"TO ASSESS THE PERFORMANCE OF *CURCUMA LONGA* L. GROWN AS AN INTERCROP UNDER TREE SPECIES"

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ABSTRACT

"TO ASSESS THE PERFORMANCE OF *Curcuma longa* L. GROWN AS AN INTERCROP UNDER TREE SPECIES"

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ABSTRACT

The present investigation was carried out at the Instructional Farm, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari during *kharif* season 2005. In all eight treatments involving sixteen year old forest tree species *Terminalia arjuna* Bedd. (T_1), *Casuarina equisetifolia* L. (T_2) and *Mitragyna parvifolia* Korth.(T_3) and open field (T_0) as main plot treatments.As an intercrop *Cucurma longa* L. with two varieties Sugundham (C_1)and Kesar (C_2) were tried with 2 x 4 Factorial Randomized Block Design with four replications.

Significantly maximum plant height, number of leaves, leaf length, leaf breadth and number of shoots were recorded when crops grown under T_3 (Kalam) as compared to T_0 (open condition). Similarly maximum rhizome length and rhizome breadth were observed under T_3 (Kalam) as compared to T_0 (open condition). However, significantly the highest yield per plant and per plot were recorded under T_3 (kalam) and lowest under T_0 (open condition).

Among trees significantly the maximum light intensity was observed under Kalam followed by Arjun and Sharu.

Significantly the superior plant height, leaf length, leaf breadth, number of shoots, rhizome length, rhizome breadth and yield were recorded in C_1 (Sugundham) Variety of *Curcuma longa* L.

From economic point of view *Curcuma longa* L. grown under T_3 (Kalam) was found more profitable than Sharu, Arjun and open condition. The yield of rhizome under Kalam trees was found to be more profitable than Arjun. Also in future tree and crop combination may be even more profitable when yield of wood will be taken into consideration while calculating the economics of the agroforestry system.

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CERTIFICATE

This is to certify that the thesis entitled **"TO ASSESS THE PERFORMANCE OF *Curcuma longa* L. GROWN AS AN INTERCROP UNDER TREE SPECIES."** submitted by Mr. **PRAJAPATI VIJAYKUMAR MANILAL** in partial fulfillment of the requirements for the award of the degree of **MASTER OF SCIENCE (FORESTRY) in AGROFORESTRY AND ECOLOGY** of the Navsari Agricultural University, is a record of bonafide research work carried out by him under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma or other similar title.

Place: Navsari **(N.S. PATIL)**

Date: 8th August, 2006. **Major Advisor**

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INTRODUCTION

I INTRODUCTION

In India, the green revolution led to increase in production through enhanced productivity. Unfortunately the population growth is increasing at a rapid rate and there is an urgent need to accelerate agricultural growth to address issues on food security, nutrition adequacy, rural income generation, employment and poverty. Despite higher production, the per capita availability of food over time has not increased significantly. About 70 to 80 per cent of our people depend on agriculture for their livelihood. Contribution of agriculture to GDP is declining, this affects the rural poor most. The urban rural divide and regional disparities are on the increase. To achieve a desirable rate of 8 per cent growth in the economy, agriculture must register a growth of not less than 4 per cent. Now it is around 2 per cent and is declining. Thus, continuous improvements in productivity are essential but these must be capable of being maintained in perpetuity. In other words, an ever green revolution rooted in the principles of ecology, economics, social and gender equity, energy conservation, employment generation and social auditing, is essential in major farming systems of India. Land, water and vegetation care constitute the foundation for building up such an evergreen revolution movement.

A major opportunity to meet the challenges exist, if only we are able to break the traditional sectoral divide between agriculture and forestry and recognized agroforestry as farmer led efforts to meet livelihood needs on a limited land base without categorical distraction between perennial (tree, shrub, palms, bamboos etc.) are deliberately added on the same land management unit with herbaceous crops and/or animals either in some form of spatial arrangement or temporal sequence (ICRAF), all over the world is the out come of the change of peoples attitude out of necessity.

An efficient agroforestry system would aims at systematically developing integrated land use systems and practices where the positive interaction between trees and crops encouraged and maximized. This seeks to achieve a more productive sustainable and diversified output from the land than is possible with the conventional mono-cropping system.

The farmers, mainly due to the economic benefits to them have adopted the trend of growing trees around agricultural land. But it will be worth while to work out an integrated approach with the help of agricultural and forestry scientists, depending on the suitability of crop and locations. Therefore, there is a great need to identify the suitable agricultural and horticultural crops, which can grow well along with tree plantation with limited solar energy available underneath the trees.

The choice of intercrop is important as the economic returns depend on particular tree species (root system, canopy, allelopathic effect of litter etc.) though the choice is also determined by the technical factors like Agroclimatic and edaphic conditions. Besides the cereals, vegetables and flowers, the medicinal and tuber crops are also grown as intercrops with trees; however, medicinal and tuber crops are found to be easily remunerative due to rhizomes and easy cultivation. Looking to above an attempt was made to evaluate the feasibility of growing different medicinal and tuber crops with forest tree species under agroforestry system.

Turmeric is the dried rhizome of *Curcuma longa* L. a herbaceous plant, native to Tropical South East Asia. India is the leading in its production (75% of world output). In India, Andhra Pradesh is the leading state followed by Maharashtra, Tamil Nadu, Orissa, Kerala and Bihar. The rhizome has 1.8 to 5.4 per cent curcumin, the pigment and 2.5 to 7.2 per cent of essential oil. It is used as an important condiment and as a dye with varied application in drug and cosmetic industries.

In *Curcuma longa* L., many improved varieties are released for different locations. We have selected 'Kesar' and 'Sugundham' varieties which are good in yield and medium duration maturity.

The judicious uses of suitable intercrops are of paramount importance in economic agricultural production and easy cultivation. No serious attempts were made in Gujarat in growing short duration economical intercrops in widely spaced forest tree species. We have therefore thought to conduct an experiment on intercropping of *Curcuma longa* L in widely spaced (10x2.5) trees like *Terminalia arjuna* Bedd. (Arjun), *Casuarina equisetifolia* L. (Sharu) and *Mitragyna parvifolia* Korth. (Kalam).

Terminaila arjuna Bedd. (Arjun) is a large handsome, evergreen tree or nearly so having large crown and drooping branches. The trunk at tree is often buttressed. This belongs to family combretaceae. It is an important multipurpose tree which originated from India and Myanmar. It is common through the greater part of Indian peninsula along rivers, steams, ravines and dry water course. The young bark contains the chlorophyll which latter on turns to light grey colour but pink inside exfoliating in thin irregular sheets. The heart wood is brown and sapwood is pinkish white in colour. The wood is very hard and can be used for building, agricultural implements, carts, boats, mine props, water troughs and other domestic purpose. The bark is used for tanning and is much collected for the purpose in central India.

Casuarina equisetifolia L. (Sharu) is a species of the Casuarinaceae with its natural distribution in Australia and parts of Asia and Oceania. It was introduced into the Indian sub-continent in the sixties of nineteenth century. It is pronouncedly dioecious moderate to large sized tree attaining a height of 30-40 m under favourable conditions. The wood is pale brown in colour, strong and heavy. It is greatly used in India for fuel. The calorific value is 4127 calories. It lends itself to topiary work and makes a good hedge, also an avenue or ornamental tree. It is also useful for preventing a landward drift of sea sand and afforestation of sandy beaches. Extract of leaves in acetic acid (1%) and sodium bicarbonate (50%) is anticancerous in nature.

Mitragyna parvifolia Korth. (Kalam) belongs to family Rubiaceae. It is a deciduous tree, growing up to 20 m height, rounded crown, trunk short and buttressed. The bark is light grey, smooth, dark patches of exfoliating scales when old. The wood is light pinkish-brown, even grained. It is fairly drought hardy and coppices well. The wood of tree is commonly used for furniture, agricultural implements and such purposes as manufacture of toys, combs, cups, bowls, platters, frames, walking sticks, handles etc. It is fairly popular for turnery and carving works.

The present investigation was, therefore, aimed to assess the intercropping of *Curcuma longa* L., in widely spaced forest trees species namely *Terminalia arjuna, Casuarina equisetifolia* and *Mitragyna parvifolia* with the following objectives.

1. To assess the performance of *Curcuma longa* L. as an intercrop under forest tree spices.
2. To work out economical gains by way of intercropping *Curcuma longa* L. with forest tree species.

REVIEW OF LITERATURE

II REVIEW OF LITERATURE

Agroforestry is relatively a new area of research; a little work has been carried out on species compatibility at field level and effect of tree species on crops.

To have better understanding on the present study, the finding of research work on various agricultural and horticultural crops with forest tree species at various locations in India and abroad have been reviewed briefly under following major heads.

2.1 Effect of forest tree species on intercrops

2.2 Effect of fruit trees on intercrops

2.3 Interaction effect between tree species and intercrops

2.3.1 Above ground interaction

2.3.2 Below ground interaction

2.1 Effect of forest tree species on intercrops

Lahiri (1972) studied the effect of twelve year old Teak (*Tectona grandis*) and Sal (*Shorea robusta*) on intercropped agricultural crops and proposed that in initial stage, agricultural crops may be intercropped with trees while turmeric may be grown in older plantation successfully as it was not much affected by shade. Likewise, Khan and Aslam (1974) studied the effect of *Dalbergia sissoo* tree on the yield of wheat crop and found that the grain yield was decreased to the tune of 30.9, 23.6 and 12.7 per cent at the distance of 3, 4.5 and 6 m from the tree, respectively as compared to the yield recorded from the centre of the field.

Dhillon *et al.* (1982) reported that Eucalyptus trees planted in N-S direction caused less reduction in crop yield than those planted in E-W direction. The shade tolerance was highest and correspondingly the yield reduction was lowest in potato followed by rice and wheat.

Balasubranian *et al.* (1984) conducted an experiment to find out the suitability of *Leucaena leucocephala* as hedge row with annual crops viz., sorghum, bajra, pearl-millet and red gram in the black cotton soils at millet Experiment Station, Kavilpatti, under dry land condition. The result showed that the crops raised along with *Leucaena* planted 6m apart and cutting at 100cm height gave the maximum yield of sorghum and bajra.

Prasad *et al.* (1985) studied the effect of 23 years old *Eucalyptus tereticornis* grown under rainfed condition on field crops viz., sorghum, green gram and black gram in *kharif* season followed by safflower and taramira (*Eruca sativa* Mill.) in *Rabi* season. They reported that sorghum was found to be more compatible than pulse in *kharif*. Taramira performed better than safflower in *Rabi* season.

Anon., (1986) studied the effect of *Acacia tortilis* on the row wise yield of different intercrops viz., Pearl-millet, greengram, cluster bean and castor at Gujarat Agricultural University, Dantiwada. The first two rows registered the maximum yield probably due to the availability of large space. There was in general no difference in the yield of other rows.

Among the different intercrops cluster bean had given the highest total income.

Shankarnarayan and Harsh (1986) conducted the experiment on intercropping of greengram and cluster bean crops with *Prosopis cineraria* and *Acacia albida* with 3 spacing. They reported that grain production of greengram and cluster bean was not affected by *Prosopis cineraria* or *Acacia albida* during third year. The yield of cluster bean was adversely affected when grown with *Acacia albida*.

Khybri *et al.* (1988) reported that the highest fodder yield of *Leucaena leucocephala* was obtained at 75cm spacing as compared to 375cm when grown alone as well as in intercropping with upland paddy-wheat rotation. *Leucaena* fodder yield was higher when grown with crops than without crops, which may be due to fertilization of crops. Although, the yield of crops was more when grown alone, but net income was highest in case of *Leucaena* + crop due to additional fuel yield of *Leucaena*.

Akbar *et al.* (1990) studied the effect of four tree species viz., *Eucalyptus camaldulensis*, *Albizia procera*, *Morus alba* and *Leucaena leucocephala* on the yield of wheat crop. They reported that the wheat yield was numerically lowest at 2m distance in case of all tree species than control. Numerically, higher wheat yield was noted at later distances. In case of all tree species including control except for *Albizia procera* numerically the highest yield was found at 6m distance. It was, therefore generalized that there was more impact of trees on wheat yield up to 2m distance, little impact up to 6m distance and almost no impact at 8, 10 and 12m distance.

The intercropping of agricultural crops like sesamum, pearl-millet (bajra), wheat and taramira (*Eruca sativa* Mill.) Subabul; (*Leucaena leucocephala*), Babul (*Acacia nilotica*) showed that the general performance of different agricultural crops was better under Babul than Subabul (Anon., 1990 a). Likewise, an investigation in which pulses were sown in association with Shisham (*Dalbergia latifolia*) at Faizabad during the year 1988-89 showed that lobia performed better in comparison with blackgram and greengram (Anon., 1990 b).

A team of research workers of Gujarat Agricultural University, Dantiwada, observed that the intercrops, viz., greengram, cluster bean, pearl-millet and castor had remarkable suppressing effect on *Acacia tortilis* growth in the initial stage. Pearl-millet gave the highest yield than other intercrops (Anon., 1990 c).

Wheat and paddy were grown as intercrops under different tree species during *Rabi* 1987-88 and *kharif* 1988 respectively at Pantnagar. The trees were pruned before planting of wheat crop to ensure sufficient light availability. Observations on light availability under different tree species were also recorded with the help of lux-meter. The results on light availability indicated that on an average, there was about 16 % reduction in light due to trees. The per cent reduction in light availability was relatively more under Semal (*Bombax ceiba*), Shisham (*Dalberiga latifolia*) and Arjun (*Terminalia arjuna*). The yield of wheat was relatively better under Shisham and Gutel, while it was lower under Subabul (*Leucaena leucocephala*). The yield of paddy was relatively higher under Bakan (*Melia azadirach* L.), Siris (*Albizia lebbeck*), Amaltas (*Cassia fistula*), Gutel (*Trewia nudiflora* L.), Teak (*Tectona grandis*), Semal (*Bombax ceiba*). However, the yield of fodder was more in Subabul followed by *Sesbania* and *Desmenthus* (Anon., 1990 d).

Gaynar and Jadhav (1992) observed significant decrease in the germination of rice and cowpea under the influence of leaf-leachate of *Terminalia tomentosa* after 3 days of sowing but it was non-significant after 5 days of sowing.

Jasural *et al.* (1993) studied the performance of two rhizomatous crop i.e. *Gingiber officinalis* (ginger) and *Curcuma longa* L. (Turmeric) was investigated in pure stand and as intercrop with 5 year old poplar planted at three spacing viz., 5 x 5, 5 x 4 and 5 x 3 m. Both crops performed better as intercrop than as pure stand. Survival was inversely correlated to light intensity. Plant height, tillers per plant and leaves per plant in ginger and leaf length and leaf breadth besides plant height in turmeric were significantly enhanced in intercropped. The rhizome length, rhizome breath, yield per plant and yield per hectare in ginger and turmeric exceeded under poplars but showed a drastic reduction under the closest poplars spacing. For quality parameters only oil content in ginger and oleoresin in turmeric showed significant difference. The cultivation of turmeric proved more remunerative than ginger. The spacing 5x4 m for ginger and 5x5 m for turmeric was proved the best.

Singh (1993) reported that the plant height and total fodder (bajara storer + tree leaves) yield/ha of pearl millet increased with the increase in tree densities of *Prosopis cineraria*. Treatment with the 50-trees/ha density improved the average number and thickness of earheads and produced a higher grain yield in addition to dry fuel wood/tree.

Bheemaiah *et al.* (1994) observed that the seed yields of sunflower and castor did not differ significantly in all alley width when grown with *Faidarabia albida*, a nitrogen fixing tree, in comparison with the seed yields of respectively sole crop in a two year study. The increment in height and girth of *F. albida* during investigation were also not affected by both the intercrops of sunflower and castor.

Chaturvedi and Jha (1994) reported beneficial effect of higher pruning intensity and lower pruning height in *Leucaena leucocephala* for high grain production. The highest grain yield of crops (wheat, maize and greengram) was obtained in the alley pruned 25 cm from base at monthly interval. Reduction of 55 and 47 per cent yield of grain of maize and wheat was recorded respectively in the lines adjacent to hedge grows in comparison to lines laying in the mid. Application of NPK @ 40-40-20 kg/ha in the Leucaena alleys gave significantly higher grain yield of maize and wheat over control.

Patel (1994) carried out a field experiment to study the effect of intercropping of solanaceous vegetables with forest tree species during *rabi* season of 1991-93 on the Farm of ASPEE College of Horticulture of Forestry, G.A.U., Navsari. Further, reported that earlier flowering of vegetables was observed under Arjun and Kalam as compared to Casuarina, which may be due to more light intensity under Kalam and Arjun. On the contrary, the higher plant height was recorded under Casuarina, while the maximum number of branches per plant was recorded under Arjun. The effect of forest species on fruit and yield attribute was found significantly maximum under Arjun.

Ramshe *et al.* (1994) studied the effect of association of tree species on grain production of rainy-season crops. Association of trees adversely affected the grain production of field crops with advancement in age. The reduction in yield was more in *Leucaena leucocephala* than with *Eucalyptus hybrid.* In closer tree row width (5.0 m) the reduction was more than wider tree row widths. Sunflower was more sensitive crop showing more reduction in grain, followed by pigeonpea and pearl millet. The annual monetary returns were higher in Leucaena + crops and Eucalyptus + crops than those taken as sole due to additional income from fuelwood.

Patel (1995) studied the effect of forest tree species on the production of agricultural crops (gram, mustard and Indian bean) during the year 1994-95 at ASPEE College of Horticulture and Forestry, G.A.U., Navsari. He further reported early flowering in agricultural crops under open field conditions as compared to intercrops with Arjun and Kalam, which may be due to more light intensity under open field. On the contrary, the highest plant height was recorded under Arjun as compared to Kalam while maximum number of branches per plant was recorded under open field and lowest under Arjun yield attributes were found significantly higher under open field conditions.

In Sri lanka, during the first 2 or 3 years after the initial planting of rubber trees i.e. before the trees have grown sufficiently to extend their canopy fully, the wide inter-row space were utilized for growing crop, which would generate and additional income during the first few unproductive years of the rubber trees, and also during wet periods when rubber tapping is not possible (Yogarantnam and Iqbal, 1995).

Lalramnghinglova and Jha (1996) collected large number of multipurpose trees and shrubs (48 species recorded) and are left deliberately as an introduced crops in cropping system to increase the productivity and finally they found the most common and successful practice of intercropping i.e. growing of *Oryza sativa* (paddy) with *Tectona grandis* (teak). This system is economically and ecologically sound.

Sodhi and Ansari (1996) observed improvement in the biological productivity as well as the economic return of the same piece of land. The different formats of farm forestry include peripheral planting on field boundaries, block plantation along with usual agricultural practices are being adopted in Haryana.

The poplar planting has been selected for an in depth study in view of its important contribution towards rural economy. To study, the economic results of the various plantation, the major component of cost benefit analysis viz., Net presenting value (NPV), benefit cost ration (BC ratio). Internal rate of return (IRR) and average annual net return (AANR) are calculated for 4, 5 and 6 years of rotation Poplar planting has been found to be more profitable than the traditional agricultural crops in Ambala, Kurukshetra and Yamunagar district of Haryana.

Subrahmanyam *et al.* (1996) conducted a field trial in the year 1991 in red sandy loams soils at students farm, College of Agriculture, Rajendranagar, Hydrabad to study the compatibility of tree crop association in Sissoo based agroforestry system under dry land situation. During two years study (1991 and 1992), the yields of arable crop viz., sunflower, castor and redgram was reduce considerably. Growing sissoo tree proved beneficial specially in improving the site by increasing organic carbon and nitrogen substantially as compared to fallow land. The results revealed that growing of Sissoo in association with arable crops provides sustainability to the traditional arable farming in dry regions.

Chauhan *et al.* (1997) studied growth and productivity of an agri-horti-silviculture system of agroforestry by planting kinnow mandarin (*Citrus nobilis* x *C. deliciosa*), Subabul (*Leucaena leucocephala*) and cultivating agricultural crops between woody perennials under irrigated conditions of subtropical low hill zone of Himachal pradesh. Observations on fruit, fodder, fuelwood, yield of agricultural crop, heights were recorded during two consecutive years. Data recorded for all the characters revealed significant results. Maximum fruit, fodder and fuelwood yield were obtained from treatment consisting of 36 trees of kinnow-mandarin plus 15 trees of Subabul and agricultural crops. Investigations also revealed that upto 45 per cent Subabul tree to that of fruit tree can be interplanted beneficially in kinnow-mandarin orchard.

Singh *et al.* (1997) studied growth, productivity and quality of eight vegetative crops grown in four crop sequences, viz., potato-onion, tomato-cowpea, and fababean-colocasia and frenchbean-turmeric in young Eucalyptus plantation. The plant height of potato, cowpea, turmeric increased while that of tomato, fababean, frenchbean and colocasia showed a decline, which may be because of shading effect of Eucalyptus. The average leaf area, number of leaves and dry matter content per plant were distinctly reduced in almost all the crops. The number of daughter rhizomes in colocasia and turmeric, pods per plant in all the beans and yield of all the intercrops decreased substantially as compared to open environment. The most deleterious effect was observed in onion, while in turmeric, shade showed minimum yield loss.

Patel *et al.* (1998) carried out a study during (1993) to identify suitable Forestry species (deshi baval, kher, gorasamli and subabul) in combination with arable crops (blackgram, greengram and pigeonpea). Amongst arable crops highest average yield over years was recorded by pigeonpea followed by greengram and blackgram. Highest survival rate was observed in deshi baval followed by subabul and kher. The growth in respect of height was highest for subabul followed by deshi baval and gorasamli. Similar trend was observed for collar diameter. Based on the result it is concluded that the agri-silvi-system of agroforestry using deshi baval + pigeonpea should be recommended for this watershed area.

Saroj *et al.* (1999) studied the productivity of ground storey crops with different species at WSCRTI, Research Farm, Solakui, Dehradun. The cropping sequence (jowar-toria) was tested with three plantations viz., *Eucalyptus hybrid*, *Bombax ceiba* and mixed plantation (natural) of *Cassia fistula*, *Bombax ceiba*, *Acacia catechu*, *Lannea Coromandalica* and *Dalbergia sissoo*. It was observed that about 14.82, 12.79 and 12.14 t/ha green fodder of jowar-toria can be obtained with *B. ceiba*, *Eucalyptus hybrid* and mixed plantation respectively. The yield of both the crops increased with increasing distance from the trunk, however, the direction did not influence the yield of ground storey crops.

Shanmughavel and Francis (1999) studied the growth performances and economic returns of pigeonpea (*Cajanus cajan*) growing as intercrop in Bamboo plantation. Pigeonpea intercropped in 1:1 rows at 3 x 3 m spacing (250 plants/ha) and in 1:2 rows at 2 m x 2m spacing (500 plants/ha) in Bamboo plantations. That on annual basis a net amounts of Rs. 7900/- at 2 x 2 m spacing and Rs. 13.300/- at 3 x 3 m spacing can be obtained. This agrisilviculture model provides fodder, fuel, fodder and timber to rural population.

Gill (2001) initiated study at NRCAF, Jansi (U.P) with twelve multipurpose tree species during 1988-89. In MPTS best growth parameters were found in *Eucalyptus* and poor in *Madhuca*. Minimum plant density gave highest yield and increase in density resulted decrease in yield. Maximum grain yield was registered from *Hardwicka binnata* and lowest in *Eucalyptus* and *leucaena*. Average minimum yield of wheat was registered at first row and increase to its maximum in fifth row.

Mahajan (2001) studied the effect of different spacements and pruning intensities of *Casuarina equisetifolia* L. on growth and yield of *Trigonella Foenum-greaecum* grown as intercrop. In all ten treatment involving three tree spacing (4 x 2 m, 6 x 2 m and 8 x 2m) with three pruning intensities in each spacement (unpruned, 50 per cent pruning and 75 per cent pruning) and open field control were tried in CRD with six replications. Under the low light condition, the number of leaves, branches, fresh weight, dry weight, leaf area per plant, Relative Growth Rate and Net Assimilation Rate of the intercrop reduced.

Nandal and Singh (2001) studied the productivity of different cropping sequences in *Dalbergia sissoo* Roxb. based agrosilviculture system. A field experiment was conducted for two years (1993-95) during the rainy and winter seasons to identify suitable cropping sequence for agroforestry. The productivity of sorghum, lentil, cowpea-wheat and mungbean-oats, cropping sequences was studied under different spacing of *D. sissoo* compared to sole cropping system. Among different crops, pulse crops of mungbean and lentil were found most sensitive to shade. Fodder crops of sorghum, cowpea and oats showed greater tolerance to shade. Plant height and stem diameter in fodder crops, poor branching and pod setting in pulse crops and reduced tillering and test weight in wheat were the main yield attributes influencing the yield of test crops under agroforestry, sorghum-oats cropping sequence followed by cowpea-wheat sequence were found most economical.

Shamughavel and Francis (2001) studied the growth performances and economic returns of soybean growing as intercrop in Bamboo plantations. Productivity of soyabean in the intercropped stand was found to be lower (1400 kg/ha) compared with pure soyabean plantation (1700 kg/ha). Similar results were observed in Bamboo. The land equivalent ratio of Bamboo producing culms (dry weight) with soyabean intercrop found in the ratio of 1:2. The results of the investigation indicated that on an annual basis a net amount of Rs. 8300/- per hectare can be obtained.

Vyas (2001) studied on tree crop interaction in agroforestry. The effect of *Prosopis cineraria* (Knejri) lives on the growth and productivity of *Cassia angustifolia* (senna), a medicinal plant under medico-forestry system in Gujarat.

Prosopis has 44.2, 29.9 and 54.0 percent more growth in height, root length and number of leaves respectively. Plants growing under the Khejri tree also had higher leaf let number (178.3%) and leaf area (15.3%). Plants under Khejri accumulated more dry matter in root, stem and leaves. The seed yield of these plants increased by 56.5 percent as compared to plants growing at the site with no tree.

Shinde (2001) studied the effect of tree species on the growth and production of forage crops. He observed maximum number of leaves, number of branches, fresh weight, dry weight and water status of leaves when crops were grown under Kalam and Arjun. Similarly, maximum root length of forest crops was also recorded in open condition followed by Kalam. However, the higher yield of forage per hectare was recorded in open condition as compared to Kalam and Arjun.

Subash (2002) studied the productivity of four common kharif field crops paddy, greengram, blackgram and groundnut in the allies of four tree species viz., *Eucalyptus tereticornis, Dalbergia sissoo, Acacia auriculiformis* and *Gmelia arborea* in a slopy barren land. The mean annual increase in tree growth (height + girth) was maximum in *Euacalyptus teriticornis* followed by *Dalbergia sissoo*. The productivity of kharif field crops were invariably maximum under the canopy of *Dalbergia sissoo* followed by *Acacia auriculiformis* but lowest yield of above crops were obtained from the inter spaces of *Eucalyptus teriticornis*.

Sunil and Sharma (2002) studied the productivity of wheat under *Populus deltoides* based agroforestry system. The study was conducted in the vertisol of Chhattisgarh in south-east of Central India to see the effect of *Populus deltoides* on the productivity of wheat crop. Wheat was grown as intercrop under five different clones (G3, 65/27, D121, G48 and 57C1). Data on crop growth and yield at different distance and four directions from the tree base and control were collected. Grain yield was found to be less near the tree and it increased with an increase in distance away from the tree. Wheat yield in the four directions of tree was maximum in the north of trees followed by west and south. Wheat productivity was affected by all the *P. deltoides* clones. A grain yield of 14.0 q/ha was obtained in the sole crop. It was maximum under D121 clone and the order of grain yield reduction due to done was : 57Cl>G48>G3>65/27>D121.

Mohapatra (2003) conducted an experiment on Silvo-pastoral system in years 1996-1998 on sloppy waste land. Six popular tree species (viz. *Eucalyptus tereticornis*, *Acacia auriculiformis*, *Acacia nilotica*, *Dalbergia sissoo*, *Samanea saman* and *Albizia lebbek*) different significantly in growth of plant height (PH) and girth at shoulder height (GSH). *Eucalyptus* showed maximum growth of PH and GSH followed by *Acacia auriculiformis*. Fodder yield of Dinanath grass in two cuts was highest under the tree canopy of *Dalbergia sissoo* followed by *Samanea saman* and lowest in the interspaces of *Eucalyptus*.

turmeric around the palms by leaving 3 meter distance under uniform care and management and found significant difference in overall performance of varieties. The highest yield was recorded by the variety Amruthapani Kothapetta (A) 72 (17.36 t/ha).

Arora and Mohan (1986) conducted research on agricultural land use system in young peach "Flodqsum" orchard in Doon valley under rainfed condition on class-II land. The study revealed that out of short duration intecrops, cowpea (517 kg/ha) and sesamum (396 kg/ha) could be grown upto 6 years and beyound this the yield may decline to uneconomic levels due to shading effect of the trees. The interaction effect of companion crops on the growth and yield of fruit crop indicated that cowpea and soybean has no marked effect on the height and crown diameter of the trees when compared with control (tree alone) upto 7^{th} year.

Intercropping of groundnut, soybean, rice, ginger and turmeric with guava produced the highest yield. The net economic returns per hectare was obtained in guava and ginger (Rs. 7930/ha) followed by turmeric and groundnut with guava (Rs. 4335 and Rs. 3600/ha). No adverse effect of intercrops was observed on the growth of guava (Anon., 1988).

Rajput *et al.* (1988) conducted experiments on intercropping of vegetables (potato, brinjal, onion, okra, chillies, tomato, colocasia, bittergourd, Indian squash, cauliflower and long melon); pulses (cowpea, blackgram, pigeonpea, pea and gram) and cereal (wheat) in young mango orchards at Lucknow.

All the intercrops grown under the canopy of Mango trees produced normal yield. In case of vegetables, the highest monetary returns (Rs. 4120/ha) were obtained from cowpea + potato + mango, whereas the returns were lowest in control (Rs. 192/ha). In second experiment, blackgram + wheat + mango gave the highest monetary return (Rs. 7992.75/ha). Whereas the lowest income was obtained in the control (Rs. 729/ha).

The experiment on agri horti-silvicultural system at Orissa University of Agriculture and Technology Bhubaneshwar indicated that *D. sissoo* + guava intercropped with rice + pigeonpea were the best combination for higher yield and income (Anon., 1989 a).

In an intercropping trial with khasi mandarin orchard on sloppy land, five arable crops (groundnut, rice, ginger, turmeric and soybean) were tested and it was reveled that mandarin + ginger land use system gave the highest net returns followed by mandarin + turmeric. No adverse effect on the growth of mandarin trees was observed (Anon., 1989 b).

Dhyani and Chauhan (1989) studied the performance of ginger, turmeric and colocasia under natural stands of Pinus Khasya on 40 per cent slope in East Khasi Hills (Meghalaya) and reported that all the three plantation crops gave higher yield in partial shade as compared to open condition and complete shade. *Pinus khasya* gave higher yield and thus proved profitable.

Das (1991) studied various coconut based farming systems and evaluated them on the basis of their economic viability. Studies on inter cropping with rice, millet, grain legumes, oilseed crops, root crops, banana, pineapple, chillies (capsicum) and vegetable mixed cropping with cocoa, black pepper (*Piper nigram*), tree species and mulberry for sericulture. More profit was recorded from integration of number of subsidizer crops and animal component with coconut than to grow it as a monocrop.

Lourduraj *et al.* (1992) conducted a field trail during summer 1990-91 at Munuthupathy in Pollachi taluka in 6 years old coconut plantation to evaluate the performance of different short duration forage crops and found that Mochai (Co-1) followed by fodder cowpea (Co-5) were the best satiated and the most remunerative intercrops in coconut, compared with other cereal fodders.

Shanmugasundaram and Subrahmaniyam (1993) conducted study on intercropping of coconut with papaya (Paw paw), pomegranate, anona (Annona spp.) ridge gourd (*Luffa acutangula*),bitter gourd (*Memordica charantia*), coriander (*Coriandrum sativum*), ginger (*Zingiber offcinale*), turmeric (*Curcuma longa*), Mentha spp., pepper (Capsicum) and betelvine (*Piper betle*) forming different layer beneath the coconuts. Results are presented for yields and economic values of the intercrops, and soil moisture contents at different depth.

Prasanna *et al.* (1995) studied the effects of intercropping in the year 1979-80, 1980-81 and 1983-84 in which bananas were grown in pure stands, with tapioca (cassava) alone or with tapioca and groundnuts or bitter gourd. Tapioca was also grown as a sole crop. Intercropping had no significant effect on yield of bananas or tapioca. Inter cropping banana with tapioca alone gave the best returns.

Sarma *et al.* (1996) conducted trial in Assam, during 1893-95 in a 30 year old coconut stand under rainfed conditions. The coconut spaced at 7.5 x 7.5 m were grown as a mono-crop or with ginger (*Zingiber officinale*) Cv. Madia, turmeric (*Curcuma longa*) Cv. Tall Clone or colocasia Cv. Gara planted in April as intercrops. Ginger gave the highest crop value (Rs. 52000/ha), but the low cultivation costs of colocasia made it the most profitable. Coconut yield was increased by all three intercrops, with colocasia resulting in the greatest increase (10.6% more than mono-crop).

Kler *et al.* (1997) studied the effects of low spacing and different intercrops (maize, raya, mung beans, soybean and lentils) on the microclimate and growth of paw paws in a field trial at Ludhiana in 1994-96. Neither plant spacing nor intercrop had a significant effect on the number of paw paws traits per plant or average fruit weight. Plant spacing had no effect on trait yield per plant but trait yield was lowest in both years when the paw paws were intercropped with raya, maize, mung beans soybeans, potatoes and wheat judged as the best intercrops the

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From an interaction point of view, the effects of trees on intercrops have been reviewed under this head.

2.3.1 Above ground interactions

Knight (1935) observed a two-third reduction in the yield of American cotton in Sudan in artificial shade under field conditions. Likewise, Tanaka *et al.* (1964) reported lower dry matter accumulation and decreased photosynthesis under shaded conditions.

Gabrielsen (1948) state that photosynthetic rate is proportional to chlorophyll content only at low light intensity. An increase in chlorophyll content does not increase photosynthetic rate as light becomes a limiting factor, through chlorophyll content under tree species increase over the control (without tree cover), the photosynthetic activity was limited by low light intensity.

Stansel *et al.* (1965) reported increased sterility, taller plants and reduction in yield under low sunlight intensity conditions in rice cultivars. The yield reduced under shaded conditions.

Cooper and Qualls (1967) observed increase in the ratio of leaf area to leaf weight which occurs with shading of legumes, which was associated with changes in leaf morphology and chlorophyll content. Alfalfa and bridsfoot trefoil had more stomata per sq. cm of leaf when grown in the sun than in the shade. Sun leaves of both species were thicker than shade leaves. Number of palisade and mesophyll cells and cell volume appeared greatest in leaves in the sun, and the palisade layer was more clearly differentiated in shaded leaves and contained more chlorophyll per unit of leaf weight and less per unit of leaf area than leaves in sun. Dolan (1972) studied the effect of temperature, photoperiod and light intensity on growth of *Pisum sativum* L. and reported that the growth was much greater at the medium temperature (17.5°C) than at either the high (25°C) or low (12°C) temperatures. The best growth was with long day (18 hours) light and high light intensity (43,000 lux) and the poorest growth was with short day (12 hours) and low light intensity (21,500 lux).

Crookston *et al.* (1975) reported that under shade (approx 3200 lux light intensity), the number, area and thickness of leaves was reduced but transpiration was not significantly affected in dry bean (*Phaseolus vulgaris* L.). Photosynthesis per unit area of shaded leaves decreased by an average of 38 per cent.

Kulasergaram and Kathiravetipillai (1976) studied the effects of two levels of light, water supply and nitrogen on growth and dominance in free growing tea plants of clone TRI-2025. Total leaf area, leaf thickness, dry matter of leaves, stems and roots, girth of stem, relative growth rate (RGR) and net assimilation rate (NAR) were also reduced under conditions of shade and restricted water supply. Leaf weight ratio (LWR) and shoot/root ratio were higher in the shaded plants when compared with the un-shaded plants.

Vegetative growth and fruiting of the cowpea Cv. Adzuki and Early Ramshorn were studied in controlled environment at two light intensities and three phosphorus levels in sand and soil media. The higher light intensity reduced plant height but improved plant growth in terms of increased branching, leaf area, plant size and seed yield (Tarila *et al.*, 1977).

Venkateshwarlu *et al.* (1977) assessed the effect of low light intensity (40 to 50% of natural light) at different growth stages and subsequent exposure to natural light on growth and productivity in two genotypes during *kharif* and three genotypes during *rabi* under two nitrogen levels. The dry matter accumulation was affected under shading at all stages, which was critical from primordial initiation (PI) onwards. The yield progressively reduced with low light intensity appearing in succession at different growth stages, particularly more critical during ripening phase. It was considered that low light intensity during monsoon season was an important constraint for higher productivity. The total chlorophyll content increased under shading irrespective of season, variety and growth phase.

Venkateshwarlu and Srinivasan (1978) studied the shading effect (40-50 per cent of natural light) on two rice crops at different stages with two different densities under field conditions and observed that the yield loss was maximum at reproductive and ripening phases.

Janardhan and Murty (1980) studied the effect of normal and low light intensities on various morphological characters. Under low light conditions; the dry matter, photosynthetic rate, relative growth rate, net assimilation rate and specific leaf weight reduced where as height, leaf area, leaf area ratio and relative leaf growth rate were increased. Dry matter production under low light was impaired through reduced photosynthetic rate despite an increase in chlorophyll content.

Nayak and Murty (1980) studied the effect of varying light intensities viz., normal light 75, 50 and 25 per cent of normal light of growth and yield attributes in rice (Cv. IR-8 and Vijaya). The grain yield was reduced due to impairment in dry matter production under low light intensities. In both cultivars, the enrichment in chlorophyll content at moderate reduction in light intensity i.e. 75 and 50 per cent was presumably to compensate the low light encountered under such treatments.

However, reduction in light intensity beyond 50 per cent of the normal light resulted in increased chlorophyll content.

Singh (1986) studied the response of four cotton genotypes (AKH-4) of *G. arboreum* L. and (SRT-1, B-1007 and C-1412) of *G. hirsutam* L. to reduction in light intensity by shading the plants under field conditions. Reduction in light intensity reduced the rate of photosynthesis as indicated by reduced NAR (net assimilation rate) and LAE (leaf area efficiency) but LAR (leaf area ratio) and SLA (specific leaf area) increased. Reduction in chlorophyll content was perhaps one of the contributing factors for reduced NAR and LAE under low intensity.

George and Nair (1987) conducted a field experiment at Trichur, during May to October, 1981 to assess the feasibility of cowpea for intercropping in coconut plantation. The results indicated that the grain yield of cowpea fell substantially because of shading. Even the low shade of 25 per cent reduced the grain yield by more than 50 per cent and with more intense shading, the yield progressively decreased. When the light intensity was reduced by 75 per cent, the yield was only one per cent of that at full sunlight.

Jaychandran *et al.* (1991) studied the performance of ginger under coconut shade and open conditions at Kottarakkara, Kerala and found higher yield of ginger at a low shade intensity (25%) as compared to open field. It can be recommended for homestead cultivation as well as for intercropping under coconut and other perennial crops where 25 to 50 per cent shade exist.

Ravindran and Kulandaivelu (1998) studied the five year old cardamom plant (*Elettaria cardamomum* Maton.), growing under natural sunlight at ICRI, Tamil Nadu. The plants of the three plots received three different light regimes viz., full light, medium light and low light. The number of suckers per plant, length of suckers, number and length of panicles per clump, number of capsules and fresh and dry weight of capsules showed the maximum values under medium light. The lowest values for these characters were obtained under full sunlight. About 40 per cent reduction in growth characters and 60 per cent reduction in yield character were observed under full as compared to medium sunlight. The medium light grown plants showed 5 and 2 fold increase in the number of panicles over that of full and low light respectively.

2.3.2 Below ground interaction

Underground root competition for moisture, nutrients and space is relatively more important in agroforestry system than above ground crown competition. The development of tree roots varies considerably from species to species and from site to site in the same species. The roots of several species go about 3 to 10 m vertically and extend 10-30 m horizontally. The finding of research work on root interaction effect of forest tree species on agricultural crops are reviewed under this head.

Singh and Dayal (1975) studied the effect of trenches dug between a 15 years old plantation of *D. sissoo* and a cotton crop and between at 15 years old plantation of *Acacia nilotica* and tobacco crop at Vasad (Rajasthan) so as to severe the lateral roots of the trees and to reduce the adverse effects of the trees on the adjacent crops. The treatment reduced the rate of moisture extraction from the soil under the agricultural crop. Yields of the cotton and tobacco on the treated plots were increased by 21 and 68 per cent, respectively.

Srivastava and Narain (1980) carried out study in a 20 years old plantation of *Eucalyptus tereticornis* at Kota (Rajasthan), revealed that the yields of rainfed blackgram, greengram and sorghum were adversely affected up to a distance of 2 m from the tree line.

Dwivedi (1987) studied the effect of *Eucalyptus tereticornis*, *Populus deltoides*, *Dalbergia sissoo* and *Acacia nilotica* grown on field bunds under different conditions on wheat, paddy, jawar, potato etc. and found that *Populus deltoides* caused the least damage to the crops of the *Rabi* season as compared to other species. Eucalyptus hybrid competes with annual crops for water and nutrients more strongly than other species and its adverse effect on agricultural crops were more visible in case of moisture stress condition.

The roots of *Eucalyptus hybrid* in combination with rainfed maize and irrigated paddy and *Populus deltoides* in combination with irrigated paddy and sugarcane were examined by Pin board, photographic and density measurement methods and found that the tree roots were generally far more extensive, more often not reaching at least 80 cm in depth and 4 m into the field, though with a far less density (0.01/cm^3). As per the orientation and vigour of the tree roots, it was found that close to the tree, the roots radiated more in the tangential plane (Parallel to the tree row) and only one third in the radial plane (right angle to the tree row). The majority of the roots descended steeply (Singhal *et al.*, 1987).

Bhatt and Todaria (1990) reported the maximum reduction in root length of *Elusine conacana*, *Glycin max* and *Herdeum vulgare* under the influence of *Adina cordifolia* trees. Reduction of root length in crops can be attributed to the effect of allopathic agents on cell elongation and ultra structure of root tip.

Sharma (1998) studied the effect of 8 years old *Eucalyptus hybrid* plantation on a kharif maize crop in humid climate of Dehra Dun, and found the reduction in yield was not conspicuous of moisture availability. But contradictory results were observed on rain fed maize and wheat.

MATERIAL AND METHODS

III MATERIALS AND METHODS

The details of materials used and the techniques adopted during the course of investigation entitled "To assess the performance of *Curcuma longa* L as an intercrop under tree species." The forest tree species *Terminalia arjuna* Bedd., *Casuarina equisetifolia* L. and *Mitragyna parvifolia* Korth. " are narrated briefly in this chapter.

3.1 Experimental site

The present investigation was carried out at the Instructional Farm, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari.

Geographically Navsari is situated at 20.95°N latitude, 75.90°E longitude and at an altitude of 10 meter above the mean sea level. The College Farm is located 3 km away in West from Navsari and 12 km away in the East from the historical place and Arabian seashore, Dandi.

3.2 Soil characteristics

The characteristics of the soil from Instructional Farm, ASPEE College of Horticulture and Forestry is placed under Jalalpur series, which included deep moderately drained clayey soils classified as "deep black soil" predomination with montmorillonite clay mineral by its origins. It is medium in fertility. The topography of the experimental plot was fairly level.

Table-3.1: Physico-chemical properties of the soil (experiment field)

Properties	Value of surface level (0-15 cm depth)	Method employed
(A) Physical characteristics		
Sand (%)	27.33	International pipette method (Piper, 1950)
Silt (%)	15.78	International pipette method (Piper, 1950)
Clay (%)	56.89	International pipette method (Piper, 1950)
Textured class	Clayey	
(B) Chemical properties		
Soil pH (1:2.5 soil water extract)	7.5	Potentiometry (Jackson, 1967)
E.C. (1:2.5 ds/m at 25°C)	0.23	Schufield method (Jackson, 1967)
Organic carbon (%)	0.65	Walkley and Black's rapid Titration method (Jackson, 1967)
Total N (%)	0.045	Modified kjeldahl's method (Jackson, 1967)
Available P_2O_5 (kg/ha)	26.238	Olsen's method (Jackson, 1967)
Available K_2O (kg/ha)	365.00	Flame photometry method (Jackson, 1967)

Soil samples have taken from surface level (0-15 cm depth) covering the whole experimental area before starting the experiment. The composite soil samples were prepared for analysis of Physico-Chemical properties as per the method mentioned in Table-3.1.

3.3 Climatic and weather conditions

The climate of South Gujarat region is typically tropical, characterized by fairly hot summer, moderately cold winter and more humid and warm monsoon with heavy rain. Monsoon commences mostly from the second week of June. Post monsoon rains of October-November are not uncommon. Most of the rainfall received from South-West monsoon concentrating in the month of July and August.

The winter season is start form November with mild cold and lasts up to February. December and January are the coldest months of the season. Summer season commences during the middle of February and ends during middle of June. April and May are the hottest months of the year.

The meteorological data of the period of investigation recorded at the meteorological observatory of the Farm, N.M. College of Agriculture, Navsari are presented in Table-3.2.

3.4 Plant materials

Forest species: The sixteen year old plantation of *Terminalia arjuna*, *Casuarina equisetifolia* and *Mitragyna*

Table-3.2: Meteorological data recorded during the investigation period (June-2005 to February- 2006)

Month	Std. Week	Temperature (°C)		R.H. (%)	Sunshine hours	Rainfall (mm)
		Max.	Min.			
June-05	24	34.75	31.50	75.81	5.6	00
	25	31.85	27.52	85.32	0.8	313.8
	26	26.92	25.81	98.76	7.2	235.8
July-05	27	28.74	27.50	89.94	6.9	26.5
	28	31.50	27.76	87.50	2.7	22.5
	29	31.66	28.25	88.59	1.2	22.6
	30	30.62	27.66	90.92	1.5	5.3
Aug-05	31	28.15	27.75	93.03	0.6	30.1
	32	29.00	26.62	88.22	3.4	237.0
	33	30.00	25.90	89.88	5.9	20.0
	34	29.50	25.22	90.05	7.9	20.0
	35	31.10	27.75	98.02	7.6	48.0
Sept. 05	36	31.28	25.61	93.02	5.9	12.2
	37	28.33	25.84	93.86	6.3	86.4
	38	27.90	25.84	93.79	8.1	69.6
	39	29.65	24.64	91.14	5.2	115.4
Oct.-05	40	32.67	24.54	94.66	8.4	34.0
	41	36.41	22.94	90.52	8.3	00.00
	42	33.66	25.00	78.66	7.9	00.00
	43	35.00	19.92	89.95	8.2	00.00
Nov.-05	44	34.50	19.6	80.00	9.1	00.00
	45	33.08	17.38	85.38	9.5	00.00
	46	34.00	18.44	68.11	9.5	00.00
	47	33.72	18.44	73.67	9.8	00.00
	48	31.66	18.75	59.12	9.6	00.00
Dec.-05	49	31.50	18.16	68.65	9.5	00.00
	50	31.00	14.00	72.22	9.6	00.00
	51	28.62	11.24	79.63	9.6	00.00
	52	29.35	12.72	83.95	8.0	00.00
Jan-06	1	28.42	14.24	80.75	8.1	00.00
	2	30.85	14.45	78.91	9.3	00.00
	3	30.64	15.71	73.01	9.6	00.00
	4	28.71	12.61	75.52	9.8	00.00
	5	33.66	15.11	69.72	9.8	00.00
Feb.-06	6	34.50	14.50	72.37	9.7	00.00
	7	34.60	16.28	87.25	9.9	00.00
	8	33.25	18.70	67.25	9.6	00.00

parvifolia planted at 10 x 2.5 m distance were used for intercropping study.

Crops: Two varieties of *Curcuma longa* L. (Turmeric) viz., 'Kesar' and 'Sugundham' were selected for the present study. The distance between two rows and plant to plant within row was 30 cm and 20 cm, respectively.

3.5 Experiment details

The experiment was conducted during *kharif*, 2005 with following details.

1. Location : Instructional Farm, ASPEE College of Horticulture and Forestry
   Navsari Agricultural University
   Navsari
2. Design : Factorial Randomized Block Design (FRBD)
3. No. of replications : 4 (four)
4. Plot size : Gross Plot : 7.2 x 3 m
   Net plot : 6.6 x 2.7 m
5. Forest tree species : (1) *Terminalia arjuna*, Bedd. (Arjun)
   (2) *Casuarina equisetifolia* L. (Sharu)
   (3) *Mitragyna parvifolia* Korth.(Kalam)
6. Crop: Two varieties : *Curcuma longa* L. (1) Var. Sugundham
   (2) Var. Kesar
7. Date of sowing :
   (1) Tree species : The plantation was done in kharif,1989.
   (2) Crops : Kharif 2005

8. Spacing : Forest tree species : 10.0 x 2.5 m

Crops : 30 x 20 cm

9. Details of treatments

A. Tree species

T_0- Control (open plot)

T_1- *Terminalia arjuna* (Arjun)

T_2- *Casuarina equisetifolia* (Sharu)

T_3- *Mitragyna parvifolia* (Kalam)

B. Crop species

C_1- *Curcuma longa*(Sugundham)

C_2- *Curcuma longa* (Kesar)

Treatment Combination:

(1) T_1C_1 (3) T_2C_1 (5) T_3C_1 (7) T_0C_1

(2) T_1C_2 (4) T_2C_2 (6) T_3C_2 (8) T_0C_2

10. Manures and fertilizers: FYM – 20 t/ha

NPK *Curcuma longa* 125-60-60

11. Plan of layout is presented in Fig.-1

3.6 Cultural operations

3.6.1 Preparation of land

The land is prepared with the receipt of early monsoon. Soil is brought to a fine tilth by giving about four deep ploughing. Weeds, stubbles, roots etc., are removed. Immediately after the receipt of pre-monsoon showers, beds of 1 to 1.5 m width, 15 cm height and of convenient length are prepared with a spacing of 40 to 50 cm between beds.

Plate-I : General view of experimental plot

Seed materials

Whole or split mother rhizomes weighing 35 to 44 g are used for planting. Healthy rhizomes are treated with 0.3 per cent Diuthane M-45 and 0.5 per cent Malathion for 30 minutes before storing.

3.6.2 Manures and fertilizers

Farm Yard manure was applied @ 20t/ha to all the plots uniformly and was incorporated in to the soil at the time of land preparation.

Nitrogen, phosphorus and potash were applied uniformly to all the plots at the rate of 25-60-60 kg/ha respectively as a basal dose. Nitrogen was applied 25 kg/ha at 30, 60, 90 and 120 days after planting.

3.6.3 Planting of crop

The rhizomes of *Curcuma long* L. were planted 30 x 20 cm distance in the plots prepared between tree rows on the 15th June 2005. The seed rate of all the crops used was 2500 kg rhizome required for one hectare.

3.6.4 After care

Weeding and hoeing were done thrice at 60, 120 and 150 days after planting. In all 15 irrigations were applied at an interval of 10 days. The ancillary observation of pest and disease was not found serious during experiment.

Plate-II:*Curcuma longa* L. grown under *Terminalia arjuna* (T_1)

e-III : *Curcuma longa* L. grown under *Mitragyna parvifolia* (T_3)

3.7 Observations recorded

The observations recorded during the course of investigation and the procedure was adopted given below. Five plants were randomly selected from each net plot of each treatment and tagged for recording the observations.

3.7.1 Plant height (cm)

Average height of plant was recorded at final harvest. The height was measured from the base of the stem at ground level to the growing tip of the plants from randomly five selected plants for taking observations and average values were calculated.

3.7.2 Number of leaves per plant

The number of leaves from the plants was counted at final harvest stage on randomly selected tagged plants and the average values were calculated.

3.7.3 Leaf length (cm)

The leaf length was measured from the same five plants used for taking plant height. Three leaves were selected randomly on one plant for the length measurement and average value was calculated.

3.7.4 Leaf breadth (cm)

The leaves taken for recording leaf length were used for measuring the leaf breadth and average value was calculated.

3.7.5 Rhizome length (cm)

The plants selected for taking height and leaf observation were used for taking rhizome length and average value was calculated.

the ground level to the tip of the apical bud of the stem with the help of 'Ravi Altimeter'. The observation of height was taken on two plants in each treatment and the averages were calculated.

3.9.2 Tree DBH (cm)

The Diameter at Breast Height (DBH) of trunk of the trees was measured in centimeters at breast height (1.37 cm from ground level) with the help of calipers. The observations on diameter were taken on two plants in each treatment and the averages were calculated.

3.9.3 Tree canopy spread (m^2)

The canopy of tree was measured in square meter. It is measured at tip of tree canopy at North-South and East-West direction with measuring tape. The two observations were multiplied and area was calculated. The observation on tree canopy was taken on two plants in each treatment and the averages were calculated.

3.10 Measurement of light intensity (klux)

The light intensity was measured daily in klux by the digital lux meter. The light intensity was measured in each treatment at 10.00, 12.00 and 16.00 hrs on three points i.e. at last row on right and left side of plot and center of plot distance from the tree base line during the experimental period.

Table -3.3: Average height, DBH and crown spread of forest tree species

Row	Tree species	Average height (m)	Average DBH (cm)	Average crown spread (m^2)
I	*Terminalia arjuna*	18.8	24.44	8.2
	Casuarina equisetifolia	21.94	29.72	8.6
	Mitragyna parvifolia	9.8	12.22	6.9
II	*Terminalia arjuna*	18.1	28.48	8.4
	Casuarina equisetifolia	26.7	25.54	8.8
	Mitragyna parvifolia	9.4	13.54	6.6
III	*Terminalia arjuna*	16.7	17.42	9.1
	Casuarina equisetifolia	24.88	25.32	8.5
	Mitragyna parvifolia	7.9	15.72	6.4

3.11 Statistical analysis

Statistical analysis of the data of various characters studied in present investigation was carried out through the procedure of factorial randomized block design (FRBD) by computer system at "The Computer Centre" Department of Agricultural Statistics, N.M. College of Agriculture, Navsari Agricultural University, Navsari.

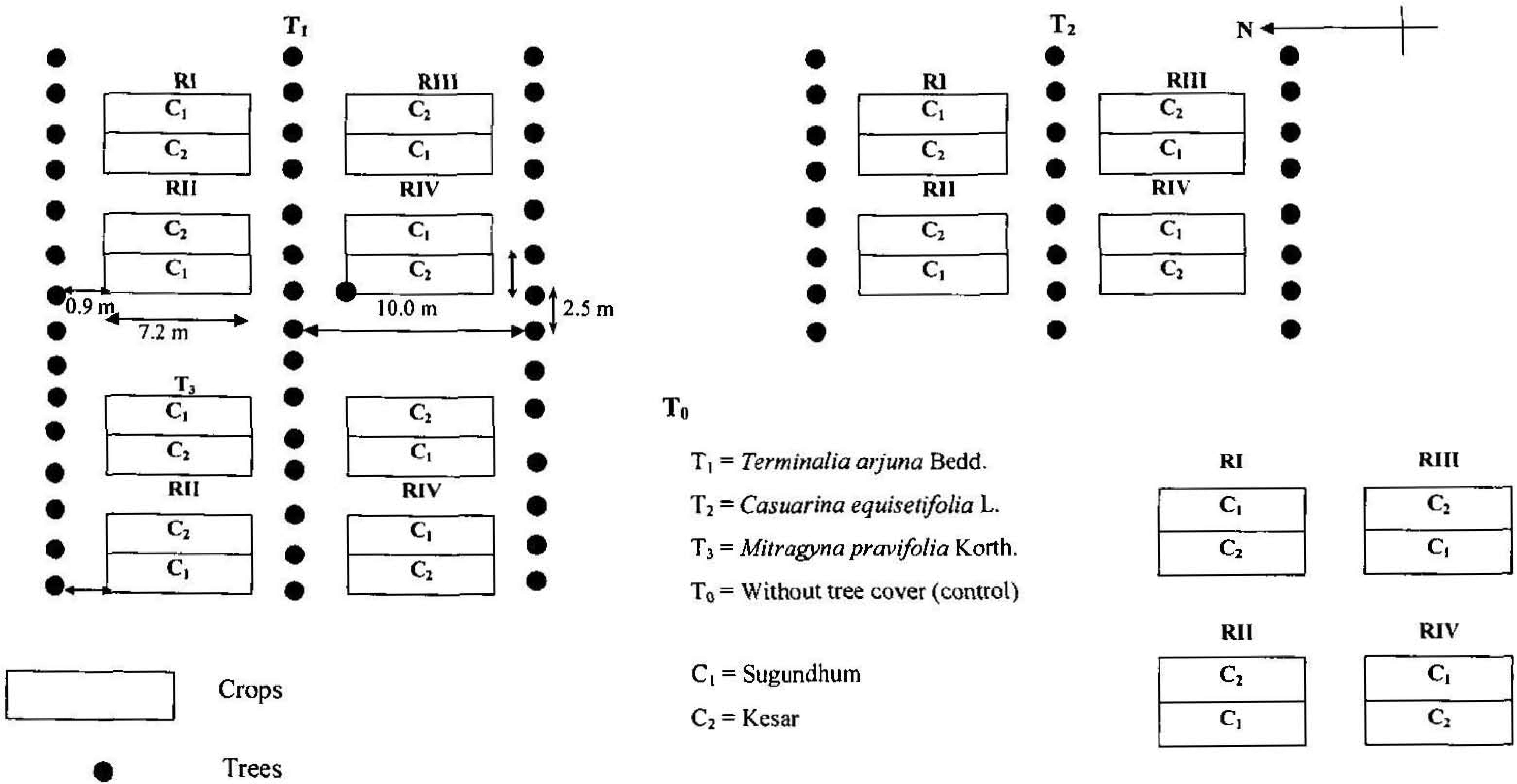

Fig.-1 : PLAN OF LAYOUT

EXPERIMENTAL RESULTS

IV EXPERIMENTAL RESULTS

The experiment entitled "To asses the performance of *Curcuma longa* L. grown as an intercrop under tree species," was studied in the year 2005 on Instructional Farm, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari. The tree species like *Terminalia arjuna* Bedd (Arjun), *Casuarina equisetifolia* L. (Sharu) and *Mitragyna parvifolia* Korth. (Kalam) and inter crop viz., different varieties of *curcuma longa* L. namely Sugundham and Kesar were selected for study. The results obtained are presented in this chapter along with statistical inference.

4.1 Effect of forest tree species on growth parameters of *Curcuma longa* L.

4.1.1 Effect of tree species on plant height (cm) of *Curcuma longa* L. at final harvesting

The analysis of variance was conducted to know the effect of trees on height of crops at final harvest. It was observed that the height of crops significantly differed due to trees, crops and interaction between trees x crops (Table-4.1).

The data presented in Table-4.1 indicated that the significantly higher plant height of crop was recorded under T_3 as compared to other tree species except T_1 which was at par with T_3.

In crop significantly the maximum height was recorded in C_1 as compared to C_2.

effect of crops was found non-significant in affecting number of leaves (Table-4.2).

Table-4.2: Number of leaves of *Curcuma longa* L. as influenced by forest tree species at harvesting

Trees	*Curcuma longa*		Mean
	C_1	C_2	
T_1	6.50	10.50	8.50
T_2	8.00	11.25	9.63
T_3	15.75	9.50	12.63
T_0	6.75	7.00	6.88
Mean	9.25	9.56	

ANOVA TABLE

Sources	S. Em. $\pm$	C.D. at 5%	C.V. %
T	0.68	2.00	20.41
C	0.48	NS	
T x C	0.96	2.82	

The data presented in Table-4.2 revealed that the significantly maximum number of leaves of crop was recorded under T_3 as compared to T_2, T_1 and T_0. T_2 was also significantly superior over control. T_1 was at par to T_2.

In tree crop interactions significantly the maximum leaves were recorded in T_3C_1 as compared to all the interactions of T with C_1 and C_2. In C_1 crop T_1C_1 and T_2C_1 was at par with T_0C_1 while, in C_2 crop T_1C_2 and T_2C_2 were significantly superior over T_0C_2. T_3C_2 and T_0C_2 were at par with each other.

4.1.3 Effect of tree species on leaf length (cm) of *Curcuma longa* L. at final harvesting

The analysis of variance was conducted to know the effect of trees on leaf length of crops at final harvest. It was observed that the leaf length of crops significantly differed due to trees and crops. The interaction between trees x crops was found non-significant (Table-4.3).

Table-4.3: Leaf length (cm) of *Curcuma longa* L. as influenced by forest tree species at harvesting

Trees	*Curcuma longa*		Mean
	C_1	C_2	
T_1	27.28	24.70	25.99
T_2	21.78	19.13	20.45
T_3	34.73	32.45	33.59
T_0	20.10	17.75	18.93
Mean	25.97	23.51	
ANOVA TABLE			
Sources	**S. Em. ±**	**C.D. at 5%**	**C.V. %**
T	0.68	1.99	7.74
C	0.48	1.41	
T x C	0.96	NS	

The data presented in Table-4.3 indicated that significantly the maximum leaf length was recorded in T_3 as compared to T_1, T_2 and T_0. T_1 and T_2 were also significantly superior over T_0.

In varieties significantly maximum leaf length was recorded in C_1.

4.1.4 Effect of tree species on leaf breadth (cm) of *Curcuma longa* L. at final harvesting

The analysis of variance was conducted to know the effect of trees on leaf breadth of crops at final harvest. It was observed that the leaf breadth of crops significantly differed due to trees and crops. The interaction between trees x crops was found non-significant (Table-4.4).

Table-4.4: Leaf breadth (cm) of *Curcuma longa* L. as influenced by forest tree species at harvesting

Trees	*Curcuma longa*		Mean
	C_1	C_2	
T_1	12.60	10.53	11.56
T_2	11.60	9.90	10.75
T_3	13.93	13.13	13.53
T_0	9.08	7.75	8.41
Mean	11.80	10.33	
ANOVA TABLE			
Sources	**S. Em. ±**	**C.D. at 5%**	**C.V. %**
T	0.34	1.00	8.68
C	0.24	0.71	
T x C	0.48	NS	

The data presented in Table-4.4 indicated that significantly the maximum leaf breadth was recorded in T_3 as compared to T_1, T_2 and T_0. T_1 and T_2 were also significantly superior over T_0.

In varieties significantly maximum leaf breadth was recorded in C_1.

4.1.5 Effect of tree species on number of shoots of *Curcuma longa* L. at final harvesting

The analysis of variance was conducted to know the effect of trees on number of shoots per plant of crops at final harvest. It was observed that the number of shoots per plant of crops significantly differed due to trees, crops and interaction between trees x crops (Table-4.5).

From the Table-4.5 indicated that significantly the maximum number of shoots per plant was recorded under T_3 as compared to T_1, T_2 and T_0. T_1, T_2 and T_0 were at par with each other.

Table-4.5: Number of shoots of *Curcuma longa* L. as influenced by forest tree species at harvesting

Trees	*Curcuma longa*		Mean
	C_1	C_2	
T_1	3.13	2.50	2.81
T_2	2.88	1.75	2.31
T_3	5.00	2.25	3.63
T_0	2.50	2.00	2.25
Mean	3.38	2.13	

ANOVA TABLE

Sources	S. Em. ±	C.D. at 5%	C.V. %
T	0.19	0.56	19.54
C	0.13	0.40	
T x C	0.27	0.79	

In varieties significantly maximum number of shoots per plant was recorded in C_1.

The interaction effect between trees and crop varieties was significantly the maximum in T_3C_1 as compared to all other combinations of T with C_1 and C_2. T_1C_1, T_2C_1 and T_0C_1 were at par with each other. T_1C_2, T_2C_2 and T_3C_2 were at par with T_0C_2.

4.1.6 Effect of tree species on rhizome length (cm) of *Curcuma longa* L. at final harvesting

The analysis of variance was conducted to know the effect of trees on rhizome length of crops at final harvest. It was observed that the rhizome length of crops significantly differed due to trees, crops and interaction between trees x crops (Table-4.6).

Table-4.6: Rhizomes length (cm) of *Curcuma longa* L. as influenced by forest tree species at harvesting

Trees	*Curcuma longa*		Mean
	C_1	C_2	
T_1	6.55	6.25	6.40
T_2	6.00	6.05	6.03
T_3	8.18	6.35	7.26
T_0	6.13	4.78	5.45
Mean	6.71	5.86	
ANOVA TABLE			
Sources	**S. Em. ±**	**C.D. at 5%**	**C.V. %**
T	0.19	0.57	
C	0.14	0.40	8.72
T x C	0.27	0.81	

The data presented in Table-4.6 indicated that significantly the maximum rhizome length was recorded in T_3 as compared to T_1, T_2 and T_0. T_1 and T_2 were at par with each other. However, they are superior over T_0.

In varieties significantly maximum rhizome length was recorded in C_1.

In interaction of trees and corps, significantly maximum rhizome length was recorded in T_3C_1 as compared to all other combinations of T with C_1 and C_2. In C_1 intercrop T_1C_1, T_2C_1 and T_0C_1 were at par with each other. In C_2 intercrop T_1C_2, T_2C_2 and T_3C_2 was found superior over T_0C_2.

4.1.7 Effect of tree species on rhizome breadth (cm) of *Curcuma longa* L. at final harvesting

The analysis of variance was conducted to know the effect of trees on rhizome breadth of crops at final harvest. It was observed that the rhizome breadth of crops significantly differed due to trees, crops and interaction between trees x crops (Table-4.7).

The data presented in Table-4.7 indicated that significantly the maximum rhizome breadth was recorded in T_3 as compared to T_1, T_2 and T_0. T_1 and T_2 were significantly superior over T_0. T_1 and T_2 were at par with each other.

In varieties significantly maximum rhizome breadth was recorded in C_1.

In interaction of tree and crops T_1C_1, T_2C_1 and T_3C_1 were found significantly superior over T_0C_1. However T_1C_1 and T_3C_1 were at par. In C_2, T_3C_2 produced significantly higher breadth of rhizome. T_1C_2 and T_2C_2 were also significantly superior over T_0C_2.

Table-4.7: Rhizomes breadth (cm) of *Curcuma longa* L. as influenced by forest tree species at harvesting

Trees	*Curcuma longa*		Mean
	C_1	C_2	
T_1	5.70	3.55	4.63
T_2	4.50	4.10	4.30
T_3	5.95	5.43	5.69
T_0	3.78	3.13	3.45
Mean	4.98	4.05	
ANOVA TABLE			
Sources	**S. Em. ±**	**C.D. at 5%**	**C.V. %**
T	0.18	0.54	
C	0.13	0.39	11.40
T x C	0.26	0.76	

4.2 Effect of forest tree species on yield attributes of *Curcuma longa* L.

4.2.1 Effect of tree species on yield per plant of *Curcuma longa* L. (g) at final harvesting

The analysis of variance was conducted to know the effect of trees on yield per plant of crops at final harvest. It was observed that the yield per plant of crops significantly differed due to trees, crops and interaction between trees and crops (Table-4.8).

From the Table-4.8 it can be seen that the significantly the maximum yield per plant of crop was recorded under T_3

(90.50) as compared to other tree species. T_2 and T_1 were also significantly superior over T_0.

Table-4.8: Yield per plant of *Curcuma longa* L. (g) as influenced by forest tree species at harvesting

Trees	*Curcuma longa*		Mean
	C_1	C_2	
T_1	62.18	54.67	58.42
T_2	74.00	63.70	68.85
T_3	84.40	65.48	74.94
T_0	53.43	45.98	49.70
Mean	68.50	57.45	
ANOVA TABLE			
Sources	**S. Em. ±**	**C.D. at 5%**	**C.V. %**
T	1.28	3.78	5.77
C	0.91	2.67	
T x C	1.82	5.34	

In crop, significantly maximum yield per plant was recorded in C_1.

In interaction of trees and corps, significantly maximum yield per plant was recorded in T_3C_1. In C_1 intercrop T_1C_1 and T_2C_1 was found significant over control T_0C_1. In C_2 intercrop T_1C_2, T_2C_2 and T_3C_2 was found superior over T_0C_2. However T_2C_2 and T_3C_2 were at par with each other.

4.2.2 Effect of tree species on yield per plot of *Curcuma longa* L. (kg) at final harvesting

The analysis of variance was conducted to know the effect of trees on yield per plot of crops at final harvest. It was observed that the yield per plot of crops significantly differed due to trees, crops and interaction effect between trees and crops (Table-4.9).

From the Table-4.9 it can be seen that, significantly the maximum yield per plot of crop was recorded under T_3 (3.71) as compared to other tree species. T_2 and T_1 were also significantly superior over T_0.

In crop significantly maximum yield per plant was recorded in C_1.

In interaction of trees and corps, significantly maximum yield per plant was recorded in T_1C_1 which is at par with T_3C_1. In C_1 intercrop T_1C_1 and T_3C_1 was significant over control T_0C_1.However T_2C_1 and T_0C_1 were at par with each other. In C_2 intercrop T_3C_2 was found superior over T_0C_2. However T_1C_2, T_2C_2 and T_0C_2 were at par with each other.

Table-4.9: Yield per plot of *Curcuma longa* L. (kg) as influenced by forest tree species at harvesting

Trees	*Curcuma longa*		Mean
	C_1	C_2	
T_1	4.03	2.63	3.33
T_2	2.79	2.35	2.57
T_3	3.78	3.65	3.71
T_0	2.35	2.15	2.25
Mean	3.23	2.69	
ANOVA TABLE			
Sources	**S. Em. ±**	**C.D. at 5%**	**C.V. %**
T	0.12	0.35	11.37
C	0.08	0.25	
T x C	0.17	0.50	

4.3 Light intensity (klux)

The data on the effect of forest tree species on light intensity reaching to the *Curcuma longa* L. crop during day time was recorded at three different timings viz, 8 am, 12 pm and 4 pm. The readings of light intensity were noted from germination to harvesting stage with digital lux meter in 100X and are presented in Table-4.10.

The analysis of variance was conducted to know the effect of trees on light intensity reaching to crops. The light intensity under trees significantly differed due to forest tree species, distance and interaction effect between trees and distance (Table-4.10).

Table-4.10: Light intensity (klux) on *Curcuma longa* L. as influenced by forest tree species

Trees	Distance			Mean
	D_1	D_2	D_3	
T_1	229	242.75	254	241.92
T_2	108.75	123.75	175.25	135.75
T_3	299	322	351	324
Mean	212.25	229.33	260.08	

ANOVA TABLE

Sources	S. Em. ±	C.D. at 5%	C.V. %
T	3.66	10.68	5.42
C	3.66	10.68	
T x C	5.17	15.08	

Average values of light intensity under open (T_0): 435 klux

D_1 and D_2 last row on right and left side of plot and D_3 center of plot distance from the tree base line respectively.

The data presented in Table-4.10 indicated that significantly higher light intensity was recorded under T_3 was called medium light as compared to open condition (T_0). Significantly lowest light intensity was recorded under T_2.

As regard the distance from the tree base line significantly the higher light intensity was recorded in D_3 as compared to D_1 and D_2.

Significantly the maximum light intensity was recorded under the interaction T_3D_3 as compared all other combinations. However, significantly lower light intensity was noted under T_1D_1 as compared to all other combinations.

4.4 Economics

The economics of treatments indicating gross realization per hectare, net realization and net return per rupee invested have been worked out form the average rhizome yield, taking into account the prevailing market price of rhizome at the time of harvesting of the crop. The cost of different treatments was worked out accounting the seed material cost and fixed cost required for different treatments are presented in Table-4.11.

In turmeric highest net realization of Rs. 52293.63 per hectare was obtained with treatment T_3C_1 followed by T_2C_1. T_3C_2,, T_2C_2. T_1C_1, T_1C_2 and T_0C_1, the corresponding figures for these treatments were Rs. 41043.64, 31822.87, 29896.47, 28229.8, 20123.75 and 18781.78 per hectare, respectively. The lowest net gain of Rs. 10719 per hectare was obtained with treatment T_0C_2.

Table-4.11 : Economics of crop production

Treatment	Yield (g/pl.)	Yield (kg/ha)	Gross realization(Rs.)	Total gross realization	Cost of turmeric materials	Sowing labour cost	Fixed cost (Rs.)	Total cost	Net realization	CBR
T_1C_1	62.16	10349.64	67272.66	67272.66	28542.86	2500	8000	39042.86	28229.80	1.723047
T_1C_2	54.67	9102.555	59166.61	59166.61	28542.86	2500	8000	39042.86	20123.75	1.515427
T_2C_1	74.00	12321	80086.50	80086.50	28542.86	2500	8000	39042.86	41043.64	2.051246
T_2C_2	63.70	10606.05	68939.33	68939.33	28542.86	2500	8000	39042.86	29896.47	1.765735
T_3C_1	84.40	14051.77	91336.49	91336.49	28542.86	2500	8000	39042.86	52293.63	2.33939
T_3C_2	65.48	10902.42	70865.73	70865.73	28542.86	2500	8000	39042.86	31822.87	1.815075
T_0C_1	53.43	8896.095	57824.62	57824.62	28542.86	2500	8000	39042.86	18781.76	1.481055
T_0C_2	45.98	7655.67	49761.86	49761.86	28542.86	2500	8000	39042.86	10719.00	1.274544

Spacing	30x20cm	Plant/ha	Fingers in no/kg	Turmeric required kg/ha	Rs.
Total pl/ha.	166500	166500	35	4757.143	6
Labour wages	Rs.50/day	166500	35	4757.143	6
Fodder selling	Rs.1 /Kg	166500	35	4757.143	6
Turmeric purchase	Rs.6/Kg	166500	35	4757.143	6
Turmeric selling	Rs.6.5/ Kg	166500	35	4757.143	6
1 kg turmeric	35	166500	35	4757.143	6
		166500	35	4757.143	6
		166500	35	4757.143	6

The highest net return per rupees invested (1:2.34) was obtained under the treatment T_3C_1 (Turmeric variety Sugundham grown under *Mitragyna parvifolia* Korth.). This was followed by treatment T_2C_1 (Turmeric variety keser grown under *Casurina equisetifolia* L.) and T_3C_2 (Turmeric variety Sugundham grown under *Mitragyna parvifolia* Korth.) i.e. 1:2.05 and 1:1.82, respectively.

In general, it was observed that turmeric variety Sugundham was found highly remunerative as compare to Kesar as it gave return of 1.48 to 2.34 per rupee invested whereas, Kesar gave return ranging from 1.27 to 1.82 per rupee invested. Looking in terms of the tree species it was observed that (T_3) was superior over other two tree species T_1, T_2 and open T_0. In the comparison among tree species Sharu (T_2) was found superior over Arjun (T_1) and open (T_0) as it recorded highest cost benefit ratio of 1.77 to 2.05 as compared to 1.52 to 1.72 in Arjun (T_1) and 1.27 to 1.48 in open (T_0).

DISCUSSION

V DISCUSSION

The experiment was conducted "To assess the performance of *Curcuma longa* L. as an intercrop under tree species". The tree species viz., *Terminalia arjuna*, Bedd. (Arjuna), *Casuarina equisetifolia* L. (Sahru) and *Mitragyna parvifolia* Korth. (Kalam). Two varieties of *Curcuma longa* L. namely 'Sugundham and 'Kesar' were selected for intercrop. The main objectives of this research endeavor were to asses the performance of *Curcuma longa* L. as an intercrop under forest tree species and to work out the economics of intercropping *Curcuma longa* L. with forest tree species. The observations on plant growth, yield and yield attributes were recorded and analyzed. The results recorded are discussed in this chapter. It is contemplated to discuss the variations noticed in growth, yield and yield attributes of crops under the influence of *Terminalia arjuna*, *Casuarina equisetifolia* and *Mitragyna parvifolia*. The associated reasons and possible explanations with observed variation recorded in the present study are depicted. For support, certain relevant studies have been quoted and the contradictory results with the present findings are also mentioned.

The meteorological data given in Table-3.2 for different parameters indicated that in general the weather was favourable for crop through out the investigation period. Standard cultural practices were followed as per recommendations for turmeric except the treatments. Therefore, variation observed in the treatment results are hence considered to be due to the response of treatment exercised in the present investigation.

5.1 Height of *Curcuma longa* L. (cm)

5.1.1 Main effects

5.1.1.1 Trees

The height of crop was significantly affected due to forest tree species at the harvest stage of observation the significantly higher height of crop was noted under T_3 (90.50). The reason for more height under T_3 may be due to partial shade as compared to T_1 and T_2. This might be due to reduction in the rate of evaporation of water from soil under T_3 and also a photosynthesis rate was proportional to chlorophyll content only at low light intensity. An increase in chlorophyll does not increase photosynthesis rate as light becomes a limiting factor, though chlorophyll content increase under tree species but the photosynthesis activity was limited by low light intensity (Gabrielsen, 1948). The low light condition may also result in more nitrogen supply to plants through water absorption which might have increase the vegetative growth of crop. Similar results were also recorded by Jaychandran *et al.* (1991), Patel (1994) and Singh *et al.* (1997).

5.1.1.2 Crop

Significantly the maximum height was recorded in C_1 (88.83) as compared to C_2 (75.25). This might be due to different genetic make up of different crops and crop varieties.

5.1.2 Interaction effects

5.1.2.1 Tree x crops

Significantly maximum plant height was observed in T_3 (103.25) followed by T_1C_1 (88.25) and T_1C_2 (82.25). This might be due to difference in shade effect under different treatments. Less light intensity under tree species might have reduced rate of evaporation of water from the soil and there by nitrogen supply may be more due to its absorption through moisture available. Thus, the partial shade reported in increasing vegetative growth. This finding is in conformity with those of Janardan and Murthy (1980), Gabrielsen (1948) and Stansel *et al.* (1965).

5.2 Number of leaves per plant

5.2.1 Main effects

5.2.1.1 Trees

Significantly the maximum number of leaves per plant were recorded under T_3 (12.63) as compared to T_2 (9.63), T_1 (8.50) and T_0 (6.88). The reason for maximum number of leaves in T_3 may be same as mentioned earlier under 5.1.2.1. Thus, the partial shade in turmeric gave more number of leaves. These results are in accordance with those of Ravindran and Kulandaivelu (1998) and Jasural *et al.* (1993).

5.2.2 Interaction effect

5.2.2.1 Tree x crops

Among the combination between trees x crops the maximum number of leaves were recorded in T_3C_2 (15.75) followed by T_2C_2 (11.25). The observed more number of leaves under present study might be due to the combined effect of crops grown under tree (T_3) and the different genetic make up of the crops. Similar results were also recorded by Ravindran and Kulandaivelu (1998) and Jasural *et al.* (1993).

5.3 Leaf length of *Curcuma longa* L. (cm)

5.3.1 Main effects

5.3.1.1 Trees

Significantly the maximum leaf length was recorded under T_3 (33.59) as compared to T_1 (25.99), T_2 (20.45) and T_0 (18.93). The reason for more leaf length under T_3 may be due to shade loving habit of Turmeric plant. Vyas (2001) also reported 178.3 per cent higher leaflet under Khejri. Extreme shade produced excessive vegetative growth in pepper was also reported by Reglos (1989). Cocoa seedlings were also exhibited maximum growth under medium light level (Gobinathan and Nair, 1982). Thus under T_3 (partial shade) more length of leaf was observed in Turmeric. Similar results were also supported by Ravindarn and Kulandaivelu (1998)

5.3.1.2 Crop

Significantly the maximum leaf length was recorded in C_1 (88.83) as compared to C_2 (75.25). This might be due to different genetic make up of different crops and crop varieties.

5.4 Leaf breadth of *Curcuma longa* L. (cm)

5.4.1 Main effects

5.4.1.1 Trees

Significantly the maximum leaf breadth was recorded under T_3 (13.53). In present study medium light condition was observed under Kalam (T_3) under which significantly maximum leaf length was recorded. Significant increase in vegetative characters of cardamom was also reported by Ravindran and

Kulandaivelu (1998). Increase in total leaf area of Senna under Khejri was also reported by Vyas (2001).

5.4.1.2 Crop

Significantly the maximum leaf breadth was recorded in C_1 (11.80) as compared to C_2 (10.33). This might be due to different genetic make up of different crops and crop varieties.

5.5 Number of shoots

5.5.1 Main effects

5.5.1.1 Trees

Significantly maximum number of shoots per plant was recorded under T_3 (3.63). The maximum number of shoots under T_3 may be because of shade loving habit of turmeric plant. The increase in number of panicles per plant in Cardamom was also reported by Ravindran and Kulandaivelu (1998) under medium light condition. This might be due to more photosynthesis activity under medium shade, which resulted in formation of more number of shoots. These results are also in accordance with those of Jasural *et al.* (1993) and Gabrielsen (1948).

5.5.1.2 Crop

Significantly the maximum number of shoots per plant was recorded in C_1 (3.38). This might be due to different genetic make up of different crops and crop varieties.

5.5.2 Interaction effect

5.5.2.1 Trees x crops

Among the combinations between trees x crops, the maximum number of shoots were recorded in T_3C_1 (5.00) and T_1C_1 (3.13). These more number of shoots might be due to the combined effect of crops grown under partial shade (T_3) and different genetic make up of the crops. This may be due to partial light availability under (T_3) which might have increased chlorophyll as well as photosynthetic activity. Similar results were also recorded by Jasural *et al.* (1993) and Gabrielsen (1948).

5.6 Rhizome length of *Curcuma longa* L. (cm)

5.6.1 Main effects

5.6.1.1 Trees

Significantly the maximum rhizome length was recorded under T_3 (7.26). The maximum rhizome length under T_3 might be due to partial shade and addition of leaf litter from tree to soil which make it friable and thus resulted in more growth. This may be due to significant increase in plant height, leaf length, leaf breadth, number of leaves and shoots under T_3 in present study. These results were supported by Jasural *et al.* (1993), Patel (1994) and Gabrielsen (1948).

5.6.1.2 Crop

Significantly the maximum rhizome length was recorded in C_1 (6.71). This might be due to different genetic make up of different crops and crop varieties.

5.6.2 Interaction effect

5.6.2.1 Trees x crops

In interaction of trees and crops significantly the maximum rhizome length was found in T_3C_1 (8.18). The lowest length of rhizome found in T_0C_2 (4.78) might be due to less moisture, low humidity and high temperature which decreases the plant growth and ultimately the rhizome length. These results were supported by Jasural *et al.* (1993), Ravindaran and Kulandaivelu (1998) and Patel (1994).

5.7 Rhizome breadth of *Curcuma longa* L. (cm)

5.7.1 Main effects

5.7.1.1 Trees

Significantly the maximum rhizome breadth was recorded under T_3 (5.69) as compared to T_1 (4.63), T_2 (4.3) and T_0 (3.45). The reason is same as mentioned earlier in 5.6.1.1. These results were supported by Jasural *et al.* (1993), Ravindaran and Kulandaivelu (1998) and Patel (1994).

5.7.1.2 Crop

Significantly the maximum rhizome breadth was recorded in C_1 (4.98) as compared to C_2 (4.05). This might be due to different genetic make up of different crops and crop varieties.

5.7.2 Interaction effect

5.7.2.1 Trees x crops

In combination of trees and crops significantly higher rhizome breadth in T_3C_1 (5.95) however T_1C_1 (5.70) and T_3C_2 (5.43) were at par. The reason was same as mentioned earlier in 5.6.2.1. This result was supported by Jasural *et al.* (1993), Ravindaran and Kulandaivelu (1998) and Patel (1994).

5.8 Yield of *Curcuma longa* L. per plant (g)

5.8.1 Main effects

5.8.1.1 Trees

Significantly the maximum yield of rhizomes per plant was recorded under T_3 (74.94) this may be due to crops grown under partial shade condition. It might be due to more height, number of leaves, number of shoots, leaf length, leaf breadth, rhizome length and breadth recorded in present study (Table-4.1-4.7), respectively which favoured increase in yield of rhizome per plant. These results were supported by Jasural *et al.* (1993), Ravindaran and Kulandaivelu (1998), Vayas (2001) and Patel (1994).

5.8.1.2 Crops

Significantly the maximum yield of rhizomes per plant was recorded in C_1 (68.50) as compared to C_2 (57.45). This might be due to different genetic make up of different crops and crop varieties.

5.8.2 Interaction effect

5.8.2.1 Trees x crops

The interaction of trees and crops significantly the maximum yield of rhizomes per plant was recorded under T_3C_1 (84.40) which was followed by T_2C_1 (74.00). This may be due to crops grown under partial shade condition. It might be due to more height, number of leaves, number of shoots, leaf length, leaf breadth, rhizome length and breadth recorded in present study (Table-4.1-4.7), respectively, which might have favored increase in yield of rhizomes per plant. These results were in accordance with work of Jasural *et al.* (1993), Ravindaran and Kulandaivelu (1998) Vayas (2001) and Patel (1994).

5.9 Yield of rhizome per plot (kg)

5.9.1 Main effects

5.9.1.1 Trees

Maximum yield of rhizome per plot was observed in T_3 (3.71). The reason is the same as mentioned earlier in point

5.8.1.1. These results are in agreement with Jasural *et al.* (1993), Vyas (2001) and Janardan *et al.* (1991).

5.9.1.2 Crops

Significantly the maximum yield per plot was recorded in C_1 (3.23) as compared to C_2 (2.69). This might be due to different genetic make up of different crops and crop varieties.

5.9.2 Interaction effect

5.9.2.1 Trees x crops

Among the combination between trees x crops, the maximum rhizomes per plot was recorded in T_1C_1 (4.03), T_3C_1 (3.78) and T_3C_2 (3.65) were at par with each other. This increase in weight of rhizomes per plot might be due to the combination effect of crop grown under partial shade (T_3) and the different genetic make up of the crops. The reason is the same as mentioned earlier in point 5.8.2.1. The similar results were also supported by Jasural *et al.* (1993), Vyas (2001) and Jaychandran *et al.* (1991).

5.10 Light intensity (klux)

The significantly low light intensity was recorded under T_2 (Sharu) as compared to T_3 Kalam (Table-4.10). This may be due to larger crown diameter and dense canopy of Sharu as compared to that of Kalam. The significantly maximum shading effect was observed near to tree base line (D_1 and D_2) as compared to D_3, which is away from tree base line i.e. in the centre of alley. This may be due to dense canopy near the tree base line as compared to thin canopy away from tree base line.

The shading effect was declined with increasing distance from tree base line in case of Sharu and Kalam.

Secondly, the more light intensity in centre of alley may be due to East West planting of rows of alley.

5.11 Economics of crop production

Economics is the need of the hour for the farmers while, taking decision regarding the adoption of a new technology. Hence, the gross realization and net return per rupee invested was calculated for different treatments (Table-4.11).

In 'Sugundham' the highest net realization of Rs. 52293.63 per hectare was obtained with treatment T_3C_1. However, in 'Kesar' the highest net realization per hectare was obtained with treatment T_3C_2 (Rs. 31822.87).

The highest cost benefit ratio per rupee invested (1:2.34) was obtained under treatment T_3C_1 in 'Sugundham' as compared to 'Kesar' as it gave the highest cost benefit ratio per rupee invested (1:1.82) with the interaction T_3C_2.

The total net returns from 'Sugundhum' was higher due to the high productivity of rhizome as compared to 'Kesar'

The comparison of three tree species showed that the highest cost benefit ratio(1:2.34) of intercropping under Kalam was followed by sharu (1:2.05). The main reason behind the higher production and net return under Kalam could be attributed to the lesser crown spread of Kalam trees as compared to other trees as seen from Table 3.1.

From above it could be seen that growing of *Curcuma longa* L. Var. 'Sugundham' under 16 year old Kalam trees (T_3) gave the highest net return of Rs. 52293.63 per hectare.

SUMMARY AND CONCLUSIONS

IV SUMMARY AND CONCLUSION

An investigation entitled "To assess the performance of *Curcuma longa* L. grown as an intercrop under tree species" was carried out at the Instructional Farm, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari during *kharif*, 2005.

In all eight treatments involving 16 years old three forest tree species viz., *Terminalia arjuna* Bedd. (T_1), *Casuarina equlsetifolia* L. (T_2), *Mitragyna parvifolia* Korth. (T_3) and one open field (T_0) were selected as main plot treatment and two varieties of *Curcuma longa* L. namely 'Sugundham' and 'Kesar' as sub plot treatments. The experiment was laid out in 4 x 2 Factorial Randomized Block Design (FRBD) with four replications. The recommended doses of manures and fertilizers were applied to the crops. Irrigation was given at 10 days interval. Other cultural practices and plant protection measures were carried as and when needed as per recommendations.

During the course of investigation treatment effect on various growth parameters (plant height, number of leaves, leaf length, leaf breadth, number of shoots, rhizome length and rhizome breadth etc.) and yield parameters (yield of *Curcuma longa* L. per plant and per plot etc.) were studied. The interaction of results presented and discussed in preceding chapter is summarized below.

6.1 Effect of crop growth characters

6.1.1 Tree species

Significantly maximum height, number of leaves, leaf length, leaf breadth, number of shoots, rhizome length and breadth were recorded when crops grown under T_3 (Kalam) in partial shade as compared to T_1 (Arjun), T_2 (Sharu) and T_0 (open).

6.1.2 Crop

Significantly superior height, leaf length, leaf breadth, number of shoots, rhizome length and breadth were recorded in variety 'Sugundham' (C_1) as compared to 'Kesar' (C_2).

6.1.3 Interaction effect

In variety Sugundham (C_1) maximum plant height, number of leaves, number of shoots, rhizome length and rhizome breadth were recorded in T_3C_1 interaction. In variety Kesar (C_2) maximum plant height, number of shoots was recorded in T_1C_2. Number of leaves was recorded in T_2C_2 and maximum rhizome length and breadth were recorded in T_3C_3 interaction.

6.2 Yield attributing characters

6.2.1 Tree species

Significantly the highest rhizome yield of crops per plant (74.94 g) and per plot (3.71 kg) as compared to Arjun (58.42 kg/plant and 3.33 kg/plot). Whereas, the lowest rhizome yield (49.70 g/plant and 2.25 kg/plot) was recorded under T_0 (open).

6.2.2 Crop

In crop, maximum yield per plant and per plot (68.50 g/plant and 3.23 kg/plot) was recorded in C_1 as compared to C_2 (57.45 g/plant and 2.69 kg/plot).

6.2.3 Interaction effect

In 'Sugundham' variety (C_1) maximum yield per plant (84.40 g) was recorded under $T_3C_1$and per plot (4.03 kg) was recorded under T_1C_1 treatment. However in 'Kesar' variety (C_2) yield per plant and per plot recorded were 65.48 g and 3.65 kg, respectively under T_3C_2 combination.

6.3 Light intensity

Significantly higher light intensity (324) was recorded under Kalam (T_3) as compared to T_1-Arjun (241.92) and T_2-Sharu (135.75).

Significantly the maximum light intensity was recorded in D_3 (351) as compared to D_2 (322) and D_1 (299).

6.4 Economics

Out of the two varieties of *Curcuma longa* L. under investigation 'Sugundham' gave higher net return per rupee invested as against that of 'Kesar'. From economic point of view, *Curcuma longa* L. grown under Kalam gave higher net realization as compared to other trees (Arjuna, Sharu) and open. Among the two forests tree species Kalam was found to be more profitable for taking inter crop as compared to that Sharu and Arjun.

CONCLUSION

From the above findings, it could be concluded that the growing of *Curcuma longa* L. in partial shade condition (T_3) resulted in significant increase in height (38.40%), number of leaves (83.58%), leaf length (77.74%), leaf breadth (60.88%), rhizome length (33.03%), rhizome breadth (62.03%), number of shoots (61.33%), yield per plant (50.78%) and yield per plot (64.89 %) over open (T_0).

Similarly, growth parameters viz., plant height, number of leaves, leaf length, leaf breadth, number of shoots, rhizome length, rhizome breadth and yield attributes viz., yield per plant and yield per plot was observed significantly maximum in C_1 (Sugundham).

From the economic point of view growing of 'Sugundham' and 'Kesar' under partial shade light of Kalam was found more profitable than T_1 (Arjun), T_2 (Sharu) and T_0 (open). The yield of rhizomes under Kalam was found more profitable than it was grown under Sharu and Arjun.

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*** Original not seen.**

APPENDIX

APPENDIX-I : Fixed cost

Sr. No.	Factors	*Curcuma longa*
1.	Land preparation	163.00
2.	Layout, bund forming, opening and preparing of channel	400.00
3.	Application of fertilizer	200.00
4.	Irrigation	1490.00
5.	Plant protection measures	272.00
6.	Harvesting and marketing	1200.00
7.	Land revenue and marketing	17.00
8.	Weeding cost	1200.00
9.	Supervision cost 10% off total cost	684.00
10.	Interest on working capital @ 12%	903.00
		8000.00

CERTIFICATE

This is to certify that I have no objection for supplying to any scientist any one copy or any part of this thesis at a time through reprographic process, if necessary for rendering reference services in a library or documentation centre.

Place: Navsari.

Date: 8th August, 2006

V.M. Prajapati

(Prajapati V.M.)