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, g - month 10

Shade condition	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	60.66	65.60	21.61	14.13	12.12	5.28
Young	58.22	81.92	43.87	15.39	17.76	3.61
Medium	48.27	49.14	40.84	10.65	14.50	4.16
Mature	38.29	43.23	27.27	11.49	8.83	1.83

CD1 (0.05) 10.548 CD2 (0.05) 10.475

CD1 Critical difference at 5 % level for comparing two species at a fixed shade
CD2 Critical difference at 5 % level for comparing two shade for a fixed or different species

par with medium oil palm canopy (40.84 g). In the case of Koduveli, Sathavari and Thippali dry matter content did not differed significantly.

Growth Stage, Month 11

The data furnished in Table VI Appendix indicated that the influence of shade on dry matter accumulation was significant. The highest dry matter accumulation was recorded under the young oil palm canopy and the lowest under mature oil palm canopy. The species differed significantly and the highest dry matter content was noticed in Chittaratha (60.14 g) (Table 18).

The results given in Table 19.11 showed that shade x species interaction was significant. Under open condition Chittaratha and Chittadalodakam produced significantly superior dry matter (62.51g and 62.33 g respectively), while the lower values were noticed for Koduveli (13.71 g), Sathavari (13.31 g) and Thippali (7.09 g). Under young oil palm canopy, Chittaratha produced the highest dry matter (84.31 g) and Thippali (3.70 g) produced the lowest. Under the medium palms, Chittadalodakam, Chittaratha and Karimkurinji produced significantly superior dry matter (50.73, 50.40 and 44.19 g respectively), while Koduveli and Thippali recorded lower values (11.62 and 4.23 g respectively). Under mature oil palm canopy, the highest dry matter content was noticed in Chittaratha (43.33 g) and Chittadalodakam (42.39 g) while Thippali (1.84 g) recorded the lowest value.

The individual crops grown under different shade situations, exhibited significant variation in this character. In Chittadalodakam, the highest dry matter production was noticed under the young palms (65.70 g), which was on par with those under open condition (62.33 g). In the case of Chittaratha, superior value was under young palms (84.31 g). In Karimkurinji, the highest dry matter production was observed under young oil palm canopy (46.57 g), which was on par with those under medium palms (44.19 g). Koduveli and Thippali did not differ significantly under the four treatments. In Sathavari the highest content was under young oil palm canopy (19.95 g) which was on par with those under medium and open (14.55 and 13.31 g respectively).

Table 19.11: **Mean dry matter production showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, g - month 11**

Shade condition	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	62.33	62.51	23.17	13.71	13.31	7.09
Young	65.70	84.31	46.57	15.32	19.95	3.70
Medium	50.73	50.40	44.19	11.62	14.55	4.23
Mature	42.39	43.33	28.65	13.02	10.05	1.84

CD1 (0.05) 7.791 CD2 (0.05) 8.463

Table 19.12: **Mean dry matter production showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, g - month 12**

Shade condition	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	64.38	60.23	25.38	13.97	14.17	7.66
Young	74.94	77.68	49.45	15.86	30.86	4.07
Medium	53.51	83.66	46.00	12.53	17.12	4.70
Mature	45.30	45.97	33.82	13.88	11.63	1.67

N.S

CD1 Critical difference at 5 % level for comparing two species at a fixed shade
CD2 Critical difference at 5 % level for comparing two shade for a fixed or different species

Growth Stage, Month 12

During the twelfth month, shade levels did not affect the dry matter production of the medicinal plant species (Table VI, Appendix). The species differed significantly and the highest dry matter content was noticed in Chittaratha (66.88 g) which was on par with Chittadalodakam (59.53 g) (Table 18).

Shade x species interaction was not significant (Table 19.12).

Growth Stage, Month 13

As against the previous month, the influence of shade levels became significant during this period (Table VI, Appendix). Highest dry matter content recorded under young oil palm canopy. Species difference was also significant and the highest value was recorded for Chittaratha (66.88 g) which was on par with Chittadalodakam (59.53 g) (Table 18).

The data showed that shade x species interaction was significant (Table 19.13). Under open condition, Chittadalodakam and Chittaratha recorded the highest values (79.64 and 77.50 g) and were on par. The lowest value was recorded by Thippali (9.76 g). Under young palms, significantly superior values were recorded by Chittaratha (98.84 g) and Chittadalodakam (90.83 g) and were on par, while Thippali (4.40 g) recorded the lowest dry weight. Chittadalodakam, Chittaratha and Karimkurinji recorded significantly superior dry matter contents (65.85, 63.30 and 58.47 g respectively). Under medium palm, Chittadalodakam recorded the highest dry matter content (65.85 g) which was on par with Chittaratha (63.30 g) and Karimkurinji (58.47 g). Under mature palms, Chittaratha recorded the highest value (58.37 g) which was on par with Chittadalodakam (52.27 g).

The data on dry matter of individual species under different shade levels showed that Chittadalodakam registered the highest dry matter under young palms (90.83 g) and the lowest under mature palms (52.27 g). Chittaratha also had highest dry matter under young palms (98.84 g) and the lowest under mature palms (58.37 g) which was on par with those under medium palms (63.30 g). Dry matter production of Karimkurinji was on par

Table 19.13: Mean dry matter production showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, g - month 13

Shade condition	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	79.64	77.50	31.55	15.64	18.30	9.76
Young	90.83	98.84	63.24	19.96	34.19	4.40
Medium	65.85	63.30	58.47	14.12	20.31	5.92
Mature	52.27	58.37	42.25	15.96	14.57	2.39

CD1 (0.05) 11.408 CD2 (0.05) 10.536

Table 19.14: Mean dry matter production showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, g - month 14

Shade condition	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	74.54	78.55	34.80	15.95	18.39	9.26
Young	86.54	96.14	68.12	21.30	36.52	5.38
Medium	71.02	61.33	63.32	14.51	21.48	6.02
Mature	54.80	64.86	47.84	17.41	15.48	2.09

CD1 (0.05) 9.744 CD2 (0.05) 9.659

CD1 Critical difference at 5 % level for comparing two species at a fixed shade
CD2 Critical difference at 5 % level for comparing two shade for a fixed or different species

under young and medium oil palm canopies (63.24 g and 58.47 g respectively)while dry matter production of Koduveli was on par under all shade levels. Sathavari recorded the highest dry matter under young oil palms (34.19 g) while the dry matter under medium and mature palms were on par with open (20.31, 14.57 and 18.30 g respectively). Thippali did not show any significant difference under the four treatments.

Growth Stage, Month 14

As recorded during the previous month, the influence of shade on the dry matter production of the crops was highly significant (Table VI, Appendix) . The highest dry matter was recorded under young oil palms. Species also differed significantly and the highest value was recorded by Chittaratha (75.22 g) which was on par with Chittadalodakam (71.72 g) (Table 18).

Shade x species interaction effect was also significant (Table 19.14). Chittaratha (78.55 g) and Chittadalodakam (74.54 g) recorded higher values under open. Under young oil palm canopy, both Chittaratha (96.14 g) and Chittadalodakam (86.54 g) recorded higher values and were on par. Chittadalodakam excelled under medium oil palm canopy (71.02 g) and the value was on par with Karimkurinji (63.32 g) and Chittaratha (61.33 g). Under mature oil palm canopy, Chittaratha produced highest the dry matter content (64.86 g).

The dry matter accumulation in species under the four treatments showed that for Chittadalodakam and Chittaratha ideal situation was under young oil palm canopy (86.54 g and 96.14 g). For Karimkurinji young and medium oil palm canopy was ideal (68.12 and 63.32 g respectively). Koduveli and Thippali were on par under the four situations. In the case of Sathavari, significantly higher dry matter production was noticed under young oil palm canopy (36.52 g).

Growth Stage, Month 15

Shade levels significantly influenced dry matter production (Table VI, Appendix) and the highest dry matter production was under young oil palm canopy. Species also differed significantly and the highest value was recorded in Chittaratha (78.33 g) which was on par with Chittadalodakam (72.78 g) (Table 18).

The results showed that shade x species interaction was also significant (Table 19.15). Chittaratha and Chittadalodakam were superior under open condition (77.26 and 72.77 g respectively). Under young oil palm canopy, Chittaratha (98.34 g) recorded the highest content. Chittadalodakam (74.36 g) and Karimkurinji (67.28 g) were better under medium oil palm canopy, while under mature oil palm canopy Chittaratha (76.75 g) and Chittadalodakam (57.97 g) were superior.

The individual species under different shade levels responded distinctly with Chittadalodakam (85.99 g), Chittaratha (98.34 g) and Karimkurinji (76.97 g) giving the best performance under young oil palm canopy. Koduveli was on par under four situations. Sathavari recorded the highest dry matter production under young oil palm canopy (37.99 g) while Thippali was on par under the four situations.

Growth Stage, Month 1 6

The influence of shade on dry matter production of the medicinal plant species was not significant (Table VI, Appendix). However, species differed significantly and the highest, dry matter content was recorded in Chittaratha (130.91 g) (Table 18).

Shade x species interaction effect was not significant (Table 19.16).

Growth Stage, Month 1 7

The influence of shade on dry matter production of medicinal plants was significant during this month (Table VI, Appendix). Higher dry matter production was noticed under the young oil palm canopy. The values under open and medium oil palm canopy were on par. Species also differed

Table 19.15: **Mean dry matter production showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, g - month 15**

Shade condition	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	72.77	77.26	36.81	17.52	20.49	9.34
Young	85.99	98.34	76.97	18.49	37.99	5.69
Medium	74.36	60.97	67.28	14.96	21.93	6.31
Mature	57.97	76.75	56.54	17.54	18.13	2.40

CD1 (0.05) 9.872 CD2 (0.05) 9.652

Table 19.16: **Mean dry matter production showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, g - month 16**

Shade condition	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	82.60	98.62	46.78	20.50	23.84	12.30
Young	92.43	281.38	96.71	19.10	44.43	7.00
Medium	89.15	66.69	78.17	16.77	25.02	7.43
Mature	68.57	76.96	69.59	21.38	20.68	2.55

N.S

CD1 Critical difference at 5 % level for comparing two species at a fixed shade
CD2 Critical difference at 5 % level for comparing two shade for a fixed or different species

significantly and the highest value was recorded in Chittadalodakam (83.98 g) which was on par with Chittaratha (80.56 g) (Table 18).

The results clearly indicated significance on interaction of the factors shade and species (Table 19.17). Under open condition, significantly superior dry matter production was observed in Chittaratha (100.12 g). Under young oil palm canopy, the highest content was noticed in Karimkurinji and Chittadalodakam (100.77 and 90.94 g), which were on par. Chittadalodakam (90.77 g) and Karimkurinji (82.38 g) were better under medium oil palm canopy, while under mature oil palm canopy, Karimkurinji, Chittadalodakam and Chittaratha were good (73.27, 70.93 and 66.14 g respectively).

Regarding intershade effect of various species, the dry matter production of Chittadalodakam was significantly superior under young and medium canopies and open condition, (90.94 g, 90.77 g and 83.27 g, respectively). However, in Chittaratha significantly superior values were observed under open condition (100.12 g). In Karimkurinji, the highest dry matter production was noticed under young oil palm canopy (100.77 g) and the lowest under open (50.66 g). In Sathavari also, higher dry matter production was under young oil palm canopy (44.56 g) and the other three conditions were on par. Thippali and Koduveli, were on par under all shade situations.

Growth Stage, Month 18

The significant influence of different shade levels on the dry matter production of medicinal plant species was continued (Table VI, Appendix) . The highest dry matter content was noticed under the young palms and the lowest under mature palms. Dry matter productions under open and medium palms were on par. Species also differed significantly and highest dry matter content recorded in Chittadalodakam (90.99 g) which was on par with Chittaratha (90.26 g) (Table 18).

Table 19.18 shows data on shade x species interaction effect. The results showed significant effect due to different shade levels. Under open condition, higher dry matter production was noticed in Chittaratha (117.27 g) and

Table 19.17: **Mean dry matter production showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, g - month 17**

Shade condition	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	83.27	100.12	50.66	19.69	25.67	13.15
Young	90.94	83.67	100.77	20.49	44.56	8.46
Medium	90.77	72.30	82.38	16.59	25.46	7.46
Mature	70.93	66.14	73.27	20.99	21.24	2.28

CD1 (0.05) 10.142 CD2 (0.05) 10.966

Table 19.18: **Mean dry matter production showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth, g - month 18**

Shade condition	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	83.41	117.27	52.69	16.48	25.68	12.85
Young	109.73	103.46	103.09	19.25	45.69	8.91
Medium	93.91	69.92	84.02	18.97	25.73	7.73
Mature	76.91	70.40	76.63	19.60	21.92	2.41

CD1 (0.05) 11.238 CD2 (0.05) 11.52

CD1 Critical difference at 5 % level for comparing two species at a fixed shade
CD2 Critical difference at 5 % level for [illegible] for a fixed or different species

Koduveli (16.48 g) and Thippali (12.85 g) recorded lower values which were on par. Under young palms, Chittadalodakam, Chittaratha and Karimkurinji produced significantly higher dry matter (109.73, 103.46 and 103.09 g respectively) and Koduveli and Thippali (19.25 g and 8.91 g respectively) recorded lower values. Under medium palms, significantly superior dry matter contents were noticed in Chittadalodakam and Karimkurinji (93.91g and 84.02 g respectively) and the lowest dry matter content in Thippali (7.73 g). Under mature palms, Chittadalodakam, Karimkurinji and Chittaratha showed higher dry matter contents of 76.91 g, 76.63 g and 70.40 g respectively. Thippali (2.41 g) was inferior to all other species.

Regarding dry matter content of various species, the results showed that Chittadalodakam was significantly superior under young oil palm canopy (109.73 g) However, in Chittaratha significantly superior values were noticed under open condition (117.27 g). In Karimkurinji, the highest dry matter production was noticed under young palms (103.09 g) and the lowest under open (52.69 g). In Sathavari also, higher dry matter production was observed under young oil palm canopy (45.69 g) and the other three shade conditions were on par. Thippali and Koduveli, were on par under all shade situations.

Comparative evaluation of the dry matter content of medicinal plants revealed that significantly higher dry matter production was noticed in plants grown under young oil palm canopy throughout the crop growth period except during the first, second, seventh, twelfth and sixteenth month where the influence of different shade levels was not visible.

Regarding species comparison, Chittaratha and Chittadalodakam excelled in dry matter production throughout the growth stages.

Under the open condition and shade levels under oil palm canopy, Chittadalodakam and Chittaratha registered significantly higher dry matter content. Under medium palms towards the later stages of crop growth (from tenth month onwards), Karimkurinji also excelled recording significantly higher dry matter content.

Assessment of the individual plant effect indicated that in Chittadalodakam, the highest dry matter was recorded under open and young palms upto eleventh month after planting. Thereafter the highest dry weight was noticed under young palms. In Chittaratha, the highest dry weight was recorded under young palms upto fifteenth month after planting. However, during last two months of crop growth, plants under open had the highest dry matter production. In Chunda, shade levels did not exhibit any significant influence on the dry weight during the first four months. However, during the last two months, significantly higher dry weight was noticed under young palms. Shade levels did not have any influence on the dry matter production in Iruveli, Patchouli and Thippali throughout the growth stage. In Kacholam also, same trend was noticed, however during the last two months of crop growth significantly higher dry weight was noticed under young palms. In Karimkurinji, upto four months after planting the dry weight was not affected by the shade levels. However during the rest of the growth stages higher dry matter production was noticed under the young and medium palms. In Sathavari, the influence of shade levels on the dry matter production was not significant during major periods of crop growth. However, during the last six months, significantly higher dry matter production was noticed under young palms.

4.1.2.2 Leaf Area Index

The leaf area index of medicinal plant species under different shade levels are presented below.

Growth Stage, Month 1

The influence of shade on leaf area index was not significant (Table VII, Appendix). However, the species differed significantly and higher index was recorded by Chittaratha (0.62) which was on par with Chittadalodakam, Chunda, Kacholam, Koduveli and Thippali (0.53,0.39,0.41,0.48,0.42 respectively) (Table 20).

Table 20 : Mean leaf area index of medicinal plant species under oil palm shade conditions at different stages of plant growth

Treatment	Growth Stage - month																	
Shade condition	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Open	0.256	0.023	0.342	0.360	0.433	0.429	0.319	0.400	0.582	0.585	0.657	0.748	0.765	0.848	0.843	0.952	1.019	1.134
Young	0.394	0.416	0.520	0.598	0.702	0.777	0.710	0.847	0.885	1.246	1.421	1.439	1.660	1.800	2.040	2.153	1.874	2.118
Medium	0.356	0.358	0.414	0.452	0.524	0.604	0.491	0.568	0.680	0.724	0.770	0.876	0.987	1.113	1.018	1.106	1.093	1.188
Mature	0.306	0.220	0.289	0.300	0.340	0.350	0.374	0.346	0.469	0.427	0.452	0.501	0.594	0.640	0.685	0.743	0.752	0.822
CD 0. 05	N.S	0.0685	0.0541	0.0822	0.0748	0.0899	0.1404	0.1293	0.2526	0.1754	0.1156	0.2812	0.1602	0.1554	0.1115	0.2396	0.2987	0.1809
Species																		
Chittadalodakam	0.534	0.206	0.242	0.249	0.306	0.351	0.371	0.435	0.489	0.586	0.681	0.793	0.930	1.038	1.058	1.104	1.117	1.122
Chittaratha	0.623	0.534	0.711	0.711	0.892	0.960	0.763	1.232	1.569	1.799	1.990	2.001	2.068	2.336	2.126	2.232	1.759	2.27[illegible]
Chunda	0.390	0.623	0.880	1.045	1.184	1.174	Crop harvested											
Iruveli	0.131	0.394	0.370	0.286	0.321	0.338	0.392	Crop harvested										
Kacholam	0.407	0.131	0.150	0.165	0.212	0.171	0.133	Crop harvested										
Karimkurinji	0.075	0.407	0.456	0.520	0.591	0.645	0.734	0.816	1.017	1.204	1.348	1.523	1.896	2.126	2.478	2.788	2.848	3.019
Koduveli	0.475	0.075	0.086	0.093	0.095	0.106	0.102	0.120	0.131	0.136	0.139	0.141	0.149	0.156	0.163	0.167	0.172	0.174
Patchouli	0.149	0.475	0.673	0.813	0.935	1.145	1.220	Crop harvested										
Sathavari	0.074	0.149	0.216	0.246	0.290	0.322	0.350	0.413	0.456	0.493	0.513	0.608	0.639	0.645	0.735	0.797	0.849	0.890
Thippali	0.421	0.074	0.129	0.146	0.171	0.185	0.197	0.227	0.261	0.255	0.279	0.279	0.327	0.299	0.320	0.345	0.362	0.409
C D 0. 05	0.2576	0.1315	0.0809	0.1509	0.1387	0.1649	0.1598	0.1494	0.2921	0.1724	0.1378	0.1905	0.8480	0.1204	0.2015	0.1658	0.2887	0.1764

The results suggested that shade x species interaction was not significant (Table 21.1).

Growth Stage, Month 2

Shade significantly influenced leaf area index (Table VII, Appendix) during the second month and the highest value was recorded under the young palms. The species differed significantly, and the highest index was obtained for Chunda (0.62) which was on par with Chittaratha (0.53) (Table 20).

The data indicated that shade x species interaction effect was significant (Table 21.2). Under open condition, Chunda recorded the highest leaf area index (0.58) which was on par with Patchouli (0.51) and Iruveli (0.35). Under young palms canopy, Karimkurinji recorded the highest leaf area index (0.88) which was on par with Chunda (0.73) and Chittaratha (0.69). Under medium oil palm canopy, Chittaratha showed the highest value (0.75) which was on par with Chunda and Iruveli (0.72 and 0.68 respectively). Under mature palms, Chunda, Patchouli, Chittaratha and Karimkurinji were on par (0.47, 0.42, 0.41 and 0.28 respectively).

Regarding the LAI recorded by different species under the four situations, Chittadalodakam, Chittaratha, Karimkurinji, Koduveli, Patchouli and Sathavari were on par. Iruveli registered the highest leaf area index under medium oil palm canopy (0.68) which was on par with those under young and open (0.40 and 0.35). Karimkurinji was the best under young palms (0.88) which was on par with that under medium palms (0.40). In the case of Thippali, the highest index was recorded under young oil palm canopy (0.13).

Growth Stage, Month 3

Shade significantly influenced the leaf area index (Table VII, Appendix) and the highest value was recorded under the young oil palm canopy. The species differed significantly and higher index was recorded by Chunda (0.88) (Table 20).

The results suggested that shade x species interaction was significant (Table 21.3). Under open condition, Chunda recorded the highest leaf area index (1.14). Under young palms, Patchouli recorded the highest leaf area index

Table 21.1 : Mean leaf area index showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth- month 1

Shade condition	Chittadalodakam	Chittaratha	Chunda	Iruveli	Kacholam	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	0.28	0.58	0.35	0.11	0.07	0.10	0.51	0.14	0.04	0.38
Young	0.69	0.73	0.40	0.14	0.88	0.07	0.56	0.15	0.13	0.16
Medium	0.75	0.72	0.68	0.10	0.40	0.07	0.42	0.15	0.09	0.14
Mature	0.41	0.47	0.14	0.13	0.28	0.05	0.42	0.14	0.04	1.00

N.S

Table 21.2 : Mean leaf area index showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth- month 2

Shade condition	Chittadalodakam	Chittaratha	Chunda	Iruveli	Kacholam	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	0.14	0.28	0.58	0.35	0.12	0.07	0.10	0.51	0.14	0.04
Young	0.38	0.69	0.73	0.40	0.17	0.88	0.07	0.56	0.15	0.13
Medium	0.16	0.75	0.72	0.68	0.14	0.40	0.07	0.42	0.15	0.09
Mature	0.14	0.41	0.47	0.14	0.10	0.28	0.05	0.42	0.14	0.04

CD1 (0.05) 0.263 CD2 (0.05) 0.258

CD1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

(1.05) which was on par with Karimkurinji (0.98). Under medium palms Chittaratha showed the highest leaf area index (0.93) which was on par with Chunda (0.86). Under mature palms, Chunda and Patchouli recorded higher values and were on par (0.67 and 0.52).

Regarding the LAI recorded by the species under different situations, Iruveli, Kacholam, Koduveli, Sathavari and Thippali were on par. Chittadalodakam was the best under young oil palm canopy (0.44) and Chittaratha under medium palms (0.93) which was on par with those under young palms (0.83). Chunda recorded the highest leaf area index under open (1.14). Karimkurinji and Patchouli produced higher values under young oil palm canopy (0.98 and 1.05 respectively).

Growth Stage, Month 4

The leaf area index was significantly influenced by shade levels (Table VII, Appendix) and the highest value was recorded under the young palms. The species differed significantly and the highest index was recorded by Chunda (1.05) (Table 20).

The data given in Table 21.4 indicated significant shade x species interaction effect. Under open condition, Chunda recorded the highest leaf area index (1.28). Under young palms, Patchouli recorded the highest value (1.22) which was on par with Chunda and Karimkurinji (1.14 and 1.10 respectively). Under medium palms, Chunda showed the highest leaf area index (1.00) which was on par with Chittaratha and Patchouli (0.84 and 0.74 respectively). Under mature oil palm canopy, leaf area index of Chunda was highest (0.76).

Regarding the leaf area index of species under different situations, Iruveli, Kacholam, Koduveli, Sathavari and Thippali were on par. Chittadalodakam registered the highest leaf area index under young palms (0.44). Chittaratha recorded the highest value under young oil palm canopy (0.98) which was on par with those under medium palms (0.84). Chunda produced the highest value under open (1.28). In the case of Karimkurinji and Patchouli, higher values were observed under young palms (1.10 and 1.22 respectively).

Table 21.3 : Mean leaf area index showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth- month 3

Shade condition	Chittadalodakam	Chittaratha	Chunda	Iruveli	Kacholam	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	0.20	0.66	1.14	0.30	0.12	0.10	0.12	0.52	0.23	0.05
Young	0.44	0.83	0.84	0.38	0.17	0.98	0.09	1.05	0.26	0.16
Medium	0.19	0.93	0.86	0.45	0.16	0.42	0.08	0.61	0.22	0.21
Mature	0.13	0.43	0.67	0.36	0.15	0.32	0.06	0.52	0.15	0.09

CD1 (0.05) 0.162 CD2 (0.05) 0.162

Table 21.4 : Mean leaf area index showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth- month 4

Shade condition	Chittadalodakam	Chittaratha	Chunda	Iruveli	Kacholam	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	0.25	0.61	1.28	0.25	0.14	0.12	0.12	0.59	0.20	0.05
Young	0.44	0.98	1.14	0.33	0.19	1.10	0.09	1.22	0.30	0.18
Medium	0.20	0.84	1.00	0.41	0.19	0.45	0.10	0.74	0.36	0.23
Mature	0.10	0.41	0.76	0.16	0.14	0.40	0.07	0.70	0.13	0.13

CD1 (0.05) 0.302 CD2 (0.05) 0.298

CD1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

Growth Stage, Month 5

Shade significantly influenced the leaf area index of the plants studied (Table VII, Appendix) and the highest value was recorded under the young oil palm canopy. The species differed significantly and the highest index was recorded by Chunda (1.18) (Table 20).

The results pointed out that shade x species interaction effect was significant (Table 21.5). Under open condition, Chunda recorded the highest leaf area index of 1.33. Under young palms, Patchouli recorded the highest value of 1.68, which was on par with Chunda (1.47). Under medium palms Chittaratha showed the highest leaf area index (1.29) which was on par with Chunda (1.08).Under mature palms, leaf area index of Chunda was the highest (0.86).

Regarding the leaf area index of different species under the four shade levels Chittadalodakam, Iruveli, Kacholam, Koduveli and Thippali were on par. For Chittaratha highest leaf area index was under medium palms (1.29), which was on par with those under young palms (1.07). Chunda recorded the highest leaf area index under young palms (1.47) which was on par with open (1.33). In the case of Karimkurinji and Patchouli, higher values were observed under young palms (1.13 and 1.68 respectively). In Sathavari higher index was observed under medium palms (0.43) which was on par with those under young and open (0.37 and 0.21 respectively).

Growth Stage, Month 6

The significant influence of shade on leaf area index was continued during this period also (Table VII, Appendix) and the highest value was recorded under the young palms. The species differed significantly and the highest index was obtained for Chunda (1.17) which was on par with Patchouli (1.15) (Table 20).

The interaction effect of shade x species was significant (Table 21.6). Under open condition, Chunda recorded the highest leaf area index (1.10) which was on par with Patchouli (0.94). Under young oil palm canopy, Patchouli recorded the highest leaf area index (1.80) which was on par with

Table 21.5 : Mean leaf area index showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth- month 5

Shade condition	Chittadalodakam	Chittaratha	Chunda	Iruveli	Kacholam	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	0.35	0.77	1.33	0.34	0.18	0.15	0.12	0.76	0.21	0.10
Young	0.47	1.07	1.47	0.29	0.21	1.13	0.10	1.68	0.37	0.23
Medium	0.23	1.29	1.08	0.41	0.21	0.56	0.09	0.69	0.43	0.25
Mature	0.17	0.44	0.86	0.23	0.25	0.53	0.07	0.61	0.14	0.10

CD1 (0.05) 0.277 CD2 (0.05) 0.273

Table 21.6 : Mean leaf area index showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth- month

Shade condition	Chittadalodakam	Chittaratha	Chunda	Iruveli	Kacholam	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	0.43	0.75	1.10	0.26	0.15	0.18	0.15	0.94	0.18	0.14
Young	0.51	1.20	1.68	0.39	0.18	0.25	0.10	1.80	0.44	0.22
Medium	0.28	1.38	1.19	0.45	0.23	0.63	0.10	0.99	0.53	0.27
Mature	0.18	0.51	0.73	0.26	0.12	0.52	0.08	0.85	0.14	0.11

CD1 (0.05) 0.330 CD2 (0.05) 0.325

CD1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

Chunda (1.68). Under medium palms, Chittaratha showed the highest value (1.38) which was on par with Chunda (1.19). Under mature palms, Patchouli recorded the highest value (0.85) which was on par with Chunda (0.73).

Regarding the leaf area index recorded by different species under the four treatments, Iruveli, Kacholam, Koduveli and Thippali were on par. Chittaratha recorded the highest leaf area index under medium palms (1.38), which was on par with young palms (1.20). Chunda produced the highest leaf area index under young oil palm canopy (1.68) which was on par with open (1.33). In the case of Karimkurinji, the highest index was observed under medium palms which was on par with mature (0.63 and 0.52 respectively). Patchouli, recorded higher values under young oil palm canopy (1.80). For Sathavari higher index was recorded under medium oil palm canopy (0.53) which was on par those under with young (0.44).

Growth Stage, Month 7

Shade levels significantly influenced the leaf area index (Table VII, Appendix) of plants and the highest value was recorded under the young palms. The species differed significantly and the highest index was observed in Patchouli (1.22) (Table 20).

The data on shade x species interaction effect showed significant difference (Table 21.7). Under open and young palms, Patchouli recorded the highest leaf area index (0.97 and 2.02 respectively). Under medium palms, Patchouli showed the highest value (0.83) which was on par with Karimkurinji, Chittaratha, Sathavari and Iruveli (0.82, 0.80, 0.55 and 0.51 respectively). Under mature palms, Patchouli recorded the highest value (1.06).

The leaf area index worked out on different species recorded under different situations indicated significant difference. Iruveli, Kacholam, Koduveli and Thippali were on par. Chittadalodakam recorded the highest leaf area index under young palms (0.54), which was on par with those under open (0.41). In Chittaratha the highest leaf area index was observed under young palms (1.13), which was on par with those under medium palms (0.80). In the case of Karimkurinji, the highest index was recorded under young oil palm canopy, which was on par with medium (1.32 and 0.82 respectively). Patchouli showed the highest index under young palms (2.02) and Sathavari under medium palms (0.55).

Growth Stage, Month 8

The significant influence of shade levels on the leaf area index was continued during this month also (Table VII, Appendix) and the highest value was recorded under the young oil palm canopy. The species differed and the highest index was obtained for Chittaratha (1.23) (Table 20).

The data suggested that shade x species interaction effect was significant (Table 21.8). Under open condition, young and medium oil palm canopies, Chittaratha recorded higher values (1.01, 2.04 and 1.17 respectively). Under mature oil palm canopy also, Chittaratha was recorded higher values (0.70) which was on par with Karimkurinji (0.65).

The leaf area index of different species under the four shade levels showed that Koduveli and Thippali were on par. Chittadalodakam and Chittaratha registered the highest value under young oil palm canopy (0.64 and 2.04). In the case of Karimkurinji, the highest index was obtained under young palms (1.45). In Sathavari, the highest index was noticed under young palms (0.57).

Growth Stage, Month 9

The four shade levels significantly influenced the leaf area index of plants studied (Table VII, Appendix) and the highest value was recorded under the young palms. The species differed significantly and the highest index was recorded by Chittaratha (1.57) (Table 20).

The results suggested that shade x species interaction effect was significant (Table 21.9). Under open condition, young and mature palm canopies, Chittaratha recorded higher values (1.82, 2.06 and 1.15 respectively). Under medium palms, Karimkurinji recorded the highest value (1.39).

The data on leaf area index of the species studied under different situations showed that Chittadalodakam, Koduveli, Sathavari and Thippali were on par. Chittaratha was superior under young oil palm canopy (2.06), which

Table 21.7 : Mean leaf area index showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth- month 7

Shade condition	Chittadalodakam	Chittaratha	Iruveli	Kacholam	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	0.41	0.52	0.20	0.07	0.21	0.12	0.97	0.22	0.16
Young	0.54	1.13	0.49	0.10	1.32	0.10	2.02	0.47	0.22
Medium	0.33	0.80	0.51	0.16	0.82	0.10	0.83	0.55	0.32
Mature	0.20	0.60	0.38	0.20	0.58	0.09	1.06	0.16	0.09

CD1 (0.05) 0.320 CD2 (0.05) 0.332

Table 21.8 : Mean leaf area index showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth- month 8

Shade condition	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	0.48	1.01	0.24	0.13	0.00	0.36	0.18
Young	0.64	2.04	1.45	0.13	0.00	0.57	0.26
Medium	0.38	1.17	0.92	0.11	0.00	0.48	0.34
Mature	0.24	0.70	0.65	0.11	0.00	0.24	0.13

CD1 (0.05) 0.298 CD2 (0.05) 0.301

CD1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

was on par with open (1.82). In the case of Karimkurinji, the highest index was obtained under young oil palm canopy (1.56) which was on par with medium (1.39).

Growth Stage, Month 10

The data given in Table VII Appendix indicated that shade significantly influenced the leaf area index of plants studied and the highest value was recorded under the young palms. The species differed significantly and Chittaratha was superior (1.80) (Table 20).

Shade x species interaction effect was significant during this period (Table 21.10). Under open condition, young and medium oil palm canopies, Chittaratha recorded the highest leaf area index (1.69, 3.33 and 1.40 respectively). Under mature oil palm canopy, Karimkurinji was superior (0.89).

The leaf area index of the ten species studied under different situations varied significantly and Koduveli, Sathavari and Thippali were on par. In Chittadalodakam, the highest index was observed under young palms, which was on par with open (0.91 and 0.66 respectively). Chittaratha was the best under young oil palm canopy (3.33). In the case of Karimkurinji, mature oil palm canopy was the best (0.89).

Growth Stage, Month 11

As recorded in the previous months shade significantly influenced the leaf area index of plants (Table VII, Appendix) and the shade level under young palms significantly increased the leaf area index of all plants. The species differed significantly and the highest index was obtained for Chittaratha (1.99) (Table 20).

The data showed that shade x species interaction effect was significant during this month also (Table 21.11). Under open condition and young palms, Chittaratha recorded the highest leaf area index (1.79 and 3.94 respectively). Under medium oil palm canopy, Karimkurinji was superior (1.71) and under mature palms Karimkurinji was the best (0.97) which was on par with Chittaratha (0.80).

Table 21.9 : Mean leaf area index showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth- month 9

Shade condition	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	0.58	1.82	0.28	0.14	0.45	0.22
Young	0.70	2.06	1.56	0.14	0.58	0.26
Medium	0.45	1.24	1.39	0.12	0.50	0.37
Mature	0.22	1.15	0.83	0.12	0.29	0.20

CD1 (0.05) 0.584 CD2 (0.05) 0.589

Table 21.10 : Mean leaf area index showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth- month 10

Shade condition	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	0.66	1.69	0.33	0.14	0.45	0.24
Young	0.91	3.33	0.22	0.15	0.59	0.27
Medium	0.48	1.40	0.36	0.13	0.59	0.37
Mature	0.29	0.77	0.89	0.13	0.34	0.14

CD1 (0.05) 0.345 CD2 (0.05) 0.359

CD1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

Regarding the leaf area index of the species grown under different situations, Koduveli and Thippali were on par. In Chittadalodakam and Chittaratha, highest index was recorded under young palms (1.07 and 3.94 respectively). In the case of Karimkurinji, the highest index was obtained under medium palms (1.71), while in Sathavari highest index was observed under young palms (0.76).

Growth Stage, Month 12

Shade levels significantly influenced the leaf area index of plants (Table VII, Appendix) and the highest value was recorded under the young oil palm canopy. The species differed significantly and the highest index was recorded by Chittaratha (2.00) (Table 20).

The results showed that shade x species interaction effect was significant (Table 21.12). Under open condition and young palms, Chittaratha recorded the highest leaf area index (2.11 and 3.46 respectively). Under medium and mature oil palm canopies, Karimkurinji was superior (1.85 and 1.19 respectively).

The data on leaf area index of the species under different situations showed that Koduveli, Sathavari and Thippali were on par. In Chittadalodakam, the highest index was under open (0.82). In Chittaratha and Karimkurinji the values were higher under young oil palm canopy (3.46 and 2.60 respectively).

Growth Stage, Month 13

Shade levels significantly influenced the leaf area index of plants (Table VII, Appendix) and the highest value was recorded under the young oil palm canopy. The species differed significantly and the highest index was recorded by Chittaratha (2.07) (Table 20).

It was observed that shade x species interaction was significant (Table 21.13). Under open condition and young palms, Chittaratha recorded the highest leaf area index (1.93 and 3.91 respectively). Under medium and mature oil palm canopies, Karimkurinji was superior (2.47 and 1.45 respectively).

Regarding difference in response of the species under different situations, Koduveli and Thippali were on par. In Chittadalodakam, Chittaratha

Table 21.11 : Mean leaf area index showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth- month 11

Shade condition	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	0.77	1.79	0.37	0.14	0.53	0.35
Young	1.07	3.94	0.35	0.15	0.76	0.26
Medium	0.55	1.43	1.71	0.13	0.45	0.36
Mature	0.34	0.80	0.97	0.14	0.31	0.15

CD1 (0.05) 0.276 CD2 (0.05) 0.276

Table 21.12 : Mean leaf area index showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth- month 12

Shade condition	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	0.82	2.11	0.44	0.14	0.61	0.37
Young	0.34	3.46	2.60	0.15	0.81	0.27
Medium	0.63	1.64	1.85	0.13	0.63	0.39
Mature	0.39	0.80	1.19	0.15	0.38	0.09

CD1 (0.05) 0.381 CD2 (0.05) 0.445

CD1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

and Karimkurinji highest index was recorded under young oil palm canopy (1.59, 3.91 and 3.14 respectively). Sathavari recorded the highest value under young oil palm canopy (0.88) which was on par with open (0.70).

Growth Stage, Month 14

During the fourteenth month shade levels significantly influenced the leaf area index of the plants studied (Table VII, Appendix). The plants under young palms significantly improved the leaf area index of all plants. The species differed significantly and Chittaratha was superior to all other plants (2.34) (Table 20).

It was found that shade x species interaction effect was significant (Table 21.14). Under open condition and young palms, Chittaratha recorded the highest leaf area index of 2.46 and 4.15. Under medium and mature oil palm canopies, Karimkurinji was superior (2.72 and 1.58 respectively).

Regarding the response of the ten species to shade levels, it was observed that Koduveli was on par. Chittadalodakam, Chittaratha, Karimkurinji, and Sathavari recorded higher values under young oil palm canopy (1.80, 4.15 and 3.51 respectively). Thippali was superior under medium oil palm canopy (0.41).

Growth Stage, Month 15

Shade levels significantly influenced the leaf area index of plants during the month (Table VII, Appendix) and the highest value was recorded under the young oil palm canopy. The species differed significantly and Karimkurinji (2.48) was superior to all other species (Table 20).

The data showed that shade x species interaction was also significant (Table 21.15). Under open condition, Chittaratha recorded the highest leaf area index (2.15). Under young, medium and mature palm canopies, Karimkurinji recorded higher values (4.61, 2.76 and 1.71 respectively).

The data on leaf area index of the species under different situations showed that, Koduveli, Sathavari and Thippali were on par. In Chittadalodakam, Chittaratha and Karimkurinji higher were recorded under young oil palm canopy (1.82, 4.19 and 4.61 respectively).

Table 21.13 : Mean leaf area index showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth- month 13

Shade condition	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	0.88	1.93	0.52	0.14	0.70	0.42
Young	1.59	3.91	3.14	0.15	0.88	0.29
Medium	0.78	1.56	2.47	0.15	0.56	0.40
Mature	0.47	0.88	1.45	0.15	0.42	0.20

CD1 (0.05) 0.268 CD2 (0.05) 0.291

Table 21.14 : Mean leaf area index showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth- month 14

Shade condition	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	0.83	2.46	0.69	0.15	0.62	0.34
Young	1.80	4.15	3.51	0.16	0.87	0.31
Medium	0.95	1.81	2.72	0.17	0.63	0.41
Mature	0.57	0.92	1.58	0.16	0.46	0.14

CD1 (0.05) 0.241 CD2 (0.05) 0.268

CD1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

Growth Stage, Month 16

The data suggested that shade levels significantly influenced the leaf area index of plants (Table VII, Appendix). The highest value was recorded under the young oil palm canopy. The species differed significantly and higher index was obtained for Karimkurinji (2.79) (Table 20).

The results given in Table 21.16 suggested that shade x species interaction was significant. Under open condition, Chittaratha recorded the highest leaf area index (2.27). Under young, medium and mature oil palm canopies, Karimkurinji recorded higher values (5.08, 2.93 and 1.92 respectively).

The data on leaf area index of the species under different situations revealed that Koduveli and Thippali were on par. In Chittadalodakam, Chittaratha, Karimkurinji and Sathavari the highest indices were noticed under young oil palm canopy (1.79, 4.32, 5.08 and 1.20 respectively).

Growth Stage, Month 17

The different levels of shade significantly influenced the leaf area index of plants (Table VII, Appendix). The results showed that the plants under young palms recorded significantly higher leaf area index. The species differed significantly and the highest index was noticed for Karimkurinji (2.85) (Table 20).

It was found that shade x species interaction was significant (Table 21.17). Under open condition, Chittaratha recorded the highest leaf area index of 2.36. Under young, medium and mature oil palm canopies, Karimkurinji was superior (5.21, 2.79 and 2.01 respectively).

The data indicated that the species differed significantly under the four shade levels and Koduveli and Thippali were on par. In Chittadalodakam, Chittaratha and Karimkurinji highest index was observed under young oil palm canopy (1.82, 2.41 and 5.21 respectively). In Sathavari, the highest index was

Table 21.15 : Mean leaf area index showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth- month 15

Shade condition	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	0.83	2.15	0.83	0.17	0.72	0.35
Young	1.82	4.19	4.61	0.15	1.15	0.31
Medium	0.92	1.17	2.76	0.17	0.64	0.45
Mature	0.65	0.98	1.71	0.16	0.44	0.17

CD1 (0.05) 0.403 CD2 (0.05) 0.384

Table 21.16 : Mean leaf area index showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth- month 16

Shade condition	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	0.84	2.27	1.22	0.18	0.81	0.40
Young	1.79	4.32	5.08	0.15	1.20	0.37
Medium	1.03	1.33	2.93	0.17	0.73	0.45
Mature	0.76	1.00	1.92	0.17	0.46	0.16

CD1 (0.05) 0.332 CD2 (0.05) 0.385

CD1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

noticed under open (0.94) which was on par with medium oil palm canopy (0.81).

Growth Stage, Month 18

Shade significantly influenced the leaf area index of plants during this month as well (Table VII, Appendix). The highest value was recorded under the young oil palm canopy. The species differed significantly and the highest index was obtained for Karimkurinji (3.02) (Table 20).

The influence of shade x species interaction was significant (Table 21.18). Under open condition, Chittaratha recorded the highest leaf area index (2.91). Under young, medium and mature oil palms, Karimkurinji was superior (5.40, 2.96 and 2.25 respectively).

The leaf area index of the ten species studied varied significantly under the four situations. Koduveli did not differ significantly under all shade levels In Chittadalodakam, Chittaratha, Karimkurinji and Sathavari higher values were under young oil palm canopy (1.77, 3.52, 5.40 and 1.30 respectively). In Thippali, highest index was recorded under young palms (0.55).

In general, leaf area index was significantly influence by shade levels and the highest value was noticed under young oil palm canopy throughout the growth period except during the first month after planting. Among the different species evaluated, Chittaratha, Chunda and Karimkurinji recorded higher values consistently.

Overall assessment of the interaction effect of the shade levels and species revealed the following facts. Under open condition, Chunda registered higher values during the first six months after planting. Patchouli also recorded significantly higher values during first, sixth and seventh month after planting. From eighth month onwards, Chittaratha recorded significantly higher values under open condition. Under young, medium and mature palms, Patchouli, Chunda, Chittaratha and Karimkurinji excelled recording higher values consistently almost throughout the growth period.

Regarding individual plant effect, in Chittadalodakam, during majority of the growth period, significantly higher leaf area index was recorded under

Table 21.17 : Mean leaf area index showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth- month 17

Shade condition	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	0.85	2.36	1.39	0.18	0.94	0.40
Young	1.82	2.41	5.21	0.17	0.16	0.48
Medium	1.04	1.32	2.79	0.17	0.81	0.43
Mature	0.76	0.95	2.01	0.17	0.49	0.13

CD1 (0.05) 0.577 CD2 (0.05) 0.604

Table 21.18 : Mean leaf area index showing the interaction effect of oil palm shade conditions x medicinal plant species at different stages of plant growth- month 18

Shade condition	Chittadalodakam	Chittaratha	Karimkurinji	Koduveli	Sathavari	Thippali
Open	0.85	2.91	1.47	0.18	0.94	0.45
Young	1.77	3.52	5.40	0.17	1.30	0.55
Medium	1.04	1.64	2.96	0.18	0.82	0.48
Mature	0.82	1.03	2.25	0.18	0.50	0.16

CD1 (0.05) 0.353 CD2 (0.05) 0.368

CD1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

Fig. 2 Net assimilation rate of medicinal plant species under open condition

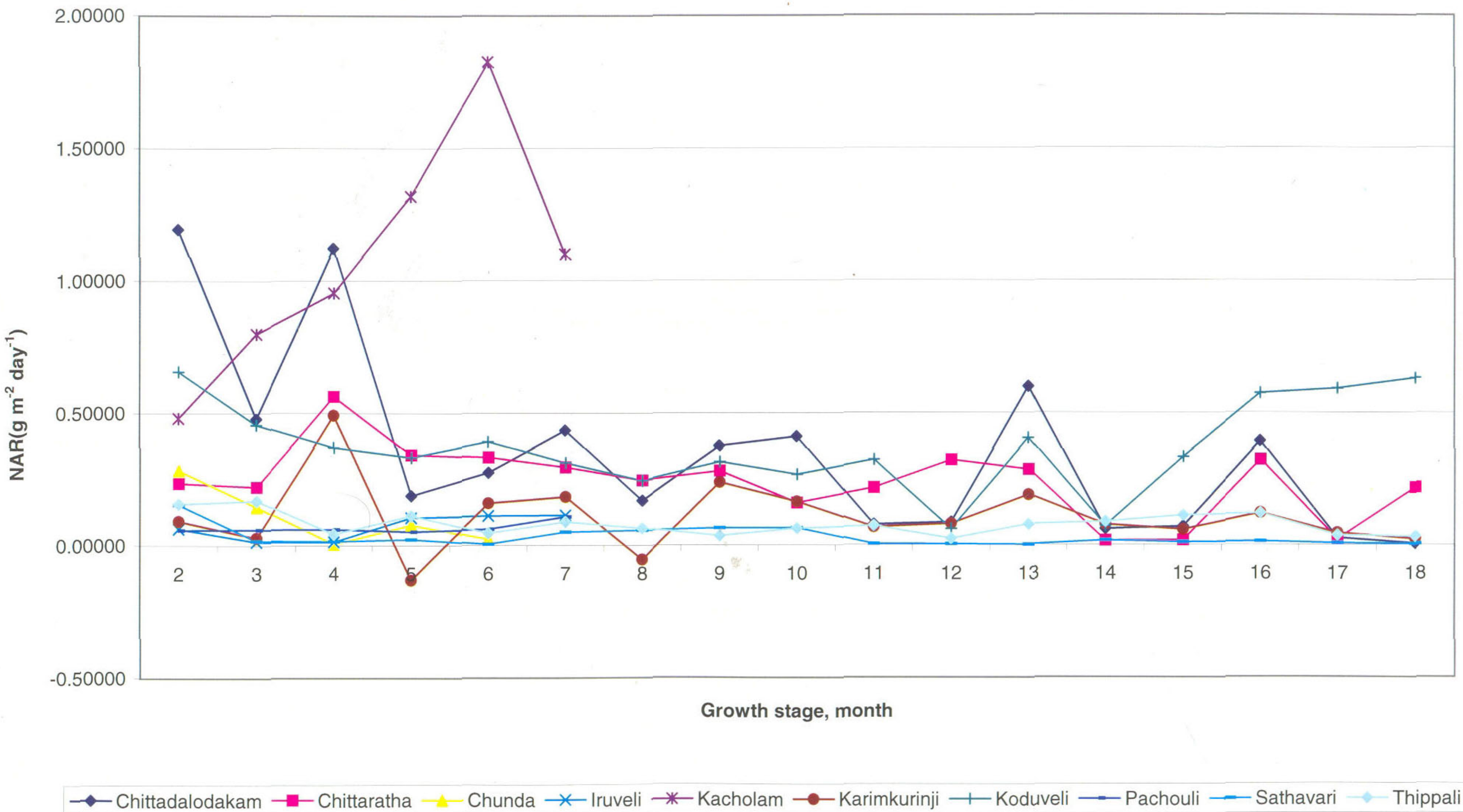


Fig.3 Net assimilation rate of medicinal plant species under young oil palm canopy

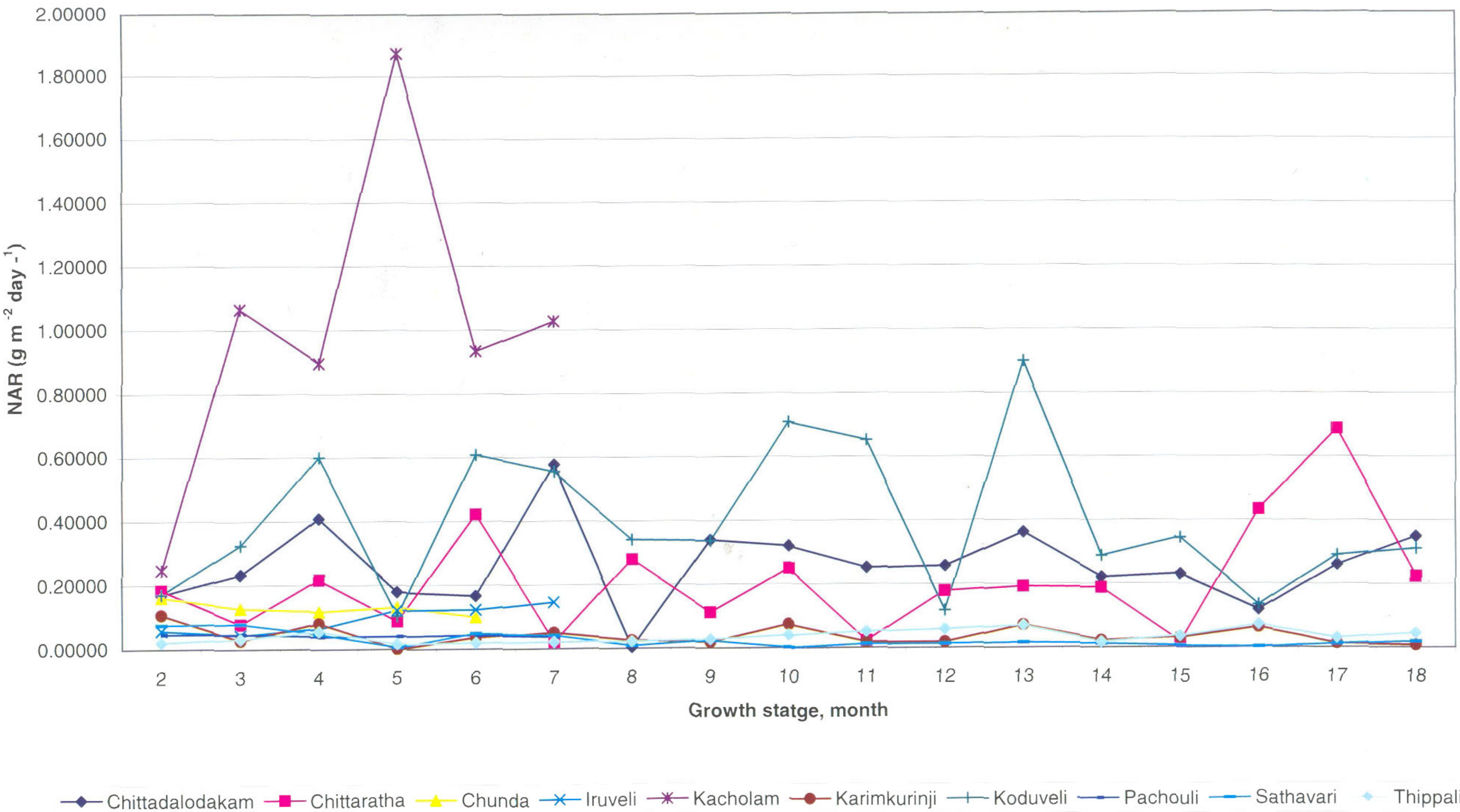


Figure 4 Net assimilation rate of medicinal plant species under medium oil palm canopy

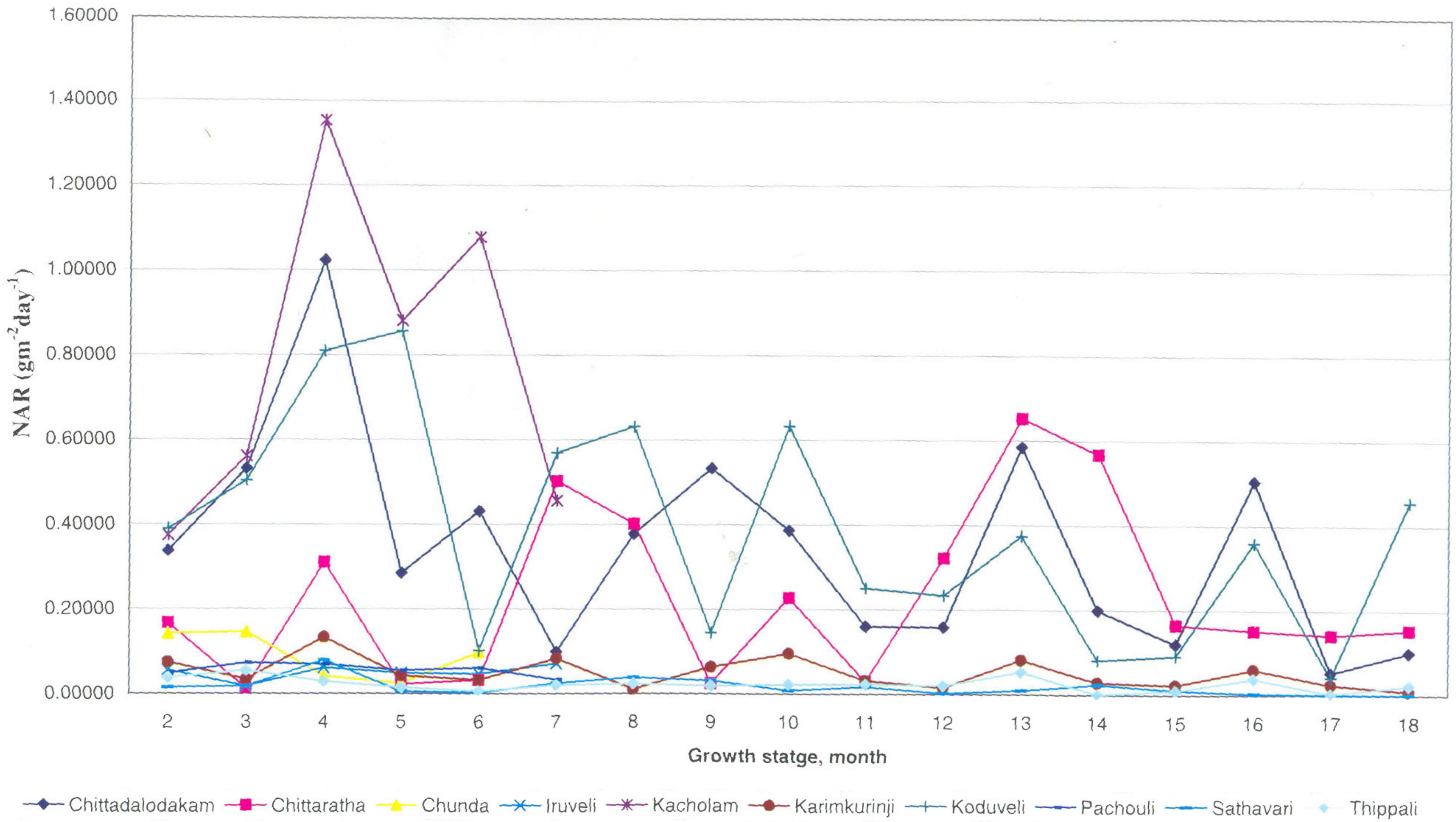


Fig. 5 Net assimilation rate of medicinal plant species under mature oil palm canopy

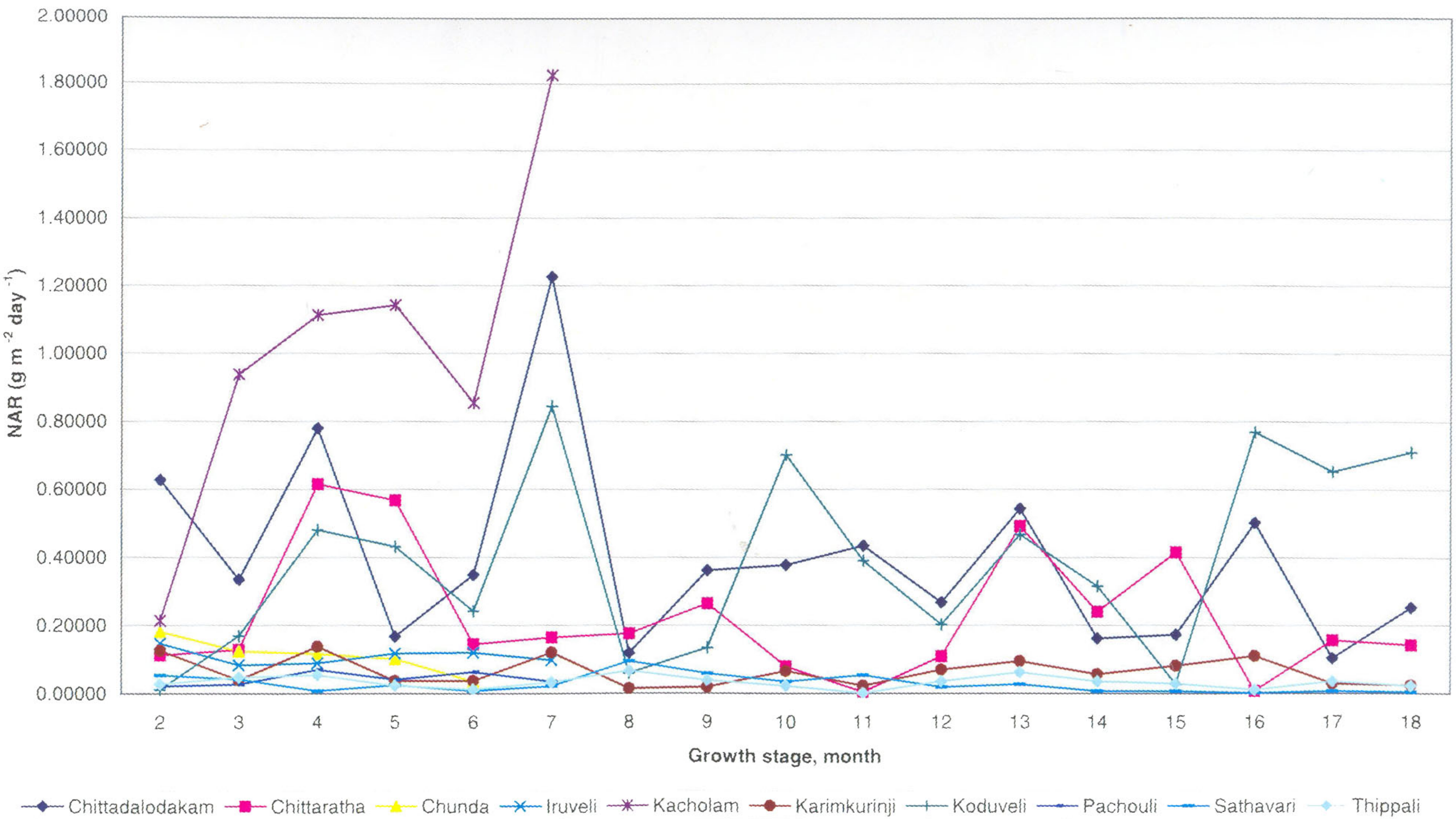


Fig. 6 Crop growth rate of medicinal plant species under open condition

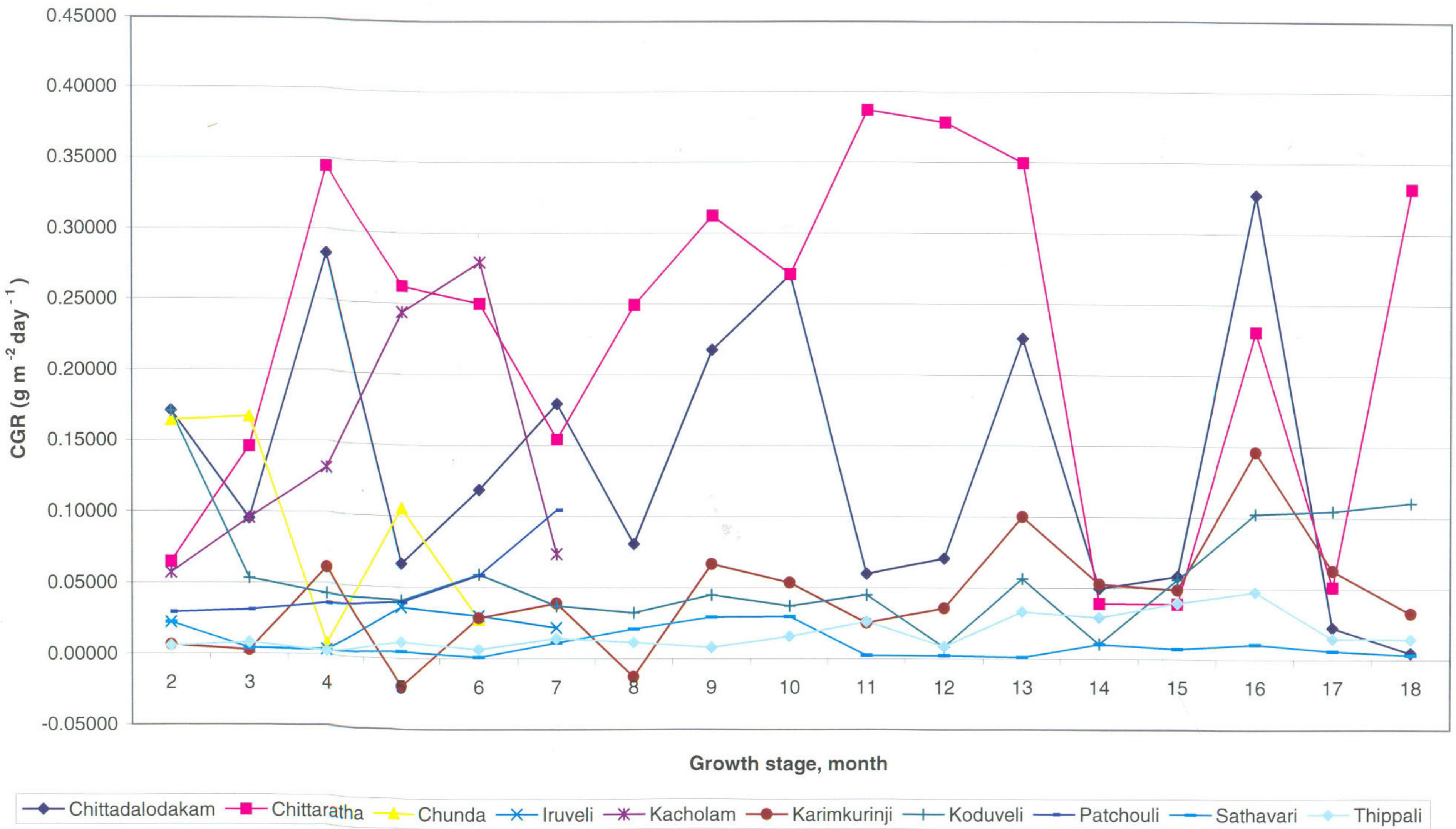


Fig. 7 Crop growth rate of medicinal plant species under young oil palm canopy

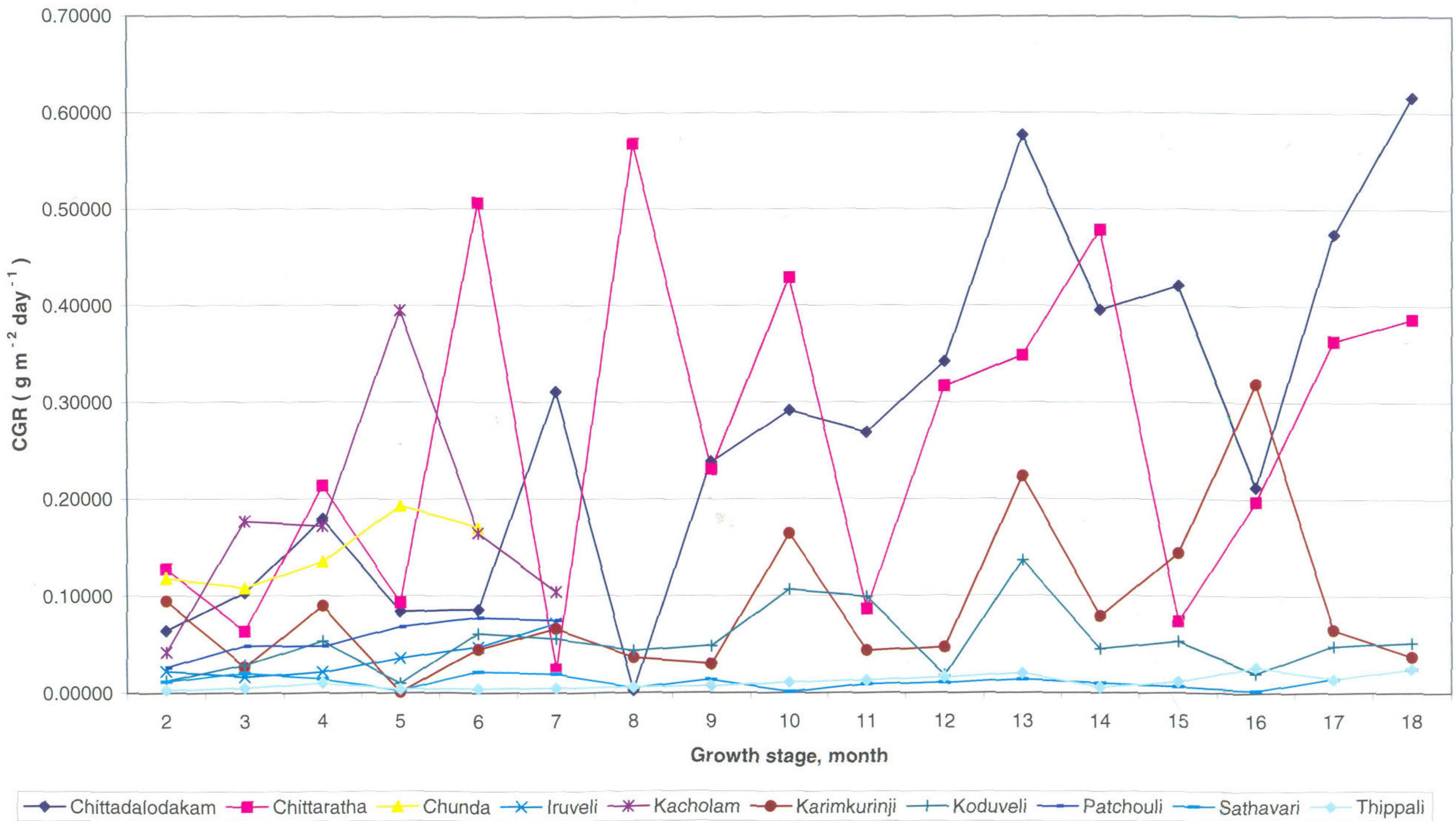


Fig. 8 Crop growth rate of medicinal plant species under medium oil palm canopy

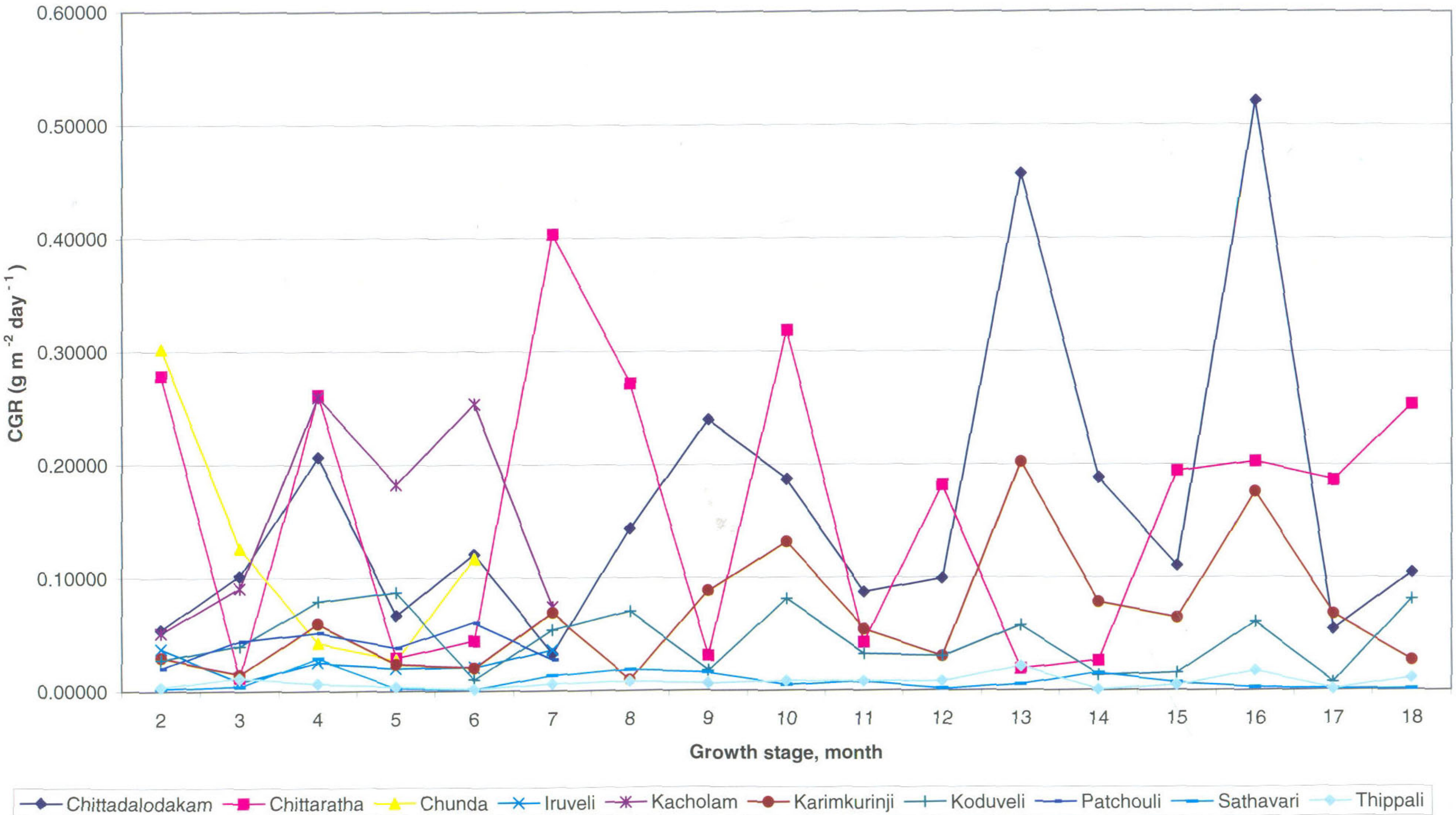


Fig.3 Net assimilation rate of medicinal plant species under young oil palm canopy

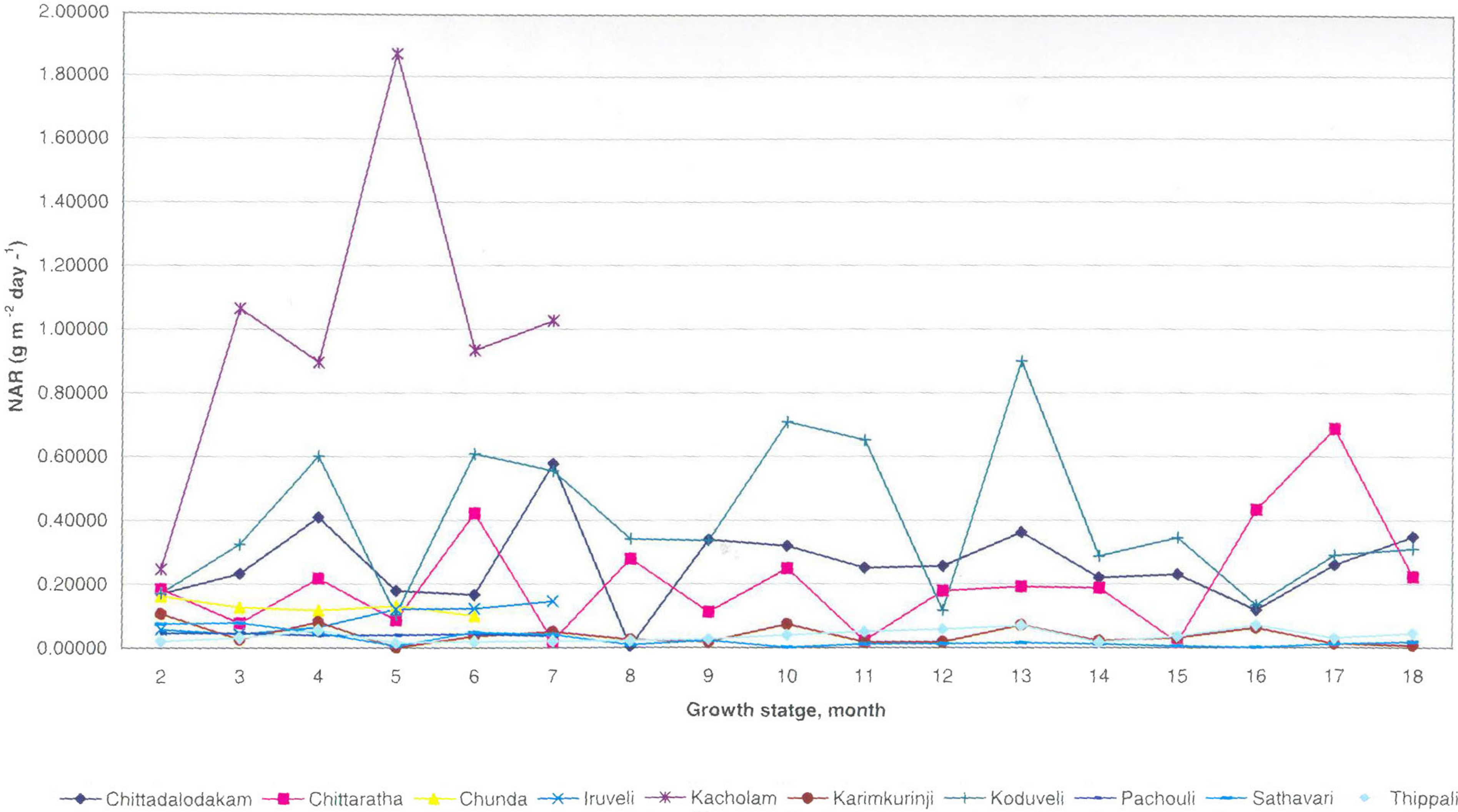


Fig. 9 Crop growth rate of medicinal plant species under mature oil palm canopy

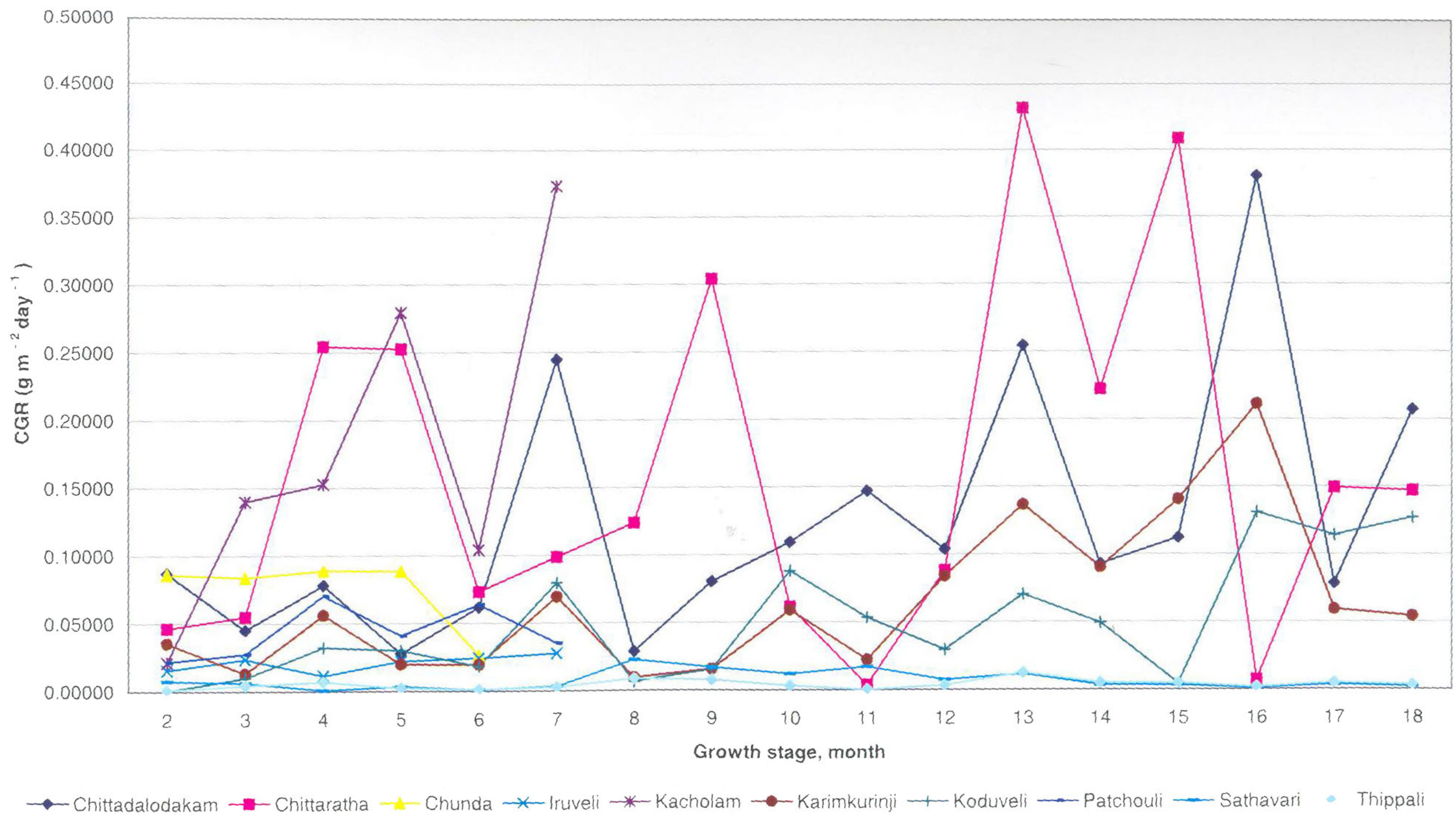


Fig. 10 Relative growth rate of medicinal plant species under open condition

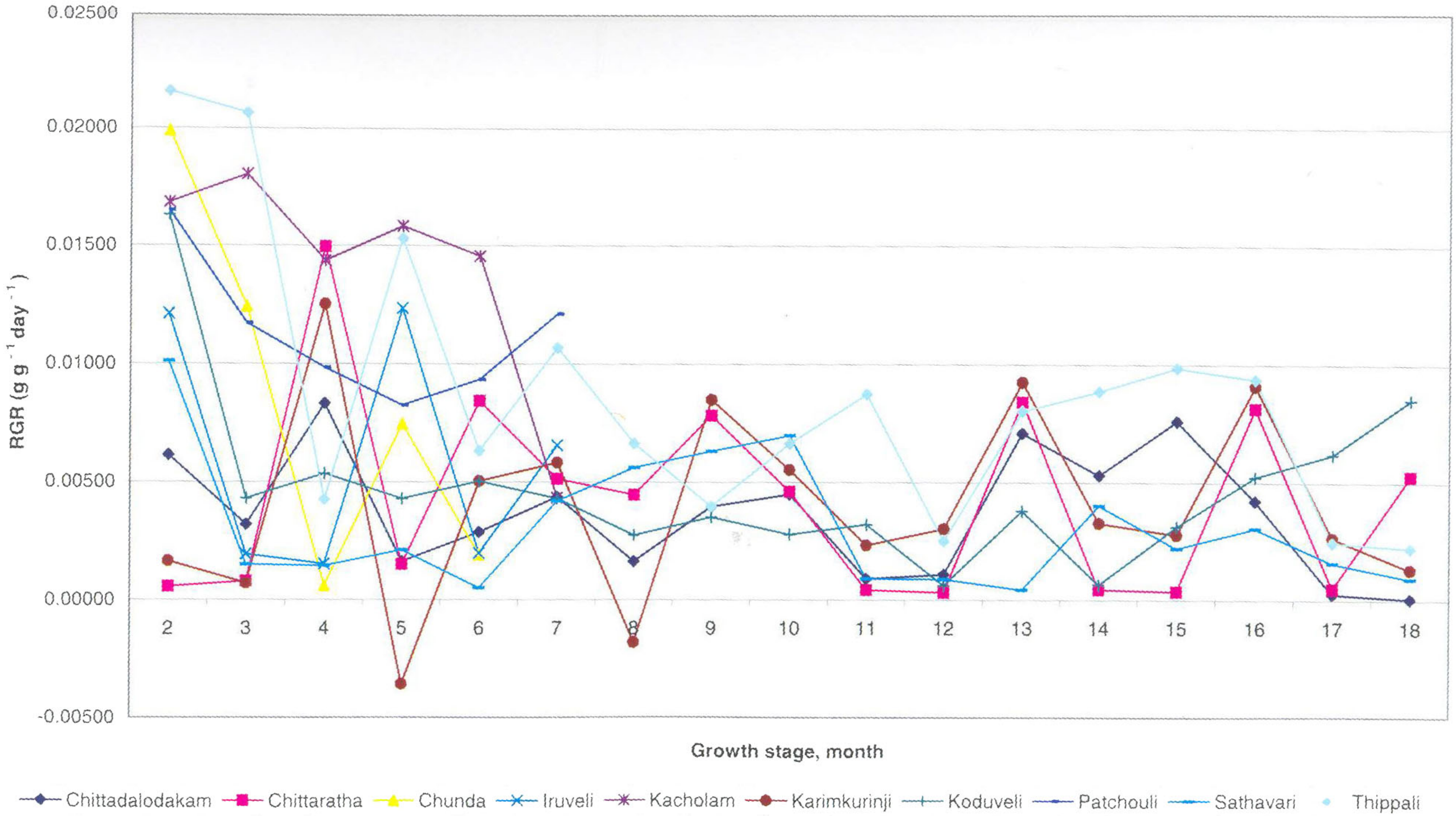


Fig. 11 Relative growth rate of medicinal plant species under young oil palm canopy

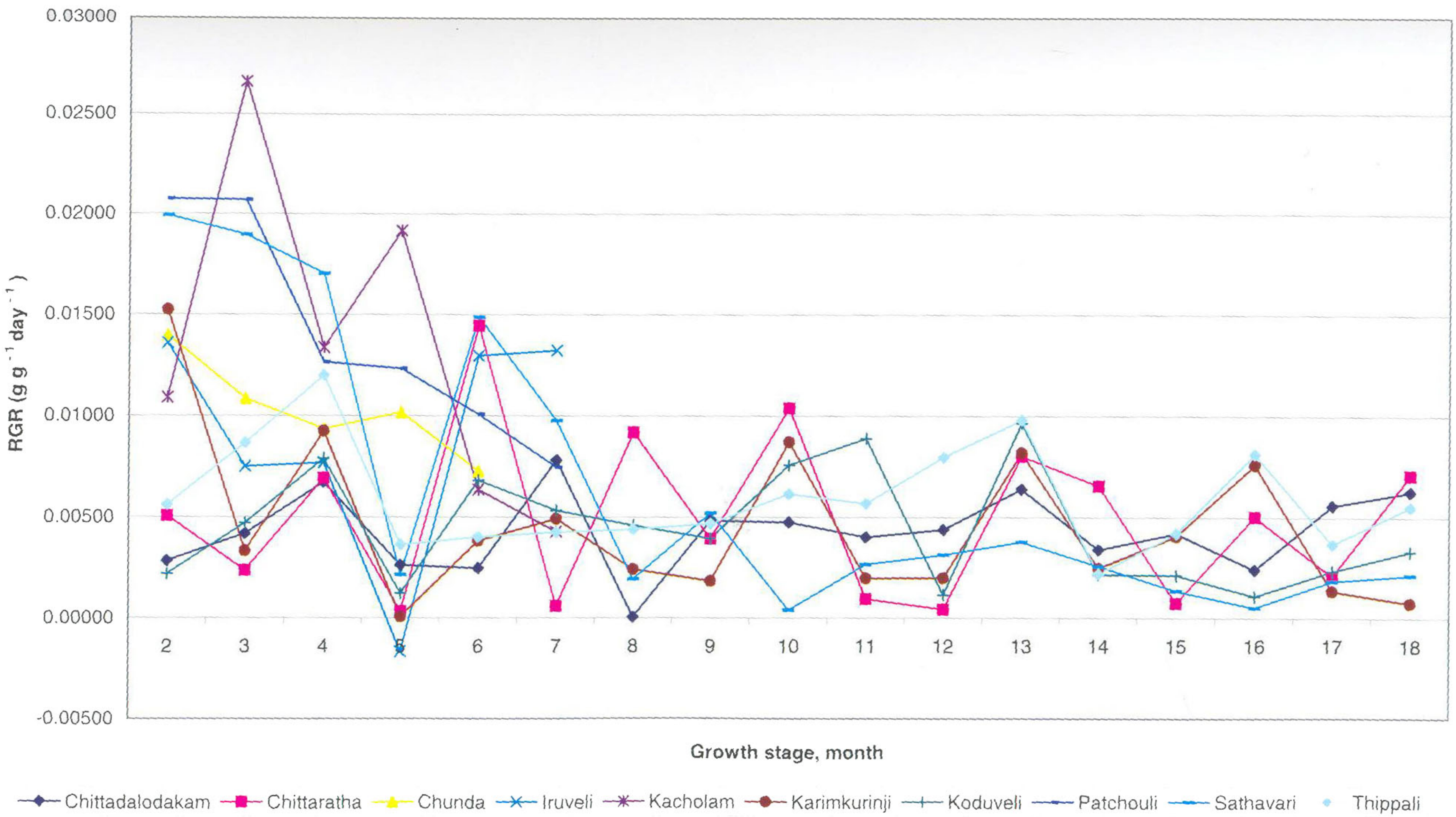


Fig. 12 Relative growth rate of medicinal plant species under medium oil palm canopy

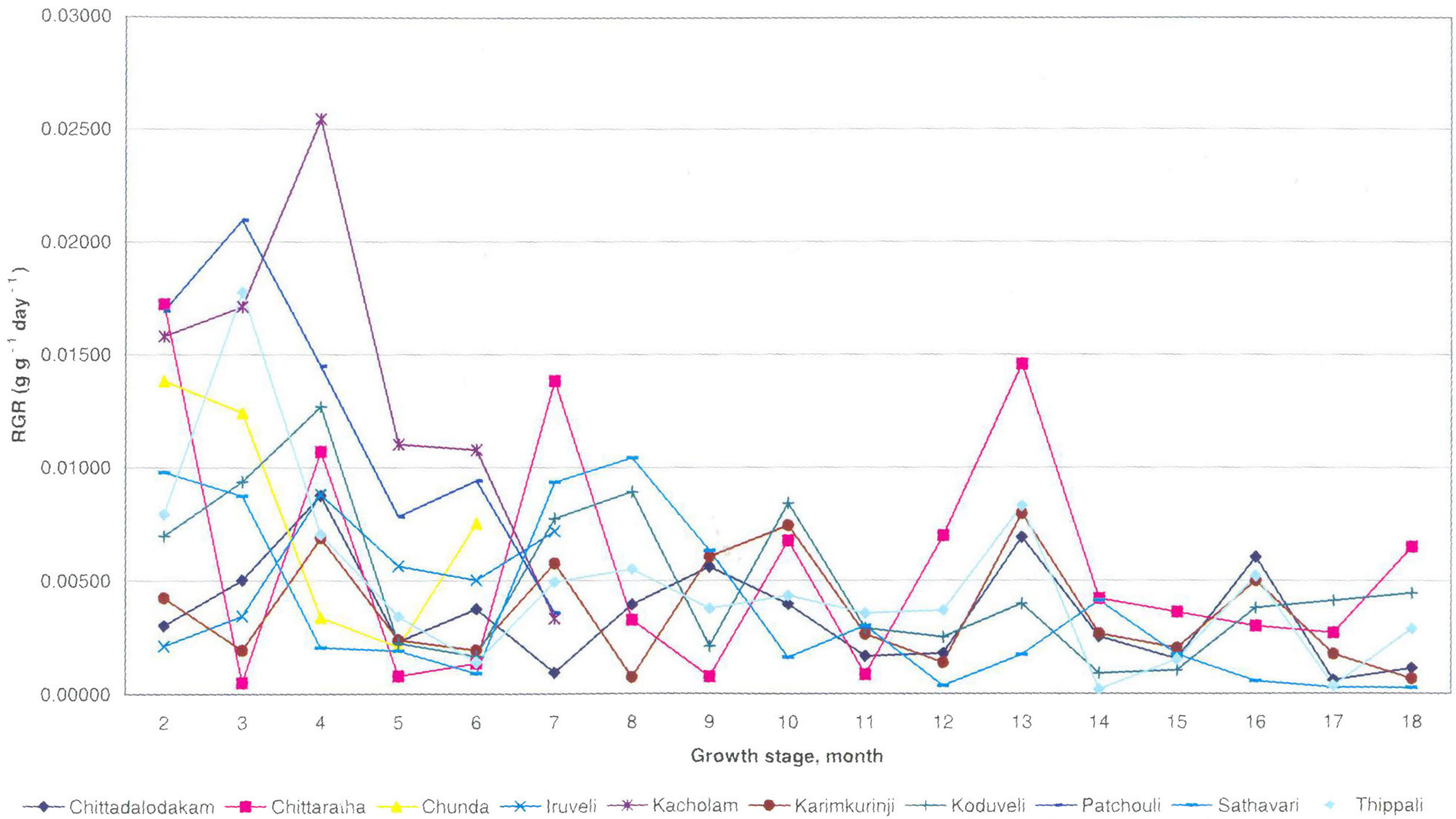


Fig. 13 Relative growth rate of medicinal plant species under mature oil palm canopy

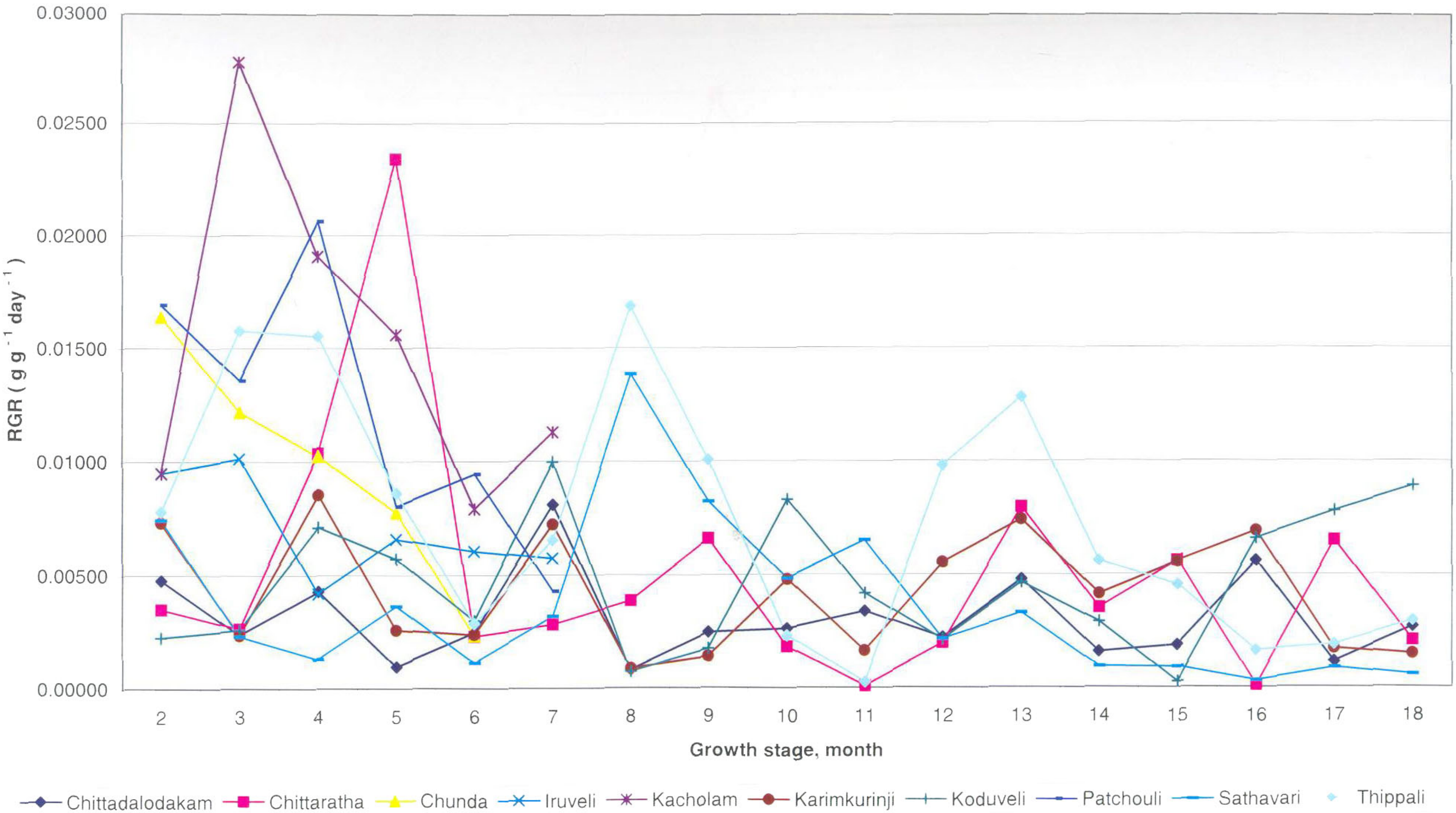


Fig. 14 Absolute growth rate of medicinal plant species under open condition

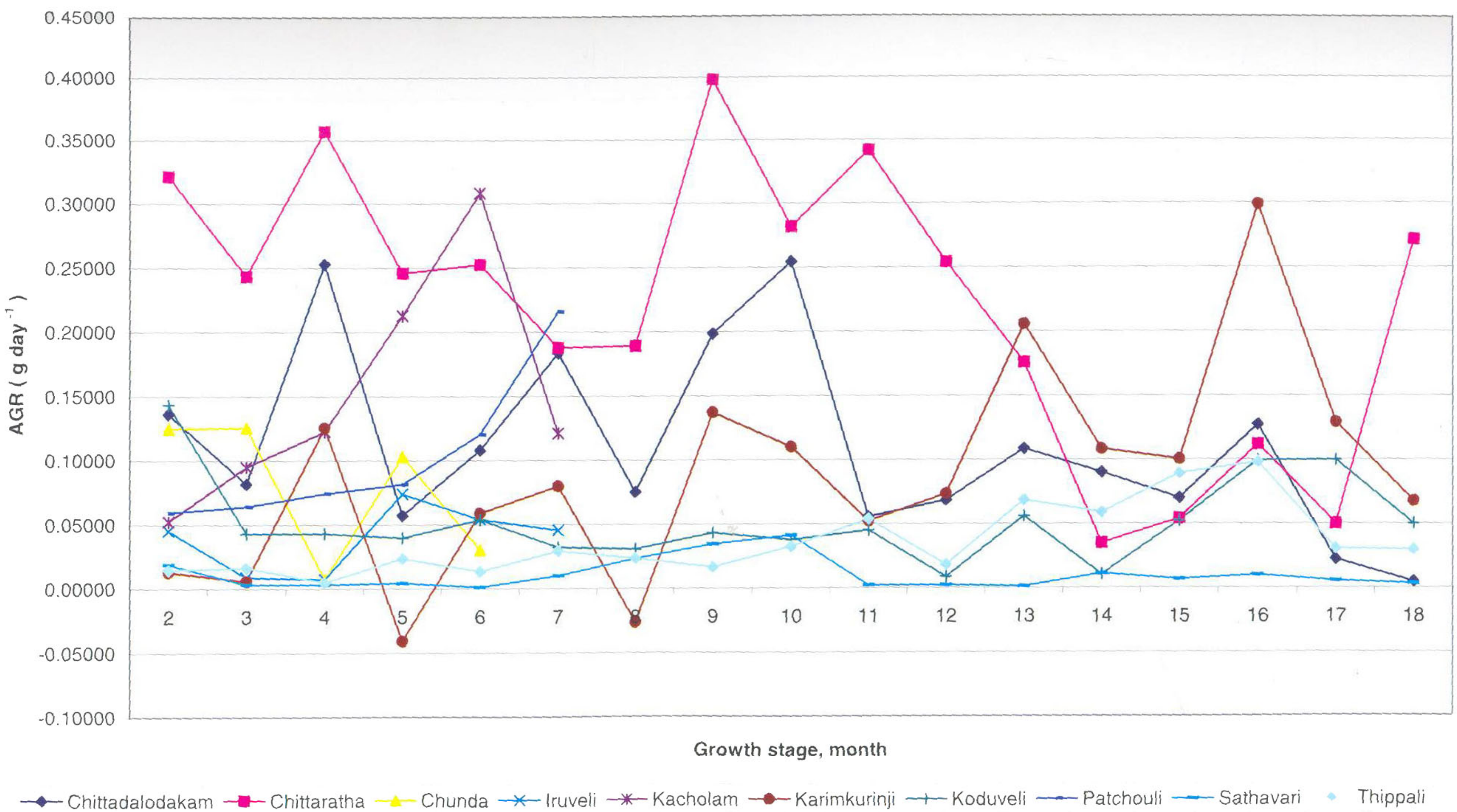


Fig. 15 Absolute growth rate of medicinal plant species under young oil palm canopy

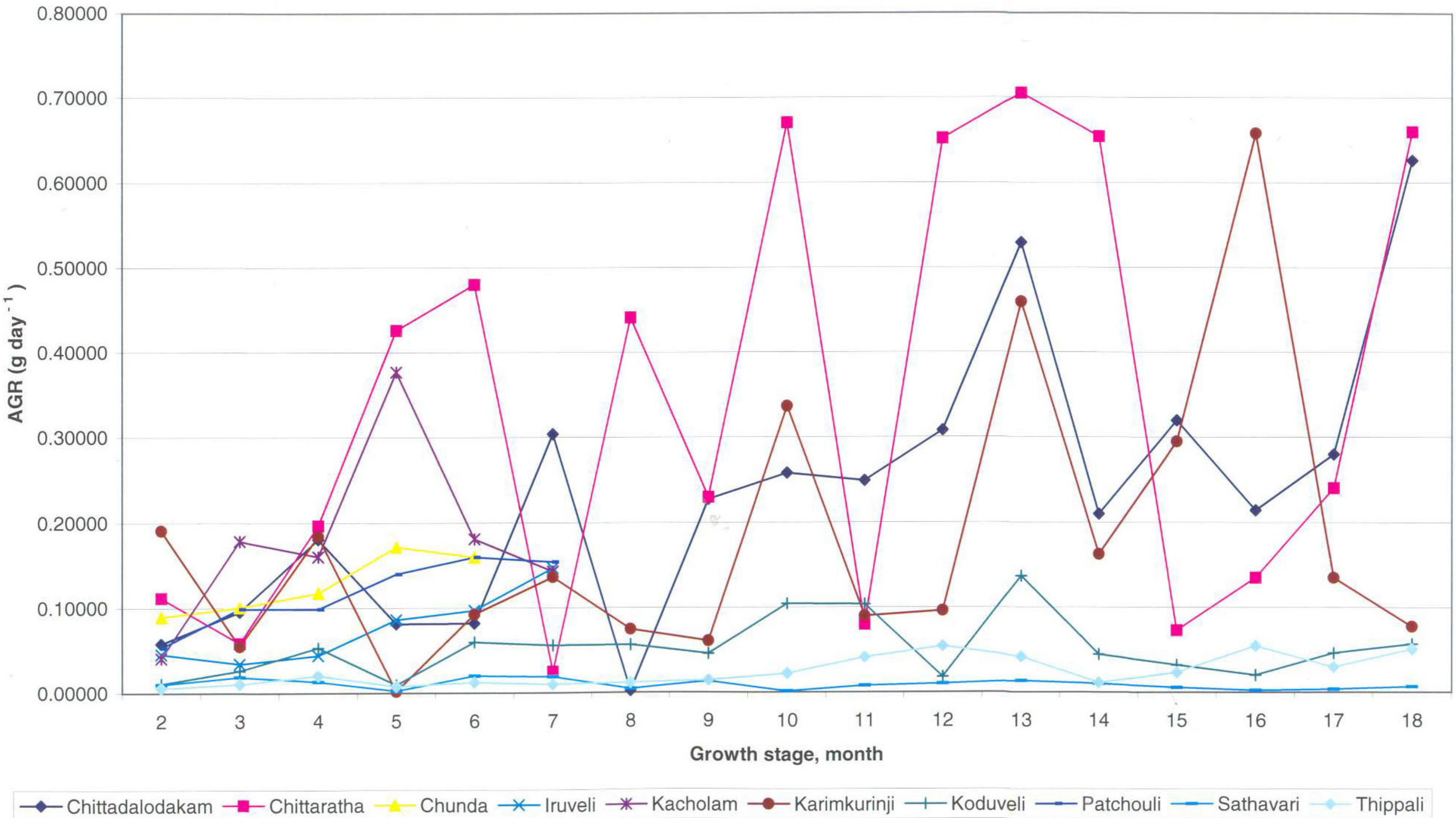


Fig. 16 Absolute growth rate of medicinal plant species under medium oil palm canopy

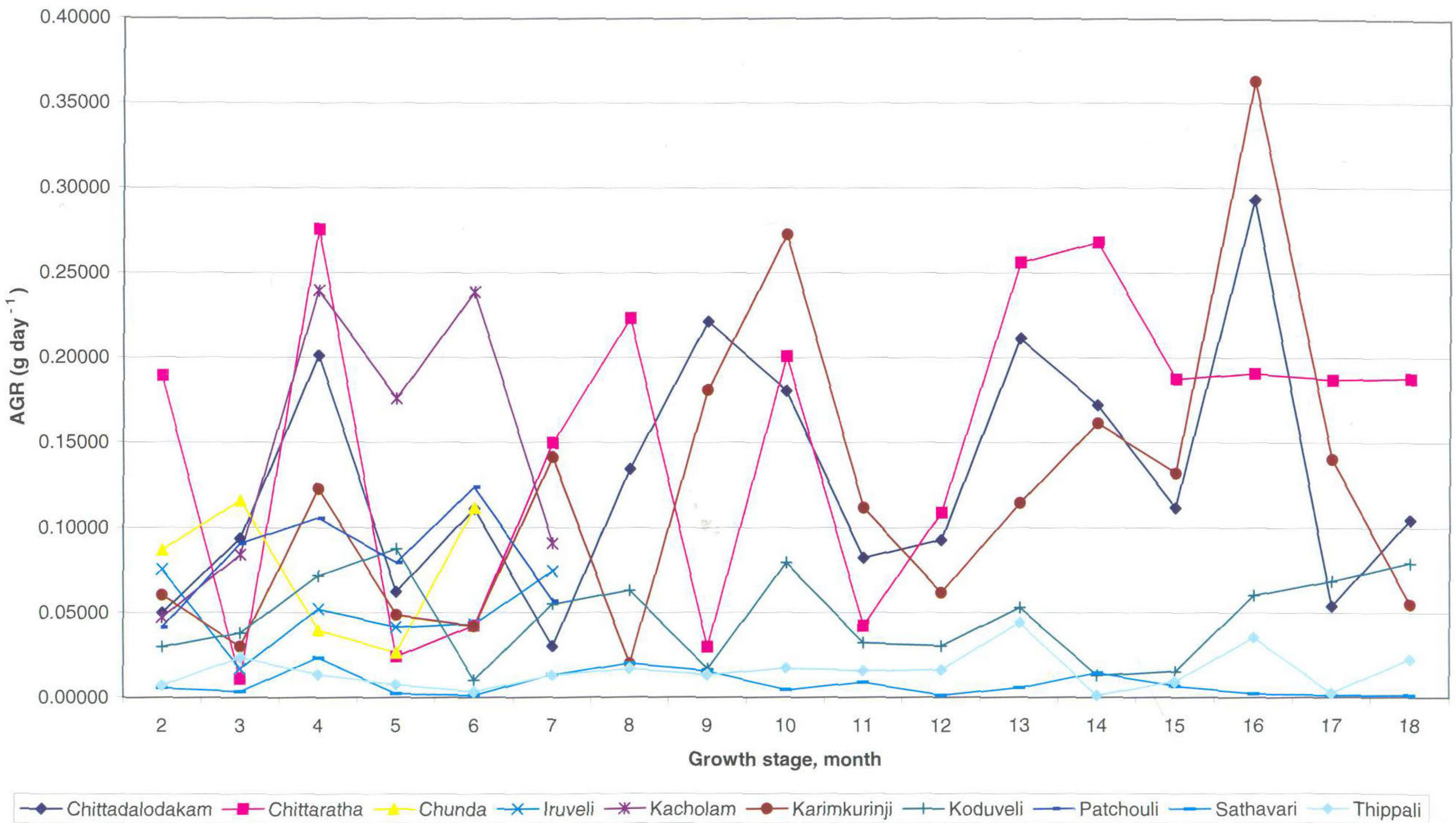
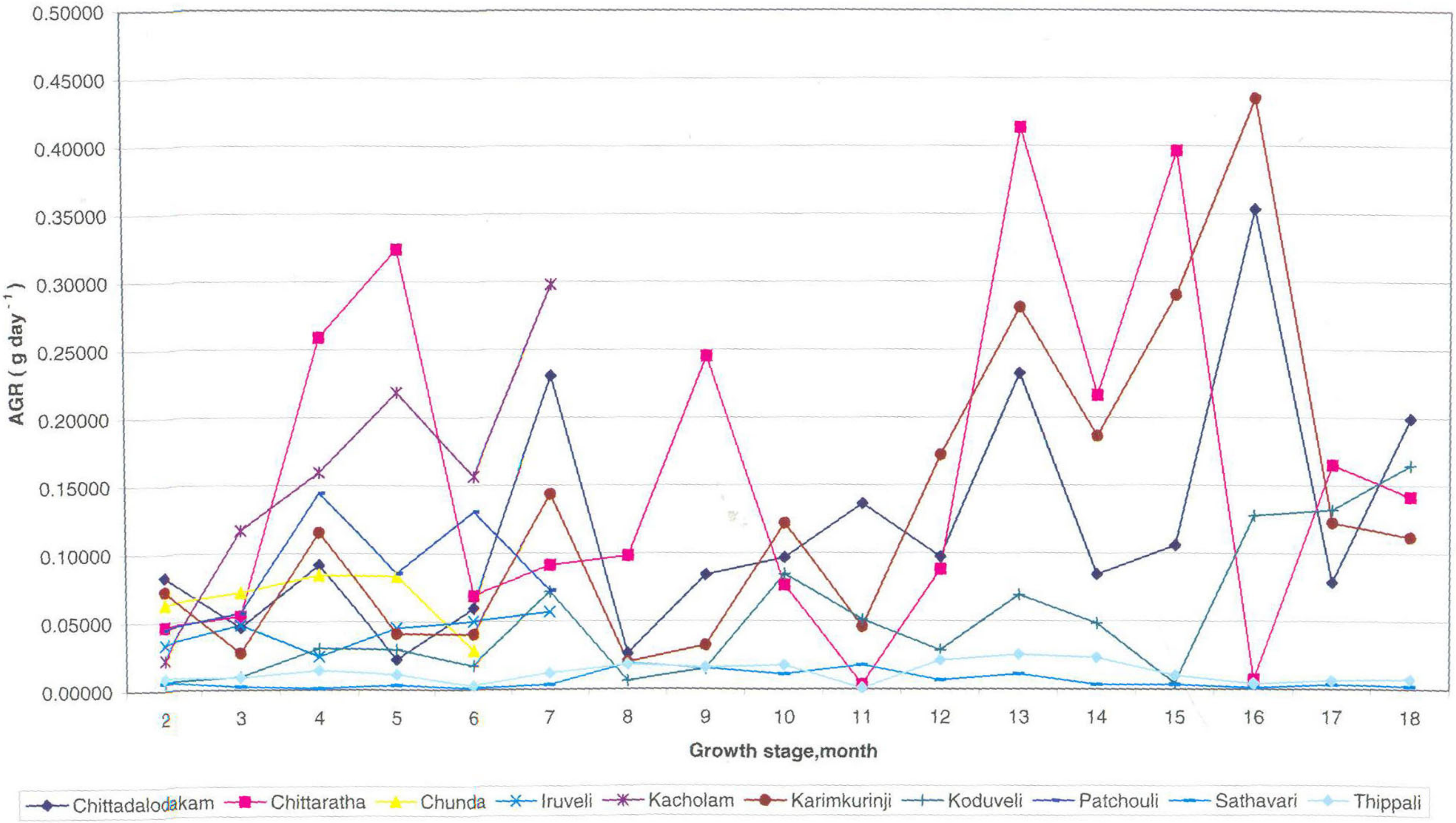


Fig. 17 Absolute growth rate of medicinal plant species under mature oil palm canopy



young palms. The values were on par under four shade levels during the first, fifth and ninth months. Chittaratha recorded the highest value under young palms during the entire growth stage. Higher values were also noticed under medium palms upto seventh month after planting. Chunda recorded highest leaf area index under open condition. During the last two months higher leaf area index was also recorded under open condition. Leaf area indices of Iruveli, Kacholam, Koduveli and Thippali were not affected by shade levels. In Karimkurinji and Patchouli significantly higher values were recorded under young palms almost during the entire growth period. Higher values were also recorded in Karimkurinji under medium and mature palms from sixth to eleventh month after planting. The influence of different shade levels on the leaf area index of Sathavari was much pronounced during the fifth, sixth, seventh, eighth, eleventh, thirteenth, fourteenth and sixteenth to eighteenth month where significantly higher values were recorded under young and medium palms.

4.1.3 Yield per Plant (In Rupees)

The per plant yield in terms of Rupees obtained from the different medicinal plant species grown as intercrop in oil palm plantations of different age groups are presented below.

Shade conditions under the oil palm canopy significantly influenced the economic yield of the medicinal plant species (Table VIII, Appendix) . Significantly, superior yield was obtained from the species grown under young oil palm canopy. The yield from species grown under open condition was on par with those obtained under medium and mature palms. The species differed significantly in per plant yield and Kacholam recorded highest per plant yield (Rs. 1.06). The lowest yield was recorded from Thippali (Rs. 0.03). Per plant yield of Iruveli and Chunda were on par (Rs. 0.10 and Rs. 0.06 respectively) (Table 22).

The data given in Table 23 indicated that shade x species interaction was also significant. Under open condition, the highest yield was obtained

Table 22 : Mean per plant yield (Rs) and harvest index for oil palm shade conditions and medicinal plant species at harvest

Treatment	Yield (Rs)	Harvest Index
Shade condition		
Open	0.40	0.57
Young	0.43	0.56
Medium	0.39	0.53
Mature	0.39	0.52
CD 0. 05	**0.011**	**0.018**
Species		
Chittadalodakam	0.64	0.55
Chittaratha	0.87	0.53
Chunda	0.06	0.19
Iruveli	0.10	0.72
Kacholam	1.06	0.51
Karimkurinji	0.51	0.55
Koduveli	0.30	0.59
Patchouli	0.20	0.83
Sathavari	0.24	0.76
Thippali	0.03	0.22
C D 0. 05	**0.012**	**0.013**

Table 23 : **Mean yield / plant showing the interaction effect of oil palm shade conditions x medicinal plant species at harvest, Rs.**

Shade condition	Chittadalodakam	Chittaratha	Chunda	Iruveli	Kacholam	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	0.64	0.86	0.05	0.07	1.11	0.48	0.26	0.21	0.23	0.05
Young	0.65	0.91	0.08	0.13	1.12	0.54	0.32	0.25	0.27	0.04
Medium	0.65	0.83	0.06	0.10	1.00	0.52	0.31	0.17	0.24	0.03
Mature	0.64	0.86	0.03	0.09	1.03	0.50	0.29	0.17	0.23	0.01

CD 1 (0.05) 0.025 CD 2 (0.05) 0.022

Table 24: **Mean harvest index showing the interaction effect of oil palm shade conditions x medicinal plant species at harvest**

Shade condition	Chittadalodakam	Chittaratha	Chunda	Iruveli	Kacholam	Karimkurinji	Koduveli	Patchouli	Sathavari	Thippali
Open	0.59	0.47	0.17	0.73	0.54	0.72	0.60	0.83	0.85	0.56
Young	0.56	0.56	0.20	0.75	0.46	0.48	0.61	0.88	0.81	0.51
Medium	0.53	0.51	0.22	0.71	0.49	0.49	0.60	0.82	0.73	0.58
Mature	0.54	0.58	0.16	0.67	0.54	0.52	0.56	0.77	0.64	0.53

CD 1 (0.05) 0.026 CD 2 (0.05) 0.028

CD1 Critical difference at 5 % level for comparing two species at a fixed shade
CD 2 Critical difference at 5 % level for comparing two shade for a fixed or different species

from Kacholam (Rs. 1.11) and the lowest from Chunda (Rs.0.05), Thippali (Rs. 0.05) and Iruveli (Rs. 0.07) which were on par. The yield from Sathavari and Patchouli were on par (Rs. 0.23 and Rs. 0.21 respectively). Under the young oil palm canopy also, Kacholam produced significantly the highest return (Rs. 1.12) and the lowest return was from Thippali (Rs. 0.04). Per plant yield of Sathavari and Patchouli were on par (Rs. 0.27 and Rs. 0.25 respectively). Under medium palms also, Kacholam produced the highest yield (Rs. 1.00) and the lowest was from Thippali (Rs. 0.03). Under mature palms shade condition also Kacholam excelled with a per plant yield of Rs. 1.03. Minimum yield was from Thippali (Rs. 0.01) which was on par with Chunda (Rs. 0.03).

Comparative evaluation of yield per plant recorded by individual species showed that Chittadalodakam was on par under different shade levels. Chittaratha produced significantly superior yield when grown under young palms (Rs. 0.91). The yield obtained under open condition (Rs. 0.86) was on par with that obtained under mature palms (Rs. 0.86), and the lowest yield was recorded under medium palms (Rs. 0.83). In general, per plant yield from Chunda was very low under all the shade levels. However, significantly superior yield was under the young oil palm canopy (Rs. 0.08) which was on par with that obtained under medium palms (Rs. 0.06). The yield under mature palms was the lowest (Rs. 0.03) which was on par with that obtained under open condition (Rs. 0.05). The general performance of Iruveli also was very poor under the different shade situations. However, significantly superior yield was produced when it was grown under young oil palm canopy (Rs. 0.13) and the lowest yield was from the open condition (Rs. 0.07) which was on par with that obtained under mature palms (Rs. 0.09). The performance of Kacholam was excellent under all the shade situations. However significantly superior yield was recorded under the young oil palm canopy (Rs. 1.12) and the lowest yield was under the medium oil palm canopy (Rs. 1.00). The general performance of Karimkurinji was also superior under the different shade situations. Significantly superior yield was under young oil palm canopy

(Rs. 0.54). Per plant yield of Karimkurinji under the open condition (Rs. 0.48) was on par with the plants under mature palms (Rs. 0.50). Koduveli produced significantly superior yield under the young oil palm canopy (Rs. 0.32) which was on par with those under medium palms (Rs. 0.31.). The lowest yield was recorded under open condition (Rs. 0.26). In the case of Patchouli, also significantly superior yield was produced under young oil palm canopy (Rs. 0.25) and the lowest yield was under medium and mature oil palm canopy (Rs. 0.17). Sathavari also produced significantly superior yield under young oil palm canopy (Rs. 0.27) and its yield under medium and mature oil palm canopies (Rs. 0.24 and Rs. 0.23) were on par with open condition Rs. 0.23). Per plant yield of Thippali was the lowest among all the medicinal plant species. Under open condition per plant yield was only Rs. 0.05 and this was on par with the plants under young oil palm canopy (Rs. 0.04). Under mature palms, its yield was only (Rs. 0.01).

4.1.4 Harvest Index

The response of different medicinal plants under the shade of oil palms of different age groups on the harvest index are presented below.

The shade levels prevailing under the oil palms of three age groups significantly influenced the harvest indices of medicinal plant species (Table VIII, Appendix) . Significantly higher values were observed in plants under the open condition which was on par with plants grown under young palms. Harvest index of species under medium oil palm canopy was on par with mature palm canopy. The various medicinal plant species also differed significantly with regard to their harvest index. Significantly superior index was noted for Patchouli (0.83) and Chunda recorded the lowest index (0.19). The harvest indices of Chittadalodakam and Karimkurinji were on par (0.55 and 0.55) (Table 22).

The shade x species interaction effect on the harvest index of medicinal plant species was also highly significant (Table 24). Under open condition, Sathavari recorded the highest harvest index of 0.85, which was on par with Patchouli (0.83) and Chunda recorded the lowest index (0.17). Under young, medium and mature oil palm canopies, Patchouli recorded the highest index (0.88, 0.82, and 0.77) and the lowest index was for Chunda (0.20, 0.22, and 0.16 respectively).

A comparison of the harvest index recorded by the selected species indicated that Chittadalodakam was significantly superior under open condition (0.59) while Chittaratha was significantly superior under mature condition (0.58). The lowest index was obtained under open condition (0.47). The harvest index of Chunda was significantly higher under the medium oil palm canopy (0.22) which was on par with those under young palms (0.20) while minimum index was noticed under mature palms (0.16). In Kacholam significantly superior values were recorded under open condition (0.54) which was on par with mature palms (0.54). Karimkurinji and Sathavari also had higher indices under open condition (0.72 and 0.85 respectively). Koduveli recorded the highest index under young oil palm canopy (0.61) which was on par with those under open and medium condition (0.60 each). Patchouli recorded significantly higher value index under young oil palm canopy (0.88) and Thippali under mature palms (0.58).

4.1.5 Economic Analysis

4.1.5.1 Yield Plant $^{-1}$ (officinal part)

The per plant yield of officinal part of different medicinal plant species grown as intercrop in oil palm plantations of various age groups are presented in Table 25.

Under open condition, the highest per plant yield was from Chittaratha (55.03 g) and the lowest for Chunda (2.71 g). Under young, medium and mature oil palm canopies also Chittaratha recorded the highest yield (57.80 g, 52.91 g and 54.61 g) and the lowest yield by Thippali (2.38 g, 1.68 g and 0.42 g).

4.1.5.2 Yield ha^{-1} (Officinal Part)

The per ha officinal part yield of different medicinal plant species grown as intercrop in oil palm plantations of various age groups are presented in Table 25.

Under open condition, the highest per ha yield of officinal part was from Chittaratha (7.34 t) and the lowest for Chunda (0.36 t). Superior yield was also recorded by Chittadalodakam (6.79 t), Karimkurinji (5.06 t), Sathavari (2.91 t), Patchouli (2.36 t) and Kacholam (2.12 t).

Under young, medium and mature oil palm canopies also Chittaratha recorded the highest yield (4.33 t, 3.96 t and 4.09 t respectively). The lowest yield was recorded by Thippali (0.18 t 0.13 t and 0.03 t respectively). In young, medium and mature oil palm canopies Chittadalodakam (3.87, 3.86 and 3.80 t respectively), Karimkurinji (3.20, 3.06 and 2.96 t respectively), Sathavari (1.94, 1.74 and 1.67 t respectively), Patchouli (1.52, 1.03 and 1.05 t respectively) and Kacholam (1.20, 1.08 and 1.11 t respectively) also recorded superior yield.

4.1.5.3 Income ha^{-1} (Rupees)

The total income per hectare of different medicinal plant species grown as intercrop in oil palm plantations of various age groups and in open condition are presented in Table 25.

Under open condition, the highest income ha^{-1} was obtained from Kacholam (Rs. 1,47,964) followed by Chittaratha (Rs. 1,15,191), Chittadalodakam (Rs. 84,603), Karimkurinji (Rs. 63,774), Koduveli (Rs, 35;264), Sathavari (Rs. 30,556), Patchouli (Rs. 28,807), Iruveli (Rs. 9,537), Thippali (Rs. 6,636) and Chunda (Rs. 6,068).

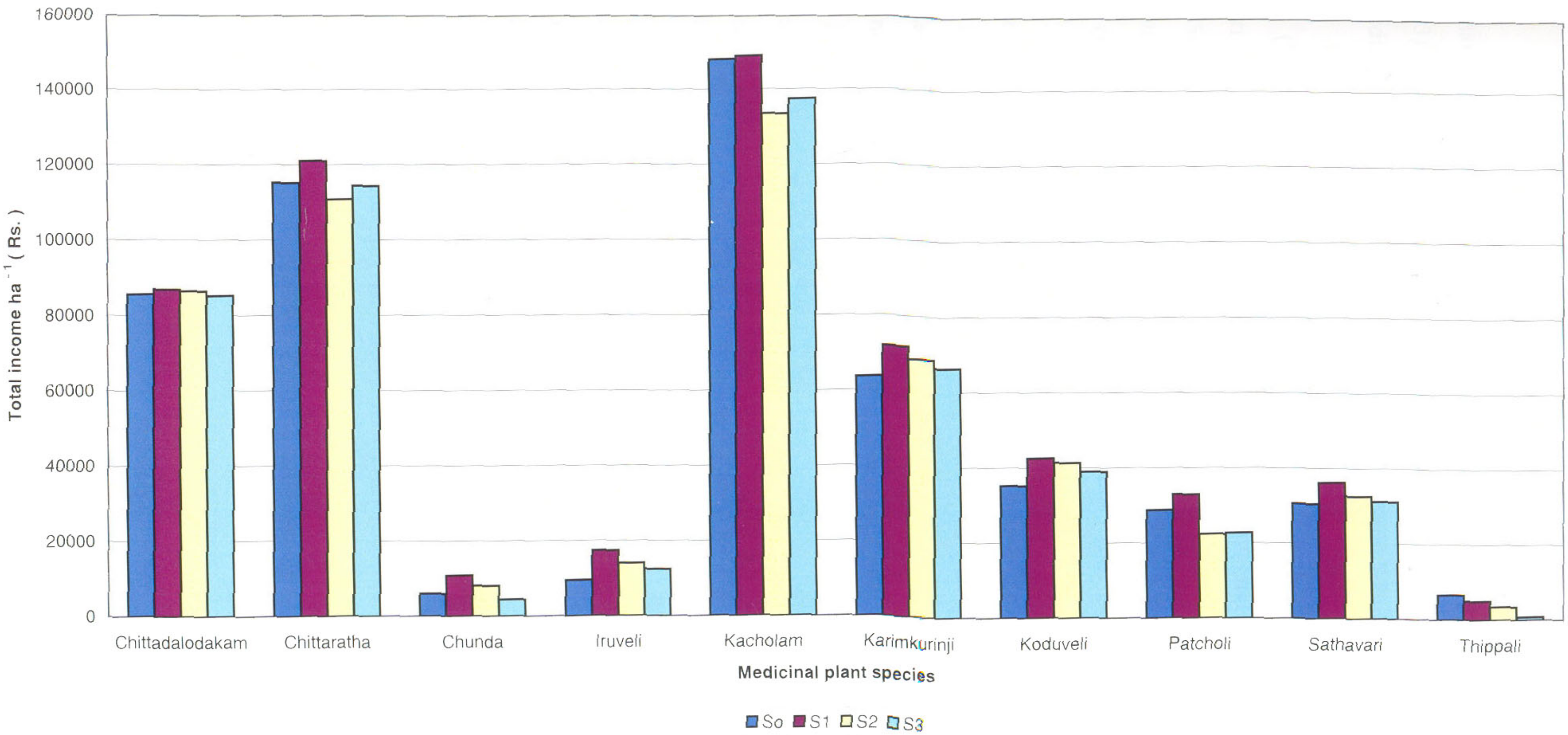
Under young oil palm canopy shade also, higher income was derived from Kacholam (Rs. 83,725) followed by Chittaratha (Rs. 67,988), Chittadalodakam (Rs. 48,817), Karimkurinji (Rs. 40,380), Koduveli

Table 25 : Income analysis of ten medicinal plant species under different oil palm shade conditions

Treatments	Per plant yield (officinal part) (g)				Yield per ha (officinal part) (t)				Price/kg (Rs)	Income/ha (Rs)			
	Open	Young	Medium	Mature	Open	Young	Medium	Mature		Open	Young	Medium	Mature
Chittadalodakam	50.95	51.71	51.47	50.76	6.79	3.87	3.86	3.80	12.60	85603	48817	48589	47924
Chittaratha	55.03	57.80	52.91	54.61	7.34	4.33	3.96	4.09	15.70	115191	67988	62242	64241
Chunda	2.71	4.84	3.62	2.00	0.36	0.36	0.27	0.15	16.80	6068	6093	4555	2521
Iruveli	5.54	10.11	8.15	7.25	0.74	0.76	0.61	0.54	12.90	9537	9769	7874	7004
Kacholam	15.92	16.03	14.36	14.79	2.12	1.20	1.08	1.11	69.70	147964	83725	75013	77218
Karimkurinji	37.96	42.77	40.83	39.51	5.06	3.20	3.06	2.96	12.60	63774	40380	38544	37304
Koduveli	9.83	11.88	11.53	10.86	1.31	0.89	0.86	0.81	26.90	35264	23943	23230	21894
Patchouli	17.71	20.27	13.76	13.96	2.36	1.52	1.03	1.05	12.20	28807	18527	12582	12758
Sathavari	21.83	25.84	23.29	22.31	2.91	1.94	1.74	1.67	10.50	30556	20330	18321	17555
Thippali	3.15	2.38	1.68	0.42	0.42	0.18	0.13	0.03	15.80	6636	2815	1989	497

Note: Medicinal plant population in open condition - 1,33,333
Medicinal plant population / ha of oil palm plantation - 74,926

Fig. 18 Total income from medicinal plant species under different shade conditions



(Rs, 23,943), Sathavari (Rs. 20,330), Patchouli (Rs. 18,527), Iruveli (Rs. 9,769), Chunda (Rs. 6,093) and Thippali (Rs. 2,815).

Under medium oil palm canopy also, the highest income was realized from Kacholam (Rs. 75,013) followed by Chittaratha (Rs. 62,242), Chittadalodakam (Rs. 48,589), Karimkurinji (Rs. 38,544), Koduveli (Rs, 23,230), Sathavari (Rs. 18,321), Patchouli (Rs. 12,582), Iruveli (Rs. 7,874), Chunda (Rs. 4,555) and Thippali (Rs. 1,989).

Under mature oil palm canopy also, the highest income was registered by Kacholam (Rs. 77,218) followed by Chittaratha (Rs. 64,241), Chittadalodakam (Rs. 47,924), Karimkurinji (Rs. 37,304), Koduveli (Rs, 21,894), Sathavari (Rs. 17,555), Patchouli (Rs. 12,758), Iruveli (Rs. 7,004), Chunda (Rs. 2,521) and Thippali (Rs. 497).

4. 1. 5. 4 Net Income ha^{-1}

The net income per hectare obtained from different medicinal plant species grown as intercrop in oil palm plantations of various age groups and in open condition are presented in Table 26.

Under open condition, the highest net profit ha $^{-1}$ was derived from Kacholam (Rs. 47,630) followed by Chittaratha (Rs. 17,551), Karimkurinji (Rs. 6,134), Sathavari (Rs. 2,382), and Chittadalodakam (Rs. 1,297). All other species recorded a net loss, and the highest net loss was recorded by Thippali (Rs. 37,671) followed by Patchouli (Rs. 18,193), Chunda (Rs. 13,146), Iruveli (Rs. 10,796) and Koduveli (Rs, 9,042).

When the plants were grown as intercrop under young oil palms, the highest net profit ha $^{-1}$ was realized from Kacholam (Rs. 28,218) followed by Chittaratha (Rs. 13,120), Karimkurinji (Rs. 7,991), Sathavari (Rs. 4,499), and Chittadalodakam (Rs. 1,442). All other species recorded a net loss, and the highest net loss was recoded by Thippali (Rs. 22,083) followed by Patchouli (Rs. 7,010), Chunda (Rs. 4,022), Koduveli (Rs, 954) and Iruveli (Rs. 782).

Under medium oil palm canopy, the highest net profit ha $^{-1}$ was recorded from Kacholam (Rs. 19,506) followed by Chittaratha (Rs. 7,375), Karimkurinji (Rs. 6,154), Sathavari (Rs. 2,490), and Chittadalodakam (Rs. 1,214). All other species recorded a net loss, and the highest net loss was registered by Thippali (Rs. 22,909) followed by Patchouli (Rs. 12,955), Chunda (Rs. 5,559), Iruveli (Rs. 2,678) and Koduveli (Rs, 1,667).

Under mature oil palm canopy condition, the highest net profit ha $^{-1}$ was obtained from Kacholam (Rs. 21,711) followed by Chittaratha (Rs. 9,373), Karimkurinji (Rs. 4,914), Sathavari (Rs. 1,724), and Chittadalodakam (Rs. 549). All other species recorded a net loss, and the highest net loss was recoded by Thippali (Rs. 24,400) followed by Patchouli (Rs. 12,779), Chunda (Rs. 7,594), Iruveli (Rs. 3,548) and Koduveli (Rs, 3,003).

4.1.5.5 Benefit Cost Ratio

The benefit cost ratio of different medicinal plant species grown as intercrop in oil palm plantations of various age groups and in open condition are presented in Table 26.

Under open condition, the highest benefit cost ratio was recorded by Kacholam (1.47) followed by Chittaratha (1.18), Karimkurinji (1.11), Sathavari (1.08), and Chittadalodakam (1.02). All other species recorded a benefit cost ratio < 1. Koduveli recorded a ratio of 0.80, followed by Patchouli (0.61), Iruveli (0.47) Chunda (0.32), and Thippali (0.15).

Under young oil palm canopy, the highest benefit cost ratio was recorded by Kacholam (1.51) followed by Sathavari (1.28), Karimkurinji (1.25), Chittaratha (1.24), and Chittadalodakam (1.03). All other species recorded a benefit cost ratio < 1. Koduveli recorded 0.96, followed by Iruveli (0.93), Patchouli (0.73), Chunda (0.60), and Thippali (0.11).

Under medium oil palm canopy, the highest benefit cost ratio was recorded by Kacholam (1.35) followed by Karimkurinji (1.19), Sathavari (1.16), Chittaratha (1.13), and Chittadalodakam (1.03). All other species recorded a benefit cost ratio < 1. Koduveli recorded 0.93, followed by Iruveli (0.75), Patchouli (0.49), Chunda (0.45), and Thippali (0.08).

Under mature oil palm canopy, the highest benefit cost ratio was recorded by Kacholam (1.39) followed by Chittaratha (1.17), Karimkurinji (1.15), Sathavari (1.11), and Chittadalodakam (1.01). All other species had a

Table 26 :Cost benefit analysis of selected medicinal plant species under different oil palm shade situations

	Expenditure ha^{-1} (Rs.)				Net profit ha^{-1} (Rs.)				BCR			
Treatments	**Open**	**Young**	**Medium**	**Mature**	**Open**	**Young**	**Medium**	**Mature**	**Open**	**Young**	**Medium**	**Mature**
Chittadalodakam	84307	47375	47375	47375	1297	1442	1214	549	1.02	1.03	1.03	1.01
Chittaratha	97640	54868	54868	54868	17551	13120	7375	9373	1.18	1.24	1.13	1.17
Chunda	19213	10115	10115	10115	-13146	-4022	-5559	-7594	0.32	0.6	0.45	0.25
Iruveli	20333	10552	10552	10552	-10796	-782	-2678	-3548	0.47	0.93	0.75	0.66
Kacholam	100333	55507	55507	55507	47630	28218	19506	21711	1.47	1.51	1.35	1.39
Karimkurinji	57640	32390	32390	32390	6134	7991	6154	4914	1.11	1.25	1.19	1.15
Koduveli	44307	24897	24897	24897	-9042	-954	-1667	-3003	0.8	0.96	0.93	0.88
Patchouli	47000	25537	25537	25537	-18193	-7010	-12955	-12779	0.61	0.73	0.49	0.5
Sathavari	28173	15831	15831	15831	2382	4499	2490	1724	1.08	1.28	1.16	1.11
Thippali	44307	24897	24897	24897	-37671	-22083	-22909	-24400	0.15	0.11	0.08	0.02

Note: Cost of planting material (Rs.) Adhatoda - 0.50, Chittaratha-0.60, Solanum - 0.01, Iruveli - 0.01, Kacholam - 0.70 Karimkurinji - 0.30, Koduveli - 0.20, Patchouli - 0.30, Sathavari - 0.10, Thippali - 0.20
Labour charges @ Rs.140 / man day

Plate 5. Performance of medicinal plants under young oil palm

Plate 6. Performance of Kacholam under four shade conditions

benefit cost ratio < 1. Koduveli had a ratio of 0.88, followed by Iruveli (0.66), Patchouli (0.50), Chunda (0.25), and Thippali (0.02).

An overall review of the influence of different shade levels on the various growth characters of the ten selected medicinal plant species are summarized below.

1. Chittadalodakam

An overall review of the influence of different shade levels on the various growth characters of Chittadalodakam revealed that shade levels significantly affected all the characters studied throughout the growth period. Significantly higher number of leaves, branches, root length and leaf area index were recorded by plants grown under young oil palm canopy during the entire growth period. Regarding plant height significantly taller plants were noticed under open condition upto eleventh month after planting and thereafter plants under young palms were taller. Similar trend was noticed for dry matter production also and dry matter content was the highest under open condition upto tenth month after planting and thereafter under young palms. Higher number of roots were recorded under open condition upto six months after planting. From sixth month upto fourteenth month the highest root number was under young palms and from fifteenth month onwards under medium palms. Yield per plant and benefit cost ratio were also the highest under young and medium palms and the highest net profit was registered under young palms.

2. Chittaratha

Highly significant influence of shade levels on the growth characters of Chittaratha was noticed throughout the growth period. Significantly taller plants were noticed under the deep shaded condition of medium palms during the active growth stage (upto eleventh month after planting) and towards the later stages of crop growth under the partial shade of young palms. Number of leaves, roots and root length were also higher under medium palms during the fifth, sixth and eighth months respectively and thereafter under young palms. Towards the early and later stages of crop growth higher tiller number was

Plate 7. Performance of Chittaratha under four shade conditions

A. Open

B. Young

C. Medium

D. Mature

recorded by plants under young and medium palms but during the eighth, ninth and tenth months higher values were recorded under open condition. Dry matter production was the highest under young palms almost throughout the growth period. Leaf area index was also the highest under young oil palm canopy during all the growth stages except second, third, fifth and sixth months. The highest per plant yield and benefit cost ratio were also recorded under young palms while the highest net income was registered under open condition.

3. Chunda

Regarding plant height, significantly taller plants were noticed under medium palms during first and third months after planting and thereafter under the young palms. Number of roots, root length and dry matter were higher under open condition during the initial growth stages and later under young palms. Number of branches was higher under young palms except during second and fifth months where the highest branches were noticed under open condition. Similar trend was noticed for leaf area index also. Per plant yield and benefit cost ratio were also the highest under young palms. Chunda recorded a net loss under all conditions, but the loss was minimum under young palms.

4. Iruveli

A comparative evaluation of the influence of shade levels on the different growth characters revealed that shade level significantly affected all the growth characters. The highest plant height, number of leaves, root length, dry matter content and leaf area index were recorded from plants under medium oil palm canopy. However number of branches and roots were higher under young palms. Per plant yield and benefit cost ratio were also the highest under young palms and the net loss was minimum under young palms.

5. Kacholam

In Kacholam, the number of leaves and leaf area index were highest under young palms upto third month after planting. From fourth month up to harvesting, the highest values for these characters were recorded under

Plate 8. Performance of Karimkurinji under four shade conditions

A. Open

B. Young

C. Medium

D. Mature

Plate 9. Performance of Sathavari under four shade conditions

Plate 10. Performance of Chittadalodakam under young palms

medium and mature palms. The number of branches, roots and root length of Kacholam were the highest under medium palms almost during the entire growth period. Dry matter production showed higher values under young palms throughout the growth period. Yield per plant and benefit cost ratio were also the highest under young palms. Highest net profit was under open condition.

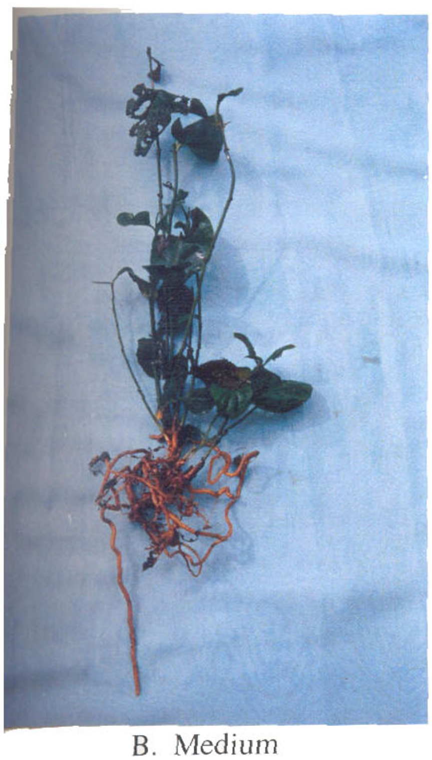
6. Karimkurinji

A perusal of the data on the influence of shade levels on the growth characters revealed that the growth of Karimkurinji was significantly affected by shade levels from first month to fifth month and again from twelfth to fifteenth month significantly taller plants were noticed under medium palms. From sixth to eleventh month, the highest plant height was recorded under young palms while during the last three months of crop growth significantly taller plants were recorded under mature palms. Under the partial shade of young palms, Karimkurinji recorded higher number of leaves, branches, dry matter content and leaf area index. During the active growth stage, higher number of roots and root length were recorded under the deep shade of medium and mature palms. However, towards the later stages of crop growth from fourteenth month, higher values for these characters were registered for plants under young palms. The highest yield per plant, net profit and benefit cost ratio were also recorded under young oil palm canopy.

7. Koduveli

Overall evaluation of the influence of shade levels on growth characters indicated that certain characters were significantly affected by shade levels. Plant height was significantly influenced by shade levels. During the initial growth stages, taller plants were noticed under open condition, but from eighth month onwards, plants under mature palms were taller. Higher number of leaves were observed under open condition except during tenth to fourteenth month. Same trend was noticed in the case of leaf area index also. However higher leaf area indices were recorded from eighth to twelfth month under

A. Young



B. Medium

C. Mature

Plate 11. Performance of Koduveli under oil palm plantations

young palms and from thirteenth to fifteenth months under medium palms. Significantly higher number of branches were recorded under young oil palm canopy. Number of roots and root length were the characters least affected by shade and significantly higher values for these characters were recorded by plants under open condition. During the initial months dry matter was also not influenced by shade but towards the later stages of crop growth (from tenth month onwards) higher values were recorded under young palms and during the last three months under mature palms.

8. Patchouli

In general the influence of shade levels on the growth characters were visible during the entire growth period. Plant height was significantly higher under mature palms. Number of branches and leaf area index were consistently higher under young palms. The influence of shade levels on the number of leaves was highly variable. Higher leaf number was recorded from plants under mature, medium and young palms and open at different growth stages. Number of roots and root length were significantly affected by shade levels. During the early growth stages higher values were recorded under mature palms and during the later stages under young palms. Even though the dry matter production was higher under open condition initially, towards the later stages, higher values were recorded under young palms. Yield per plant and BC ratio were also the highest under young palms and the net loss was also the lowest under young palms.

9. Sathavari

In Sathavari, influence of shade levels on various growth characters was much pronounced. Plant height was significantly affected by shade levels from fifth month onwards and significantly taller plants were recorded under mature and medium palms upto tenth month after planting. From eleventh month onwards, taller plants were noticed under young palms. From seventh month onwards, number of leaves, branches, roots, root length, dry matter production and leaf area index were also the highest under the young palms. Similarly yield per plant, net profit and benefit cost ratio were also the highest under this condition.

10. Thippali

In Thippali, highest plant height, number of leaves, branches, roots and leaf area index were recorded under medium palms almost throughout the growth period. Root length was initially higher under young palms and during the later stages under medium palms. Dry matter production was significantly superior under open condition from seventh month onwards. Thippali recorded higher yield per plant and benefit cost ratio under open condition. Net loss was minimum under young palms.

4.1.6 Photosynthetically Active Radiation

The incident solar energy in the open condition and under oil palms of various age groups are presented in Table 27.

Table 27 PAR in the interspaces of oil palm of various age groups

Shade condition	PAR (μ mol m^{-2} sec^{-1})	% of open
Open	1756	100
Young	737	42
Medium	334	19
Mature	386	22

The pattern of distribution of solar energy indicated that there was considerable variation in the interception of sunlight by oil palm canopies of different age groups. There was a sharp decline in PAR values under youmg palms by 42 %, which again tented to be lower under medium palms (19 %).Under mature palms there was a slight increase in PAR values (22 %). The data thus suggested that middle-aged palms let in only 19 % of the light through their canopies and hence shade level is the highest under this situation

4.1.7 Soil Analysis

The available nitrogen, phosphorous and potassium content in the experimental plots before and after the experiment are given in Table 28.

Table 28. Chemical analysis of the soil under the oil palms of various age groups

	Before Experiment (kg ha^{-1})			After Experiment (kg ha^{-1})		
	N	P	K	N	P	K
Open	287.54 (High)	27.5 (High)	291.2 (Low)	203.84 (Medium)	23.37 (High)	209.07 (Low)
Young	274.22 (High)	29.25 (High)	268.8 (Low)	238.33 (Medium)	24.17 (High)	215.73 (Low)
Medium	265.37 (High)	29.5 (High)	291.2 (Low)	247.74 (Medium)	24.50 (High)	201.60 (Low)
Mature	291.14 (High)	30.5 (High)	268.8 (Low)	254.01 (Medium)	24.92 (High)	194.13 (Low)

Rating:

Nitrogen: (kgha^{-1}) 140 – Low, 140 – 280 –Medium, >280 – High

Phosphorous: (kgha^{-1}) 11 – Low, 11 – 22 –Medium, >22 – High

Potassium: (kgha^{-1}) 280 – Low, 280 – 560 –Medium, >560 – High

Nitrogen the major nutrient required for the vegetative growth of the plant was rated to be high under the four shade situations before the initiation of the experiment (open – 287.54 kg ha^{-1}, young-274.22 kg ha^{-1}, medium-265.37 kg ha^{-1} and mature-291.14 kg ha^{-1}). After experiment the nitrogen status was found to be in the medium range under all the four shade situations (open – 203.84 kg ha^{-1}, young - 238.33 Kg ha^{-1}, medium - 247.74 kg ha^{-1} , mature-254.01 kg ha^{-1}).

With respect to phosphorus, a significant nutrient for root development and other physiological activities like energy transfer in the form of ATP, ADP molecules, similar results were obtained. The soil phosphorus status of the experimental site was rated high before and after the experiment under all shade situations (open – 27.5 kg ha^{-1} , young-29.25 kg ha^{-1} , medium-29.5 kg ha^{-1} , mature-30.5 kg ha^{-1} before the experiment and open – 23.37 kg ha^{-1} , young - 24.17 kg ha^{-1} , medium - 24.50 kg ha^{-1} , mature - 24.92 kg ha^{-1} after the experiment) .

In the case of potassium a major nutrient for osmotic functions, development of resistance etc, the status was rated as low both before and after the experiment under the four shade situations. The values before experiment were, open – 291.2 kg ha^{-1} ;young-268.8 kg ha^{-1} ; medium-291.2 kg ha^{-1} ; mature-268.8 kg ha^{-1} whereas the values after the conduct of the experiment were, open – 209.07 kg ha^{-1} ;young - 215.73 kg ha^{-1} ; medium - 201.60 kg ha^{-1} ; mature-194.13 kg ha^{-1} .

4.2 Phase II Experiment

The results of the spacing trial on Kacholam under different oil palm canopy shade levels and open condition are presented below.

4.2.1 Growth Characters

Various growth characters at three stages of plant growth viz., 60, 120 and 180 days after planting (DAP) were recorded, analyzed and the results are presented below.

4.2.1.1 Number of Tillers

Shade levels significantly influenced the number of tillers produced at 60 DAP (Table IX, Appendix) and significantly, superior tiller number was noticed under young palms (8.11).

The influence of planting density on tiller production was also significant at 60 DAP and the highest tiller number was noticed at 20 x 20 cm spacing and the lowest at 20 x 10 cm spacing (8.67 and 4.25 respectively) (Table 29).

At 120 DAP also, the number of tillers varied significantly with shade levels and the highest tiller number was noticed under the young oil palm canopy (11.44) and the lowest under the mature palms (6.56).

The influence of planting density on tiller number was significant during this growth stage also and significantly superior value was recorded under the lowest planting density i.e. 20 x 20 cm spacing (11.83) and the lowest tiller number at 20 x 10 cm spacing (5.50) (Table 30).

The significant influence of shade on number of tillers continued at 180 DAP and significantly higher number was recorded under young palms (12.22) and the lowest under mature palms, which was on par with those under medium palms (7.89 and 9.11 respectively).

Planting density significantly influenced the character during this stage also and the highest tiller production was noticed at 20 x 20 cm spacing (12.17) and the lowest at 20 x 10 cm spacing (7.50) (Table 31).

The data revealed that shade x spacing interaction had no significant influence on number of tillers during all the growth stages studied.

4.2.1.2 Number of Leaves

Shade levels significantly influenced the number of leaves produced at 60 DAP (Table X, Appendix) and significantly higher leaf number was noticed under the young palms (7.00) which was on par with those under medium palms (6.44).

Planting density also significantly influenced the number of leaves produced by Kacholam at 60 DAP, and the highest leaf number was noticed at a

Table 29: Mean number of tillers of Kacholam showing the interaction effect of oil palm shade conditions x spacing at 60 DAP

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	4.00	7.33	8.00	6.44
Young	5.00	8.00	11.33	8.11
Medium	4.67	7.00	8.00	6.56
Mature	3.33	5.00	7.33	5.22
Marginal Mean	4.25	6.83	8.67	
CD 0.05 (Shade)		**0.981**		
CD 0.05 (Spacing)		**0.850**		
CD 0.05 (Shade x spacing)		**NS**		

Table 30: Mean number of tillers of Kacholam showing the interaction effect of oil palm shade conditions x spacing at 120 DAP

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	4.33	9.00	11.67	8.33
Young	7.67	11.00	15.67	11.44
Medium	5.67	8.00	11.00	8.22
Mature	4.33	6.33	9.00	6.56
Marginal Mean	5.50	8.58	11.83	
CD 0.05 (Shade)		**1.208**		
CD 0.05 (Spacing)		**1.047**		
CD 0.05 (Shade x spacing)		**NS**		

N S - Non Significant

Table 31 : Mean number of tillers of Kacholam showing the interaction effect of oil palm shade conditions x spacing at 180 DAP

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	7.67	9.33	12.00	9.67
Young	9.33	12.33	15.00	12.22
Medium	7.00	9.33	11.00	9.11
Mature	6.00	7.00	10.67	7.89
Marginal Mean	7.50	9.50	12.17	
CD 0.05 (Shade)		1.347		
CD 0.05 (Spacing)		1.167		
CD 0.05 (Shade x spacing)		NS		

Table 32 : Mean number of leaves of Kacholam showing the interaction effect of oil palm shade conditions x spacing at 60 DAP

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	5.33	6.00	5.67	5.67
Young	5.67	7.00	8.33	7.00
Medium	5.33	6.00	8.00	6.44
Mature	3.33	5.67	6.00	5.00
Marginal Mean	4.92	6.17	7.00	
CD 0.05 (Shade)		1.089		
CD 0.05 (Spacing)		0.943		
CD 0.05 (Shade x spacing)		N S		

N S - Non Significant

Table 33 : Mean number of leaves of Kacholam showing the interaction effect of oil palm shade conditions x spacing at 120 DAP

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	7.67	9.00	10.67	9.11
Young	8.33	11.00	12.67	10.67
Medium	7.67	11.00	13.00	10.56
Mature	10.00	9.67	11.33	10.67
Marginal Mean	8.42	10.17	12.70	
CD 0.05 (Shade)		**NS**		
CD 0.05 (Spacing)		**1.555**		
CD 0.05 (Shade x spacing)		**NS**		

Table 34 : Mean number of leaves of Kacholam showing the interaction effect of oil palm shade conditions x spacing at 180 DAP

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	11.00	14.67	18.33	14.67
Young	15.00	16.00	17.33	16.11
Medium	12.00	13.67	17.33	14.33
Mature	13.00	14.33	17.33	14.89
Marginal Mean	12.75	14.67	17.58	
CD 0.05 (Shade)		**NS**		
CD 0.05 (Spacing)		**1.316**		
CD 0.05 (Shade x spacing)		**NS**		

N S - Non Significant

lower planting density, 20 x 20 cm spacing (7.00) which was on par with 20 x 15 cm spacing (6.17). The lowest leaf number was recorded at the closer spacing of 20 x 10 cm (4.92) (Table 32).

At 120 DAP, leaf number at the different shade levels was on par. However, higher number of leaves was noticed under the young and mature canopies (10.67). Spacing significantly influenced the number of leaves produced at 120 DAP, and the highest leaf number was recorded at 20 x 20 cm spacing (12.70) (Table 33).

The influence of shade on leaf production was not significant at 180 DAP. However, the influence of spacing was significant and the highest number of leaves was recorded at 20 x 20 cm spacing (17.58) (Table 34).

The results suggested that shade x spacing interaction was not significant during the three growth stages.

4.2.1.3 Leaf Area

Shade levels significantly influenced leaf area of the plants studied at 60 DAP (Table XI, Appendix) . Significantly higher value was noticed under young palms (69.35 cm2) which was on par with those under medium palms (65.36 cm^2). The leaf area under open condition (52.35 cm^2) and mature palms (51.10 cm^2) was on par. Planting density also influenced this character significantly and the highest value was recorded at 20 x 20 cm spacing (70.59 cm^2) and the lowest at 20 x 10 cm spacing (47.75 cm^2) at 60 DAP (Table 35).

At 120 DAP, the influence of shade on leaf area was not significant. However, the trend was continued during this growth stage and the highest leaf area was obtained at 20 x 20 cm spacing (130.22 cm^2) and the lowest at 20 x 10 cm spacing (84.79 cm^2) (Table 36).

At 180 DAP the influence of shade on leaf area became much pronounced and the highest leaf area was obtained under young palms (169.40 cm^2) which was on par with those under medium and mature oil palms (160.38 and 168.06 cm^2 respectively). Significant influence of planting density on leaf area continued during this growth stage and the highest leaf area

Table 35 : Mean leaf area of Kacholam showing the interaction effect of oil palm shade conditions x spacing at 60 DAP, cm^2

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	49.53	56.76	53.76	52.35
Young	55.40	69.28	83.38	69.35
Medium	53.25	60.32	82.50	65.36
Mature	32.83	57.76	62.72	51.10
Marginal Mean	47.75	61.02	70.59	
CD 0.05 (Shade)		**10.814**		
CD 0.05 (Spacing)		**9.365**		
CD 0.05 (Shade x spacing)		NS		

Table 36 : Mean leaf area of Kacholam showing the interaction effect of oil palm shade conditions x spacing at 120 DAP, cm^2

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	72.82	89.08	107.70	89.87
Young	82.84	110.37	135.22	109.48
Medium	79.55	115.62	140.15	111.77
Mature	103.94	104.47	137.82	115.41
Marginal Mean	84.79	104.89	130.22	
CD 0.05 (Shade)		NS		
CD 0.05 (Spacing)		**16.752**		
CD 0.05 (Shade x spacing)		NS		

Table 37 : Mean leaf area of Kacholam showing the interaction effect of oil palm shade conditions x spacing at 180 DAP, cm^2

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	105.80	146.93	188.31	147.01
Young	152.42	163.70	192.08	169.40
Medium	132.17	150.06	198.90	160.38
Mature	144.07	159.00	201.11	168.06
Marginal Mean	133.62	154.92	195.10	
CD 0.05 (Shade)		**16.580**		
CD 0.05 (Spacing)		**14.359**		
CD 0.05 (Shade x spacing)		**NS**		

Table 38 : Mean fresh weight of leaves of Kacholam showing the interaction effect of oil palm shade conditions x spacing at 60 DAP, g

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	1.60	1.77	1.70	1.69
Young	2.80	2.10	3.13	2.68
Medium	2.13	2.40	3.20	2.58
Mature	1.33	2.27	2.40	2.00
Marginal Mean	1.97	2.13	2.61	
CD 0.05 (Shade)		**0.476**		
CD 0.05 (Spacing)		**0.412**		
CD 0.05 (Shade x spacing)		**NS**		

was obtained at 20 x 20 cm spacing (195.10 cm^2) and the lowest at 20 x 10 cm spacing (133.62 cm^2) (Table 37).

The data revealed that shade x spacing interaction was not significant at all growth stages studied.

4.2.1.4 Fresh Weight of Leaves

The fresh weight of leaves was significantly different at 60 DAP (Table XII, Appendix). Significantly higher fresh leaf weight was recorded under young palms (2.68 g) which was on par with those under medium palms (2.58 g). The fresh weight of leaves under mature palms (2.00 g) and open (1.69 g) was on par. Planting density also significantly influenced this character and significantly highest value was recorded at 20 x 20 cm spacing (2.61 g). The fresh leaf weight at 20 x 15 cm (2.13 g) and 20 x 10 cm spacing (1.97 g), at 60 DAP (Table 38) were on par.

At 120 DAP significantly, higher fresh weight was recorded under medium palms (4.41 g) which were on par with mature palms (3.86 g) and the lowest fresh leaf weight was recorded under open condition (2.62 g). The effect of spacing on fresh weight of leaves was also significant and highest value was noted at 20 x 20 cm spacing (4.23 g) which was on par with 20 x 15 cm spacing (3.56 g) (Table 39).

At 180 DAP the data did not show significant difference. However, spacing levels significantly influenced fresh weight of leaves and the highest value was noted at 20 x 20 cm spacing (5.17 g) which was on par with 20 x 15 cm spacing (5.05 g) and the lowest under 20 x 10 cm spacing (4.25 g) (Table 40).

The data on interaction effect of shade and spacing was not significant at any of the growth stages.

4.2.1.5 Fresh Weight of Roots

Shade levels significantly influenced the fresh weight of roots 60 DAP (Table XIII, Appendix). Significantly, higher weight was recorded under young palms (4.04 g) and the lowest under open condition (0.97). The effect of

Table 39: Mean fresh weight of leaves of Kacholam showing the interaction effect of oil palm shade conditions x spacing at 120 DAP, g

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	2.23	2.63	3.00	2.62
Young	3.17	3.60	4.00	3.59
Medium	3.13	4.50	5.60	4.41
Mature	3.73	3.50	4.30	3.86
Marginal Mean	3.07	3.56	4.23	
CD 0.05 (Shade)		**0.520**		
CD 0.05 (Spacing)		**0.450**		
CD 0.05 (Shade x spacing)		**NS**		

Table 40: Mean fresh weight of leaves of Kacholam showing the interaction effect of oil palm shade conditions x spacing at DAP, g

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	4.07	5.30	5.63	5.00
Young	4.07	5.30	5.63	5.00
Medium	4.80	4.83	4.70	4.78
Mature	4.07	4.77	4.70	4.51
Marginal Mean	4.25	5.05	5.17	
CD 0.05 (Shade)		**NS**		
CD 0.05 (Spacing)		**0.458**		
CD 0.05 (Shade x spacing)		**NS**		

Table 41 : Mean fresh weight of roots of Kacholam showing the interaction effect of oil palm shade conditions x spacing at 60 DAP, g

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	0.57	0.83	1.50	0.97
Young	2.93	4.30	4.90	4.04
Medium	1.33	2.10	2.53	1.99
Mature	1.13	1.50	1.47	1.37
Marginal Mean	1.49	2.18	2.60	
CD 0.05 (Shade)		**0.292**		
CD 0.05 (Spacing)		**0.253**		
CD 0.05 (Shade x spacing)		**0.505**		

Table 42 : Mean fresh weight of roots of Kacholam showing the interaction effect of oil palm shade conditions x spacing at 120 DAP, g

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	0.73	0.97	1.83	1.18
Young	3.10	4.03	3.30	3.48
Medium	1.93	2.57	2.93	2.48
Mature	1.50	1.77	1.93	1.73
Marginal Mean	1.82	2.33	2.50	
CD 0.05 (Shade)		**0.223**		
CD 0.05 (Spacing)		**0.194**		
CD 0.05 (Shade x spacing)		**0.387**		

N.S. Non Significant

Table 43: Mean fresh weight of roots of Kacholam showing the interaction effect of oil palm shade conditions x spacing at 180 DAP, g

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	0.83	1.10	2.07	1.33
Young	3.20	4.53	4.21	3.98
Medium	4.40	2.67	3.07	2.71
Mature	1.83	2.10	2.23	2.06
Marginal Mean	2.07	2.60	2.90	
CD 0.05 (Shade)		**0.228**		
CD 0.05 (Spacing)		**0.197**		
CD 0.05 (Shade x spacing)		**0.394**		

Table 44 : Mean fresh weight of rhizome of Kacholam showing the interaction effect of oil palm shade conditions x spacing at 60 DAP,g

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	11.40	15.47	16.90	14.59
Young	10.13	14.13	18.87	14.38
Medium	7.40	9.33	15.73	10.82
Mature	9.40	11.27	19.33	13.33
Marginal Mean	9.58	12.55	17.71	
CD 0.05 (Shade)		**1.066**		
CD 0.05 (Spacing)		**0.923**		
CD 0.05 (Shade x spacing)		**1.846**		

N.S - Non Significant

spacing was also significant and the highest root weight was recorded at 20 x 20 cm spacing (2.60 g) and the lowest at 20 x 10 cm spacing (1.49 g) (Table 41).

At 120 DAP, significantly higher fresh root weight was recorded under young oil palm canopy (3.48 g) and the lowest under open condition (1.18 g). The effect of spacing on root fresh weight was also significant and the highest value was recorded at 20 x 20 cm spacing (2.50 g) which was on par with 20 x 15 cm spacing (2.33 g) (Table 39). Shade x spacing interaction was also significant and the highest fresh root weight was noticed under young palms at 20 x 15 cm spacing (4.03 g) (Table 42).

At 180 DAP also the fresh root weight varied with different shade levels and significantly, superior weight was recorded under young oil palm canopy (3.98 g). The spacing effect was also significant and the highest value was recorded at 20 x 20 cm spacing (2.90 g). Regarding interaction effect, significantly superior values were recorded under young palms at 20 x 15 cm and 20 x 20 cm spacing (4.53 and 4.21 g respectively) and under medium palms canopy at 20 x 10 cm spacing (4.40 g) (Table 43).

4.2.1.6 Fresh Weight of Rhizome

Shade significantly affected the fresh rhizome weight at 60 DAP (Table XIV, Appendix) and the highest weight was under open condition (14.59 g) which was on par with those under young palms (14.38 g). Fresh rhizome weight was also affected by spacing and the highest fresh weight was noticed at 20 x 20 cm spacing (17.71 g). Interaction effect was also significant and the highest weight was recorded under mature palms at 20 x 20 cm spacing (19.33 g) which was on par with those under young palms at the same spacing (18.87 g) (Table 44).

At 120 DAP also the effect of shade on fresh rhizome weight was significant and the highest value was noted under young palms (26.15 g). The spacing effect was also significant and the highest weight was recorded at 20 x 20 cm spacing (27.23 g) Interaction effect, however, was not significant during this growth stage (Table 45).

Table 45 : Mean fresh weight of rhizome of Kacholam showing the interaction effect of oil palm shade conditions x spacing at 120 DAP,g

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	13.80	19.27	24.07	19.04
Young	22.13	25.33	31.00	26.15
Medium	13.50	19.17	24.60	19.09
Mature	17.67	21.10	29.27	22.68
Marginal Mean	16.78	21.22	27.23	
CD 0.05 (Shade)		**2.021**		
CD 0.05 (Spacing)		**1.750**		
CD 0.05 (Shade x spacing)		NS		

Table 46 : Mean fresh weight of rhizome of Kacholam showing the interaction effect of oil palm shade conditions x spacing at 180 DAP,g

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	19.87	25.27	28.47	24.53
Young	25.00	27.40	32.80	28.40
Medium	18.53	23.67	29.00	23.73
Mature	21.43	25.23	33.51	26.72
Marginal Mean	21.21	25.39	30.94	
CD 0.05 (Shade)		**1.866**		
CD 0.05 (Spacing)		**1.616**		
CD 0.05 (Shade x spacing)		**NS**		

N.S - Non Significant

At 180 DAP influence of shade on fresh weight was significant and the highest value was recorded under young palms (28.40 g) which was on par with those under mature palms (26.72 g). Spacing also affected this character significantly with the highest value recorded at 20 x 20 cm spacing (30.94 g).

Interaction effect was not significant at 180 DAP (Table 46).

4.2.2 Physiological Parameters

4.2.2.1 Dry Matter Content of Leaves

Shade significantly influenced the dry weight of the leaves at 60 DAP (Table XV, Appendix) and the highest was recorded under young palms (1.70 g) which was on par with those under medium palms (1.51 g). The leaf dry weights recorded under open condition (1.10 g) and mature palms (1.30 g) were on par. The effect of spacing on leaf dry weight was not significant during this growth stage (Table 47).

At 120 DAP the influence of shade on leaf dry weight was not significant, while spacing levels exerted significant influence. Significantly, superior leaf dry weight was recorded at 20 x 20 cm spacing (1.97 g) and the lowest at 20 x 10 cm spacing (1.62 g) (Table 48).

At 180 DAP both shade and spacing significantly influenced leaf dry weight. The highest leaf dry weight was recorded from mature oil palm canopy (3.91 g) which was on par with the value under young palms and open (both 3.62 g). The lowest leaf dry weight was recorded under medium palms (2.96 g). Significantly highest value was recorded at 20 x 20 cm spacing (4.01 g) and the lowest value at 20 x 10 cm spacing (3.01g) (Table 49).

Shade x spacing interaction was not significant during all growth stages.

4.2.2.2 Dry matter Content of Roots

The effect of different levels of shade and spacing, and their interaction on root dry weight was significant at 60 DAP (Table XVI, Appendix). The highest dry weight was recorded under young oil palm canopy (1.74 g). Among spacing levels, significantly superior value was recorded at 20 x 20 cm spacing

Table 47 : Mean dry weight of leaves of Kacholam showing the interaction effect of oil palm shade conditions x spacing at 60 DAP, g

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	1.04	1.15	1.11	1.10
Young	1.83	1.37	1.89	1.70
Medium	1.39	1.57	1.57	1.51
Mature	0.87	1.48	1.57	1.30
Marginal Mean	1.28	1.39	1.54	
CD 0.05 (Shade)		0.317		
CD 0.05 (Spacing)		NS		
CD 0.05 (Shade x spacing)		NS		

Table 48 : Mean dry weight of leaves of Kacholam showing the interaction effect of oil palm shade conditions x spacing at 120 DAP, g

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	1.52	1.79	2.04	1.79
Young	1.55	1.85	1.95	1.78
Medium	1.60	1.93	1.98	1.84
Mature	1.81	1.92	1.92	1.88
Marginal Mean	1.62	1.87	1.97	
CD 0.05 (Shade)		N S		
CD 0.05 (Spacing)		0.159		
CD 0.05 (Shade x spacing)		N S		

Table 49: **Mean dry weight of leaves of Kacholam showing the interaction effect of oil palm shade conditions x spacing at 180 DAP, g**

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	2.94	3.84	4.08	3.62
Young	2.94	3.84	4.08	3.62
Medium	2.48	2.88	3.51	2.96
Mature	3.67	3.68	4.38	3.91
Marginal Mean	3.01	3.56	4.01	
CD 0.05 (Shade)		0.333		
CD 0.05 (Spacing)		0.288		
CD 0.05 (Shade x spacing)		NS		

Table 50: **Mean dry weight of roots of Kacholam showing the interaction effect of oil palm shade conditions x spacing at 60 DAP, g**

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	0.27	0.40	0.72	0.46
Young	1.26	1.85	2.11	1.74
Medium	0.57	0.90	1.09	0.85
Mature	0.50	0.66	0.64	0.60
Marginal Mean	0.65	0.95	1.14	
CD 0.05 (Shade)		0.127		
CD 0.05 (Spacing)		0.110		
CD 0.05 (Shade x spacing)		0.219		

(1.14 g). Interaction effect showed that the highest values were recorded under young palms at 20 x 20 cm spacing (2.11 g) (Table 50).

At 120 DAP the same trend was continued and significantly superior dry weight was observed under young palms (1.86 g) at 20 x 20 cm spacing (1.30 g). Regarding interaction effect, significantly higher root dry weight was at 120 DAP under young palms at 20 x 20 cm spacing (2.26 g) (Table 51).

At 180 DAP also the same trend continued and during this stage, significantly superior value was observed under young oil palm canopy (1.97 g) at 20 x 20 cm spacing (1.42 g). With regard to interaction effect, the highest dry weight of roots was recorded under young palms at 20 x 20 cm spacing (2.39 g) (Table 52).

4.2.2.3 Dry Matter Content of Rhizomes

The effect of different levels of shade, spacing and their interaction effect on rhizome dry matter was significant at 60 DAP (Table XVII, Appendix) . Significantly superior values were recorded under open condition (8.43 g) which was on par with those under young palms (7.92 g). Among different levels of spacing 20 x 20 cm recorded highest value of 9.70 g. Regarding interaction effect, the highest values were recorded at 20 x 20 cm spacing under mature, open, young and medium palm canopies (10.22, 9.77, 9.72 and 9.10 g respectively) and at 20 x 15 cm spacing under open condition (8.94 g) (Table 53).

At 120 DAP also the effect of shade and spacing was significant and significantly superior values were recorded under young oil palm canopy (15.63 g) and at 20 x 20 cm spacing (15.71 g) (Table 54).

At 180 DAP, the effect of shade on rhizome dry weight was not significant. However, significant difference was observed with regard to spacing and the highest value was noted at 20 x 20 cm spacing (18.22 g) (Table 55).

The data suggested that shade x spacing interaction was not significant during the 120 DAP and 180 DAP.

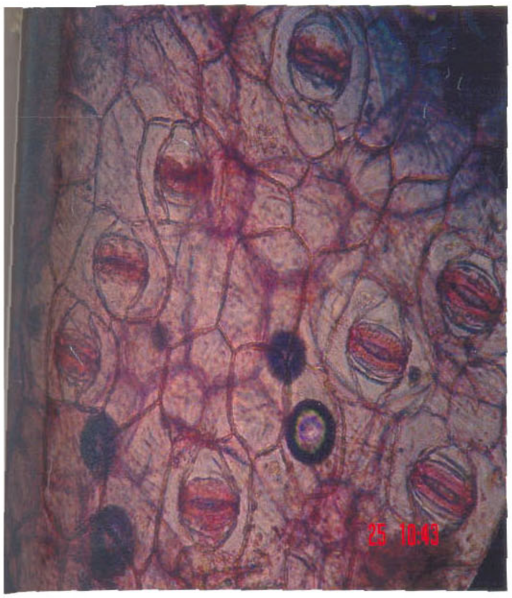
Table 51: Mean dry weight of roots of Kacholam showing the interaction effect of oil palm shade conditions x spacing at 120 DAP, g

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	0.36	0.48	0.90	0.58
Young	1.34	1.98	2.26	1.86
Medium	0.83	1.11	1.20	1.05
Mature	0.66	0.78	0.85	0.77
Marginal Mean	0.80	1.09	1.30	
CD 0.05 (Shade)		**0.120**		
CD 0.05 (Spacing)		**0.104**		
CD 0.05 (Shade x spacing)		**0.208**		

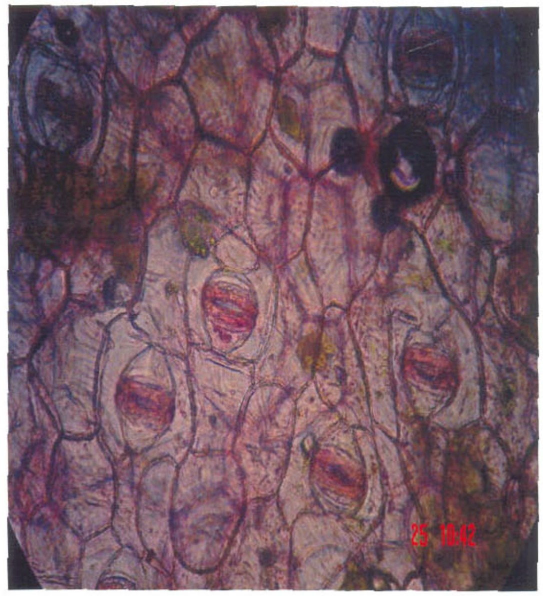
Table 52 : Mean dry weight of roots of Kacholam showing the interaction effect of oil palm shade conditions x spacing at 180 DAP, g

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	0.39	0.52	0.97	0.63
Young	1.38	2.14	2.39	1.97
Medium	1.04	1.15	1.32	1.17
Mature	0.81	0.93	0.99	0.91
Marginal Mean	0.90	1.18	1.42	
CD 0.05 (Shade)		**0.101**		
CD 0.05 (Spacing)		**0.087**		
CD 0.05 (Shade x spacing)		**0.175**		

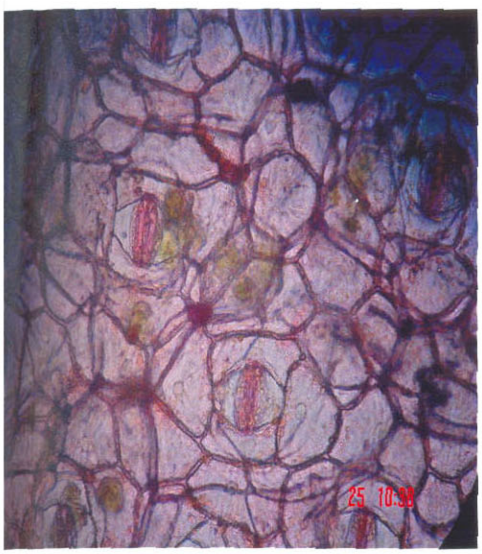
N.S. - Non Significant



A. Open



B. Young



C. Medium

D. Mature

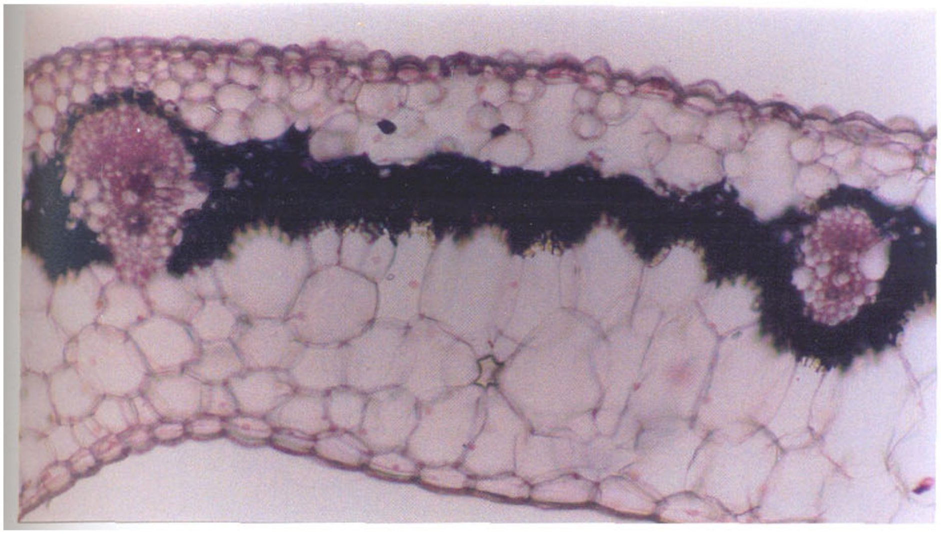
Plate No. 12 Stomatal density of Kacholam under different shade conditions

Table 53: Mean dry weight of rhizome of Kacholam showing the interaction effect of oil palm shade conditions x spacing at 60 DAP, g

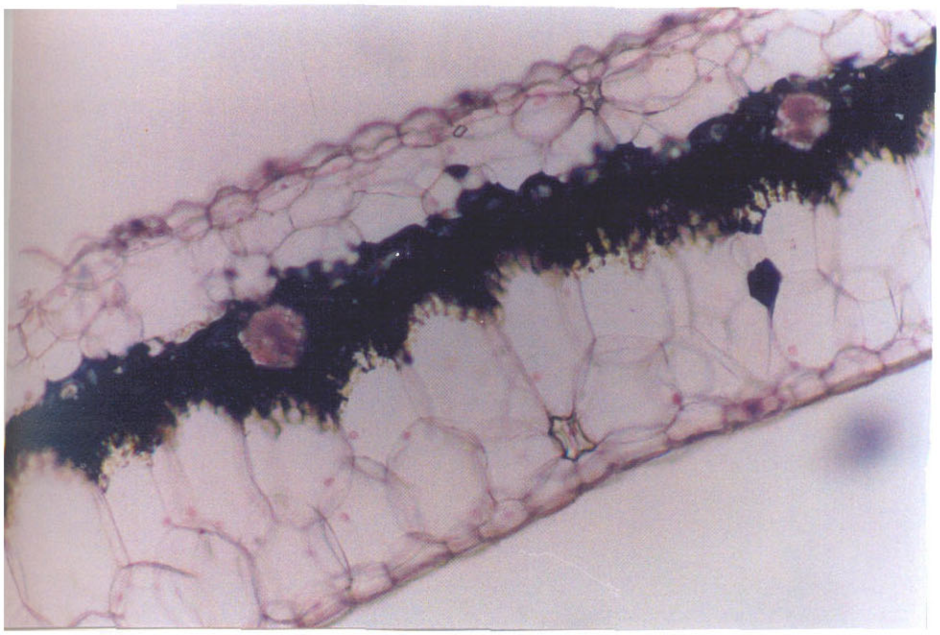
Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	6.57	8.94	9.77	8.43
Young	5.85	8.17	9.72	7.92
Medium	4.28	5.40	9.10	6.26
Mature	5.40	6.51	10.20	7.38
Marginal Mean	5.54	7.26	9.70	
CD 0.05 (Shade)		0.771		
CD 0.05 (Spacing)		0.668		
CD 0.05 (Shade x spacing)		1.336		

Table 54 : Mean dry weight of rhizome of Kacholam showing the interaction effect of oil palm shade conditions x spacing at 120 DAP, g

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	9.62	11.51	14.38	11.84
Young	13.23	15.14	18.53	15.63
Medium	8.07	11.45	13.46	10.99
Mature	10.56	12.61	16.46	13.21
Marginal Mean	10.37	12.68	15.71	
CD 0.05 (Shade)		1.316		
CD 0.05 (Spacing)		1.140		
CD 0.05 (Shade x spacing)		NS		



A. Open



B. Young

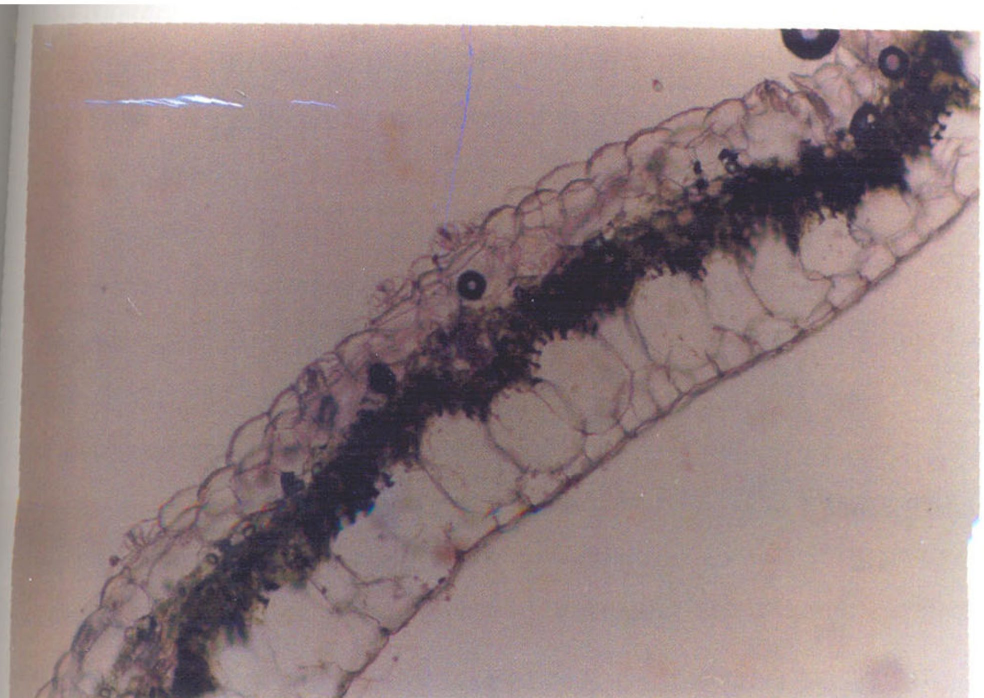
Plate 13. Variation in leaf anatomy of Kacholam under open and young oil palm shade conditions

Table 55: Mean dry weight of rhizome of Kacholam showing the interaction effect of oil palm shade conditions x spacing at 180 DAP, g

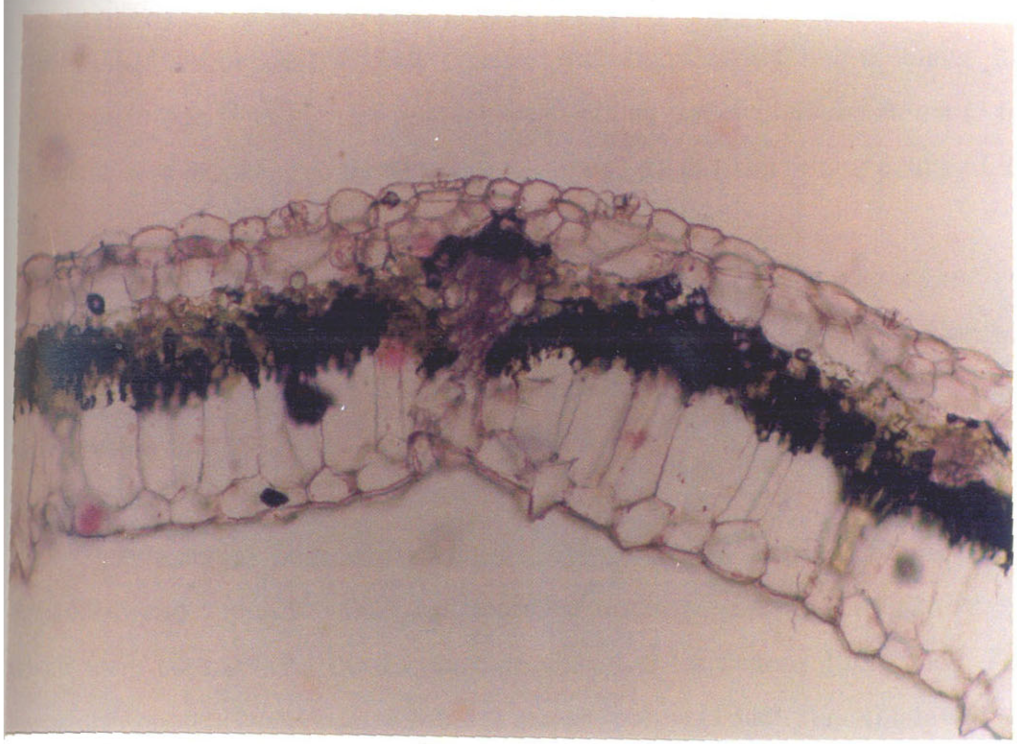
Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	11.97	15.22	17.14	14.77
Young	15.06	16.50	19.75	17.10
Medium	14.17	14.90	17.20	15.42
Mature	12.91	15.20	18.77	15.63
Marginal Mean	13.52	15.45	18.22	
CD 0.05 (Shade)		NS		
CD 0.05 (Spacing)		1.525		
CD 0.05 (Shade x spacing)		NS		

Table 56 : Mean leaf area index of Kacholam showing the interaction effect of oil palm shade conditions x spacing at 60 DAP

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	0.25	0.28	0.27	0.27
Young	0.28	0.35	0.42	0.35
Medium	0.27	0.30	0.41	0.33
Mature	0.16	0.29	0.31	0.26
Marginal Mean	0.24	0.31	0.35	
CD 0.05 (Shade)		0.054		
CD 0.05 (Spacing)		0.047		
CD 0.05 (Shade x spacing)		NS		



C. Medium



D. Mature

Plate 14. Variation in leaf anatomy of Kacholam under medium and mature oil palm shade conditions

4.2.2.4 Leaf Area Index

Shade levels exhibited significant influence on leaf area index at 60 DAP (Table XVIII, Appendix). Significantly superior value was noted under young palms (0.35) which was on par with medium palms (0.33). The lowest index was under mature palms (0.26) which were on par with open (0.27). Spacing levels also significantly influenced leaf area index at this stage and the highest index was noted at 20 x 20 cm spacing (0.35) and the lowest at 20 x 10 cm spacing (0.24) (Table 56).

At 120 DAP shade levels did not significantly alter the leaf area index . However, spacing levels exhibited pronounced effect and the highest value was observed at 20 x 20 cm spacing (0.43) (Table 57).

At 180 DAP, influence of shade on leaf area index became pronounced and the highest value was superior index recorded under young oil palm canopy (0.42) which was on par with medium and mature palms (0.40 and 0.42 respectively). Levels of spacing also produced significant influence and the highest value was registered at 20 x 20 cm spacing (0.49) (Table 58).
The data revealed no significant difference with respect to shade x spacing interaction.

4.2.2.5 Specific Leaf Weight (SLW)

At 60 DAP, shade levels significantly influenced specific leaf weight (Table XIX, Appendix) and significantly higher value was recorded under open and young oil palm canopy (0.03). Spacing also affected this character significantly and the highest value was recorded at 20 x 10 cm spacing (0.03) which was on par with that at 20 x 20 cm spacing (0.03) (Table 59).

The influence of shade on specific leaf weight was significant at 120 DAP also and the highest values were recorded under open condition (0.03). Spacing and interaction effects did not alter this character during this stage (Table 60).

Specific leaf weight was significantly influenced by both shade and spacing at 180 DAP. Significantly, higher values were noted under open condition and under young oil palm canopy (0.03, 0.03). Spacing also altered

Table 57 : Mean leaf area index of Kacholam showing the interaction effect of oil palm shade conditions x spacing at 120 DAP

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	0.24	0.30	0.36	0.30
Young	0.28	0.37	0.45	0.37
Medium	0.27	0.39	0.47	0.37
Mature	0.35	0.35	0.46	0.39
Marginal Mean	0.28	0.35	0.43	
CD 0.05 (Shade)		NS		
CD 0.05 (Spacing)		0.056		
CD 0.05 (Shade x spacing)		NS		

Table 58 : Mean leaf area index of Kacholam showing the interaction effect of oil palm shade conditions x spacing at 180 DAP

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	0.26	0.37	0.47	0.37
Young	0.38	0.41	0.48	0.42
Medium	0.33	0.38	0.50	0.40
Mature	0.36	0.40	0.50	0.42
Marginal Mean	0.33	0.39	0.49	
CD 0.05 (Shade)		0.042		
CD 0.05 (Spacing)		0.036		
CD 0.05 (Shade x spacing)		NS		

N.S : Non Significant

Table 59 : Mean specific leaf weight of Kacholam showing the interaction effect of oil palm shade conditions x spacing at 60 DAP, g cm $^{-2}$

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	0.03	0.03	0.03	0.03
Young	0.03	0.02	0.02	0.03
Medium	0.02	0.02	0.02	0.02
Mature	0.02	0.02	0.02	0.02
Marginal Mean	0.03	0.02	0.03	
CD 0.05 (Shade)		**0.004**		
CD 0.05 (Spacing)		**0.003**		
CD 0.05 (Shade x spacing)		**N.S.**		

Table 60 : Mean specific leaf weight of Kacholam showing the interaction effect of oil palm shade conditions x spacing at 120 DAP, g cm $^{-2}$

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	0.03	0.03	0.03	0.03
Young	0.03	0.02	0.02	0.02
Medium	0.02	0.02	0.02	0.02
Mature	0.02	0.02	0.02	0.02
Marginal Mean	0.03	0.02	0.02	
CD 0.05 (Shade)		**0.003**		
CD 0.05 (Spacing)		**NS**		
CD 0.05 (Shade x spacing)		**NS**		

N S - Non Significant

this character and the highest value was noted at 20 x 20 cm spacing (0.03) which was on par with 20 x 10 cm and 20 x 15 cm spacing (0.03, 0.03) (Table 61).

The results indicated that shade x spacing interaction effect was not significant at all the growth stages.

4.2.2.6 Water Potential

Shade levels significantly affected water potential of the leaves at 180 DAP (Table XX, Appendix) and significantly higher values were recorded under medium palms (0.23 Mpa) and the lowest under open (0.10 Mpa). Spacing did not significantly changed water potential. However, the interaction effect was significant. The highest value was recorded under medium palms at 20 x 10 cm spacing (0.27) which was on par with those under mature palms at 20 x 20 cm spacing (0.25) (Table 62).

4.2.2.7 Stomatal conductance

Shade levels significantly influenced the stomatal conductance of the leaves (Table XX, Appendix) and the highest value was recorded under open condition (0.095 µmol sec^{-1}) and the lowest under medium palms (0.016 µmol sec^{-1}).

It was found that the interaction effect between shade and spacing was not significant (Table 63).

4.2.2.8 Photosynthetically Active Radiation (PAR)

Shade levels significantly influenced the PAR on the leaf surface at 180 DAP (Table XX, Appendix), and the highest value was recorded under the open condition (625.44 µmol sec^{-1}) and the lowest value under medium palms (164 µmol sec^{-1}). The interaction of shade and spacing was not significant (Table 64).

4.2.3 Anatomical Characters

The data on the anatomical characters of leaves of Kacholam at 180 DAP are presented below.

Table 61 : Mean specific leaf weight of Kacholam showing the interaction effect of oil palm shade conditions x spacing at 180 DAP, g cm $^{-2}$

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	0.03	0.03	0.03	0.03
Young	0.03	0.03	0.03	0.03
Medium	0.02	0.02	0.02	0.02
Mature	0.03	0.02	0.02	0.02
Marginal Mean	0.03	0.03	0.02	
CD 0.05 (Shade)		**0.003**		
CD 0.05 (Spacing)		**0.002**		
CD 0.05 (Shade x spacing)		**NS**		

Table 62 : Mean water potential of Kacholam showing the interaction effect of oil palm shade conditions x spacing at 180 DAP, Mpa

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	0.09	0.10	0.11	0.10
Young	0.12	0.21	0.16	0.16
Medium	0.27	0.21	0.20	0.23
Mature	0.20	0.15	0.25	0.20
Marginal Mean	0.17	0.17	0.18	
CD 0.05 (Shade)		**0.015**		
CD 0.05 (Spacing)		**NS**		
CD 0.05 (Shade x spacing)		**0.025**		

N S - Non Significant

Table 63 : Mean stomatal conductance of Kacholam showing the interaction effect of oil palm shade conditions x spacing at 180 DAP, μ mol m^{-2} s^{-1}

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	0.09	0.10	0.09	0.10
Young	0.08	0.08	0.07	0.07
Medium	0.02	0.15	0.02	0.02
Mature	0.04	0.04	0.04	0.04
Marginal Mean	0.06	0.06	0.06	
CD 0.05 (Shade)		0.006		
CD 0.05 (Spacing)		NS		
CD 0.05 (Shade x spacing)		NS		

Table 64: Mean photosynthetically active radiation of Kacholam showing the interaction effect of oil palm shade conditions x spacing at 180 DAP, μ mol m^{-2} s^{-1}

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	602.67	648.00	625.67	625.44
Young	226.33	223.33	222.00	223.89
Medium	166.00	163.33	162.67	164.00
Mature	276.00	274.67	282.33	274.67
Marginal Mean	317.75	327.33	323.17	
CD 0.05 (Shade)		15.252		
CD 0.05 (Spacing)		NS		
CD 0.05 (Shade x spacing)		NS		

N.S - Non Significant

4.2.3.1 Stomatal Density

The various shade levels under which the plants were grown had significant influence on the stomatal density of the leaves (Table XXI, Appendix). The highest stomatal density was noted under open condition (3.44 mm^{-2}) while the values under young, medium and mature palm canopies were on par (2.00, 1.78 and 2.22 mm^{-2} respectively). Spacing levels and shade x spacing interaction did not significantly affect stomatal density of Kacholam (Table 65).

4.2.3.2 Epidermal Thickness

The different shade levels significantly affected the epidermal thickness (Table XXI, Appendix) . Significantly higher values were recorded under open condition (104.04 μm) Epidermal thickness of leaves under young and mature oil palm canopies was on par (58.69 and 54.50 μm respectively). Minimum epidermal thickness was noted under medium palms (45.97 μm). The epidermal thickness varied significantly under different levels of spacing and the highest thickness was recorded at 20 x 20 cm spacing (73.46 μm) and the lowest at 20 x 10 cm spacing (58.02 μm). Shade x spacing interaction had no significant influence on epidermal thickness of Kacholam leaves (Table 66).

4.2.3.3 Mesophyll Thickness

The shade levels significantly affected the mesophyll thickness of the leaves (Table XXI, Appendix). The highest thickness was recorded under open condition (861.31 μm) and the lowest value under medium oil palm canopy (541.18 μm). The influence of spacing on mesophyll thickness was also significant and the highest value was recorded under 20 x 20 cm spacing (731.73 μm) The values under 20 x 15 cm and 20 x 10 cm spacing were on par (674.57 and 628.83 μm respectively). However, shade x spacing interaction had no significant influence on the mesophyll thickness of Kacholam leaves (Table 67).

Table 65 : Mean stomatal density of Kacholam showing the interaction effect of oil palm shade conditions x spacing at 180 DAP, mm^{-2}

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	3.00	3.33	4.00	3.44
Young	2.00	2.00	2.00	2.00
Medium	1.67	2.00	1.67	1.78
Mature	2.00	2.33	2.33	2.22
Marginal Mean	2.17	2.42	2.50	
CD 0.05 (Shade)		**0.479**		
CD 0.05 (Spacing)		**NS**		
CD 0.05 (Shade x spacing)		**NS**		

Table 66 : Mean epidermal thickness of Kacholam showing the interaction effect of oil palm shade conditions x spacing at 180 DAP, µm

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	100.61	104.04	107.47	104.04
Young	48.02	58.31	69.74	58.69
Medium	41.16	42.30	51.45	44.97
Mature	42.30	56.02	65.17	54.50
Marginal Mean	58.02	65.17	73.46	
CD 0.05 (Shade)		**6.064**		
CD 0.05 (Spacing)		**5.251**		
CD 0.05 (Shade x spacing)		**NS**		

N S - Non Significant

4.2.3.4 Number of Vascular Bundles

Shade significantly influenced the number of vascular bundles in the leaves (Table XXI, Appendix) and the number was higher under open condition (10.22 cm^{-1}). The lowest number was recorded under medium palms (5.78 cm^{-1}). Planting density also significantly influenced the number of vascular bundles and the highest number was noted at 20 x 20 cm spacing (8.83 cm^{-1}) which was on par with that at 20 x 15 cm spacing (8.08 cm^{-1}). Shade x spacing interaction was not significant (Table 68).

4.2.4 Biochemical Characters

Data on biochemical characters viz; starch, ash, chlorophyll 'a', chlorophyll 'b' and total chlorophyll were recorded at 180 DAP by analyzing the plant samples and oil and oleoresin by analyzing the rhizome samples at harvest.

4.2.4.1 Starch Content

Shade levels significantly influenced the starch content of Kacholam (Table XXII, Appendix). Starch content was significantly higher under the shade conditions. The highest content was noticed under medium palms (3.67 %) which was on par with those under mature (3.45 %) and young palms (3.22 %).

Levels of spacing also significantly influenced the starch content and the highest value was recorded at 20 x 20 cm spacing (3.56 %) which was on par with 20 x 15 cm spacing (3.47 %). Shade x spacing interaction was not significant (Table 69).

4.2.4.2 Ash

Ash content was significantly influenced by shade (Table XXII, Appendix) and superior value was recorded under medium palms (20.70 %) which were on par with those under young oil palm canopy (20.55 %). The lowest ash content was observed under mature palms (13.93 %), which was on par with open condition (14.97 %).

Table 67 : Mean mesophyll thickness of Kacholam showing the interaction effect of oil palm shade conditions x spacing at 180 DAP, µm

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	788.90	846.06	948.97	861.31
Young	651.70	708.87	754.60	705.06
Medium	491.63	548.80	583.10	541.18
Mature	583.10	594.53	640.27	605.97
Marginal Mean	628.83	674.57	731.73	
CD 0.05 (Shade)		**55.969**		
CD 0.05 (Spacing)		**48.470**		
CD 0.05 (Shade x spacing)		**NS**		

Table 68 : Mean number of vascular bundles of Kacholam showing the interaction effect of oil palm shade conditions x spacing at 180 DAP, 0. 5 cm^{-1}

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	9.00	10.33	11.33	10.22
Young	6.67	7.33	8.00	7.33
Medium	5.00	5.67	6.67	5.78
Mature	8.33	9.00	9.33	8.89
Marginal Mean	7.25	8.08	8.83	
CD 0.05 (Shade)		**0.778**		
CD 0.05 (Spacing)		**0.674**		
CD 0.05 (Shade x spacing)		**NS**		

N S - Non Significant

Table 69 : Mean Starch content of Kacholam rhizome showing the interaction effect of oil palm shade conditions x spacing at 180 DAP, %

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	2.32	3.09	3.15	2.85
Young	2.25	3.65	3.77	3.22
Medium	3.55	3.70	3.73	3.67
Mature	3.31	3.46	3.58	3.45
Marginal Mean	2.86	3.47	3.56	
CD 0.05 (Shade)		0.493		
CD 0.05 (Spacing)		0.427		
CD 0.05 (Shade x spacing)		NS		

Table 70 : Mean Ash content of Kacholam showing the interaction effect of oil palm shade conditions x spacing at 180 DAP, %

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	11.77	14.32	18.81	14.97
Young	12.20	23.89	25.55	20.55
Medium	15.21	20.81	26.09	20.70
Mature	12.54	11.67	17.57	13.93
Marginal Mean	12.93	17.67	22.01	
CD 0.05 (Shade)		4.296		
CD 0.05 (Spacing)		3.721		
CD 0.05 (Shade x spacing)		NS		

NS - Non Significant

Ash content varied significantly with planting density and highest value was at 20 x 20 cm spacing (22.01 %) and the lowest at 20 x 10 cm spacing (12.93 %). Interaction effect on ash content was not significant (Table 70).

4.2.4.3 Chlorophyll 'a'

Neither shade nor spacing levels influenced the chlorophyll 'a' content of Kacholam leaves significantly (Table XXII Appendix and Table 71).

4.2.4.4 Chlorophyll 'b'

Shade had significant influence on chlorophyll 'b' content (Table XXII, Appendix). The highest value was noted under medium oil palm shade (0.064 mg g^{-1}) which was on par with young oil palm canopy (0.055 mg g^{-1}). Spacing levels also significantly influenced chlorophyll 'b' content. The highest value was recorded at 20 x 10 cm spacing (0.062 mg g^{-1}) and the values at 20 x 15 cm and 20 x 20 cm spacing were on par (0.046 and 0.042 mg g^{-1} respectively).

Shade x spacing interaction effect was also significant and the highest value was noted under young oil palm canopy at 20 x 10 cm spacing (0.093 mg g^{-1}) (Table 72).

4.2.4.5 Total chlorophyll

The total chlorophyll content of Kacholam leaves was significantly altered by shade levels (Table XXII, Appendix). The highest value was recorded under medium palms (0.209 mg g^{-1}) and the lowest under open condition (0.062 mg g^{-1}). This was on par with mature palms (0.069 mg g^{-1}). Planting density also affected total chlorophyll content and significantly superior value was observed at 20 x 10 cm spacing (0.125 mg g^{-1}) which was on par with 20 x 20 cm spacing (0.118 mg g^{-1}). Shade x spacing interaction was also significant and the highest content was noted under medium oil palm canopy at 20 x 10 cm spacing (0.232 mg g^{-1}) which was on par with 20 x 20 cm spacing (0.223 mg g^{-1}) (Table 73).

4.2.4.6 Volatile Oil

Shade levels significantly influenced the volatile oil content of Kacholam (Table XXII, Appendix) and the highest value was noted under

Table 71: Mean content of chlorophyll ' a' of Kacholam showing the interaction effect of oil palm shade conditions x spacing at 180 DAP, mg g^{-1}

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	0.08	0.13	0.02	0.08
Young	0.05	0.15	0.03	0.08
Medium	0.09	0.08	0.08	0.08
Mature	0.03	0.02	0.03	0.03
Marginal Mean	0.06	0.96	0.04	
CD 0.05 (Shade)		NS		
CD 0.05 (Spacing)		NS		
CD 0.05 (Shade x spacing)		NS		

Table 72 : Mean content of chlorophyll ' b' of Kacholam showing the interaction effect of oil palm shade conditions x spacing at 180 DAP, mg g^{-1}

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	0.04	0.04	0.04	0.04
Young	0.09	0.04	0.04	0.06
Medium	0.06	0.07	0.07	0.06
Mature	0.05	0.04	0.03	0.04
Marginal Mean	0.06	0.05	0.04	
CD 0.05 (Shade)		**0.011**		
CD 0.05 (Spacing)		**0.009**		
CD 0.05 (Shade x spacing)		**0.018**		

N S - Non Significant

Table 73 : Mean total chlorophyll content of Kacholam showing the interaction effect of oil palm shade conditions x spacing at 180 DAP, mg g $^{-1}$

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	0.07	0.07	0.06	0.06
Young	0.13	0.11	0.13	0.12
Medium	0.23	0.17	0.22	0.21
Mature	0.08	0.07	0.06	0.07
Marginal Mean	0.13	0.10	0.12	
CD 0.05 (Shade)		**0.008**		
CD 0.05 (Spacing)		**0.007**		
CD 0.05 (Shade x spacing)		**0.014**		

Table 74 : Mean content of essential oil of Kacholam rhizome showing the interaction effect of oil palm shade conditions x spacing at harvest, %

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	1.54	1.56	1.63	1.58
Young	1.94	1.84	1.97	1.91
Medium	1.36	1.51	1.55	1.48
Mature	1.06	9.00	1.38	1.11
Marginal Mean	1.48	1.45	1.63	
CD 0.05 (Shade)		**0.134**		
CD 0.05 (Spacing)		**0.112**		
CD 0.05 (Shade x spacing)		**NS**		

N S - Non Significant

young oil palm canopy (1.91 %). The volatile oil content under open condition (1.58 %) was on par with those recorded under medium palms (1.48 %).

Spacing also affected the volatile oil content of the rhizomes and the highest content was at 20 x 20 cm spacing (1.63 %). Interaction effect was not significant (Table 74).

4.2.4.7 ***Oleoresin***

Shade significantly influenced the oleoresin content of Kacholam rhizomes (Table XXII, Appendix) and the highest content was recorded under open condition (4.66 %) which was on par with those under young oil palm canopy (4.53 %). Spacing levels did not affect oleoresin content while the interaction effect was significant. The highest value was observed under open condition at 20 x 15 cm spacing (4.71 %) (Table 75).

4.2.5 Harvest Index

Shade significantly affected the harvest index of Kacholam (Table XXIII, Appendix) and the highest value was recorded under open condition (0.576) and the lowest under mature palms (0.455). Spacing levels also influenced harvest index and significantly superior value was recorded at 20 x 10 cm spacing (0.531) which was on par with 20 x 15 cm spacing (0.523).

Shade x spacing interaction was also significant and the highest value was recorded under open condition at 20 x 15 cm spacing (0.596) which was on par with the value at 20 x 20 cm spacing (0.579) (Table 76).

4.2.6 Benefit Cost Analysis

4.2.6.1 Yield ha^{-1}

The per ha yield of Kacholam rhizomes grown in open and as intercrop in oil palm plantations of various age groups at different levels of spacing are presented in Table 77.

Under open condition the highest yield was obtained from plants grown at 20 x 10 cm spacing (5.68 t ha^{-1}) and the lowest from plants grown at 20 x 20 cm spacing (2.87 t ha^{-1}). The yield from 20 x 15 cm spacing was 3.80 t ha^{-1}.

Table 75 : Mean content of oleoresin of Kacholam showing interaction effect of oil palm shade conditions x spacing at 180 DAP, %

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	4.63	4.71	4.65	4.66
Young	4.37	4.60	4.62	4.53
Medium	4.30	4.40	4.53	4.41
Mature	4.50	4.36	4.32	4.35
Marginal Mean	4.45	4.52	4.50	
CD 0.05 (Shade)		**0.136**		
CD 0.05 (Spacing)		**NS**		
CD 0.05 (Shade x spacing)		**0.236**		

Table 76: Mean harvest index of Kacholam showing the interaction effect of oil palm shade conditions x spacing at harvest

Shade condition	Spacing			
	20 x 10 cm	20 x 15 cm	20 x 20 cm	Marginal Mean
Open	0.55	0.60	0.58	0.58
Young	0.56	0.53	0.47	0.52
Medium	0.53	0.50	0.49	0.51
Mature	0.48	0.47	0.42	0.46
Marginal Mean	0.53	0.52	0.49	
CD 0.05 (Shade)		**0.014**		
CD 0.05 (Spacing)		**0.012**		
CD 0.05 (Shade x spacing)		**0.025**		

N S - Non Significant

Under young oil palm canopy the highest yield was derived from plants grown at 20 x 10 cm spacing (3.16 t ha^{-1}) and minimum from plants grown at 20 x 20 cm spacing (1.62 t ha^{-1}). The yield from 20 x 15 cm spacing was 2.12 t ha^{-1}.

Under medium oil palm canopy, higher yield was realised from plants grown at 20 x 10 cm spacing (3.13 t ha^{-1}) and the lowest from plants grown at 20 x 20 cm spacing (1.62 t ha^{-1}). The yield from 20 x 15 cm spacing was 2.10 t ha^{-1}.

Under mature oil palm canopy the highest yield was recorded from plants grown at 20 x 10 cm spacing (3.08 t ha^{-1}) and the lowest from plants grown at 20 x 20 cm spacing (1.58 t ha^{-1}). The yield from 20 x 15 cm spacing was 2.06 t ha^{-1}.

4.2.6.2 Income ha^{-1}

The total income of Kacholam grown in open and as intercrop in oil palm plantations of various age groups at different levels of spacing are presented in Table 77.

Under open condition, the highest income was obtained from plants grown at 20 x 10 cm spacing (Rs. 3,95,571) and the lowest from plants grown at 20 x 20 cm spacing (Rs. 1,99,778). The income from 20 x 15 cm spacing was Rs. 2,64,991.

When Kacholam was grown as intercrop under young oil palm canopy, higher income was recorded from plants grown at 20 x 10 cm spacing (Rs. 2,20,048) and the lowest from plants grown at 20 x 20 cm spacing (Rs. 1,13,101). The income from 20 x 15 cm spacing was Rs. 1,47,658.

Under medium oil palm canopy, higher income was obtained from plants grown at 20 x 10 cm spacing (Rs. 2,18,269) and the lowest from plants grown at 20 x 20 cm spacing (Rs. 1,12,622). The income from 20 x 15 cm spacing was Rs. 1,46,571.

Kacholam grown as intercrop under mature oil palm canopy recorded higher income from plants grown at 20 x 10 cm spacing (Rs. 2, 14,659) and the lowest from plants grown at 20 x 20 cm spacing (Rs. 1,09,901). The income from 20 x 15 cm spacing was Rs. 1,43,256.

4.2.6.3 Net Income ha^{-1}

The net income obtained from Kacholam grown in open and as intercrop in oil palm plantations of various age groups at different levels of spacing are presented in Table 77.

When Kacholam was grown under open condition, the highest net profit was obtained from plants grown at 20 x 10 cm spacing (Rs. 38,571) and the lowest from plants grown at 20 x 20 cm spacing (Rs. 17,778). The net profit from 20 x 15 cm spacing was Rs. 24,658.

Under young oil palm canopy, the highest net profit was derived from plants grown at 20 x 10 cm spacing (Rs. 19,393) and the lowest at 20 x 20 cm spacing (Rs. 7,375). The income from 20 x 15 cm spacing was Rs. 11,555.

Under medium oil palm canopy shade, the highest net profit was obtained from plants grown at 20 x 10 cm spacing (Rs. 17,614) and the lowest from plants grown at 20 x 20 cm spacing (Rs. 6,896). The income from 20 x 15 cm spacing was Rs. 10,468.

Kacholam grown as intercrop under mature oil palm canopy produced the highest net profit at 20 x 10 cm spacing (Rs. 14004) and minimum from plants grown at 20 x 20 cm spacing (Rs. 4176). The income from 20 x 15 cm spacing was Rs. 7153.

4.2.6.4 Benefit Cost Ratio

The benefit cost ratio of Kacholam grown in open and as intercrop in oil palm plantations of various age groups at different levels of spacing are presented in Table 77.

When Kacholam was grown under open condition, the highest benefit cost ratio was recorded from plants grown at 20 x 10 cm spacing (1.108) and the lowest ratio was recorded from plants grown at 20 x 20 cm spacing (1.098). The benefit cost ratio at 20 x 15 cm spacing was 1.103.

Under young oil palm canopy, the highest benefit cost ratio was derived from plants grown at 20 x 10 cm spacing (1.097) and the lowest from plants

Table 77 : Cost benefit analysis of Kacholam spacing trail in oil palm plantations

Shade	Open			Young			Medium			Mature		
Spacing	20 x 10 cm	20 x 15 cm	20 x 20 cm	20 x 10 cm	20 x 15 cm	20 x 20 cm	20 x 10 cm	20 x 15 cm	20 x 20 cm	20 x 10 cm	20 x 15 cm	20 x 20 cm
Plant population ha^{-1}	500000	333333	250000	276650	184433	141037	276650	184433	141037	276650	184433	141037
Yield ha^{-1} (t)	5.675	3.802	2.866	3.157	2.118	1.623	3.132	2.103	1.616	3.080	2.055	1.577
Income ha^{-1} (Rs)	395571	264991	199778	220048	147658	113101	218269	146571	112622	214659	143256	109901
Expenditure	357000	240333	182000	200655	136103	105726	200655	136103	105726	200655	136103	105726
Net income ha^{-1} (Rs)	38571	24658	17778	19393	11555	7375	17614	10468	6896	14004	7153	4176
BC ratio	1.108	1.103	1.098	1.097	1.085	1.070	1.088	1.077	1.065	1.070	1.053	1.039

grown at 20 x 20 cm spacing (1.070). The benefit cost ratio at 20 x 15 cm spacing was 1.085.

Under medium oil palm canopy, the highest benefit cost ratio was recorded from plants grown at 20 x 10 cm spacing (1.088) and the lowest from plants grown at 20 x 20 cm spacing (1.065). The benefit cost ratio at 20 x 15 cm spacing was 1.077.

When Kacholam was grown as intercrop under mature oil palm canopy, the highest benefit cost ratio was registered from plants grown at 20 x 10 cm spacing (1.070) and lowest from plants grown at 20 x 20 cm spacing (1.039).

The benefit cost ratio at 20 x 15 cm spacing was 1.053.

4.2.7 Yield of Oil Palm

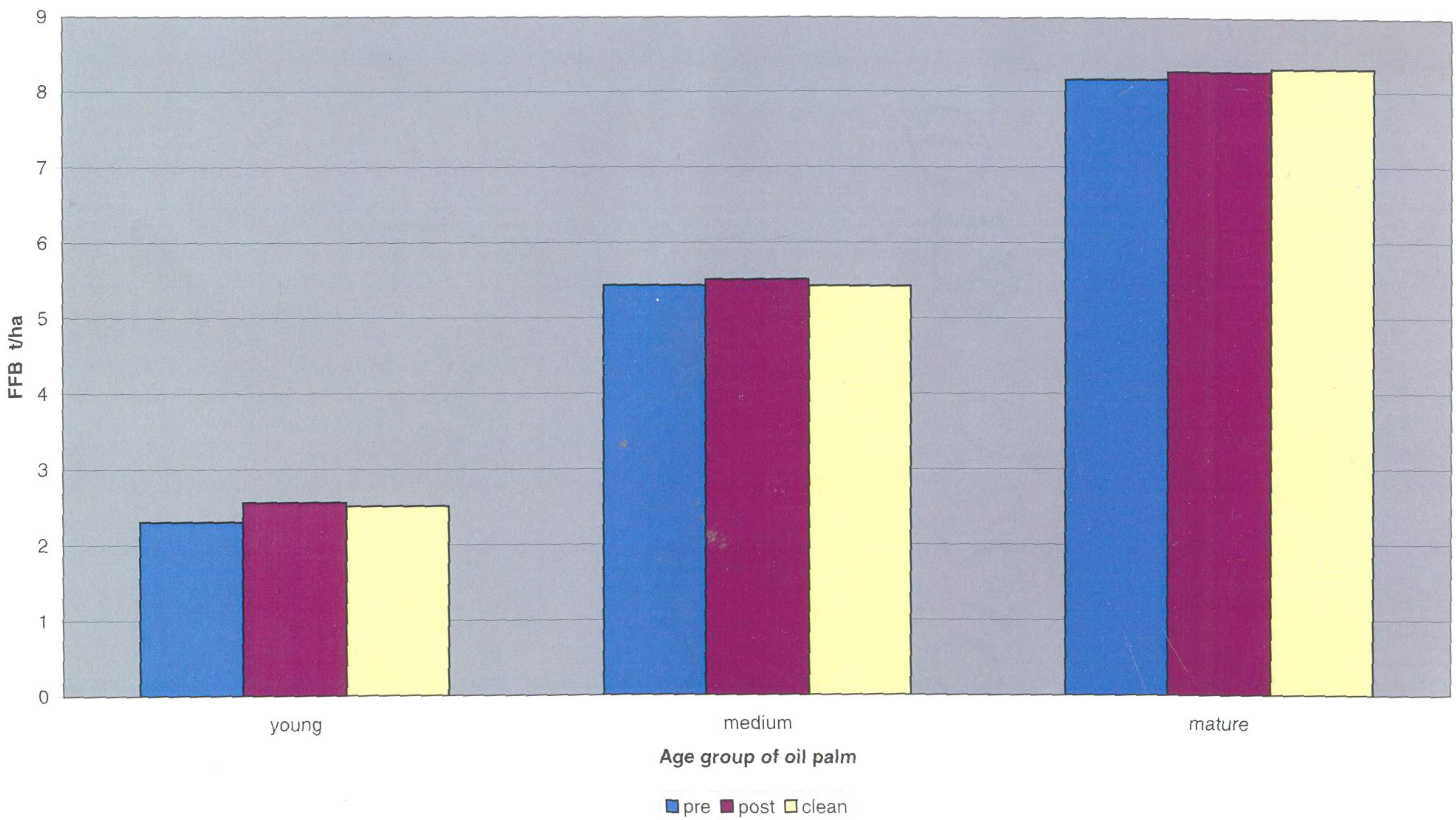
The data on yield of oil palm during the pre experimental period, experimental period and post experimental period and of the clean weeded palms is given in Table 78.

In the case of young oil palm, both the number of bunches palm^{-1} and average bunch weight were not seen affected by intercropping. The mean number of bunches produced by the palms before the experiment, after the experiment and that of the clean weeded palms were 2.3, 2.5 and 2.5 respectively whereas the average bunch weight was 7.0, 7.2 and 7.1 kg palm $^{-1}$ respectively, same was the case with medium and mature palms. In medium palm, the average bunch number was 4.5, 4.3 and 4.3 respectively in the pre, post experimental and clean weeded palms whereas the average bunch weight was 8.5, 8.8 and 8.7 kg palm $^{-1}$ respectively. In the mature palms the corresponding values for bunch number were, 4.7, 4.8 and 4.8 and for bunch weight, 12.3, 12.0 and 12.1 kg palm $^{-1}$. The data thus clearly pointed out that inclusion of medicinal plants in oil palm plantations of different age groups did not affect the palm yield.

Table 78. Yield of Oil Palm

	Pre experimental period				Post experimental period				Clean veeded palms			
Age group	**Palm No**	No of bunches/ palm	Average bunch weight kg/bunch	FFB yield t ha^{-1}	**Palm No**	No of bunches/ palm	Average bunch weight kg/bunch	FFB yield ha^{-1} $year^{-1}$	**Palm No**	No of bunches/ palm	Average bunch weight kg/bunch	FFB yield ha^{-1} $year^{-1}$
Young	**1**	2	7.1	2.03	**1**	2	7.4	2.12	**1**	2	7.3	2.09
	2	2	7.3	2.09	**2**	3	6.9	2.96	**2**	3	7.1	3.05
	3	3	6.8	2.92	**3**	2	7.8	2.23	**3**	2	7.2	2.06
	4	2	7.2	2.06	**4**	2	7.3	2.09	**4**	3	6.8	2.92
	5	3	6.1	2.62	**5**	3	6.4	2.75	**5**	2	7.1	2.03
	6	2	7.5	2.15	**6**	3	7.6	3.26	**6**	3	6.9	2.96
Mean		2.33	7.00	2.31		2.50	7.23	2.57		2.50	7.07	2.52
Medium	**1**	4	8.2	4.69	**1**	3	7.6	3.26	**1**	4	7.8	4.46
	2	5	7.9	5.65	**2**	5	7.8	5.58	**2**	4	8.3	4.75
	3	5	8.1	5.79	**3**	4	8.8	5.03	**3**	4	8.9	5.09
	4	4	9.3	5.32	**4**	5	9.2	6.58	**4**	5	8.7	6.22
	5	4	8.9	5.09	**5**	5	9.5	6.79	**5**	5	9.4	6.72
	6	5	8.5	6.08	**6**	4	10.2	5.83	**6**	4	9.3	5.32
Mean		4.50	8.48	5.44		4.33	8.85	5.51		4.33	8.73	5.43
Mature	**1**	5	12.2	8.72	**1**	5	11.8	8.44	**1**	4	12.4	7.09
	2	4	13.6	7.78	**2**	5	12.4	8.87	**2**	5	11.2	8.01
	3	5	10.8	7.72	**3**	5	11.3	8.08	**3**	4	13.1	7.49
	4	5	11.4	8.15	**4**	5	10.9	7.79	**4**	5	12.3	8.79
	5	4	12.9	7.38	**5**	5	12.4	8.87	**5**	5	11.8	8.44
Mean		4.58	11.56	7.53		4.89	11.28	7.93		4.56	11.59	7.54

Fig. 19 Yield of oil palm before and after the experiment



DISCUSSION

5. DISCUSSION

The use of herbal remedies is on the increase all over the world. Unfortunately, the resource base of herbal medicines and cosmetics is from wild plants, which are fast depleting due to large-scale habitat disturbance and disappearance of forests. This necessitates domestication and commercial cultivation of these plants by sustainable management of the renewable resources. The increasing demand for medicinal plants and the depletion of the forest resources often lead to high cost of collection of these plants from the wild sources. In order to provide regular and sustained supply of medicinal and aromatic plants, it is essential to domesticate medicinal and aromatic plants and develop suitable agricultural practices for their commercial cultivation. The future of these plants as commercial crops in pure culture seems to be restricted in view of the serious limitation of cultivable land.

Oil palm based farming appears to be a potential area for introduction of many medicinal plants. It is a possible way to enhance the net return from the oil palm plantations. The present project was envisaged to evolve a medicinal plant based oil palm farming system suitable for Kerala. The proposed objectives were, to study the adaptability and performance of ten selected medicinal plant species as intercrop in oil palm plantations of various age groups and to work out the economics of cultivation. Analysis of the morphological, physiological, anatomical and biochemical mechanism of shade tolerance and standardization of optimum spacing, for plants adaptable to intercropping was also envisaged in the study.

5.1 PHASE I EXPERIMENT

During the first phase of the experiment, a screening trial was conducted to evaluate the adaptability and performance of ten medicinal plant species, namely, *Adhatoda beddomei* (Chittadalodakam), *Alpinia galanga* (Chittaratha), *Solanum incanum* (Chunda), *Coleus zeylanicus* (Iruveli), *Kaempferia galanga* (Kacholam), *Strobilanthes haenianus* (Karimkurinji), *Plumbago rosea* (Koduveli), *Pogostemon patchouli*

(Patchouli), *Asparagus racemosus* (Sathavari), and *Piper longum* (Thippali) under different shade conditions.

To study the influence of shade, the shade under the young oil palm canopy (below five years), medium oil palm canopy (between five and eleven years) and mature oil palm canopy (above eleven years) were selected to grow the ten medicinal plant species. Simultaneously, these species were grown in the adjacent open area also, for comparison.

When plants are grown together in a community they will interact one another and there is interference or competition among them (Harper, 1961). Competition is likely to occur above ground as a shading effect (reduction in radiation flux) and below ground as a root system overlap (Beets, 1982; Ong *et al.*, 1991). In general, the degree of overlap between different root systems and their spacing distribution determine the competition intensity (Cable, 1969; Trenbath, 1975). Snaydan and Harris (1981) indicated that plant interactions below ground are normally more intense than those above ground. Competitions within a plant community depend upon the resource level supply like soil nutrients, moisture and solar radiation.

Successful integration of oil palm based medicinal plant production system includes both the main crop (oil palm) and the intercrop (medicinal plant) as important components. The harmonious apportioning of the growth factors like light, moisture and nutrient availability and the selection of suitable species determine the economic viability of this agro forestry system.

5.1.1 Soil Nutrient Status of the Experimental Area

The fertility status of the experimental plots did not vary with respect to the different shade conditions namely, open, young, medium and mature as evidenced by the results of the soil sample analysis. The results of the soil analysis also showed that there was a marked depletion of nutrients such as nitrogen, phosphorous and potash after the experiment. This is a reflection of the quantum of nutrients utilized by the intercrops. The maintenance of the soil nutrient status both before and after the experiment can possibly be attributed to the addition of nutrients by the decomposition of litter returned to soil and addition of humus to the experimental plots. The decline in nitrogen status from high to medium range can be attributed to the uptake of nitrogen by oil palm and the intercropped medicinal plants, besides the usual losses of nitrogen such as leaching, volatilization, etc.

5.1.2 Humidity, Evaporation and Soil Water under the Palm Canopy

Wilson and Ludlow (1991) indicated that air relative humidity under a tree canopy is likely to be increased compared with that in the open or above a tree canopy. Decreased radiation load under the shade of tree canopies should benefit the water relations of the intercrop species. Leaf water potentials are higher in plants under shade than in full sun (Wong and Wilson, 1980). Evaporative demand will be greatly reduced in the shaded environment and soil water availability for the intercrop will be maintained at a higher level than in the open, through combined effect of less evaporation from the soil and lower transpiration rates of the intercrop (Wilson and Wild, 1991).

5.1.3 Light Interception in the Plantation

When the canopy of one component of a crop association is set higher than the others, the taller canopy is likely to utilize the greatest part of the light (Beets ,1982) and light penetrating the plant stand will be diminished through interception and absorption (Trenbath, 1981). Shelton *et al.* (1987) stressed that the level of shade is the most significant factor determining the output from intercrop grown in plantations.

In the present study, the pattern of distribution of solar energy indicated that there was considerable variation in the interception of sunlight by palm canopies of different age groups. The range of light conditions under the canopy was grouped as young palms having moderate light transmission, medium and mature having poor light transmission, varying with increase in height and change in leaf orientation. Corley (1973) also has reported that oil palm canopy closure takes place when the crop is about four years old and canopies reach a constant by 9 -10 years.

5.1.4 Comparison of Shade Conditions

A perusal of the data on the performance of ten medicinal plant species under the four shade situations revealed that the performance of all species with respect to yield was higher under the young oil palm canopy. Height of medicinal plants showed an increasing trend with increasing shade level up to one year after planting and the highest plant heights were recorded under medium oil palm canopy, where the shade level was the highest. Thereafter the plant heights under young and medium oil palm canopy were on par and during the last two months of crop growth, the highest plant height was under young oil palm canopy. Plants grown under open condition and mature palms were shorter throughout the growth period. Evans (1992) has noted that generally high levels of shade will encourage plants to become more etiolated where they grow taller in an effort to gain better access to available light. Higher plant height under 50 per cent shade compared to open condition was reported in *Phyllanthus stipulatus*, a medicinal plant used for the treatment of kidney stones, by Filho *et al.*, (1997). In *Cassia angustifolia* the promotional effect of shade on plant height, number of nodes and mean internodal length was most marked at 25 per cent shade and the impact of further increase in the shade level was marginal (Vyas and Nein, 1999).

On an average, the number of branches, number of leaves, root number and root length, leaf area index, and dry matter production were the highest under young oil palm canopy, where the available PAR was 42 per cent of the open. Such enhanced vegetative growth (height), fresh weight, dry weight and leaf and branch number in the shade compared with plants grown in full sun had been reported in *Enicostemma littorale*, a medicinal plant well known for its diuretic and anti diabetic properties, by Sharma *et al.* (1994). But under medium and mature oil palm canopy where the PAR was 19 and 22 per cent of the total, all these characters were decreased and were almost equal to that under open condition. This observation is in conformity with the findings of Maschinski *et al.* (1997) who reported that at natural light levels lower than 40 per cent, plants had lower stem production and photosynthetic rates than plants grown at higher levels.

In general, shade affects the growth and morphological development of plants. Production of tillers, leaves, stems and roots of forage grasses are often reduced at low light (Wong *et al.*, 1985). Morphological acclimatization of plants to light attenuation is an adaptive strategy to compensate at least partially, for the lower photosynthetic rate per unit leaf area (Wong and Wilson, 1980). These changes improve the competitive ability of the intercrop by increasing interception of light and reducing respiratory load (Trenbath, 1976). Such morphogenetic changes will be greater in shade intolerant species than shade tolerant species (Smith, 1982). Since the selected medicinal plant species are identified as shade tolerant, such morphological adaptations became more visible only beyond a certain threshold level of shade. Because of the inherent shade tolerant nature of these species, higher yields were obtained under partial shade of young oil palm canopy, compared to open condition and deep shade situations (medium and mature palm canopy). Samarakoon *et al.* (1990) reported such increased yield responses under shade compared with full sun in forage grasses, *Stenotaphrum secundatum, Axonopus compressus* and *Pennisetum clandestinum*. This response was up to 68 per cent shade for the first two species while maximum yield of the third species was reached at 42 per cent shade. In Malaysia, Suparjo *et al.* (1991) found that for *Asystasia intrusa* the optimum rate of photosynthesis was 11.9 μ mol CO_2 m^{-2} s^{-1}, with best growth at one third of full sun (i.e., in the shade of oil palm).

5.1.5 Adaptability Studies of Selected Species as Intercrop and as Pure Crop

5.1.5.1 Chittadalodakam – Malabar nut (Adhatoda beddomei)

An assessment of the performance of Chittadalodakam as intercrop in oil palm canopies of different age group and under open condition revealed that the general performance with regard to morphological characters, yield, net income and benefit cost ratio was the highest when it was grown under young oil palm canopy. On an average, morphological characters like plant height, leaf number, branch number, number of roots and length of roots were the highest under young oil palm canopy. Similar cases of increase in plant height and number of branches in the intercrop compared to pure crop was reported in Chittadalodakam (KAU, 1999). It was also reported that since the yield difference of officinal part in the intercrop and pure crop were not significant, Chittadalodakam could be considered as adaptable to intercropping.

Physiological characters like total dry matter production, leaf area index, net assimilation rate, crop growth rate, absolute growth rate and relative growth rate also were higher when it was grown under the young oil palm canopy. The yield plant $^{-1}$ was also higher under the young oil palm canopy. However the per plant yield in rupee equivalent was on par under the four situations. All these characters were found to decrease under medium oil palm canopy and further under mature oil palm canopy (higher shade levels). Chittadalodakam being a shade tolerant crop, optimum performance was exhibited under partial shade (under young oil palm canopy). Nevertheless, when the shade levels were further increased, a gradual decline in the performance was noticed. From the economic analysis however, it was observed that the benefit cost ratio was almost equal under the three shade conditions and open. This indicates its suitability for cultivation under oil palms of all age groups. The superior performance of *Adhatoda beddomei* under deep shade of rubber plantations and 8-20 year old coconut plantations have been reported (RRII, 1989; Nair *et al.*, 1991).

5.1.5.2 Chittaratha – Lesser galangal (Alpinia calcarata)

An assessment of the performance of Chittaratha during the different growth stages revealed that, on an average, the performance was the best under young oil palm canopy. A perusal of the data on the morphological, physiological and yield characters revealed an increase of all these characters under the young oil palm canopy. Regarding height of the plants, during the first two months after planting no difference under open and various shade conditions were noticed. Gradually the effect of shade on plant height became prominent and the highest plant height under the deep shade of medium oil palm canopy was recorded from fifth month up to eleventh month. Thereafter plant height under young oil palm canopy showed an increasing trend and maintained it until harvest. The height under mature canopy was the lowest throughout the growth period. In the case of number of leaves, up to nine months after planting the effects of shade were not visible. Thereafter leaf production increased significantly under young oil palm canopy. However, lower leaf number was noticed under mature canopy throughout the growth period. Tiller production in Chittaratha was significantly influenced by shade and highest number was recorded under young and medium palms up to six months after planting. The highest tiller production was under young oil palm canopy throughout the growth period. Root number was significantly higher under the three shade levels than open during first four months of crop growth. Thereafter root number under young and medium canopy increased. From tenth month up to harvesting, plants grown under young canopy produced the highest number of roots while minimum root production was under mature oil palm canopy. The effect of shade on root length was not significant throughout the growth period. However, higher root length was recorded from plants under young and medium oil palm canopy. All the above observations indicate that Chittaratha grows vigorously in the shaded condition compared to open. In their natural habitat, Alpinia grows as understorey plants in the tropical rain forests, so they prefer filtered sun light (Chen, 1987).

In the case of physiological parameters, the response of Chittaratha was slightly different. Regarding total dry matter production, during the initial months of planting no significant influence of shade was noticed, but during later stages of crop growth dry matter production under young canopy was higher. However, during the last two months of crop growth, highest dry matter production was noticed under open condition. The report of Monteith (1969) that maximum amount of dry matter production by a crop is strongly correlated with the amount of light intercepted by its foliage, supports the above finding. Significant influence of shade on leaf area index was noticed throughout the growth period and maximum leaf area index was noticed under young oil palm canopy (partial shade) followed by medium oil palm canopy (deep shade). However, minimum leaf area index was recorded under mature canopy (deep shade) throughout the growth period. Similar case of decrease in LAI in cassava under high shade levels have been reported by Fukai *et al.* (1984).

Growth analysis of the plants revealed that net assimilation rate, crop growth rate, absolute growth rate and relative growth rate were also the highest under the young oil palm canopy. This observation indicates that, for optimum growth, it prefers partial shade condition compared to deep shade.

From the economic analysis of the yield data, it was shown that, highest per plant yield was from the plants grown under young oil palm canopy. Per plant yield under open and mature palm canopy were on par. On the other hand, the highest harvest index was under mature palms and the lowest under open condition. Among the different shade levels compared, highest net profit and benefit cost ratio recorded under young oil palm canopy, make it a crop suitable for intercropping with young oil palms. However the parity of net profit and benefit cost ratio under open condition with other two shade conditions (under the deep shade of medium and mature palms) indicates its suitability as intercrop under medium and mature palm canopy also. The capacity of plants to accumulate soluble carbohydrate reserves is greatly diminished under shade (Wilson, 1982), hence those species with a large reserve of biomass in roots and/ or rhizomes and stolons may be persistent under heavy shade (Wilson, 1991). Chittaratha being a rhizomatous crop, the improved performance under partial and deep shade may be due to the biomass reserve in its rhizomes. Such improved performance of stoloniferous grass species under strong shade has been reported by Rika *et al.* (1981); Watson and Whiteman (1981); Chen and Othman (1984); Farlane and Shelton (1986).

5.1.5.3 Chunda – Medicinal solanum (Solanum incanum)

The overall performance of Chunda with regard to growth and yield characters was very poor both under the intercropped and open conditions. The influence of shade on plant height was not significant and remained the same at different shade levels almost throughout the growth period. The plants in general had a stunted growth. Similarly, not much difference was noticed in the number of leaves under full irradiance and under various shade levels. But leaf number was always less under the mature oil palm canopy. The number of branches per plant showed higher values under young oil palm canopy compared to open. However, with increase of shade, the branch number tended to decline. According to Holmes (1981), as sunlight passes through the tree canopy in plantations, its quality is altered because the leaves preferentially absorb the light in the 400-700 nm wave band. Blue and red light are reduced compared with green and far-red. Because of the differential absorption of red and far-red light the ratio of red to far-red (R/FR) falls. These spectral changes, perceived by the plants through the phytochrome system, may induce marked morphogenetic changes in plants (Smith, 1982). Stem elongation can be promoted (Child *et al.,* 1981) and tillering and branching inhibited (Deregibus *et al.,* 1985; Casal, 1988; Thompson and Harper, 1988). These responses will be more in shade intolerant species than shade tolerant species. Compared to other medicinal plant species Chunda may be less shade tolerant and this may be the reason for poor branching under the deep shade conditions of medium and mature oil palm canopy. The number of roots and root length increased under shade, up to 68 per cent (under young oil palm canopy). However, there was a decline in root production beyond this shade level (under medium and mature oil palm canopy). In ginger, Ajithkumar (1999) reported maximum root length under 60 percent shade; but root length decreased beyond that level. Both dry matter production and leaf area index and per plant yield showed a decline under the mature oil palm canopy and this may be due to the poor performance of Chunda under the mature oil palm canopy. The lowest crop growth rate and absolute growth rate recorded for Chunda under mature oil palm canopy supports this conclusion. Chunda recorded a net loss when grown under all shade and open conditions. However minimum loss was under young palms and maximum under mature canopy. The benefit cost ratio worked out was <1 under all situations and was the least under mature canopy. The deep shade condition prevailing under the mature oil palm canopy together with the root interference from the palms might be responsible for the poor performance of Chunda under the mature oil palm canopy.

5.1.5.4 *Iruveli - Hribera* (*Coleus zeylanicus*)

Being a herbaceous perennial plant, the influence of shade on various morphological characters was more visible in Iruveli, compared to other species. The plant height showed an increasing trend with increasing shade levels, and the highest plant height was recorded from medium and mature oil palm canopy. On the other hand, number of leaves showed no significant variation under the different situations throughout the growth period. Branch production though slightly increased under young oil palm canopy, declined under medium and mature canopies. The increased plant height and reduced branching noted under the shade condition presumably due to the plant morphological adjustment to light attenuation. Root number and length showed an increasing trend under the shade conditions compared to open. Dry matter production and leaf area index were not affected by shade throughout the growth stage. Iruveli recorded comparatively poor crop growth rate, absolute growth rate, relative growth rate and net assimilation rate under all the situations evaluated. The general performance of Iruveli was poor both in the open and under oil palm canopy as indicated by the net loss and <1 benefit cost ratio both under the shade level of oil palm and open condition. All these observations point towards its unsuitability as an intercrop in oil palm plantations. In contrast to this study, Rajagopalan *et al.* (1992) reported higher yield in Iruveli under different shade levels of coconut. According to him maximum additional income of Rs 20,300/- per hectare was obtained by growing Iruveli as intercrop in coconut gardens.

5.1.5.5 Kacholam - Galanga (Kaempferia galanga)

In general, influence of shade on the morphological, physiological and yield characters of Kacholam were not much pronounced. Compared to open, the number of leaves produced was slightly higher under young oil palm canopy and minimum leaf number noticed under the mature canopy. The average tiller number during all growth stages showed an increase under the young oil palm canopy, but with further increase in shade, showed a declining trend under the medium and mature oil palm canopy. On the other hand, the root number showed a gradual increase with increasing shade level. However, the effect of shade on root length was not significant throughout the growth period. Similarly, no reduction in the dry matter production was noticed in Kacholam due to increasing levels of shade. The leaf area index showed an increasing trend under the shaded condition. Kacholam recorded relatively higher crop growth rate, relative growth rate, absolute growth rate and net assimilation rate both under open condition and under varying shade levels. Compared to other species, per plant yield was the highest under all situations and maximum yield was noted under young oil palm canopy. Harvest index was the highest under open condition but was on par with that under mature oil palm canopy. Economic analysis of the yield data revealed the highest net profit under the young oil palm canopy, which was almost equal to the yield under open condition. The benefit cost ratio under all situations were >1. In general, the performance of Kacholam was equally good at all the shade levels even though slight yield decline was noticed under medium canopy. Superior performance of Kacholam under the partial shade of coconut was reported earlier (Maheswarappa, 1999; KAU, 1999). Kacholam has been identified as a potential intercrop under the deep shade of immature rubber plantation also (RRII, 1989). Rajagopalan *et al.* (1992) also reported higher yield in Kacholam under different shade levels of coconut.

5.1.5.6. Karimkurinji – Medicinal Strobilanthes (Strobilanthes haenianus)

A perusal of the data on morphological, physiological and yield characters revealed superior performance of these factors under the shade conditions. Consistently, Karimkurinji intercropped under different shade levels showed higher height, than the plants raised in the open plots. Number of leaves, branches, roots and root length were higher under the different shade condition. Drymatter production and leaf area index also showed an increasing trend under shade. Majority of the strobilanthes species originated from forest understorey and are 'shade' species according to Blackman's (1961) definition. Wong (1991) in a recent review on the shade tolerance of tropical forages, defined shade tolerance (agronomically) as the relative growth performance of plants in shade compared to that in full sunlight. Generally shade imposes a limitation to biological productivity in plants although the extent of limitation varies with shade tolerance of the species. For species reported to be shade tolerant, the yield was maximized at much lower light levels (Eriksen and Whitney, 1981). In the present study, in Karimkurinji, which is a reputed shade tolerant species (Vijayakumar *et al.,* 1989) yield per plant was the highest under the different shade levels, compared to open. Neerakkal *et al.* (2003) also reported higher dry matter production under shade in Karimkurinji. According to them increased photosynthetic rate due to increased leaf area enhanced the drymatter production even though lower Pn values were recorded under shade compared to open. However, the harvest index was higher under open condition. In the present study, higher net profit and benefit cost ratio recorded under the shade situations makes it a suitable intercrop for oil palm plantations of all age groups. The superior performance of Karimkurinji in the deep shade of immature rubber canopy has been reported (RRII, 1989).

5.1.5.7 Koduveli- Rosy leadwort (Plumbago rosea)

In the present study, the different levels of shade under which the crop was grown, did not have much influence on the morphological characters and yield, except plant height, which increased with increasing levels of shade during the later stages of crop growth. Such height increment at 12 and 18 months after planting in Plumbago raised as an intercrop in coconut plantations, was reported (KAU 1999). In the present study, the highest per plant yield was recorded under young oil palm canopy (partial shade) and per plant yield of crop raised under medium oil palm canopy was on par with mature palm canopy. Yield was the least under open condition. Neerakkal *et al.* (2003) have reported that the highest total drymatter production was at 70 per cent shade compared to open in Plumbago. In Koduveli, the net assimilation rate and relative growth rate were equal under all situations. However, absolute growth rate and relative growth rate were lower under the different shade conditions compared to open. Intercropping studies conducted at RRII in young rubber plantations identified *Plumbago rosea* as a potential intercrop, which will come up well under deep shade (RRII, 1989). Studies conducted by Nair *et al.* (1991) on intercropping medicinal plants in twelve year old coconut plantation also revealed the possibility of growing Plumbago as an intercrop in these gardens. Economic analysis of the yield data of the present study however recorded a net loss under all situations and the benefit cost ratio recorded was also < 1 under all situations, possibly due to the high cost of the planting material compared to the benefit from the officinal part.

5.1.5.8 Patchouli (Pogostemon patchouli)

A perusal of the data on the effect of shade on morphological, physiological and yield characters of patchouli grown under different shade situations of oil palm canopy revealed that certain characters were affected by shade, but majority of the characters remained unaffected. Height increase was noticed under shade throughout the growth period and lower plant height was observed under open condition. The height increment under deep shade may be an adaptive mechanism to gain better access to available light (Evans, 1992). The morphological characters which were unaffected by shade were, number of leaves, number of roots and root length which remained more or less same under open condition and different levels of shade, almost throughout the growth period. Branching on the other hand, was higher when the plants were grown under shade and the highest branching was recorded under young and medium oil palm canopy. The increased branching can be attributed to the vigorous growth of the plants under shaded condition, as such it can rightly be construed that it is a shade tolerant species. The growth analysis of the plants also revealed higher absolute growth rate, crop growth rate and relative growth rate under young oil palm canopy. The drymatter production was found to increase under shade during the later stages of crop growth. Leaf area index was the maximum under young oil palm canopy, which may be the reason for higher drymatter production. Beyond a certain level of shade, the leaf area index showed a decreasing tendency with a consequent reduction in dry matter content. Per plant yield was the highest under young oil palm canopy compared to open and deep shade situations. Better growth and yield of patchouli under partially shaded condition in coconut plantations was reported from the intercropping studies conducted in the Kerala Agricultural University (KAU, 1992). In Indonesia patchouli had been recommended as a profitable intercrop in young oil palm plantations (Soepadyo and Tan, 1968). However, in the present study, after considering the cost of cultivation incurred and per ha yield of herbage, a net loss was recorded both under open and shade conditions. However the per hectare loss was the minimum under young oil palm canopy. The benefit cost ratio recorded was <1 under all situations.

5.1.5.9 Sathavari- Asparagus (Asparagus racemosus)

In Sathavari, plant growth was unaffected by the various shade conditions during the initial period of growth. However, during later stages i.e., from sixth month after planting, the influence of shade could be noticed in certain morphological characters. A progressive increase in plant height with respect to shade was noticed. But beyond 50 per cent shade the height increment was less and higher plant heights were recorded under young oil palm canopy. Height increase in Sathavari grown as intercrop in coconut gardens (27 to 35 per cent light infiltration) has been reported from Kerala Agricultural University (KAU, 1999). Other growth characters like number of leaves, roots and root length were also influenced by shade levels and higher values for these characters were observed under the partial shade of young oil palm canopy. Shade levels beyond this, had a declining effect on the morphological characters and the lowest leaf number was noted under mature oil palm canopy. Branching in Sathavari was not affected by shade and the highest number of branches was recorded under open condition. This finding is also in conformity with the findings of Kerala Agricultural University (KAU, 1999). Physiological attributes like total dry matter production and leaf area index were maximum under young oil palm canopy. Consequent to the increase in all the above characters under partial shade, the per plant yield was also the highest under young oil palm canopy. An economic analysis of the yield data recorded a net profit under all situations and the maximum net profit was from young oil palm plantation . Based on the benefit cost ratio, Sathavari was found to be most suited for cultivation under young oil palm plantations followed by medium and mature oil palm plantations as compared to pure crop.

5.1.5.10 Thippali – Long pepper (Piper longum)

In general, growth of Thippali was very poor and not uniform under shade as well as open situations. Up to six months after planting, plant height was higher under shaded condition and less under open. However, during later stages of crop growth, uniform heights were measured from open condition and under young and medium oil palm canopy. Plants under mature canopy showed a stunted growth. Other morphological characters like leaf number, root number, root length and physiological parameters like total dry matter production, leaf area index etc showed no significant variation when grown under open conditions and different shade situations. Growth analysis of the plants recorded higher crop growth rate and relative growth rate under the partial shade of young oil palm canopy. Regarding per plant yield, the highest value was recorded from plants grown under open condition. Economic analysis of the yield data showed a net loss under all situations and the benefit cost ratio recorded for thippali were the lowest among all species, under all situations. Even though thippali has been recommended as a profitable intercrop in irrigated coconut gardens (KAU, 1992), in the present study its performance was very poor. The reason for poor performance may be the moisture stress during the growth period. The natural habitat of Thippali is on the borders of streams and in sholas and the crop is indigenous to the wet and warmer parts of India. Irrigation is necessary to maintain good growth of the crop (Viswanathan, 1995).

5.2 PHASE II EXPERIMENT

STANDARDIZATION OF SPACING FOR KACHOLAM AND STUDY OF SHADE TOLERANCE MECHANISM

In the present investigation, effect of different shade levels and plant population levels on growth, yield and quality of Kacholam were studied to find out suitable spacing at different shade levels of oil palm canopy. The morphological, physiological and biochemical mechanism of shade tolerance in Kacholam were also analysed in the study.

5.2.1 Morphological Characters

5.2.1.1 Number of Tillers

In the study, the significant influence of shade on tiller production was noticed throughout the growth period. Higher tiller production was recorded under the partial shade of young oil palm canopy and increase in shade level beyond that limit had a declining effect on tiller production. Well documented instances of higher tiller production under moderate shade than under full sunlight have been reported by many authors in Kacholam (Maheswarappa, 1999) and in *Enicostemma littorale*, a medicinal plant well known for its diuretic and antidiabetic properties, by Sharma *et al.* (1994).

The influence of planting density on tiller production was also significant and the highest tiller production was noticed at the widest spacing and lower under narrow spacing. The higher plant production at narrow spacing resulted in competition within the plant community and this might be the reason for lower tiller production. Supporting evidence for this finding has been reported in Kacholam grown as intercrop in coconut garden by Maheswarappa (1999).

5.2.1.2 Number of Leaves and Total Leaf Area

The influence of shade on number of leaves and leaf area was quite visible during the crop growth stage, both leaf number, and area showed an increase with increasing shade level. Such a response to shade was reported from Kerala Agricultural University (KAU, 1999) also, when Kacholam was intercropped with coconut. This increase in leaf area under low light is to maximize light interception thereby enhancing the efficiency of carbon utilization.

An increase in leaf number and leaf area with decreasing plant population was noticed throughout the growth stage. In an intercropping study of Kacholam with coconut, same response was reported (Maheswarappa, 1999). Cheon *et al.* (1991) also reported decreasing leaf area per plant with increasing plant density in Korean ginseng (*Panax ginseng*).

5.2.1.3 Fresh Weight of Leaves, Roots and Rhizome

The fresh weight of all plant parts increased under shade. However, the increase in fresh weight was not in proportional to the increase in shade levels and the highest fresh weight was noticed under the partial shade of young oil palm canopy throughout the crop growth, where the performance of Kacholam was the best. Significantly higher fresh weight of Kacholam rhizomes under intercropped situation compared to pure crop has been reported earlier (KAU, 1999).

Higher root, shoot and rhizome fresh weight were noticed under wider spacing because of better crop growth due to minimum competition under lower plant density, throughout the crop growth period.

5.2.2 Physiological Characters

5.2.2.1 Dry Matter Production

Total dry matter production was the highest under the partial shade of young oil palm canopy, because the plants produced higher number of leaves, tillers, roots and rhizome under this shade level. Increased leaf area per plant enhances the total photosynthetic out put per plant, which in turn caused increased dry matter production under low irradiance.

Similarly, total dry matter production also tended to increase with decreasing planting density under all shade situations. At lower plant populations, the individual plants were able to exploit the higher quantum of resources available for each plant, thus producing higher dry matter compared to higher plant density.

5.2.2.2 Leaf Area Index

Leaf area index was found to be increasing with increasing levels of shade and lower leaf area index was noticed under open condition. Higher leaf area index under low light may be an adaptation to expose longer photosynthetic surface under limited illumination as reported by Attridge (1990). Similar findings were reported in ginger by Ravisankar and Muthuswamy (1988) and Ancy (1992). Contrary to this, Bai (1981) reported that leaf area index was not influenced by shade intensities in ginger, turmeric and coleus.

Planting density also significantly influenced leaf area index, and the highest leaf area index was noted in low-density population. At higher population level, the leaf area produced for the given area was higher due to narrow spacing within the rows resulting in higher leaf area index compared to lower plant population which has wider spacing within the rows.

5.2.2.3 Specific Leaf Weight (SLW)

Specific leaf weight decreased with shade. The highest SLW was recorded under open and partial shade of young oil palm canopy. Leaves in shady environment typically have lower SLW than leaves grown in sunny conditions. Low SLW represents a complement of leaf characteristics including decreased leaf thickness, decreased palisade cell development, lower photosynthesising cells per unit leaf area, decreased assimilatory apparatus per unit area, lower light saturation point and/ or decreased respiration rate (Boardman, 1977). Ajithkumar (1999) reported higher SLW under open and low shade levels in ginger. SLW is a good indicator of photosynthetic efficiency, growth of plant and of relative ability to adapt to shade (Neerakkal *et al.*, 2003).

SLW was not influenced by planting density.

5.2.2.4 Water Potential

Leaf water potential increased with shade and the maximum water potential was recorded under medium oil palm canopy where the shade level was the highest. Generally, leaf water potential is higher in plants under shade than in full sun (Wong and Wilson, 1980). This is because evaporation will be greatly reduced in the shaded environment; at the same time soil water availability for the intercrop will be maintained at a higher level compared to open through the combined effect of less evaporation from the soil and lower transpiration from the intercrop (Wilson and Wild, 1991). Xiang *et al.* (2000) have reported increased relative water content and chlorophyll content of leaves with increasing shade intensity in ginkgo. In *Encelia farinosa,* dark respiration decreased with decreasing leaf water potential in sun plants, but remained unchanged in shade plants (HeHui *et al.*, 1995).

Planting density had no effect on leaf water potential.

5.2.2.5 Stomatal Conductance

In the present study, stomatal conductance was found to be the highest under open condition and the least under medium oil palm canopy. Stomatal conductance is inversely related to light level usually. In the present study, there was a negative correlation between leaf water potential and stomatal conductance, because both the variables co varied with irradiance. Studies conducted in Sri Lanka to examine the variation of leaf stomatal conductance and leaf water potential in selected forest trees under varying levels of shade, revealed that there was a positive relationship between leaf water potential and stomatal conductance under open, medium and full shade. However, the relationship was the strongest under open condition and become weaker with increasing shade. Under full shade, variation in stomatal conductance was brought about by leaf temperature and light intensity (Costa *et al.*, 2000). Absolute biomass gain and relative growth rate (RGR) had significant positive correlation with water potential and stomatal conductance and leaf chlorophyll content. Multiple regression analysis identified leaf water potential and stomatal conductance as the factors, which contributed the most to the observed variation of absolute biomass gain and RGR (Costa and Rozana, 2000).

Plant density did not show any effect on stomatal conductance.

5.2.2.6 Photosynthetically Active Radiation (PAR) on Leaf Surface

In the present study, the highest PAR on the leaf surface was recorded in plants grown under open condition and the values decreased with increasing shade levels. The lowest value was recorded under medium oil palm canopy. As sunlight passes through the tree canopy in plantations, the leaves absorb the light in the 400-700 nm wave bands preferentially and the photon irradiance (PAR) incident on the herbaceous understorey may be substantially lower than for full sunlight (Baldocchi *et al.*, 1984). The average percentage of incoming radiation incident on the pasture in a 5.5 year old oil palm plantation comes to around 47 per cent (Chen and Bong, 1983). In the present study, light interception in the young palms (below five years) was recorded to be around 36 per cent of the PAR measured in the open. Since the canopies of the palm were not closed, there was moderate light transmission. In the medium age oil palm plantation, the light transmission was less because the canopy was closed. In the mature canopy, also poor light transmission was observed as the trees were not very high which prevented sufficient entry of sunlight.

5.2.3 Foliar Characters

5.2.3.1 Stomatal Density

Stomatal density was found to be the highest in plants grown under open condition and was lower under shaded conditions. In Kacholam coconut intercropping system, higher stomatal density for pure crop was noticed compared to intercrop (KAU, 1999). Higher stomatal density was observed in *Valeriana jatamansi* grown under shaded habitats compared to those in open condition as reported by Pandey and Nagar (2000). The exchange of water vapour, CO_2 and O_2 are largely influenced by the stomata, which subsequently enhanced the photosynthetic efficiency of the plants.

5.2.3.2 Foliar Anatomy

Generally, leaves of plants under shade are thin and this is evident from the data of a single species grown under different light intensities (Boardman, 1977). Foliar anatomical studies of Kacholam leaves from different shade situations in the present study revealed that the epidermal thickness, mesophyll thickness and vascular bundle number were higher in leaves collected from open condition. All these characters were found to decrease with increasing levels of shade and the minimum values were noted in leaves grown under medium oil palm canopy. Shade led to a decrease in the number of palisade layers. A decrease in cell number also occurred under shade. Thicker leaves in plants grown at high irradiance have been attributed primarily to increase in the thickness of the palisade layer (Huang and Kuo, 1996). Decrease in spongy mesophyll thickness was noted in shade plants. Thicker leaves in sun plants than those in shaded plants, attributable to increased size of the palisade and spongy parenchyma tissues, has been earlier reported (Huang and Kuo, 1996). The greater mesophyll thickness in high irradiance grown plants might have led to chloroplast shading one another within the leaf, which might have resulted in saturation of photosynthesis at higher light intensities than in plants grown at low irradiance (Neerakkal *et al.*, 2003).

5.2.4 Biochemical Characters

5.2.4.1 Starch Content

Starch content in Kacholam was found to increase with increasing shade level and the highest content was noted under medium oil palm canopy. This is contrary to the finding of Ajithkumar (1999) who reported a decrease in starch content in ginger at higher shade levels. However, Melitiou-Christou *et al* (1994) assumed that variation in accumulation of starch in sun and shade plants represent a species-specific response.

In the present study, starch content also varied with planting density and the highest content was recorded at lower planting density. This observation is in conformity with the findings of Maheswarappa (1999) who reported a similar response in Kacholam.

5.2.4.2 Ash content

Ash content of shade-grown plants was higher compared to open-grown plants. It also varied with plant density and highest content was at higher spacing. The possible reason for higher ash content at higher shade level might be due to higher silica content and lignification and increase in cell wall content under low light intensity as reported by Deinum and Dirven (1972) in forage species.

5.2.4.3 Chlorophyll Content

One of the major effects of shade on shade-adapted plant is the increase in concentration of chlorophyll pigments in leaves. In the present study, there was increase in chlorophyll 'b' and total chlorophyll, which was directly proportional to the degree of shade. Chlorophyll 'a' content was not affected by shade. Chlorophyll 'b' and total chlorophyll content was the lowest in unshaded or open plants. This is supported by the findings of Goldsborough and Kemp (1988). An increase in chlorophyll 'b' under shade as observed in the present study is in conformity with the report of Sondergaard and Bonde (1988), that chlorophyll 'b' can harvest light prevailing in shaded habitats more efficiently than chlorophyll 'a'. Higher content of chlorophyll 'a', 'b' and total chlorophyll in Kacholam under shade has also been reported earlier (KAU, 1999).

In the present investigation, the chlorophyll content also varied with planting density and higher chlorophyll 'a' and total chlorophyll content was noted at closer spacing. This result is contrary to the finding of Maheswarappa (1999) who reported no significant variation in chlorophyll content due to planting density.

5.2.4. 4 Volatile Oil Content

Higher volatile oil content of Kacholam rhizomes was recorded under the partial shade of young oil palm canopy. However, at higher shade intensity the oil content decreased and was equal to that under open condition. Maheswarappa *et al.*(b) (1998) also reported higher volatile oil content of intercropped Kacholam in coconut plantations. The report of George (1992), Ancy (1992), Babu (1993), Nizam (1995) and Ajithkumar (1999) on the favourable effect of shade on volatile oil content of ginger, also supports the present finding. However Kurian *et al.* (2000) observed slightly lower oil content for Kacholam intercrop compared to pure crop.

Oil content also increased with decreasing planting density and higher content was noted in plants at a wider spacing. This may be due to higher amount of light intercepted by each plant or due to the better distribution of light to individual plant at lower plant densities and synthesis of secondary plant metabolites will be generally higher when plants intercept more light.

5.2.4.5 Oleoresin

Oleoresin content was the highest under open condition, which was on par with that under young oil palm canopy. This is in conformity with the findings of Kurian *et al.* (2000) who reported slightly higher oleoresin content in Kacholam pure crop compared to intercrop. In ginger rhizomes, Babu (1993) reported the highest content of non volatile ether extract (NVEE) from open condition followed by 25 per cent shade.

5.2.5 Harvest Index

The harvest index, which indicates the efficiency of accumulation of photosynthates in economic parts, was significantly higher under open condition compared to various shade levels. This might be due to the high rate of photosynthesis and higher dry matter partitioning into the rhizomes under open condition compared to shade.

Harvest index also varied with planting density and was the least under lower planting density. This might be due to higher vegetative growth and lower translocation of drymatter into rhizomes at lower planting density.

5.2.6 Cost Benefit Analysis

5.2.6.1 Yield of Rhizome (t ha^{-1})

The highest dry rhizome yield was under open condition because of the higher plant population. With regard to yield, Kacholam performed equally well under both partial shade and deep shade. However, under mature oil palm canopy, its performance was slightly lower and this possibly might be due to the increased root competition from the mature oil palm trees. Better performance of Kacholam under the deep shade of rubber and coconut has been reported earlier (RRII, 1989, Nair *et al.*, 1991).

Spacing also affected rhizome yield and the highest per hectare yield was at lower spacing (20 x 10 cm). Even though the growth components and per plant yield were higher at wider spacing, the total yield was higher at lower spacing because of the higher plant population per ha. Since the shade x spacing interaction was not significant under all the shade levels, the closest spacing of 20 x 10 cm is advantageous for getting higher yield. This is in conformity with the findings of Maheswarappa (1999).

5.2.6.2 Net Income and Benefit Cost Ratio

The highest net profit was recorded when Kacholam was grown under open condition. Among different shade situations, the highest net profit was from young oil palm canopy followed by medium and mature. This indicates the suitability of Kacholam as intercrop in oil palm plantations of all age group. Maximum net profit was obtained from the lowest spacing of 20 x 10 cm under all situations. This can be recommended as the optimum spacing for intercropping Kacholam in oil palm plantations. Based on benefit cost ratio the ideal shade condition for intercropping Kacholam is under young oil palm plantation followed by medium and mature. Perusal of the benefit cost ratio also indicates the superiority of 20 x 10 cm spacing for getting higher yield and profit. Kurian *et al.* (2000) reported 20 x 10 cm to be the best spacing for getting higher yield for Kacholam as an intercrop in coconut plantations.

5.2.7 Yield of Oil palm

A perusal of the yield data of oil palms in the experimental plots before and after the experiment revealed that the yield of young, medium and mature palms was not affected by intercropping with medicinal plant species. Analysis of the soil samples from the experimental plots before and after the experiment also revealed not much reduction in the soil nutrient status, after the experiment. Reports of intercropping studies in oil palm by Amoah *et al.* (1995) and Salako *et al.* (1995) also supports the above conclusion.

Performance analysis of the ten medicinal plant species under the four shade levels during the first phase of investigation revealed that the performance of all species was better under the young oil palm canopy followed by medium and mature, which were on par with open.

Among the ten species evaluated, Chittadalodakam, Chittaratha, Kacholam, Karimkurinji and Sathavari were identified as economic intercrops in oil palm plantations. Out of the five species, Kacholam emerged as the most profitable crop under young, medium as well as mature plantations and hence selected for the phase II study.

An analysis of the data on the morphological, physiological, anatomical and biochemical characters during the second phase of the experiment revealed the shade tolerant nature of Kacholam. Increased number of leaves, tillers, total leaf area and increased fresh weight of all plant parts clearly indicated the superior performance of Kacholam under shade. Physiological attributes like, total dry matter production, leaf area index, specific leaf weight and water potential were also found to be higher under shaded condition compared to open, indicating its shade tolerant behaviour. Lower stomatal density, decreased epidermal and mesophyll thickness and lower number of vascular bundles noticed in Kacholam leaves grown under shade, compared to open, are clear indications of the adaptive mechanism of Kacholam under shade. Higher content of chlorophyll ‘a’, ‘b’ and total chlorophyll recorded under shade also indicate the biochemical mechanism of shade tolerance in Kacholam.

As a part of standardizing the cultivation packages for Kacholam as an intercrop in oil palm plantations, the spacing trial was conducted in which 20 x 10 cm spacing was found to be the most suitable under palms of all age groups.

For recommending Kacholam as a sustainable intercrop in oil palm plantations, standardization of its manurial requirement is also necessary and hence the next phase of experimentation proposed is a comprehensive manurial trial for Kacholam under oil palm plantations of different age groups.

SUMMARY

6. SUMMARY

The present investigation entitled 'Techno economic study on intercropping medicinal plants in oil palm plantations' was carried out at Kulathupuzha oil palm estate during the period 1999 - 2002, to study the adaptability and performance of ten medicinal plant species as intercrop in oil palm plantations of different age groups. The experimental material consisted of ten medicinal plant species viz; *Adhatoda beddomei* (Chittadalodakam), *Alpinia galanga* (Chittaratha), *Solanum incanum* (Chunda), *Coleus zeylanicus* (Iruveli), *Kaempferia galanga* (Kacholam), *Strobilanthes haenianus* (Karimkurinji), *Plumbago rosea* (Koduveli), *Pogostemon patchouli* (Patchouli), *Asparagus racemosus* (Sathavari), and *Piper longum* (Thippali).The experiment was conducted in two phases. During the first phase, the selected medicinal plant species were screened for their adaptability and shade tolerance under three oil palm canopy shade levels (young, medium and mature) and in the open by conducting growth, yield and economic analyses. Based on the economic analysis, the potential species under the three oil palm shade levels was selected for further studies.

In the second phase, as a part of developing package of practices for the potential crops, a spacing trial with three levels of spacing was carried out to standardize the optimum spacing for the selected crop under the three oil palm canopy shade levels. The morphological, anatomical, physiological and biochemical characters associated with shade tolerance of the selected species were also analyzed in the experiment.

The salient findings of the two experiments are summarized below.

6.1 PHASE I EXPERIMENT

In the study, the pattern of distribution of solar energy indicated that there was considerable variation in the interception of sunlight, by palm canopies of different age groups. The range of light condition available in the plantation was grouped as, young palms with moderate light transmission (PAR

42 % of open), medium and mature palms having poor light transmission, improving with increase in palm height and also change in leaf orientation (PAR 19 and 22 % of open respectively).

6.1.1 Comparison of Different Oil Palm Age Groups with Regard to Intercrop Performance

The performance of all ten species with regard to morphological characters and yield were better under the young oil palm canopy. Height of medicinal plants showed an increasing trend with increasing shade levels upto one year after planting and maximum plant heights were recorded under medium oil palm canopy where the shade level was the highest. Plants grown under open condition and also mature palms were shorter throughout the growth period. Other morphological and physiological characters like number of branches, number of leaves, number of roots, leaf area index and total dry matter production were maximum under young oil palm canopy. Under medium and mature oil palm canopy all these characters decreased and were almost equal to that under open condition.

Regarding growth analysis of the species, Kacholam recorded the highest net assimilation rate under open condition and various shade conditions. Under young oil palm canopy, Koduveli, Sathavari and Karimkurinji also had higher net assimilation rate values. The highest values of crop growth rate under open and mature canopy was recorded for Chittaratha while under young and medium canopy, Chittadalodakam recorded higher rates. Absolute growth rate was the highest for Karimkurinji under medium and mature canopy while under open and young canopy, Chittaratha recorded higher rates. On the other hand, Chunda recorded the highest relative growth rate under open condition, while under all shade conditions relative growth rate values were higher for Kacholam.

Significant influence of shade on per plant yield of the medicinal plants was also noticed in the study. Significantly higher per plant yield was recorded for the species grown under young oil palm canopy. The per plant yield of species grown under open condition was on par with that under medium and mature oil palm canopy.

The different shade conditions prevailed under the oil palm canopy significantly influenced the harvest indices of the medicinal plant species grown under them. Significantly higher harvest index was recorded for species under open condition, which was on par with that under young oil palm canopy.

Among the three shade conditions studied, the net income per hectare and benefit cost ratio of the medicinal plant species were the highest when they were grown under the young oil palm canopy shade level.

From the above findings, it can be concluded that among the different oil palm canopy shade levels, young oil palm canopy shade is the most profitable situation for intercropping medicinal plant species. Intercropping of shade tolerant medicinal plants under medium and mature oil palm canopy is also beneficial for getting reasonable additional income from the plantations.

6.1.2 Adaptability Studies of Selected Species as Intercrop and as Pure Crop

Chittadalodakam - Malabar nut (*Adhatoda beddomei*)

An assessment of the performance of Chittadalodakam as intercrop in oil palm canopies of different age groups and under open condition revealed that, among the shade conditions evaluated, the general performance with regard to morphological characters, yield, net income and benefit cost ratio was the highest when it was grown under young oil palm canopy. Growth analysis also revealed the highest crop growth rate for Chittadalodakam, under young and medium oil palm canopy. In the economic analysis, it was also observed that the net profit ha^{-1} and benefit cost ratio were comparable under the three shade conditions and open. This indicates its suitability for cultivation under oil palms of all age group.

Chittaratha (*Alpinia galanga*)

An assessment of the performance of Chittaratha during the different growth stages revealed that, on an average, the performance was the best under young oil palm canopy. A perusal of the data on the morphological, physiological and yield characters revealed an increase of all these characters under the young oil palm canopy. Growth analysis of the plants also revealed its superior performance under the various shade situations. Highest net profit and benefit cost ratio recorded under young oil palm canopy makes the crop most suitable for intercropping under young oil palm canopy. However, the comparable net profit and benefit cost ratio under other two shade conditions (under the deep shade of medium and mature palms) indicates its suitability as intercrop under medium and mature oil palm canopy also.

Chunda - Medicinal solanum (*Solanum incanum*)

The overall performance of Chunda with regard to growth and yield characters was very poor under both the intercropped situation and open condition. The indicators of growth analysis also underline this fact. Chunda recorded a net loss when grown under different oil palm canopy shade and open condition. The benefit cost ratio worked out was <1 under all situations and hence can not be recommended as an intercrop in oil palm plantations.

Iruveli - Hribera (*Coleus zeylanicus*)

The general performance of Iruveli was poor both in the open and under oil palm canopy shade as indicated by the growth and economic analyses. Net loss and <1 benefit cost ratio under all shade levels points towards its unsuitability for that particular agroclimatic condition.

Kacholam - Galanga *(Kaempferia galanga)*

Economic analysis of the yield data of Kacholam revealed the highest net profit among all crops; under the young oil palm canopy, which was almost equal to the yield under open condition. The benefit cost ratio under all situations was > 1. In general, the performance of Kacholam was equally good at all shade conditions and hence can be recommended as the most suitable intercrop in oil palm plantations of all age groups.

Karimkurinji - Medicinal strobilanthes (*Strobilanthes haenianus*)

Higher net profit and benefit cost ratio recorded under the shade situations makes Karimkurinji, a suitable intercrop for oil palm plantations of all age groups.

Koduveli - Rosy leadwort (*Plumbago rosea*)

In the present study, different shade levels under which the plants were grown did not have much influence on the morphological characters and yield except plant height, which increased with increasing levels of shade during the later stages of crop growth. The highest per plant yield was recorded under young oil palm canopy and yield under medium and mature palms were on par. Economic analysis of the yield data of Koduveli recorded a net loss under all shade situations and the benefit cost ratio recorded was also < 1 under all situations and hence can not be recommended for intercropping in oil palm plantations.

Patchouli (*Pogostemon patchouli*)

The data on the morphological characters and growth analysis revealed better performance of Patchouli as an intercrop in oil palm plantations of different age groups. However, after considering the cost of cultivation incurred and per hectare yield of herbage, a net loss was recorded both under open and shade conditions. Nevertheless, the per ha loss was minimum under young oil palm canopy. The benefit cost ratio recorded was < 1 under all situations and hence can not be recommended as an economic intercrop in oil palm plantations.

Sathavari - Asparagus (*Asparagus racemosus*)

The overall performance of Sathavari was satisfactory under the three oil palm canopy shade levels. Economic analysis of the yield data recorded a net profit under all situations and maximum net profit was from young oil palm plantation. The benefit cost ratio of Sathavari showed that it is most suited for cultivation under young oil palm plantations followed by medium and mature.

Thippali - Long pepper *(Piper longum)*

In general, plant growth was very poor and not uniform under all situations as indicated by the data on various morphological characters and growth analysis. Economic analysis of the yield data showed a net loss under all situations and the benefit cost ratio recorded for Thippali were the lowest among all species, under all situations and hence can not be recommended as an economic intercrop in oil palm plantations.

PHASE II EXPERIMENT

In the present investigation, the effect of different levels of shade and plant population, on growth, yield and quality of Kacholam was studied to find out suitable spacing for Kacholam at different shade levels of oil palm canopy. The morphological, physiological, anatomical and biochemical mechanism of shade tolerance in Kacholam were also analyzed in the study.

The highest net profit was recorded when Kacholam was grown under young oil palm canopy and the profit was slightly higher than that obtained from open crop. The net profit from other two shade situations was also not much lower than under open condition. This indicates the suitability of Kacholam as intercrop in oil palm plantations of all age groups. Maximum net profit was obtained from the lowest spacing of 20 x 10 cm under all situations. The spacing, 20 x 10 cm can be recommended as the optimum spacing for intercropping Kacholam in oil palm plantations. Based on benefit cost ratio, it can be concluded that the ideal shade condition for intercropping Kacholam is under young oil palm canopy followed by medium and mature canopy. Perusal of the benefit cost ratio also indicates the superiority of 20 x 10 cm spacing for getting maximum yield and profit.

An analysis of the various morphological characters like number of tillers, leaves, and leaf area, stomatal density, anatomical characters like thickness of epidermal and mesophyll layers, number of vascular bundles, physiological attributes like leaf area index, specific leaf weight, water potential and biochemical characters like starch, ash and chlorophyll content, revealed the shade tolerant nature of Kacholam.

In brief, phase I experiment revealed the feasibility of growing medicinal plants as intercrop in oil palm plantations of all age groups studied. Among the ten medicinal plant species evaluated, Kacholam emerged as the most profitable intercrop for oil palm plantations under southern Kerala conditions. Hence Kacholam was selected as the test crop for the standardization of cultivation packages, and as a first step, the spacing trial was conducted to fix the ideal planting density under the different shade levels prevailed in oil palm plantations of various age groups. The trial revealed that 20 x 10 cm spacing was the ideal planting distance for intercropping Kacholam in young, medium and mature plantations. However, for recommending Kacholam as a sustainable intercrop in oil palm plantations, standardization of its manurial requirement is also necessary and hence the next phase of experimentation proposed is a comprehensive manurial trial for Kacholam under the above conditions.

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* Originals not seen

APPENDIX

APPENDIX

Table 1 Analysis of variance (mean square) for plant height at different stages of plant growth, cm

Source	df	Growth Stage (month)						
		1	2	3	4	5	6	7
Replication	2	0.51	49.53	33.58	79.68	24.42	21.03	55.15
Shade	3	79.10	201.71	386.08 **	508.16**	297.24	763.30 **	1039.99**
Error (a)	6	50.49	58.16	24.20	50.80	100.55	18.62	20.36
Species	8	261.99 **	475.44 **	586.43**	828.23**	1058.54 **	1653.15 **	1462.32**
Shade X Species	24	62.25 *	88.05**	134.51**	261.14 **	283.68 **	436.34 **	408.82**
Error (b)	64	33.99	27.38	22.54	80.52	71.83	36.80	48.77
Total	107							

* * **Significant (p < 0 . 0 1)** * **Significant (p < 0 . 0 5)**

Source	df	Growth stage (month)										
		8	9	10	11	12	13	14	15	16	17	18
Replication	2	58.88	62.64	9.07	32.88	113.00	15.23	1.34	144.52	47.91	7.63	41.66
Shade	3	965.63**	1248.75**	1188.5**	1565.14**	2186.74**	3438.15**	3814.64**	3468.17**	3495.91**	4581.63**	5304.32**
Error (a)	6	28.08	11.97	42.22	48.95	92.99	24.24	105.29	21.54	135.36	128.38	43.98
Species	5	2389.67**	2141.74**	2849.07**	3478.12**	4174.26**	5224.67**	6618.43**	8967.43**	10614.39**	10335.24**	10039.34**
Shade X Species	15	500.64**	449.81	425.45**	641.60**	879.85**	1134.99**	1379.94**	1494.49**	1907.78**	2130.53**	2530.99
Error (b)	40	25.84	69.57	54.79	74.88	52.73	46.54	40.53	91.59	70.58	88.61	62.74
Total	71											

* * **Significant (p < 0 . 0 1)** * **Significant (p < 0 . 0 5)**

Table 11 Analysis of variance (mean square) for leaf number at different stages of plant growth

Source	df	Growth Stage		(month)			
		1	2	3	4	5	6
Replication	2	38.93	103.22	247.43	457.50	286.42	417.13
Shade	3	238.36**	1674.34**	2002.05**	2829.94*	3081.96**	4973.06**
Error (a)	6	22.66	121.13	101.18	356.27	269.61	134.22
Species	9	485.86**	2970.55**	3858.92**	5241.51**	6576.82**	8009.66**
Shade x Species	27	84.73**	736.20**	867.40**	1073.25**	1071.30**	1300.89**
Error (b)	72	18.04	132.71	106.70**	429.41	342.50	276.58

Source	df	Month
		7
Replication	2	244.06
Shade	3	4562.58**
Error (a)	6	311.61
Species	8	11279.14**
Shade X Species	24	1517.01**
Error (b)	64	346.11

* * Significant (p < 0 . 01) * Significant (p < 0 . 05)

Source	df	8	9	10	11	12	13	14	15	16	17	18
Replication	2	294.04	88.88	537.04	350.04	29.59	223.19	107.27	89.34	63.38	62.84	74.25
Shade	3	5380.57**	5056.46**	12604.19**	15957.28**	17010.93**	23550.64**	27628.75**	41349.17**	49869.71**	39200.17**	43088.77**
Error (a)	6	268.76	105.21	592.67	115.43	431.41	136.97	239.47	102.77	188.09	180.89	84.77
Species	5	18423.26**	26820.23**	40441.17**	52446.23**	66824.46**	98651.56**	128132.2**	173831.4**	227792.8**	253396.8**	260100.9**
Shade X Species	15	2248.88**	3122.60**	6026.59**	7250.66**	7882.01**	11794.58**	13056.44**	18904.53**	24228.46**	22208.35**	21405.4**
Error (b)	40	351.60	107.91	621.16	181.50	215.29	154.68	195.67	168.98	73.18	119.31	43.22

* * Significant (p < 0 . 01) * Significant (p < 0 . 05)

Table III Analysis of variance (mean square) for branch number at different stages of plant growth

Source	df	Growth Stage			(month)				Source	df	Month
		1	2	3	4	5	6				7
Replication	2	0.30	0.61	0.33	0.93	2.36	9.18		Replication	2	0.68
Shade	3	2.36	12.37**	31.90**	28.06**	48.67**	47.27**		Shade	3	34.48**
Error (a)	6	1.08	0.42	1.14	2.02	1.56	1.70		Error (a)	6	2.05
Species	9	67.93**	99.99**	106.04**	121.39**	186.06**	170.52**		Species	8	144.48**
Shade X species	27	1.83**	5.89**	3.76**	6.75**	8.05**	7.02**		Shade X Species	24	11.00
Error (b)	47	0.59	1.88	1.22	2.52	1.56	2.64		Error (b)	43	1.31

* * **Significant (p < 0 . 01)** * **Significant (p < 0 . 05)**

Source	df	8	9	10	11	12	13	14	15	16	17	18
Replication	2	2.347*	0.51	1.06	0.88	50.67	1.06	3.18	2.35	3.17	0.68	3.43
Shade	3	49.38**	28.481**	44.685**	58.458**	121.98	142.98**	142.83**	129.5**	110.09**	102.07**	96.00**
Error (a)	6	0.33	0.94	0.30	2.15	53.76	2.54	2.50	1.50	9.24	4.53	6.30
Species	5	260.35**	337.32**	436.22**	580.625**	923.27**	1156.76**	1513.38**	1567.01**	1622.09**	1672.86**	1773.39**
Shade X Species	15	19.23**	24.20**	27.84**	37.5361**	99.59	71.37**	69.995**	62.41**	63.14**	62.22**	60.83**
Error (b)	31	1.35	1.28	0.99	1.37	54.14	1.12	3.60	3.96	4.00	2.85	5.33

* * **Significant (p < 0 . 01)** * **Significant (p < 0 . 05)**

Table IV **Analysis of variance (mean square) for root number at different stages of plant growth**

		Growth Stage			(month)				Source	df	Month
Source	df	1	2	3	4	5	6				7
Replication	2	4.03	0.22	5.66	6.48	7.11	3.31		Replication	2	2.53
Shade	3	2.03	22.03	48.96	232.39**	208.47**	329.82**		Shade	3	394.98**
Error (a)	6	4.72	4.89	10.91	12.16	4.61	9.33		Error (a)	6	15.78
Species	9	56.28**	98.06**	135.87**	206.29**	231.41**	259.87**		Species	8	456.77**
Shade X Species	27	8.80**	13.73**	19.35**	26.62**	30.47**	54.01**		Shade X Species	24	83.96**
Error (b)	72	3.09	5.40	5.51	11.09	7.06	5.82		Error (b)	64	9.25

*** * Significant (p < 0 .01)** *** Significant (p < 0 .05)**

Source	df	8	9	10	11	12	13	14	15	16	17	18
Replication	2	7.54	60.67	2.54	25.68	48.50	21.06	6.01	29.26	58.04	22.10	108.10
Shade	3	253.96**	401.46**	620.26**	490.13**	1259.76**	813.48**	952.06**	756.94**	770.46**	677.89**	1215.72**
Error (a)	6	12.73	22.44	20.97	10.24	32.65	4.65	18.63	13.65	16.93	38.43	12.75
Species	5	326.03**	876.13**	690.07**	679.25**	1707.97**	1373.09**	1583.09**	1811.02**	1889.79**	2116.92**	2395.81**
Shade X Species	15	57.02**	170.13**	117.66**	78.63**	361.36**	210.84**	251.36**	219.38**	286.99**	284.9**	324.76**
Error (b)	40	8.98	19.50	14.83	10.53	39.28	16.53	17.12	15.41	19.88	24.58	59.77

*** * Significant (p < 0 .01)** *** Significant (p < 0 .05)**

Table V Analysis of variance (mean square) for root length at different stages of plant growth, cm

Source	df	Growth Stage (month)							Source	df	Month
		1	2	3	4	5	6				7
Replication	2	3.56	13.61*	10.36	0.94	7.00	13.51		Replication	2	5.04
Shade	3	59.11	15.21*	52.67*	122.16*	63.31**	74.01**		Shade	3	70.32*
Error (a)	6	16.52	2.38	9.95	13.30	6.11	3.19		Error (a)	6	13.14
Species	9	47.59**	78.89**	88.69**	90.03**	121.05**	134.03**		Species	8	122.14**
Shade X Species	27	24.91	39.22**	27.53**	29.51*	33.55**	47.46**		Shade X Species	24	18.56
Error (b)	72	7.36	9.30	6.04	16.71	9.10	6.90		Error (b)	64	13.62

* * Significant (p < 0 .01) * Significant (p < 0 .05)

Source	df	8	9	10	11	12	13	14	15	16	17	18
Replication	2	3.82	277.57	2.30	0.67	10.46	4.12	2.22	39.23*	39.70	5.48	40.61*
Shade	3	97.996**	352.56	105.09**	154.50**	179.77**	296.34**	378.38**	349.88	363.89**	485.88**	476.53**
Error (a)	6	4.58	207.03	3.61	6.07	15.65	4.23	21.82	7.28	11.60	2.39	5.78
Species	5	214.74**	387.60*	216.09**	233.56**	285.78**	299.35**	341.85**	559.09**	916.07**	937.53**	1066.44**
Shade X Species	15	61.15**	149.86	49.64**	42.94**	53.70**	53.59**	69.42**	94.63**	97.64**	124.81**	127.20**
Error (b)	40	4.90	147.20	5.87	4.60	9.97	9.35	11.39	14.04	14.50	15.12	10.51

* * Significant (p < 0 .01) * Significant (p < 0 .05)

Table VI Analysis of variance (mean square) for dry matter production at different stages of plant growth, g

Source	df	Growth Stage		(month)			
		1	2	3	4	5	6
Replication	2	4.95	23.51	7.11	13.33	8.97	5.63
Shade	3	7.75	18.99	32.27*	47.32*	59.8*	168.34**
Error (a)	6	20.63	10.71	3.81	9.83	6.15	6.43
Species	9	599.40**	647.00**	665.55**	1110.42**	1076.13**	1509.60**
Shade X Species	27	18.19**	9.12	12.02**	14.83	26.30**	27.57**
Error (b)	72	7.80	9.26	3.09	14.65	8.01	5.11
Total	119						

Source	df	Month
		7
Replication	2	2.34
Shade	3	125.24
Error (a)	6	37.62
Species	8	2328.60**
Shade X Species	24	43.12**
Error (b)	64	18.43**
Total	107	

* * Significant (p < 0 . 01)   * Significant (p < 0 . 05)

Source	df	8	9	10	11	12	13	14	15	16	17	18
Replication	2	14.11	1.93	75.03	2.30	96.36	45.21	24.64	0.55	3606.34	17.21	57.02
Shade	3	221.23**	303.86**	685.09**	787.83**	927.50	1374.10**	1132.77**	962.94**	8855.83	748.13**	1352.47**
Error (a)	6	15.01	15.55	26.26	32.38	220.37	3.96	21.91	18.45	3639.71	53.14	42.45
Species	5	3498.61**	4638.50**	6294.58**	6621.34**	7831.47**	10489.58**	10573.89**	11501.93**	26616.76**	14272.83**	17437.57**
Shade X Species	15	72.44**	94.39**	188.99**	198.72**	213.42	272.71**	227.42**	252.01**	.4778.58	376.81**	537.56**
Error (b)	40	16.33	20.98	40.86	22.29	183.80	47.79	34.87	35.79	3508.07	37.78	46.38
Total	71											

* * Significant (p < 0 . 01)   * Significant (p < 0 . 05)

Table VII **Analysis of variance(mean square) for leaf area index at different stages of plant growth**

Source	df	Growth Stage (month)					
		1	2	3	4	5	6
Replication	2	0.130	0.010	0.020	0.038	0.001	0.069
Shade	3	0.110	0.28**	0.30**	0.503**	0.715**	1.088**
Error (a)	6	0.080	0.010	0.007	0.016	0.014	0.020
Species	9	0.49**	0.49**	0.93**	1.28**	1.717**	2.039**
Shade X Species	27	0.120	0.05**	0.073**	0.08**	0.144**	0.141**
Error (b)	72	0.090	0.020	0.009	0.034	0.028	0.041

Source	df	Month
		7
Replication	2	0.072
Shade	3	0.808**
Error (a)	6	0.044
Species	8	1.606**
Shade X Species	24	.15148**
Error (b)	64	0.038

* * Significant (p < 0 .01) * Significant (p < 0 .05)

Source	df	8	9	10	11	12	13	14	15	16	17	18
Replication	2	0.001	0.170	0.025	0.048	0.035	0.001	0.028	0.005	0.069	0.118	0.124
Shade	3	0.91384**	0.5603*	2.269**	3.154**	2.834**	3.934**	4.59**	6.72**	7.089**	4.19**	5.618**
Error (a)	6	0.025	0.096	0.046	0.020	0.119	0.039	0.036	0.019	0.086	0.134	0.049
Species	5	2.0537**	3.512**	4.85**	6.40**	6.378**	7.812**	10.38**	10.95**	13.31**	11.80**	14.80**
Shade X Species	15	0.20165**	0.2461*	0.705**	1.010**	0.810**	1.187**	1.32**	1.76**	1.83**	1.37**	1.59**
Error (b)	40	0.033	0.125	0.044	0.028	0.053	0.026	0.021	0.060	0.040	0.122	0.046

* * Significant (p < 0 .01) * Significant (p < 0 .05)

Table VIII Analysis of variance (mean square) for yield and harvest index

Source	df	Yield (Rs)	Harvest Index
Replication	2	0.0000324	0.000940
Shade	3	0.0118500**	0.020469**
Error (a)	6	0.0007815	0.0008487
species	9	1.5306000**	0.5203000**
Shade X species	27	0.0015950**	0.0086130**
Error (b)	72	0.0001304	0.0002560

Table IX Analysis of variance (mean square) for number of tillers at different stages of plant growth

Source	df	Growth Stage		
		60 DAP	120 DAP	180 DAP
Replication	2	0.583	0.528000	0.111
Shade	3	12.620**	37.435**	29.963**
Spacing	2	59.083**	120.361**	65.778**
Shade x Spacing	6	1.898	2.435	0.963
Error	22	1.008	1.528	1.898
*Significant ($p < 0.05$) **Significant ($p < 0.01$)				

Table X Analysis of variance (mean square) for number of leaves at different stages of plant growth

Source	df	Growth Stage		
		60 DAP	120 DAP	180 DAP
Replication	2	4.694	3.250	9.75*
Shade	3	6.917**	5.213	5.407
Spacing	2	13.194**	42.25**	71.083**
Shade x Spacing	6	1.528	2.324	3.491
Error	22	1.239	3.371	2.417
*Significant ($p < 0.05$) **Significant ($p < 0.01$)				

Table XI. Analysis of variance (mean square) for leaf area, cm^2 at different stages of plant growth

Source	df	Growth Stage		
		60 DAP	120 DAP	180 DAP
Replication	2	477.863	347.547	825.031
Shade	3	718.240**	1177.927	948.521*
Spacing	2	1578.102**	6220.891**	11696.690**
Shade x Spacing	6	172.156	223.609	288.573
Error	22	122.347	391.435	287.588
*Significant ($p < 0.05$) **Significant ($p < 0.01$)				

Table XII Analysis of variance (mean square) for fresh weight of leaves at different stages of plant growth, g

Source	df	Growth Stage		
		60 DAP	120 DAP	180 DAP
Replication	2	0.900*	0.071	0.839
Shade	3	2.001**	5.033**	0.486
Spacing	2	1.330*	4.117**	2.988**
Shade x Spacing	6	0.488	0.660	0.520
Error	22	0.237	0.283	0.293
*Significant (p < 0.05) **Significant (p < 0.01)				

Table XIII Analysis of variance (mean square) for fresh weight of roots at different stages of plant growth, g

Source	df	Growth Stage		
		60 DAP	120 DAP	180 DAP
Replication	2	0.303	0.012	0.057
Shade	3	16.845**	8.914**	11.396**
Spacing	2	3.761**	1.523**	2.115**
Shade x Spacing	6	0.404**	0.373**	0.355**
Error	22	0.089	0.052	0.054
*Significant (p < 0.05) **Significant (p < 0.01)				

Table XIV. Analysis of variance (mean square) for fresh weight of rhizome at different stages of plant growth, g

Source	df	Growth Stage		
		60 DAP	120 DAP	180 DAP
Replication	2	2.578	5.637	5.382
Shade	3	26.885**	104.014**	40.443**
Spacing	2	202.850**	330.612**	286.183**
Shade x Spacing	6	6.531**	2.660	4.959
Error	22	1.188	4.274	3.643
*Significant (p < 0.05) **Significant (p < 0.01)				

Table XV Analysis of variance (mean square) for dry weight of leaves at different stages of plant growth, g

Source	df	Growth Stage		
		60 DAP	120 DAP	180 DAP
Replication	2	0.271	0.031	0.156
Shade	3	0.593**	0.020	1.463**
Spacing	2	0.191	0.393	3.040**
Shade x Spacing	6	0.174	0.027	0.141
Error	22	0.104	0.035	0.116
*Significant (p < 0.05) **Significant (p < 0.01)				

Table XVI Analysis of variance (mean square) for dry weight of roots at different stages of plant growth, g

Source	df	Growth Stage		
		60 DAP	120 DAP	180 DAP
Replication	2	0.056	0.022	0.005
Shade	3	2.968**	2.862**	3.002**
Spacing	2	0.735**	0.768**	0.791**
Shade x Spacing	6	0.074**	0.094**	0.134**
Error	22	0.017	0.015	0.011
*Significant (p < 0.05) **Significant (p < 0.01)				

Table XVII Analysis of variance (mean square) for dry weight of rhizome at different stages of plant growth, g

Source	df	Growth Stage		
		60 DAP	120 DAP	180 DAP
Replication	2	0.094	1.334	10.806
Shade	3	7.783**	36.940**	8.710
Spacing	2	52.488**	85.954**	66.792**
Shade x Spacing	6	1.646*	0.681	1.620
Error	22	0.622	1.811	3.243
*Significant (p < 0.05) **Significant (p < 0.01)				

Table XVIII Analysis of variance (mean square) for leaf area index at different stages of plant growth

Source	df	Growth Stage		
		60 DAP	120 DAP	180 DAP
Replication	2	0.012*	0.004	0.005
Shade	3	0.018**	0.013	0.006*
Spacing	2	0.040**	0.069**	0.073**
Shade x Spacing	6	0.004	0.002	0.002
Error	22	0.003	0.004	0.002
*Significant ($p < 0.05$) **Significant ($p < 0.01$)				

Table XIX, Analysis of variance (mean square) for specific leaf weight at different stages of plant growth, g cm $^{-2}$

Source	df	Growth Stage		
		60 DAP	120 DAP	180 DAP
Replication	2	0.000010	0.000004	0.000009
Shade	3	0.000057*	0.000067**	0.000044**
Spacing	2	0.000045*	0.000024	0.000027
Shade x Spacing	6	0.000032	0.000006	0.000010
Error	22	0.000013	0.000007	0.000007
*Significant ($p < 0.05$) **Significant ($p < 0.01$)				

Table XX Analysis of variance (mean square) for physiological characters at 120 DAP

Source	df	Water Potential (Mpa)	Stomatal Conductance m mol m $^{-2}$ sec $^{-1}$	PAR m mol m $^{-2}$ sec $^{-1}$
Replication	2	0.00011	0.00002	211.630
Shade	3	0.02790**	0.01090**	385894.500**
Spacing	2	0.00049	0.00002	277.130
Shade x Spacing	6	0.00542**	0.00004	446.290
Error	22	0.00023	0.00004	243.380
*Significant ($p < 0.05$) **Significant ($p < 0.01$)				

Table XXI Analysis of variance (mean square) for anatomical characters at 120 DAP

Source	df	Mesophyl thickness m mol	Epidermal thickness m mol	No.of Vascular Bundles	Stomatal Density mm^{-2}
Replication	2	1600.50	74.83	1.69	0.03
Shade	3	174730**	6223.19**	33.30**	4.99**
Spacing	2	31894.50**	716.02**	7.53**	0.36
Shade x spacing	6	1656.17	55.45	0.27	0.21
Error	22	3277.05	38.47	0.63	0.24
*significant ($p < 0.05$)		**significant ($p < 0.01$)			

Table XXII Analysis of variance (mean square) for biochemical characters at 120 DAP

Source	df	Chlorophyll a mg g^{-1}	Chlorophyll b mg g^{-1}	Total Chlorophyll mg g^{-1}	Essential Oil %	Oleoresin %	Ash %	Starch %
Replication	2	0.004	0.0001	0.00026	0.00497	0.0075	26.54	0.528
Shade	3	0.006	0.0013**	0.04140**	0.97800**	0.1670**	116.09**	1.079*
Spacing	2	0.010	.0012**	0.00133**	0.11400**	0.0149	247.24**	1.757**
Shade xspacing	6	0.004	.0008**	0.00076**	0.03860	.05270*	22.97	0.370
Error	22	0.005	0.0001	0.000067	0.01870	0.0193	19.31	0.254
*significant ($p < 0.05$)		**significant ($p < 0.01$)						

ABSTRACT

TECHNO ECONOMIC STUDY ON INTERCROPPING MEDICINAL PLANTS IN OIL PALM PLANTATIONS

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8. ABSTRACT

An investigation entitled 'Techno economic study on intercropping medicinal plants in oil palm plantations' was carried out at Kulathupuzha oil palm estate during the period 1999 - 2002, to study the adaptability and performance of ten medicinal plant species as intercrop in oil palm plantations of different age groups. The specific objectives were to standardize the optimum spacing for the potential species under the different oil palm canopy shade levels and to study the morphological, anatomical, physiological and biochemical mechanism of shade tolerance of the selected species.

In the study, the pattern of distribution of solar energy indicated that there was considerable variation in the interception of sunlight, by palm canopies of different age groups. The range of light condition available in the plantation was grouped as, young palms with moderate light transmission (PAR 42 % of open), medium and mature palms having poor light transmission, improving with increase in palm height and also change in leaf orientation (PAR 19 and 22 % of open respectively).

The experiment revealed the feasibility of growing medicinal plants as intercrop in oil palm plantations of all age groups studied. The performance of all ten species with regard to morphological characters and yield were better under the young oil palm canopy. The per plant yield of species grown under open condition was on par with that under medium and mature oil palm canopy. The net income per hectare and benefit cost ratio of the medicinal plant species were the highest when they were grown under the young palms. The study suggests that among the different oil palm canopy shade levels, young oil palm canopy is the ideal condition for intercropping medicinal plant species. Intercropping of shade tolerant medicinal plants under medium and mature oil palm canopy is also beneficial for getting reasonable additional income from the plantations.

Among the ten medicinal plant species evaluated, Kacholam emerged as the most profitable intercrop for oil palm plantations under southern Kerala conditions. Other profitable intercrops identified were Chittadalodakam, Chittaratha, Karimkurinji and Sathavari.

The spacing trial of Kacholam under the different shade levels prevailed in oil palm plantations of various age groups revealed that 20 x 10 cm spacing was the ideal planting distance in young, medium and mature plantations for getting highest yield and profit. The highest net profit was recorded when Kacholam was grown under young oil palm canopy and the profit was slightly higher than that obtained from open crop. The net profit from other two shade situations was also not much lower than under open condition. This indicated the suitability of Kacholam as intercrop in oil palm plantations of all age groups. A higher net profit was obtained from the lowest spacing of 20 x 10 cm under all situations. The spacing, 20 x 10 cm can be recommended as the optimum spacing for intercropping Kacholam in oil palm plantations. Based on benefit cost ratio, it can be concluded that the ideal shade condition for intercropping Kacholam is under young oil palm canopy followed by medium and mature canopy.

An analysis of the morphological, physiological, anatomical and biochemical characters of Kacholam revealed its shade tolerant nature. Increased number of leaves, tillers, total leaf area and increased fresh weight of all plant parts clearly indicated the superior performance of Kacholam under shade. Physiological attributes like, total dry matter production, leaf area index, specific leaf weight and water potential were also found to be higher under shaded condition compared to open, indicating its shade tolerant behaviour. Lower stomatal density, decreased epidermal and mesophyll thickness and lower number of vascular bundles noticed in Kacholam leaves grown under shade, compared to open, are clear indications of the adaptive mechanism of Kacholam under shade. Higher content of chlorophyll 'a', 'b' and total chlorophyll recorded under shade also indicated the biochemical mechanism of shade tolerance in Kacholam.

Analysis of the yield data of oil palms in the experimental plots before and after the experiment revealed that the yield of young, medium and mature palms was not affected by intercropping with medicinal plant species.