

**FEASIBILITY OF GROWING AROMATIC GRASSES IN
AGROFORESTRY SYSTEM**

A

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ARVIND DINUBHAI CHAVDA

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DEPARTMENT OF FORESTRY

ASPEE COLLEGE OF HORTICULTURE AND FORESTRY

GUJARAT AGRICULTURAL UNIVERSITY

NAVSARI CAMPUS, NAVSARI - 396 450

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ABSTRACT

"FEASIBILITY OF GROWING AROMATIC GRASSES IN AGROFORESTRY SYSTEM"

Name of Student

Mr. A. D. Chavda

Major Advisor

Dr. R. R. Shah

ASPEE College of Horticulture and Forestry,
Gujarat Agricultural University,
Navsari Campus, Navsari.

ABSTRACT

The present investigation was carried out on the farm of ASPEE College of Horticulture and Forestry, Gujarat Agricultural University, Navsari Campus, Navsari during the year 2001-2002. The main plot treatments comprised of twelve year old two forest tree species (*Arjun-Terminalia arjuna* Bedd. and *Kalam-Mitragyna parvifolia* Korth.) and one control in open field while sub-plot treatments constituted of two different aromatic grasses (*Lemongrass-Cymbopogon flexuosus* var. OD-19 and *Palmarosa-Cymbopogon martini* var. OD-29). These six treatment combinations were tried in Split-Pot Design (SPD) with three replications.

Significantly maximum aromatic grass height was recorded under *Arjun* trees (89.11 cm) at the time of first cutting and under *Kalam* trees (92.53 cm) at the time of second cutting. On the other hand, minimum height was recorded in control at the time of first cutting and under *Arjun* trees at the time of second cutting stages.

Significantly maximum (28.6 and 35.75) number of tillers were recorded under control (T₃-open field) at both the cutting stages respectively.

Significantly maximum fresh weight (398.83 and 453.33 g) as well as dry weight (150.33 and 183.28 g) per plant was recorded in control (T₃-open field) and it was minimum under Arjun (T₂) trees at both the cutting stage observations.

Oil content (percentage) of aromatic grasses (0.29 and 0.26%) was maximum in control (T₃- open field) and higher oil yield (115.26 and 175.85 ml/plot) was recorded in control (T₃-open field) while least under Arjun (T₂) trees at both the cutting stages.

Total oil yield of two cuttings (291.11 ml/plot) was also significantly higher in control as compared to oil yield under both the tree species. Among the aromatic grasses, Palmarosa registered considerably higher oil yield (190.96 ml/plot) than lemongrass (150.97 ml/plot).

Significantly highest fresh herbage yield of aromatic grasses per plot (33.20 and 52.33 kg) and per hectare (8364.82 and 13185.51 kg) was recorded in control (T₃- open field) while lowest under Arjun (T₂) trees (3884.26 and 5459.01 kg), respectively, at the first and second cutting stages. Similarly, total yield per plot (first + second cutting) (86.20 kg) was recorded in control (T₃-open field conditions). Among the aromatic grass, the total herbage yield of Palmarosa (59.85 kg/plot) was more than the herbage yield of lemongrass (55.77 kg/plot).

Higher light intensity just before first (931.52 klux) and second (780.44 klux) cutting stages were recorded at 12.00 noon under Kalam (T_1) trees as compared to that under Arjun (T_2) trees. Significant increase in light intensity was observed with increasing distance from the base line; highest being at 5m distance from the tree base line.

From the results, it may be pointed out that the competitive effect in agri-silvicultural agroforestry system was less with Kalam as compared to Arjun as tree component of the system. Among the aromatic grasses, Palmarosa performed better with Kalam as compared to lemongrass.

Dr. R.R. Shah
Associate Professor of Plant Physiology
ASPEE College of Horticulture and Forestry
Gujarat Agricultural University
Navsari Campus, Navsari-396 450

C E R T I F I C A T E

This is to certify that the thesis entitled "**FEASIBILITY OF GROWING AROMATIC GRASSES IN AGROFORESTRY SYSTEM**" submitted by Mr. **ARVIND DINUBHAI CHAVDA** in partial fulfilment of the requirements for the award of the degree of **MASTER OF SCIENCE (FORESTRY) in AGROFORESTRY** of the Gujarat Agricultural University is a record of bonafied 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


(**Dr. R.R. Shah**)

Date : February, 2002.

Major Advisor

DECLARATION

This is to declare that the whole of the research work reported in this thesis for the partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (FORESTRY) in AGROFORESTRY** by the undersigned is the results of investigation done by him under direct guidance and supervision of **Dr. R.R. Shah**, Associate Professor of Plant Physiology ASPEE College of Horticulture and Forestry, Gujarat Agricultural University, Navsari campus, Navsari, and that no part of the work has been submitted for any other degree so far.

Place : Navsari

Date : February, 2002.



(A. D. Chavda)

Countersigned by



(Dr. R.R. Shah)

Associate Professor of Plant Physiology
ASPEE College of Horticulture and Forestry
Gujarat Agricultural University
Navsari Campus, Navsari-396 450

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(A. D. Chavda)

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INTRODUCTION

I INTRODUCTION

Population explosion, both in case of human being and livestock has exerted tremendous pressure on forestland, which has aggravated the problem of fuel, fodder and timber. With the beginning of the 21st century, the country has to produce more than 220 million tons of food grains, over 2000 million tons of green and dry fodder, 350 million tons of fuel-wood and about 60 million m³ timber to meet the need of about 1000 million people and 600 million animal population. The rural people are over dependent on the natural forests. Cutting of forest and growing of agricultural crops is a very old practice all over the world. The rapid depletion of forest resources in India and elsewhere has been a matter of grave concern to policy makers and citizens alike and has now emerged as one of the most serious threats to sustained agricultural development and environment stability. The best solution is to grow necessary fuel-wood and fodder on private land along with food crops.

Though traditionally and historically forestry and agriculture are looked upon as competitive and not as complementary activities, the recent emphasis on Agroforestry, i.e., a collective name for land use system and technologies in which woody perennials (trees, shrubs, palms, bamboo's, etc.) are deliberately combined on the same land management unit with herbaceous crops and/or animals either in the same form of spatial arrangement or temporal sequence all over the world is the outcome of the change of people's attitude out of necessity.

In India, arid and semi-arid regions cover about 11.8% in the states of Rajasthan, Gujarat, Haryana, Maharashtra, Karnataka and Andhra Pradesh. Unfortunately in seventy per cent area of the Indian arid zone, the soils are sandy having problems of wind erosion, low moisture holding capacity, high evaporation, deep percolation and poor soil fertility. Agroforestry system in these areas is a boon, as the poverty seems to be inescapable evil of farmers out there, where agriculture never be a stable enterprise due to poor yields and frequent crop failures by low and erratic rainfall. Agroforestry compensates the failure atleast partly by providing income from products other than the crops and further do play a role in moderation of microclimate in the vicinity of trees, which will benefit field crops.

A multitude of benefits like nutrient re-cycling, minimization of soil water evaporation, provision of food, wood and fertilizer (green manures) has been attributed through the land use system of Agroforestry (Myers, 1980). Nevertheless farmers have voiced concern about the harmful effect of trees on cultivated lands and standing crops. Crop yield reduction (yield penalty) in a tree-crop mixed system is invariable ascribed to competition for resource pools of light, moisture and nutrients (Loomis and Whitman, 1983).

Because Agroforestry is relatively a new area, little work has been done on the species compatibility (Wood, 1988). In selecting tree species and agricultural crops for intercropping, climate considerations are of prime importance. Besides the agroclimatic factors, compatibility of tree species in the farming system of a given area is a considerable importance. Not only intercropping increases the yield and net profit but also curtails the cost of cultivation. It

also helps in minimizing problems of weed, pest and disease management to some extent.

Among different herbaceous crops, which need consideration, aromatic grasses may be given more weightage looking to low input requirement and handsome returns to the farmers. It is however, necessary to work out suitable management systems, which could improve the yield and quality of aromatic herbs without impairing the yield of the main plantation sector. Aromatic plants can be cultivated on agricultural lands as well as afforested area. Their cultivation as associate crop may save expenditure on several costly inputs. Moreover, aromatic intercrops would lead to increased cash return from tree plantation and help to generate employment in rural area.

Among different aromatic (essential oil) grasses under cultivation, Lemongrass (*Cymbopogon flexuosus*) also known as lilichaha, laghu rohis grass, is found widely in many tropical and subtropical parts of Asia, Africa and America. *C. flexuosus* is indigenous to India and large variability occurs in the western Ghats comprising Kerala, Karnataka and Tamil Nadu and Arunachal Pradesh. Systematic cultivation and distillation of the crop commenced as early as 1888 in Kerala (Pillai, 1961). It is a perennial grass about 2 m tall with profuse tillering habit. The leaves are lanceolate, often hairy and linear with size 80-125x1.25-1.175 cm. and distinct ligules, culm length usually varies between 25 and 35 cm.

The strong lemon like odour of the oil contained in the leaves of the grass is responsible for its nomenclature. Due to this characteristic smell, the oil is extensively used for scenting soap.

detergents and an array of other products, Citral extracted from the oil form an important raw material for perfumery, confectionery, beverages and the starting material for the manufacture of ionones. The oil is also used for the production of vitamin -A and synthetic violets. Citral rich oils are also known for their germicidal, medicinal and flowering properties.

Another important cultivated aromatic grass, Palmarosa (*Cymbopogon martini*) is a tall perennial tufted hedge, native of most parts of subtropical India. It is also found in lesser frequency in Karnataka, Tamil Nadu and parts of Uttar Pradesh where sporadic collections are made. Besides Palmarosa, the species occurs in another form called ginger grass (*Cymbopogon martini* Stapf. var. Sofia). The Palmarosa grass attains a height of 1.75 m under favourable growing condition in forests and upto 2.5 m under cultivation. It is a drought hardy species and moderately tolerates saline conditions. The leaves are long (35 x 1.8 cm), linear lanceolate, ligulates glabrous beneath, partly sheathing the stem with cordate to sub-cordate base. Although the whole part of the plant contains essential oil, commercially oil is extracted from aerial part of the plant and before plant flowers profusely. Palmarosa oil is extremely used in India for adulterating Attar of roses. It is also used as bases for several perfumes and in cosmetics. Along with sandal wood oil, it is used in ointments for warding off mosquitoes. In medicine, it is hoed as a remedy for lumbago and stiff joints and in skin diseases. It is said to be a cure for baldness. It serves as a remedy for bilious complaints, if taken internally in a small dose. Palmarosa oil is chiefly used as soap perfumes.

Terminalia arjuna Bedd. (Arjun) belongs to the family Combretaceae. It is an important multipurpose tree which originated from India and Burma. It is common throughout the greater part of Indian peninsula along the rivers, streams, ravines and dry watercourses. It reaches a large size on fertile alluvial loam soils. It extends northward to the sub-Himalayan tract.

It is a large handsome tree, evergreen or nearly so. The trunk of the tree is often buttressed. It has a large crown and drooping branchlets. The bark of tree is smooth, exfoliating in thin irregular sheets, green when newly exposed. The young bark contains the chlorophyll and it turns into light-grey colour but pink inside. The tree resembles *Terminalia tomentosa* except for its smooth bark, the narrower wings to the fruits and the fact that one of the characteristics of the banks of streams. It sometimes attains an enormous girth.

The heartwood is brown and sapwood is pinkish white colour. The wood is very hard and can be used for building agricultural implements, carts, boats, pit props, water troughs and other domestic purposes. The bark is used for tanning and is much collected for the purpose in central India. *Terminalia arjuna* is 10 to 15 per cent heavier than teak and 35 per cent harder. In shock resistance and shear, it is 35 to 40 per cent stronger than teak, but in other strength functions it is 25 per cent below teak (Troup, 1986).

Mitragyna parvifolia Korth. (Kalam) is a large deciduous tree with a full rounded crown and bole often short, fluted and buttressed. The bark is upto 0.8 inch thick, grey, smooth and exfoliated in scales, which leaves shallow depressions. The wood is light pinkish brown, evenly grained and a shade lighter than teak but

of some hardness. In strength, it is about shearing strength, in which it is about equal to teak. Under favourable conditions the tree reaches large dimensions.

The wood of tree is commonly used for building, furniture, agricultural implements and such purposes as toy making, turnery and the manufacture of combs. Cups, platters, bowls, frames, waking sticks, handles and such like articles. It is recommended for certain types of bobbins, penholders and mathematical instruments (Troup, 1986).

The farmers can get more production and profit with judicious use of suitable intercrops which are paramount importance in economic agricultural production. No serious attempt seems to have been made in Gujarat or elsewhere to obtain or determine economical intercrops in widely spaced forest tree species like *Terminalia arjuna* Bedd. and *Mitragyna parvifolia* Korth.

With this background present investigation is an attempt to assess the affect of 12th year old plantation of *Terminalia arjuna* and *Mitragyna parvifolia* on growth and yield of aromatic grasses (*Palmarosa* and lemongrass) as intercrops.

The present investigation was, therefore, aimed at assessing the "Feasibility of growing Lemongrass (*Cymbopogon flexuosus*) and Palmarosa (*Cymbopogon martini*) in agroforestry system (*Terminalia arjuna* and *Mitragyna parvifolia*)" with the following objectives.

1. To study the effect of forest tree species on growth of aromatic grasses.
2. To study the effect of forest tree species on the forage yield and oil quality of aromatic grasses.
3. To find out the best combination of forest tree species with aromatic grasses for higher production.

REVIEW OF LITERATURE

II REVIEW OF LITERATURE

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

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

2.1 Growth and yield (grasses + tree)

2.2 Growth and yield (grasses + agriculture crops)

2.3 Shading effect

2.1 Growth and yield (grasses + tree)

Vinod Shankar *et al.* (1976) reported the experimental evidences relating to the crop improvement effect of Khejri (*Prosopis cineraria*) on forage grasses. The dry herbage under khejri tree was 2.3 t/ha as against 1.66, 1.32, 0.85 and 0.78 t/ha under Rohida (*Tecomella undulata*), Siris (*Albizzia labbeck*), Vilayti Babool, (*Prosopis juliflora*) and Kummut (*Acacia senegal*), respectively. Marked improvement in vigour of major grasses under Khejri was also noticed. The sown pastures of Anjan grass (*Cenchrus ciliaris*) showed gradual and significant difference in plant height, tussock diameter and herbage yield as the distance from Khejri tree increased.

Muthana and Shankarnaryan (1978) described the fuller utilization of inter spaces between tree rows for intercropping with

good compatible forage grasses. Results have shown that there were no significant differences in dry grass yield under different tree species and that tree growth and height were unaffected by intercropping.

Bordoloi *et al.* (1985) in numerous trials with *Eucalyptus citriodora*, *Aeolanthus gamwelliate* and five *Cymbopogon*, three *Mentha* and three *Ocimum* species, examined the optimum planting time, spacing, N, P and K fertilizer rates and cutting intervals. The results showed that the new *C. winterianus* cv. Jor Lab C2 yielded 22.1 t/ha herbage with 1.48 per cent oil yield compared with 12.5 t/ha and 1.32 per cent oil of the local unimproved Jorhat strain. Mixed cropping of *C. winterianus* with *M. arvensis*, *M. piperata* or *E. citriodora* invariably reduced herbage and oil yields compared with pure stands, though oil content and composition were unaffected.

Opitz and Seemer (1986) studied the management of grass pasture under double utilization. It consisting of thirty-year-old poplar stands with a grass cover of *Lolium*. The tree canopy reduced photosynthetically active light reaching the grass by more than 50 per cent. In the spring, the mass of tree foliage impeded development of the first growth of grass, the extent of this effect depending on density of the tree stands. Competition from the tree also persistently reduced the amount of water available to the grass. The stand density of the trees also had a marked effect on the grass yield as affected by N supply and weather conditions. Competition from the trees also significantly decreased the effectiveness of N fertilizers.

Adkins (1988) reported promising early result (first year) with intercropping trials of *Eucalyptus camaldulensis* with *Cymbopogon* Spp. (*C. martini*, Palmarosa grass and *C. nardus*,

Citronella grass) and of *Populus deltoides* clones with *Mentha arvensis* (mint) have been established at the Medicinal Herbs Farm, Tamaghari, Bara District, Nepal. The aim was to produce fuelwood for distillation of the essential oil along with the oil producing plants.

Singh *et al.* (1989) carried out a 60month study on amount of litter fall, its chemical composition, and nutrient addition to and changes in chemical constituents of the soil were studied under agroforestry system involving *P. deltoides* or *Eucalyptus hybrid* with intercrops in *Cymbopogon martini* or *C. flexuosus* in the Tarai tract of the Kuman Hills, U.P. Herb and oil yields of grasses were significantly reduced under tree (5.4 and 15.4% respectively) but neither grass affected tree performance. The *P. deltoides* plantation was superior to that of *E. hybrid* in enriching the soil.

Six species of aromatic plants (*Mentha arvensis*, *M. spicata*, *M. citrata* [*M. piperita* var. *citrata*], *M. piperita*, *Cymbopogon winterianus* (citronella) and *C. flexuosus* var. (lemon grass) were planted as intercrops immediately after planting the trees by Kamla Singh *et al.* (1990). Intercropping had no adverse affect on poplar growth. Herbage and oil yields of *Mentha* spp. were not affected in the first year but fell by 10-26 and 8-24 per cent, respectively, over the next two years, probably because of shading by the trees. For *Cymbopogon* spp., however, there was only a very small reduction in herbage and oil yields over the three years (1.3 to 2.4 and 0.5 to 4.5 per cent, respectively). It is suggested that intercropping with perennial *Cymbopogon* spp. should provide an economic return for at least three to four year.

Ella *et al.* (1991) reported that the longer cutting interval produced a higher yield in the first wet season harvested but not in later harvested when rainfall was lower. In the wet season, the shorter cutting interval tended to produce higher grass yield at the higher densities, while no difference between cutting intervals occurred at the lower tree densities. However, in the dry season, grass yield were higher overall at the longer cutting interval and the higher tree densities. The total DM production of *P. maximum* was highest when grown with *S. grandiflora* (11.1 t/ha/year).

Dastnagir and Suresh (1991) conducted the experiment with four grass-legume mixture combinations (*Cenchrus ciliaris* with *Clitoria teratea*, *Desmodium spp.*, *Desmanthus spp.* or *Stylosanthes spp.*) intercropped with the fodder tree *Acacia leucophloea* under a silvipastoral system. Fodder production from intercrops increased over the 3 years of the study, and was not markedly different between crop combinations. Growth of *Acacia leucophloea* was higher in all intercropping combinations than alone, and best when intercropped with *Cenchrus ciliaris* alone.

Horne and Blair (1991) conducted a field experiment to assess the forage yield of *L. leucocephala* and grasses in a wet tropical environment (Ciawi, West Java and Indonesia). The highest leaf production was in the *S. sphacelata* monoculture (20.8 t/ha/year) and the low cut *S. sphacelata/L. leucocephala* mixture (18.5 t/ha/year) with the grass dominating production (> 88%). *L. leucocephala* shoot production in low cut treatment was reduced from a mean of 8.8 t/ha/year in the monoculture to 1.5 t/ha/year in the mixtures. The mixture of the *S. sphacelata* and high cut *L. leucocephala* produced a

considerable leaf yield in the former (6.2 t/ha/year) with no reduction in leaf yields of the latter.

The results of a field trial conducted from 1988 to 1991 at the livestock Research Station, Thiruvazhamkunnu, Kerala, to study the compatibility of different component in a silvopastoral system, Mathew (1992) showed that growth and yield of fodder species were significantly influenced by the tree components only after tree canopy formation. The fodder species *Pennisetum purpureum*, *Panicum maximum*, *Brachiaria ruziziensis* and *Euchlaena (zea) mexicana* grown in association with *Casuarina equisetifolia* and *Ailanthus malabarica* recorded comparatively higher forage yield even after canopy formation. However, fodder crops grown in combination with *Acacia auriculiformis* and *Leucaena leucocephala* registered relatively lower values for growth and yield.

Meera bai *et al.* (1992) conducted an experiment on congosignal grass in a 40-year-old coconut garden. Based on pooled data, there was significant increased in green and dry fodder yields with the application of 100 kg N/ha over 50 kg N/ha. Beyond 100 kg N/ha, the increase in fodder yield was non-significant. However, difference in dry fodder yield were significant between different cutting intervals.

Experiment conducted by Singhal *et al.* (1994) on agroforestry practices in the Tarai areas of U.P with poplar as tree crop and *Mentha* spp. and *Cymbopogon* spp. as non-conventional crops for one year showed promising trend. The herb and oil yield of *Mentha* spp. decreased when the poplar reached two years old whereas yields of *Cymbopogon* spp. [*C. flexuosus*, lemon grass, *C. winterianus*,

Citronella Java) did not increase or decrease in the second year or thereafter. They concluded the latter are, therefore, quite suitable for growing under poplar.

A field experiment conducted at Forage Research Farm, Tamil Nadu by Chandramala *et al.* (1996) showed that raising of *Cenchrus glaucus* (CO-1) in between the alley of subabul spaced at 4 m interval with application of 20 kg N ha⁻¹ in combination with application of 2 kg of *Azospirillum* ha⁻¹ after each cutting resulted in the higher green fodder and dry matter yield. It could also result in higher crude protein yield with better quality fodder. In addition, these treatments fetched better economic returns under rainfed conditions.

Hazra *et al.* (1996) evaluated five different winter maize varieties for their herbage yield under three trees species viz., *Leucaena leucocephala*, *Acacia nilotica* and *Hardwickia binnata*. The relative yield of maize varieties under *H. binnata* were 94 per cent for green and 99 per cent for dry matter, whereas corresponding yields were 44 and 45 per cent under *A. nilotica* and 31 and 34 per cent under *L. leucocephala*.

Faiz *et al.* (1996) examined agroforestry trial on juvenile (2 and 3 year old) stands of *Populus deltoides* intercropped with 5 *Mentha* spp. and 3 *Cymbopogon* spp. The plantation intercropped with *Mentha* produced more litter than pure plantation or those intercropped with *Cymbopogon* spp. The litter produced by the intercropped stands had higher N, P and K contents than the pure stands. The available N, P and K contents of soil under the pure stands were higher than that under intercropped stands.

Faiz *et al.* (1996) reported the result of field experiments carried out at the CIMAP Regional Center, Pantnagar, U.P., in which poplar (*Populus deltoides*) G-3) of different age groups at 5 x 4 m spacing was intercropped with mint (*Mentha arvensis*, *M. piperita*, *M. citrata* [*M. piperita* var. *citrata*], *M. spicata*, *M. cardiaca*) and *Cymbopogon* spp. (*C. flexuosus*, *C. winterianus*, *C. martini*). Poplar grown in stands intercropped with mint and *Cymbopogon* spp. attained better height and diameter per breast height than tree monocultures at both early (2 and 3 years) and more advance (6 and 7 years age) stages. However, the bole wood contribution to the total biomass was greater in the tree alone than in the intercropped stands, and the contribution of branches, foliage and bark was highest in the stands intercropped with *M. arvensis* and lowest in tree alone stands. Respective values in other intercropped stands were in between those of the tree alone and *M. arvensis* treated stands at all ages.

Misra *et al.* (1996) planted *Populus deltoides* clone D-61 at various spacing/densities in 20 x 20m plots on a sandy loam well drained soil in a mixed cropping system under Tarai conditions in Pantnager U.P. Intercrops were wheat/soyabeans in the first 3years and Lemongrass (*Citronella* [*Cymbopogon*]) for the next three years with the tree rows themselves not cropped. The 5x5 and 5x3.75 m spacings gave greater trees height, diameter at breast height, mean annual increment in d.b.h. and basal area of individual trees. Tree survival was also significantly greater at the 5 x 5-m spacing. No data are given on crop yields.

Patel (1996) carried out a field experiment to study the productivity of agricultural crop in agrisilvicultural system. He pointed

out that the competitive effect in agrisilvicultural agroforestry system was less with Kalam as tree component as compared to *Terminalia Arjuna* as tree component of the system. The yield reduction noted under Kalam was only 4.66% as compared to 19.11% under Arjun over the control. Among agricultural crop gram performed better with Kalam as compared to mustard and Indian bean.

Faiz *et al.* (1996) reported the result of a field trial conducted at the Central Institute of Medicinal and Aromatic plants, Regional Centre, Pantnagr. Annual litter production increased with increasing age (2 to 7 year old) in *Eucalyptus hybrid* (*E. tereticornis*) plantations, both in monocultures and in stands intercropped with *Mentha* spp. (*M. arvensis*, *M. piperita*, *M. citrata* [*M. piperita* var. *citrata*], *M. spicata*, *M. cardiaca* [*M. gracilis*] and *Cymbopogon* spp. (*C. flexuosus*, *C. winterianus*, *C. martini*). A higher concentration of N, P and K was found in the litter of the intercropped stands, which decreased with increasing age of the stands. The total addition of nutrients through litterfall to the soil was higher in the intercropped than in the pure stands, but the available N, P and K contents of the soil under the pure stands was higher than under the intercropped stands.

Chauhan *et al.* (1997) carried out a field study during 1994-95 to quantify litter fall and the change in soil chemical properties under 5 to 6-year-old *Eucalyptus hybrid* [*E. tereticornis*] and poplar trees interplanted with aromatic crops like Lemongrass (*Cymbopogon flexuosus*), citronella Java (*C. winterianus*), Palmarosa (*C. martini*) and Japanese mint (*Mentha arvensis*) at the CIMAP field Station, Pantnagar. Herb and oil yields of interplanted aromatic crops

decreased under *Eucalyptus*. The extent of the reduction was 61.6 and 67.13% in Japanese mint, 30.71 and 42.22% in palmarosa, 42.9 and 51.6% in citronella Java, and 16.6 and 22.7% in Lemongrass as intercrops (compared with them as sole crops). The extent of reduction under poplar intercropping was low compared with that under *Eucalyptus*.

Chauhan *et al.* (1997) conducted agroforestry trial at the CIMR field station Nainital, U.P. to examine the performance of aromatic crops such as Lemongrass (*Cymbopogon flexuosus*), citronella Java (*C. winterianus*), Palmarosa (*C. martini*) and Japanese mint (*Mentha arvensis*) in *Eucalyptus hybrid* plantation. Results indicated the *Eucalyptus* growth, in terms of height and diameter was improved by the intercrops. Amongst the intercrops, herb and oil yield were lowest for Lemongrass, while oil yield was highest for citronella Java and intermediate in palmarosa. Herb and oil yields of Lemongrass did not decrease with increase in the age of the trees, while oil yield in citronella and Palmarosa decreased with increasing tree age after the third year when compared with the sole crop. Lemongrass performance was judged to be the best with respect to sustained herb and oil productivity during the entire growth period.

Effect of different treatments on production potential, quality and carrying capacity of improved grassland (silvipastoral system) by Premi *et al.* (1998) was studied with *Setaria* (*Setaria anceps*), *Setaria* + Siratro (*Macroptilium atropurpureum*) in native vegetation as well as between hedge rows of Robinia (*Robinia pseudoacacia*). Both the systems proved equally effective in relation to

production. All *Setaria* introduced treatment benefited the farmers to carry almost three times livestock with them.

Anil Kumar (2001) ^{Ref.} tested Lemongrass with three spacing and four fertility levels under poplar (*Populus deltoides* G-3) for its performance in Kumaun foothills for two years (1993-1994). The treatment combination S₂F₃. (Spacing 45 x 45 cm and fertility level N₂₅₀, P₁₀₀ and K₈₀) proved to be superior in respect of number of tillers (78 and 114), plant height (153 and 150 cm), herbage yield (57.6 and 68 t/ha) and oil yield (260.9 and 309.4 kg/ha) when compared to other treatments in the first and second years, respectively.

2.2. Growth and yield (grasses + agriculture crops)

According to Rai (1987), in the hilly areas of Meghalaya, *Pennisetum polystachyon*, *Cymopogon flexuosus*, *C. winterianus* and *Setaria sphacelata* grown on the terrace risers gave higher fresh herbage yield than *Stylosanthes hamalta*, *S. guyanensis*, *S. humilis* or *Macroptillum atropurpurem* and were also superior to the legumes in plant height and root biomass accumulation.

Rai and Suresh (1988) reported two studies in India. In the first, the sorghum showed increased height and DM production under the tree canopy compared with in the open. In the second study, alley cropping experiment set up at the Forest Research Station, Mettupalayam, to determine the optimum crop combinations with *Casuarina equisetifolia*; *Leucaena leucocephala* and *Eucalyptus tereticornis* showed BN-2 fodder grass (*Pennisetum* sp.) to be highly compatible with *C. equisetifolia* in general, this tree species also had the least determinate effect on the growth of associate crops while *E.*

tereticornis had the most. Growth and yield of sorghum, maize and cowpea were depressed when allay cropped with all three species.

Prakasa Rao *et al.* (1988) made a study to explore the initial lag phase of *Cymbopogon winterianus* essential oil crop intercropped with food crops. An experiment conducted during 1982-1984 showed that cowpea (*Vigna unguiculata*), black gram (*V. mungo*) or green gram (*V. radiate*) could be intercropped in the initial stages, to give extra yields over and above that of citronella which remained unaffected by the presence of the intercrops. Another experiment (1984-85) showed that a two crop rotation system could be intercropped in citronella without affecting the yields of the main crop.

Singh and Ram (1991) conducted field studies over two seasons to determine the most profitable intercrop for *Cymbopogon winterianus*. The results indicated that *Mentha arvensis* and *M. spicata* as intercrops did not affect significantly the herb and oil yields of citronella and their use gave the highest monetary returns of Rs. 7442 and 6902/ha respectively, compared with a sole crop of citronella. Intercropping with cowpea (*Vigna unguiculata*) gave the lowest return of Rs. 891 /ha.

Singh and Kohli (1992) in a field experiment, confirmed the presence of allelochemicals in the soil beneath the *Eucalyptus* plantations, which had inhibitory effect on growth of *Phaseolus aurens* (*Vigna radiata*).

Tripathi *et al.* (1994) tested cereal fodder for their efficacy for rowing under agroforestry situation in relation to their N-requirement. Crops like maize, safflower,, oats were tested under seven

year old *Albizia lebbek* tree. Significant response to crops was observed upto 40 to 60 kg/N/ha for safflower, On the other hand, oat maize responded upto 80 kg/N/ha and barley upto 120 kg/ha. Oat and Chinese cabbage yielded up to 72-80 per cent of open canopy under tree.

Maheshwari *et al.* (1995) examined the effect of spatial arrangement on performance of palmarosa-pigeonpea intercropping. Higher total tonnage was recorded from intercropping of pigeonpea in the intermittent (alternate) rows parallel to palmarosa. This spatial intercropping system always resulted in higher oil yield equivalent of Palmarosa over other systems. This system resulted in higher income equivalent ration (IER 1.17). Sowing of pigeonpea in alternate rows parallel to Palmarosa proved most efficient and economic, as it provided higher economic returns, bonus income and monetary advantage. The oil content and quality in terms of total geraniols of Palmarosa were not adversely affected by adoption of intercropping.

Maheshwari *et al.* (1996) conducted field studied *Cajanus cajan* cv. jawahar Arhar and intercropped with *Cymbopogon martini* var. motia in a 1:1 row ratio produced *C.cajan* seed yield of 1.36 t/ha, and *C.martini* herbage and essential oil yields of 5.86 t and 48.9 liters/ha, respectively and gave the highest returns.

Maheshwari *et al.* (1997) tested Palmarosa (*C. martini*) and pigeon peas (*C. cajan*) were grown alone or intercropped in palmarosa: pigeonpea row ratio of 1:1 or 2:1 pigeonpea seed yield was markedly decreased in the 2:1 row ratio intercrop by the smothering effect of palmarosa. Palmarosa grown alone produced mean oil yield of 115.8 liter/ha and the highest returns.

Gill *et al.* (1997) carried out agri-silviculture studies by raising crops in inter space of fruit crops along with the introduction of multipurpose tree species. The results revealed that *leucaena* plant growth was slightly better under control as compared to agroforestry system. On an average (1990-1994), maximum green fodder (112.17 g/ha and dry matter 35.63 q/ha) yield was recorded under control (5 x 5 m fruit spacing as compared to the yield recorded under 5 x 5m, 5 x 10 m and 10 x 10 m) fruit tree spacing with crops in the interspaces. Among the fruit tree species, maximum green and dry matter yield was registered from the interspaces of Annar followed by citrus (kinnow), guava and minimum in case of *Zyziphus mauritiana*.

Singh and Sivaraj (1998) explored the possibility of intercropping food legumes with *C. flexuosus* cv. Cauvery. An experiment was conducted during 1992-1993 in India with *C. flexuosus* slips planted at a spacing of 60 cm between rows and 30 cm between plants. Food legumes and soyabeans (cv. Hardee) could be intercropped during the initial stages of *C. flexuosus* growth without affecting *C. flexuosus* yield. On the other hand *C. flexuosus* yield (essential oil and herb yield/ha) was promoted by increasing rates of N.

Singh *et al.* (1998) examined the productivity and economic viability of a Palmarosa pigeonpea intercropping system. Two pigeonpea cultivars, Bahar (late maturing) and UPAS 120 (early maturing), were intercropped at different row spacing (180, 240 or 300 cm) with Palmarosa at a row spacing of 60 cm. Intercropping with the late maturing cv. Bahar at 300 cm row spacing produced 1.26 t/ha grain (2 year mean), without affecting the growth and yield of the palmarosa.

It improved the relative net return by 58 per cent and net economic return by Rs. 12500/ha over a sole Palmarosa crop.

Shinde (2001) studied *Vigna unguiculata*, *Vigna radiata* crops under two tree species. Significant maximum number of leaves, number of branches, fresh weight, dry weight and water status of leaves were recorded when crops grown under T₀ (open condition) as compared to T₂ (Kalam) and lowest under T₁ (Arjun). Similarly, significantly the highest yield of forage per hectare was recorded in T₀ (open condition) as compared to T₂ (Kalam) and lowest under T₁ (Arjun) trees.

2.3 Shading effect

Knight (1935) observed two third reduction in American cotton yield in Sudan in artificial shade under field conditions. Similarly, Eaton and Ergle (1954) reported decrease in fresh weight, taller plants and reduction in yields of cotton plants under artificial shaded conditions in a field.

Tanaka *et al.* (1964) reported lower dry matter accumulation and decreased photosynthesis in rice under shaded conditions.

Stansel *et al.* (1965) reported increased sterility, taller plants and reduction in yield under low light intensity conditions in rice cultivars. The yields were reduced from late primordial initiation under shade.

Cooper and Qualls (1967) observed that the increasing the ratio of leaf area to leaf weight which occurs with shading of legumes.

was associated with changes in leaf morphology and chlorophyll content. Alfalfa and birdsfoot had more stomata per cm^2 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 sun leaves, and the palisade layer was more clearly differentiated.

Dolan (1972) studied the effect of temperature, photoperiod and light intensity on growth of *Pisium 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) temperature. He observed the best growth with long day (18 hrs light) and high light intensity (43,000 klux).

Wattal and Asana (1974) observed that the net assimilation rate (NAR) and growth rate during the tillering phase of two tall (NP 823 and NP 824), one semi-dwarf (Kalyansona) and one dwarf (HD 1949) cultivars of wheat (*Triticum aestivum* L.) were saturated at a light intensity of about 3,000 foot candles (ft. c.) but their tiller number increased with light intensity upto that of full sunlight (4,900 ft. c.). When light intensity varied during grain development, the final grain yield leveled off around 3,000 and 4,000 ft. c. in 'NP 823' and 'HD 1949', respectively, and increased upto full sunlight (around 6,500 ft. c.) in 'Kalyansona' and 'NP 824'. The cultivar 'NP 824' was superior to '823' in grain yield under full sunlight, but inferior under lower light intensities. The cultivar 'Kalyansona' was the highest yielder. Grain weight was depressed more than grain number by decrease in light intensity.

Crookston *et al.* (1975) reported that under shaded light (approx. 3,200 klux light intensity), the number, area and thickness of leaves were reduced but transpiration was not significantly affected in dry bean (*Phaseolus vulgaris* L.). Photosynthesis per area of shaded leaves was decreased by an average of 38 per cent.

Venkateswarlu *et al.* (1977) reported the effect of low light intensity (40 to 50 per cent of natural light) at different growth stage and subsequent exposure to natural light on growth and productivity of rice in two genotypes during Kharif and three during *Rabi* under 2 N levels. The leaves from the continuously shaded plants showed more chlorophyll content at flowering stage. The dry matter accumulation was affected under shading at all stage, which was critical from premordial initiation (PI) onwards. The grains / panicle were reduced by shading from PI onwards. The yield were 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.

Venkateswarlu and Srinivasan (1978) studied the shading effect (40 to 50 per cent of natural light) on two rice crop at different stage with two different densities under field conditions and observed that there was a decrease in the total dry matter content and reduction in tillering under shading irrespective of growth phase. The yield losses were maximum at reproductive and ripening phases.

Rao and Singh (1980) conducted a field trial to investigate the effect of shading and defoliation on the grain yield and its attributes in bajara and reported that a cut in photosynthetic surface

area either by shading or defoliation at the time of anthesis causes reduction in grain number ear, grain size, rate of grain development and the final grain yield almost in proportion to the cut in leaf area.

Janardhan and Murty (1980) observed that dry matter, photosynthetic rate, relative growth rate, net assimilation rate and specific leaf weight were reduced whereas height, leaf area ratio and relative leaf growth were increased under low light as compared to normal light conditions. Dry matter production under low light was impaired through reduced photosynthetic rate despite an increase in chlorophyll content. They stated that grain yield of tall and semi-dwarf rice cultivars reduced under low light, due to low grain number per panicle and small grain size.

In another field study, low light (915 to 20 klux) was imposed during ripening period in four tall indices and four semi-dwarf rice cultivars by Janardhan *et al.* (1980) to study low light effect on yield and translocation of nitrogen and carbohydrates to panicle. Grain yield was reduced under low light due to low grain number per panicle and grain size. Due to better mobilization capacity the tall indices particularly the late maturing types recorded higher yield than the semi-dwarfs under low light.

Naik and Murty (1980) studied the effect of varying light intensities viz., normal light ($400 \text{ cal cm}^{-2} \text{ d}^{-1}$), 75% light (NL) on yield and growth attributes in rice in two rice cultivars, IR-8 (shade sensitive) and Vijaya (shade adapted). The grain yield, in general, was reduced by 47%, 57% and 74% in S1, S2 and S3, respectively mostly due to impairment in dry matter production, HI, panicle number and grains per panicle. Exposure to low light from primordial initiation to

harvest was more detrimental to yield than from establishment (15 DAP) to harvest from flowering to harvest.

Pareek and Gupta (1985) studied the shading effect on Lemongrass inter crop in coconut gardens. The plant (Lemongrass) does not tolerate when the plant is grown under diffused light. Data from the on going trials at this station indicating poor tillering, lean and lanky growth and reduced oil yield when the crop is grown in inter crop in coconut gardens; the oil content was also found to be reduced by 20 per cent.

Singh (1986) studied the response of four cotton genotypes (AKH 4 of *G. arboreum* and SRT 1, B 1007 and C 1412 of *G. hirsutum* L.) to reduction in light intensity by shading the plants under field conditions and reported that reduction in light intensity reduced the rate of photosynthesis as indicated by reduced net assimilation ratio (NAR) and leaf area efficiency (LAE) but leaf area ratio (LAR) and specific leaf area (SLA) increased. Dry matter of the genotypes increased significantly with 35 per cent reduction in light intensity. When it was further reduced to 65 per cent the dry matter of SRT 1 and B 1007 remained unchanged, that of AKH 4 was the same as under natural light but reduced significantly in C 1412. The genotypes AKH 4 and C 1412 appeared outstanding as they maintained higher seed cotton yields and higher fruiting coefficients by apportioning more photosynthates for cotton seed production even when the light intensity was reduced to 65 per cent.

George and Nair (1987) conducted a field experiment at the College of Horticulture, Trichur during May to October, 1981 to assess the feasibility of cow pea (var. Kanakamani) for intercropping in

coconut garden and found that the grain yield of cowpea was fell substantially because of shading. Even the low shade of 25 per cent with more intense shading the yield. Progressively decreased. When the light intensity was reduced by 75 per cent, the yield was only 9 per cent of that at full sunlight.

Jayachandran *et al.* (1991) studied the performance of ginger under shade and open condition at NARP Kottarakkara, Kerala and found that ginger produced higher yield at a low shade intensity (25%) as compared to open field. The yield was decreased under 50 per cent shade intensity. Ginger cv. Rio-de-Janerio can be recommended for homestead cultivation as well as for intercropping under coconut and other perennial crops where low to medium (25 to 50 per cent) shade intensities exist.

The effect of shade of rubber tree, on the growth performance and output of pigeon pea intercrop, showed that gradual increase in shade progressively decreased the plant height, number of branches, number of pods and seed per plant and finally per hectare grain yield. Lateral growth parameters and pulse yield data of pigeonpea were higher in first, second and third year of Rubber (GT-1) growth, but become abruptly reduced in the fourth year due to closure of tree canopy, thereby indicating that pigeonpea can be grown in the inter row space profitably in the first 3 years and its continuation beyond third year will not be economical (Brahman *et al.*, 1997).

Ravindran and Kulandaivell (1998) observed that the reduction in the yield components of Cardamom under full sunlight may be attributed to excessive sunlight during summer months combined with high temperature and low humidity and soil moisture.

all of which are determinate to vegetative growth and flower initiation. The decrease in the yield at low light could be due to reduced photosynthesis during winter months. Though cardamom is regarded as shade loving plant, low light condition was not conducive to the optimum growth and productivity.

A two year study was undertaken in the coconut based homesteads of southern Kerala during 1995-96 to assess the light available at the floor of the home garden for the under storey crops after interception by a coconut in sole stand and on inter planting with certain perennial multipurpose trees. It was observed that the amount of light transmitted in coconut sole stand was only 36 per cent of that available. When interplanted with multipurpose tree, the light availability was reduced to as low as less than the low productivity annual intercrops in coconut based homesteads. Farmers who practice the system are not fully aware or conscious of the specific requirements of the crops. Advocating meticulous selection of under storey crops/varieties, timely planting of intercrops following the temporal sharing concept and selective and timely pruning of over storey canopy strata could mitigate the problems of low light availability and utilization immensely, (Johan and Nair, 1999).

Mahajan (2001) the effect of different spacing and pruning intensities of *Casuarina equisetifolia* on growth and yield of *Trigonella*. The result revealed that height increase with the partial reduction in the light. However, it diminished in low light condition yield attributed showed the maximum yield in open field conditions than with tree crops.

**MATERIAL
AND
METHODS**

III MATERIALS AND METHODS

The details of materials used and the techniques adopted during the course of investigation entitled "Feasibility of growing aromatic grasses -Lemongrass (*Cymbopogon flexuosus*) and Palmarosa (*Cymbopogon martini*) in agroforestry system (*Terminalia arjuna* Bedd. and *Mitrogyna parvifolia* Korth.)" are narrated briefly in this chapter.

3.1 Experimental site

The present investigation was carried out at the Instruction Farm, ASPEE College of Horticulture and Forestry, Gujarat Agricultural University, Navsari Campus, Navsari. The college farm is located 3 km away in the east from Navsari and geographically, it is situated at 20.95° North latitude, 75.90° East longitude and at an altitude of ten metres above the mean sea level.

3.2 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 and post monsoon rains in October-November are not uncommon. Most of the rainfall is received from south-west monsoon concentrating in the months of July and August. The average annual precipitation of the last 13 years (1988-1999) is 1355 mm.

The winter season starts from November with mild cold and lasts up to February; December and January are the coldest months of the season. The 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 for the period of investigation, recorded at the meteorological observatory in the farm of N.M. College of Agriculture, Gujarat Agricultural University, Navsari are presented in Table-3.1.

3.3 Soil characteristics

The characteristics of the soil of the Instructional Farm, ASPEE College of Horticulture and Forestry is placed under Jalalpor Series, which includes deep, moderately drained clayey soils classified as deep black soil predominating with montmorillonite clay mineral by its origins. It is medium in fertility. The topography of the experimental plant was fairly level. Soil samples were presented in Table-3.2.

3.4 Plant materials

3.4.1 Forest species

The twelve year old plantation of *Terminalia arjuna* Bedd. (Arjun) and *Mitrogyana parvifolia* Korth. (Kalam) planted at 10 m x 2.5 m distance were used for intercropping study.

**Table 3.1: Weekly average meteorological data during the investigation period
(from February 2001 to August 2001)**

Month	Std. week	Temperature (°C)		Relative Humidity (%)		Sunshine Hours/day	Rainfall (mm)
		Max.	Mine.	Morning	Evening		
Feb-2001	6	32.5	11.5	72	19	10.3	000.0
	7	37.8	13.2	82	26	9.8	000.0
	8	33.1	15.3	89	30	10.1	000.0
	9	32.9	17.3	75	38	9.5	000.0
Mar-2001	10	32.6	18.3	19	46	9.4	000.0
	11	32.1	19.8	87	48	10.2	000.0
	12	32.6	21	89	45	10.4	000.0
	13	32.5	20.7	88	54	10.2	000.0
Apr-2001	14	36.3	22.1	84	36	10.5	000.0
	15	37.1	23.9	74	34	10.4	000.0
	16	33.9	24.6	84	43	10.6	000.0
	17	37.1	25.5	84	41	10.5	000.0
May-2001	18	33.8	29.4	82	61	10.6	000.0
	19	32.6	28.3	75	54	10.6	000.0
	20	32.9	28.5	74	60	10.4	000.0
	21	35.0	28.3	73	56	9.4	000.0
June-2001	22	32.6	27.9	77	65	6.6	019.3
	23	32.4	27.5	84	67	7.1	014.0
	24	29.0	26.0	89	85	2.4	403.0
	25	30.3	27.7	83	75	3.6	044.0
	26	31.5	28.0	80	69	6.1	012.1

Contd ...

Month	Std.week	Temperature (°C)		Relative Humidity(%)		Sunshine Hours/day	Rainfall (mm)
		Max.	Mine.	Morning	Evening		
July-2001	27	28.6	25.7	94	81	2.1	162.6
	28	28.8	26.0	90	82	3.6	120.0
	29	28.4	26.1	88	81	1.8	96.1
	30	28.8	26.0	91	83	3.4	61.3
	31	29.8	25.4	92	73	4.6	32.0
Aug.-2001	32	27.1	25.1	96	92	0.6	494.0.
	33	28.7	25.8	90	80	3.4	241.2
	34	29.5	25.6	96	28	5.9	022..2
	35	30.2	26.7	83	26	7.9	1.5

Source : Meteorological observatory, N. M. College of Agriculture, Gujarat Agricultural University, Navasari.

Table 3.2 : Physico-chemical properties of soil of experimental field

Particulars	Values at different depths (cm)		Methods employed
	0-15	15-30	
[A] Physical characteristics			
Sand (%)	12.40	12.65	International pipette method (Piper, 1950)
Silt (%)	19.85	20.15	
Clay (%)	67.75	67.20	
[B] Chemical characteristics			
Soil pH (1:2.5) soil : water ratio)	7.9	7.8	Blackman's pH meter (Jackson, 1967)
Electrical conductivity 1:2.5 (m mhos/cm at 25°C)	0.24	0.32	Schofield method (Jackson, 1967)
Organic carbon (%)	0.38	0.46	Walkley and Black's rapid titration methods (Jackson, 1967)
Total nitrogen (%)	0.048	0.049	Modified kjeldahl's method (Jackson, 1967)
Available P ₂ O ₅ (kg/ha)	28.90	31.25	Olsen's method (Jackson, 1967)
Available K ₂ O (kg/ha)	375.00	371.00	Flame photometry method (Jackson, 1967)

3.4.2 Aromatic grasses

Important essential oil and commercial aromatic grasses, viz., Lemongrass (*Cymbopogon flexuosus*) var. OD-19 and Palmarosa (*Cymbopogon martini*) var. OD-29 were selected for the present study.

3.5 Experimental details

The experiment was conducted during winter 2001 with the following details.

1. Location : Instructional Farm, ASPEE College of Horticulture and Forestry, Gujarat Agricultural University, Navsari Campus, Navsari-396450
2. Design : Split Plot Design
3. No. of replication : 3 (Three)
4. Plot size : (a) Gross plot : 7.5m x 8.10m
: Net plot : 6.3m x 6.3m
: (b) Spacing
(1) Forest species: 10m x 2.5m
(2) Aromatic grass:
(a) Lemongrass: 45cm x 30cm
(b) Palmarosa: 45cm x 30cm
(c) (i) Numer of row in net plot:
(1) Lemongrass : 14
(2) Palmarosa : 14

(ii) Number of forest trees per treatment

	Gross plot	Net plot
1. Arjun	3	3
2. Kalam	3	3

5. Forest tree species : (i) Arjun- *Terminalia arjuna* Bedd.
(ii) Kalam- *Mitragyna parvifolia* Korth.
6. Aromatic grasses : (1) Lemongrass *Cymbopogon flexuosus*
(2) Palmarosa- *Cymbopogon martini*
7. Date of sowing/planting :
- (1) Tree species : Kharif 1989
- (2) Aromatic grasses : 8th February, 2001
8. Date of harvesting : (1) First cutting : 5th June 2001
: (2) Second cutting : 28th Aug 2001
9. Details of treatments :
- 1) Main plot treatment : 3 (two tree species + one control)
- a) T₁ : *Terminalia arjuna* Bedd. (Arjun).
- b) T₂ : *Mitragyna parvifolia* Korth. (Kalam).
- c) T₃ : Control : open land (without tree cover).

2) Sub-plot treatment : 2 [intercrops (aromatic grasses)]

a) S_1 : *Cymbopogon martini* (Palmarosa grass)

b) S_2 : *Cymbopogon flexuosus* (lemon grass)

10. Treatment combination : Six (6)

1. T_1S_1 2. T_1S_2

3. T_2S_1 4. T_2S_2

5. T_3S_1 6. T_3S_2

11. Plan of layout and allotment to plot is presented in fig-1.

3.6 Cultural operations

3.6.1 Preparation of land

The experimental field was thoroughly prepared by ploughing and repeated harrowing with the help of cultivator and disc harrow planking.

3.6.2 Manure and fertilizers

FYM was applied @ 10 t/ha to all the plots uniformly and was incorporated into the soil at the time of land preparation.

DAP, urea and murate of potash were applied uniformly to all the plot at the rate of 64, 17 and 50 (g), respectively as a basal dose, i.e. 3.17 kg/ha N, 4.85 kg/ha P and 3.78 kg/ha K.

3.6.3 Sowing of field crops (aromatic grasses)

The rooted slips of *Cymbopogon flexuosus* and *Cymbopogon martini* were transplanted at a distance of one metre

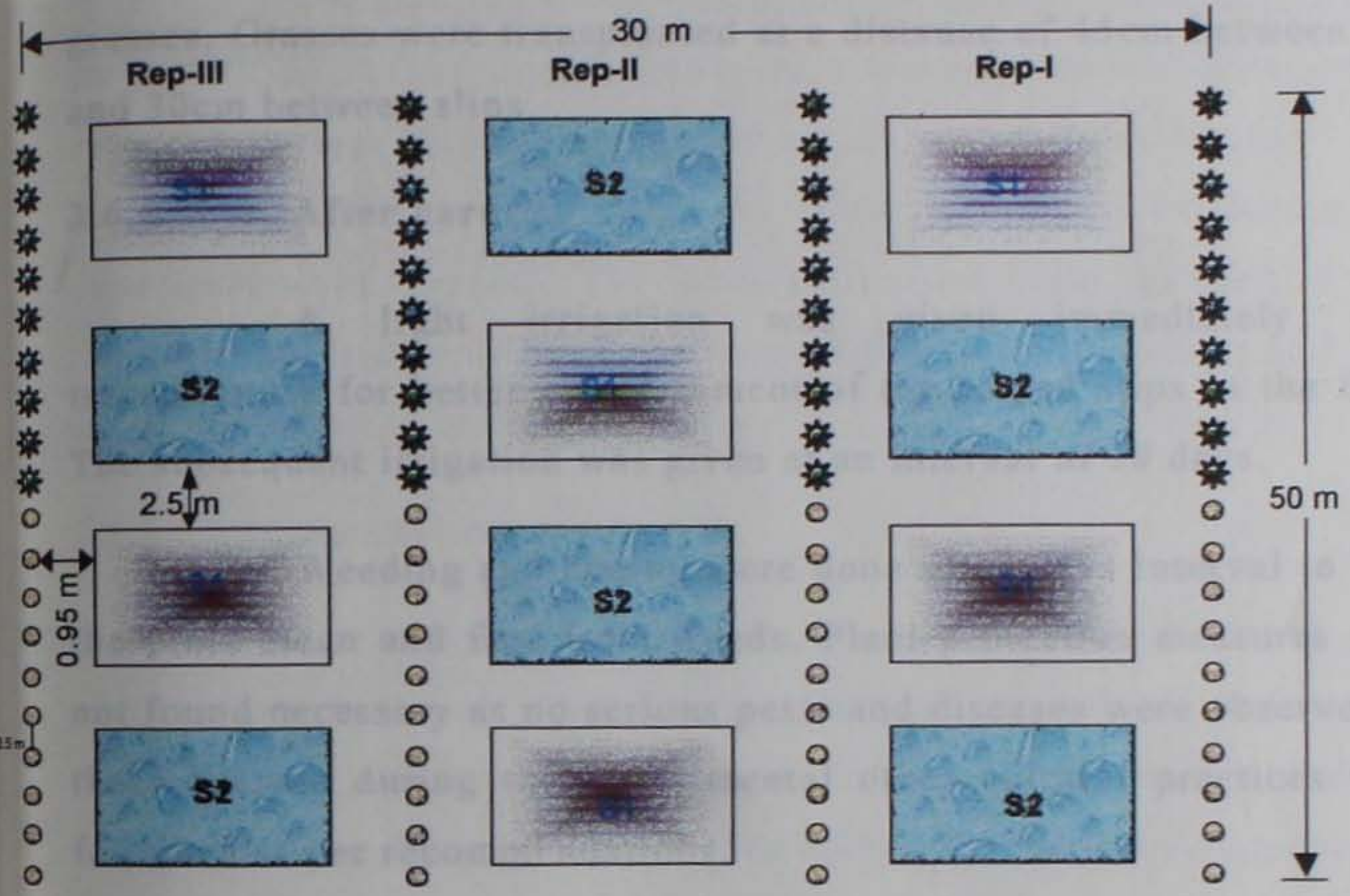
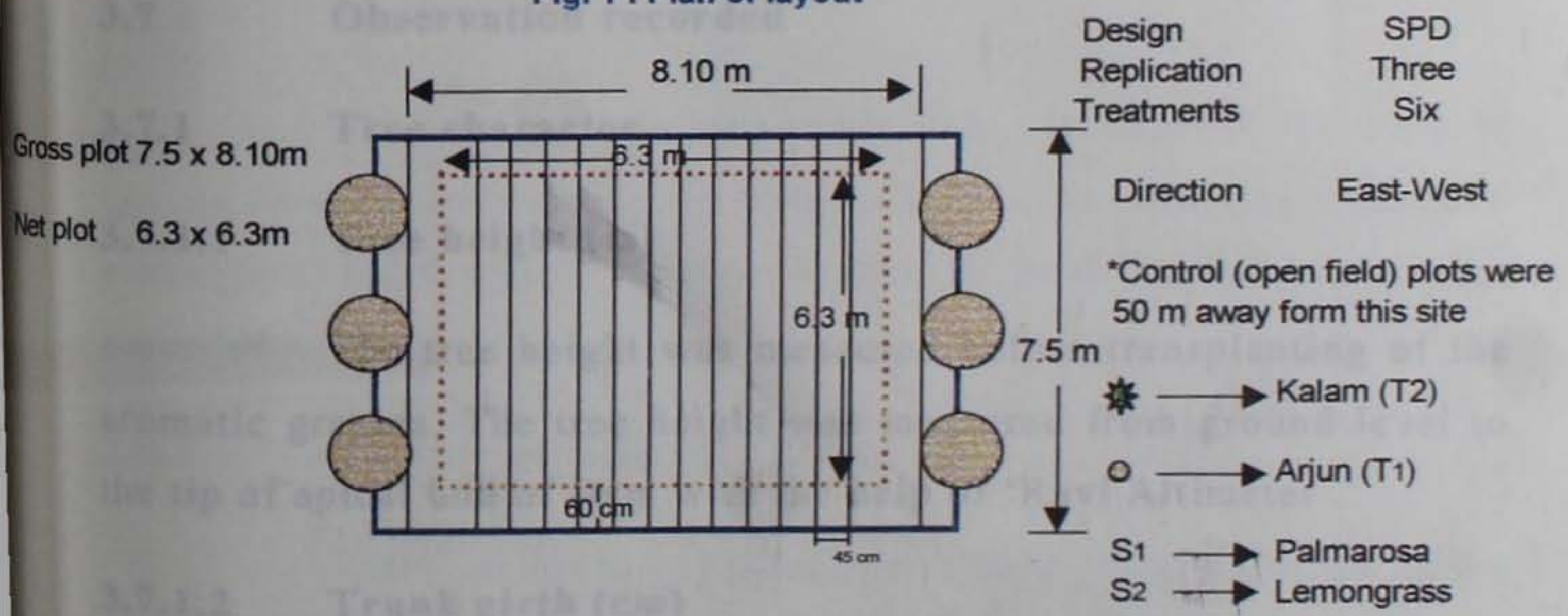


Fig. 1 : Plan of layout



Arrangement of components for palmarosa and lemongrass

away from the tree base line. Gap filling was done twice with the same aged rooted slips to maintain plant population of both the grasses. Grasses were transplanted at a distance of 45cm between row and 30cm between slips.

3.6.4 After care

A light irrigation was given immediately after transplanting for better establishment of the rooted slips in the field. The subsequent irrigation was given at an interval of 10 days.

Weeding and hoeing were done at 18 days interval to keep the plots clean and free from weeds. Plant protection measures were not found necessary as no serious pests and diseases were observed on these grasses during the experimental other cultural practices were followed as per recommendations.

3.7 Observation recorded

3.7.1 Tree character

3.7.1.1 Tree height (m)

The tree height was measured before transplanting of the aromatic grasses. The tree height was measured from ground level to the tip of apical bud of stem with the help of 'Ravi Altimeter'.

3.7.1.2 Trunk girth (cm)

The diameter of trunk of the tree was measured in centimeters at breast height (1.37 m from ground level) with the help of diameter tape.

3.8 Measurement of light intensity

The light intensity was measured in klux using digital klux meter (DX-100). The light intensity was measured in each treatment at 8.00, 12.00 and 16.00 O'clock and at 1m, 3m and 5m distance from the tree base line on both the side of the plot during the experimentation period. The observation on light intensities was recorded twice during the experimental period, viz., before and after the first cutting of aromatic grasses.

3.9. Aromatic grasses

The observations of different parameter on both the grass species were recorded. Two cuttings were taken (for both grasses) and the following observation was taken at both the times. The data so obtained was separately analysed for both the cuttings in each species.

3.9.1 Plant height (cm)

The height was measured from the base of the stem at ground level to the growing tip of the plants from randomly selected 5 plants/plot from which average height at final harvest stage was recorded.

3.9.2 Number of tiller per plant

Total number of tiller per plant was recorded from randomly selected 5 plants/plot and, finally average number of tillers per plants was calculated.

3.9.3 Fresh weight of plant (g)

The weight of some randomly selected five plants from each plot was recorded in gram with the help of electronic balance and average was calculated.

3.9.4 Dry weight of plant (g)

Plants which were used for fresh weight measurement were cut into small pieces and dried in oven at 70°C till constant dry weight of dried plants was noticed. The dry weight was recorded in gram with the help of electronic balance and average was calculated.

3.9.5 Yield per plot (kg)

The fresh yield of aromatic grasses harvested from the net plot of each treatment was weighted. Two harvests were possible and yield per plot was recorded separately for both the harvests and then pooled to calculate total yield of two harvests per plot.

3.9.6 Yield per hectare (Kg)

The yield per hectare was calculated from the yield of aromatic grasses obtained per net plot using 251.95 conversion factor.

3.9.7 Oil content (ml/kg) per net plot and hectare

Oil was extracted through steam distillation in case of the grasses. It is expressed as ml/kg of grasses; from which oil ml/net plot and oil ml/hectare was calculated and recorded.

Table 3.3 : Average height and girth of forest tree species

Replication	Tree species	Average height (m)	Average girth (cm)
I	<i>Terminalia arjuna</i>	13.12	65.44
	<i>Mitragyna parvifolia</i>	9.69	51.94
II	<i>Terminalia arjuna</i>	12.69	75.71
	<i>Mitragyna parvifolia</i>	7.50	44.12
III	<i>Terminalia arjuna</i>	12.56	78.74
	<i>Mitragyna parvifolia</i>	7.75	49.19

3.9.8 Oil content (g/net plot and kg/ha)

The data on oil content in ml/net plot and ml/ha was converted to g/net plot and kg/ha using its specific gravity value (obtained by weighing ml of oil on electronic balance).

3.10 Statistical analysis

Statistical analysis of the data of various characters studied in present investigation was carried out through the procedure of Split Plot Design by computer system at "The Information Technology Center", Department of Agriculture Statistics, N.M. College of Agriculture, Gujarat Agriculture University, Navsari Campus, Navsari. Significant differences were tested by the 'F' test at 5 per cent level of significance. The coefficient of variation (CV%) based on data is given at appropriate places in concerned tables.

EXPERIMENTAL RESULTS

IV EXPERIMENTAL RESULTS

Agrisilviculture of aromatic grasses viz., *Cymbopogon flexuosus* var. OD-19 and *C. martini* var. OD-29 with forest tree species viz., *Terminala arjuna* Bedd. and *Mitragyna parvifolia* Korth. were studied in the *kharif* season of 2000-2001 at the farm of Forestry, ASPEE College of Horticulture and Forestry, GAU, Navsari. The results obtained are presented in this chapter along with statistical inferences.

4.1 Height of aromatic grasses (cm)

The data on height of aromatic grasses as influenced by forest tree species are presented in Table 4.1.

4.1.1 Effect of tree species on height of aromatic grasses at the time of first cutting

Tree species showed significant effect on height of aromatic grasses in first cutting, significantly maximum height of grass was registered under Arjun (T_2 , 89.11 cm) which was at par with Kalam (T_1 , 84.90 cm), while significantly minimum grass height was recorded under control (T_3 , 70.20 cm).

At the time of first cutting of grasses, height of grass was significantly influenced. In case of Palmarosa, the height obtained in open field conditions (i.e. control) was significantly higher than under both the tree species. On the other hand, Lemongrass registered significantly more height under tree species as compared to open field conditions. At the time of first cutting, the Palmarosa height was not

influenced by tree species, but Lemongrass recorded significantly higher height under Arjun trees as compared to Kalam trees.

The interaction effect between tree species and grasses was found to be significant. Significantly maximum grass height was found under treatment combination control with Palmarosa (T_3S_1 , 188.06 cm). This was followed by treatment combination Kalam with Palmarosa (T_1S_1 , 127.93 cm). Significantly minimum height was noticed under treatment combination control with Lemongrass (T_3S_2 , 22.33 cm).

4.1.2 Effect of tree species on height of aromatic grasses at the time of second cutting

Perusal of the data in Table 4.1 showed significant effect on grass height at the time of second cutting. Significantly maximum grass height (92.52 cm) was recorded under Kalam (T_1) that was at par with control (T_3 , 91.31 cm). Significantly minimum grass height was found under Arjun (T_2 , 63.03 cm) tree.

At the time of second cutting Palmarosa under Kalam recorded excellent growth registering highest plant height (199.33 cm) over all other treatments. However, the growth of Palmarosa was suppressed under Arjun trees, which was nearly 66.45 per cent less than height under Kalam trees and 53.10 per cent less than the control. On the other hand, Lemongrass under both the trees recorded higher height than the control.

Interaction between tree species and aromatic grasses was found to be significant. Treatment combination Kalam with Palmarosa recorded maximum (T_1S_1 , 199.33 cm) grass height, followed by

Table 4.1: Height (cm) of aromatic grasses at the time of first and second cuttings as influenced by forest tree species

Tree species	First cutting			Second cutting		
	Palmarosa (S ₁)	Lemongrass (S ₂)	Mean	Palmarosa (S ₁)	Lemongrass (S ₂)	Mean
Kalam (T ₁)	127.93	41.86	84.90	199.33	65.73	92.53
Arjun (T ₂)	125.13	53.10	89.11	66.86	59.20	63.03
Control (T ₃)	188.06	22.33	70.20	142.56	40.06	91.31
Mean	123.71	39.10		109.58	55.00	
Anova						
Source	S.E.m ±	C.D. at 5%	C.V.%	S.E.m. ±	C.D. at 5%	C.V.%
T	1.413	5.550	4.25	1.863	7.314	5.55
S	0.126	2.861	3.05	1.797	6.221	6.55
T x S	1.432	4.956	-	3.113	10.77	-

control with Palmarosa (T_3S_1 , 142.56 cm). Significantly minimum height of grass was noticed in control with Lemongrass (T_3S_2 , 40.06 cm).

4.2 Number of tiller per plant

A perusal of data on number of tillers per plants of aromatic grasses as influenced by forest tree species was found to be significant and the data are presented in Table 4.2.

4.2.1 Effect of tree species on number of tillers per plants at the time of first cutting

The data revealed significant effect on number of tillers per plant. Significantly maximum (28.65) tillers was recorded in control (T_3) while significantly minimum under Arjun (T_2 , 8.56) trees.

Among the aromatic grasses significantly maximum (17.61) tillers was observed in Palmarosa (S_1), which was nearly 16.24 per cent higher than Lemongrass tillers.

The interaction effect between tree species and aromatic grasses was found to be significant. Significantly maximum number of tiller per plant was recorded in treatment combination control with Palmarosa (T_3S_1 , 35.43) which was followed by control with Lemongrasses (T_3S_2 , 21.86). Significantly minimum (6.40) number of tillers per plants was observed in treatment combination Arjun with Palmarosa (T_2S_1).

Table 4.2 : Number of tillers per plant of aromatic grasses at the time of first and second cutting as influenced by forest tree species

Tree species	First cutting			Second cutting		
	Palmarosa (S ₁)	Lemongrass (S ₂)	Mean	Palmarosa (S ₁)	Lemongrass (S ₂)	Mean
Kalam (T ₁)	11.00	11.66	11.33	19.93	18.53	19.23
Arjun (T ₂)	6.40	10.73	8.56	8.76	11.96	10.36
Control (T ₃)	35.43	21.86	28.65	46.00	25.50	35.75
Mean	17.61	14.75	-	24.90	18.66	
Anova						
Source	S.E.m ±	C.D. at 5%	C.V.%	S.E.m. ±	C.D. at 5%	C.V.%
T	0.684	2.687	10.36	0.571	2.242	6.42
S	0.530	1.834	9.83	1.544	5.343	21.27
T x S	0.918	3.176	-	2.674	9.255	-

4.2.2 Effect of tree species on number of tillers per plant at the time of second cutting

The data presented in Table 4.2 showed significant effect on number of tillers per plants. Significantly maximum (35.75) tillers per plant was observed in control (T_3) while minimum under Arjun (T_2 , 10.36).

Number of tillers in two aromatic grasses showed significant difference. Significantly maximum (24.90) number of tillers was observed in Palmarosa (S_1) and minimum (18.66) tillers per plant was recorded in Lemongrass (S_2).

The interaction effect was also significant on number of tillers per plant. Maximum number of (46.0) tillers was recorded in treatment combination control with Palmarosa (T_3S_1) which was followed by control with Lemongrass (T_3S_2 , 25.50) that was at par with Kalam with Palmarosa (T_1S_1 , 19.93) and Kalam with Lemongrass (T_1S_2 , 18.53) significantly minimum number of tiller was recorded under Arjun in Palmarosa (T_2S_1 , 8.76).

4.3 Fresh weight (g)

The data presented in Table 4.3 showed significant effect on fresh weight of aromatic grasses as influenced by tree species.

4.3.1 Effect of tree species on fresh weight of aromatic grasses at the time of first cutting

It is apparent from the data that effect of tree species on fresh weight of grasses was significant. Maximum fresh weight (398.83 g) was noticed in control (T_3) which was significantly higher

than rest of the treatments. Minimum fresh weight of grasses was recorded under Arjun (T₂, 127.33 g). The difference among aromatic grasses was also significant, maximum fresh weight (229.77 g) was noticed in Palmarosa (S₁) while minimum in Lemongrass (167.51 g).

The interaction effect between tree species and aromatic grasses was found significant. Maximum fresh weight (626.66 g) aromatic grasses was noticed in treatment combination control with Palmarosa (T₃S₁), which was significantly higher than all other treatment combinations. This was followed by Kalam with Palmarosa (T₁S₁, 78.66 g) that was followed by Kalam with Lemongrass (T₁S₂, 171 g) control with Lemongrass (T₃S₂, 171 g) and Arjun with Lemongrass (T₂S₂, 160.66 g) all of which were at par. Palmarosa under Arjun recorded minimum fresh weight and was significantly less than fresh weight recorded with all the other treatment combinations.

4.3.2 Effect of tree species on fresh weight of aromatic grasses at the time of second cutting

The data presented in Table-4.3 showed significant effect of the species on fresh weight of aromatic grasses at the time of second cutting. Significantly maximum (453.33 g) fresh weight of aromatic grasses was noticed in the control (T₃) followed by under Kalam (T₁, 244.96 g) while minimum (T₂, 138.66 g) fresh weight of grasses was registered under Arjun.

The two aromatic grasses difference in fresh weight was found to be non-significant.

Table 4.3 : Fresh weight (g) of aromatic grasses at the time of first and second cuttings as influenced by forest tree species

Tree species	First cutting			Second cutting		
	Palmarosa (S ₁)	Lemongrass (S ₂)	Mean	Palmarosa (S ₁)	Lemongrass (S ₂)	Mean
Kalam (T ₁)	178.66	171.00	174.83	239.93	250.00	244.96
Arjun (T ₂)	94.00	160.66	127.33	110.33	167.00	138.66
Control (T ₃)	626.66	171.00	398.83	556.66	350.00	453.33
Mean	299.77	167.55		302.31	255.66	
Anova						
Source	S.E.m ±	C.D. at 5%	C.V.%	S.E.m. ±	C.D. at 5%	C.V.%
T	9.820	38.55	10.29	17.642	69.26	15.49
S	5.905	20.43	7.58	17.733	NS	19.07
T x S	10.228	35.39	-	30.715	106.29	-

The interaction between tree species and aromatic grasses gave significant result on fresh weight of aromatic grasses. Significantly maximum (556.66g) fresh weight was recorded in treatment combination control with Palmarosa (T_3S_1). This was followed by control with Lemongrass (350.00g), which was at par with Kalam with Lemongrass (T_1S_2). While significantly minimum fresh weight of grasses was noticed under Arjun in Palmarosa (T_2S_1 , 110.33 g).

4.4 Dry weight (g)

The data on dry weight of aromatic grasses as influenced by tree species are given in Table 4.4.

4.4.1. Effect of tree species on dry weight of aromatic grasses at the time of first cutting

An appraisal of the data showed significant effect on dry weight of aromatic grasses as influenced by tree species. Maximum dry weight (150.33 g) of aromatic grasses was observed in control (T_3) which was followed by under Kalam (T_1 , 60.23) and minimum under Arjun (T_2 , 42.49 g).

The data on dry weight of aromatic grasses further revealed significant difference among two aromatic grasses. Maximum dry weight (111.31 g) was observed in Palmarosa (S_1), which was approximately 48.44 per cent higher than recorded with Lemongrass.

The interaction between tree species and aromatic grasses was found to be significant. Maximum dry weight (238.70g) was

Table 4.4 : Dry weight (g) of aromatic grasses at the time of first and second cuttings as influenced by forest tree species

Tree species	First cutting			Second cutting		
	Palmarosa (S ₁)	Lemongrass (S ₂)	Mean	Palmarosa (S ₁)	Lemongrass (S ₂)	Mean
Kalam (T ₁)	63.89	56.58	60.23	81.49	90.16	85.82
Arjun (T ₂)	31.34	53.64	42.49	37.13	55.58	46.36
Control (T ₃)	238.70	61.97	150.33	215.33	151.23	183.28
Mean	111.31	57.39		111.32	98.99	
Anova						
Source	S.Em ±	C.D. at 5%	C.V.%	S.Em. ±	C.D. at 5%	C.V.%
T	5.479	21.510	15.91	4.300	16.884	10.02
S	1.868	6.464	6.64	6.320	NS	18.03
T x S	3.235	11.196	-	10.947	37.88	-

observed under treatment combination control with Palmarosa (238.70g), which was significantly higher than the rest of treatments.

4.4.2 Effect of tree species on dry weight of aromatic grasses at the time of second cutting

The data showed significant effect of tree species on dry weight of aromatic grasses. Maximum (183.21 g) dry weight was noticed in control (T₃), which was followed by Kalam (T₁, 85.82 g) dry weight, was considerably reduced under Arjun (T₂, 46.36 g). The difference in dry weight of two aromatic grasses was found to be non-significant.

The interaction between tree species and aromatic grasses showed significant effect on dry weight of aromatic grasses. Maximum (215.33g) dry weight was noticed under treatment combination control with Palmarosa (T₃S₁). This was followed by control with Lemongrass (T₃S₂, 151.23 g). While minimum dry weight was recorded under Arjun in Lemongrass (T₂S₁, 37.13 g).

4.5 Oil content (%)

The data on per cent oil content in two aromatic grasses as influenced by tree species are presented in Table 4.5.

4.5.1 Effect of tree species on per cent oil content at the time of first cutting

Tree species significantly affected per cent oil content. The highest oil content (0.29 %) was recorded in open field conditions. Oil content of two aromatic grasses under tree species was

at par and no significant difference was noticed in oil content under Kalam and Arjun trees.

Lemongrasses recorded significantly higher per cent oil (0.28%) as compared to Palmarosa (0.24%).

The interaction effect was also significant. The highest per cent oil (0.35%) was registered in treatment combination control with Lemongrass. This was followed by Kalam with Palmarosa treatment combination (0.26%). The lowest per cent oil (0.23%) was recorded in treatment combinations viz., Kalam with Lemongrass, Arjun with Palmarosa and control with Palmarosa.

4.5.2 Effect of tree species on per cent oil content at the time of second cutting

The highest per cent oil (0.26%) was noticed in control grasses (open field conditions). However, no difference was observed in oil content of grasses under tree species as well as open field conditions.

Among the aromatic grasses, Palmarosa recorded significantly higher per cent oil (0.28 %) than Lemongrass. There was increase in per cent oil in Palmarosa over the per cent oil at the time of first cutting whereas the trend was reversed with Lemongrass.

Interaction effect was significant. All the treatment combinations with Palmarosa registered significantly higher per cent oil than all the treatment combination with Lemongrass.

Table 4.5 : Oil content (per cent)of aromatic grasses at the time of first and second cuttings as influenced by forest tree species

Tree species	First cutting			Second cutting		
	Palmarosa (S ₁)	Lemongrass (S ₂)	Mean	Palmarosa (S ₁)	Lemongrass (S ₂)	Mean
Kalam (T ₁)	0.26	0.23	0.25	0.30	0.15	0.23
Arjun (T ₂)	0.23	0.24	0.24	0.26	0.19	0.21
Control (T ₃)	0.23	0.35	0.29	0.29	0.23	0.26
Mean	0.24	0.28		0.28	0.19	
Anova						
Source	S.Em ±	C.D. at 5%	C.V.%	S.Em. ±	C.D. at 5%	C.V.%
T	0.010	3.953	9.55	0.011	NS	11.00
S	0.008	0.029	9.83	0.006	1.997	7.30
T x S	0.015	0.050	-	0.010	3.460	-

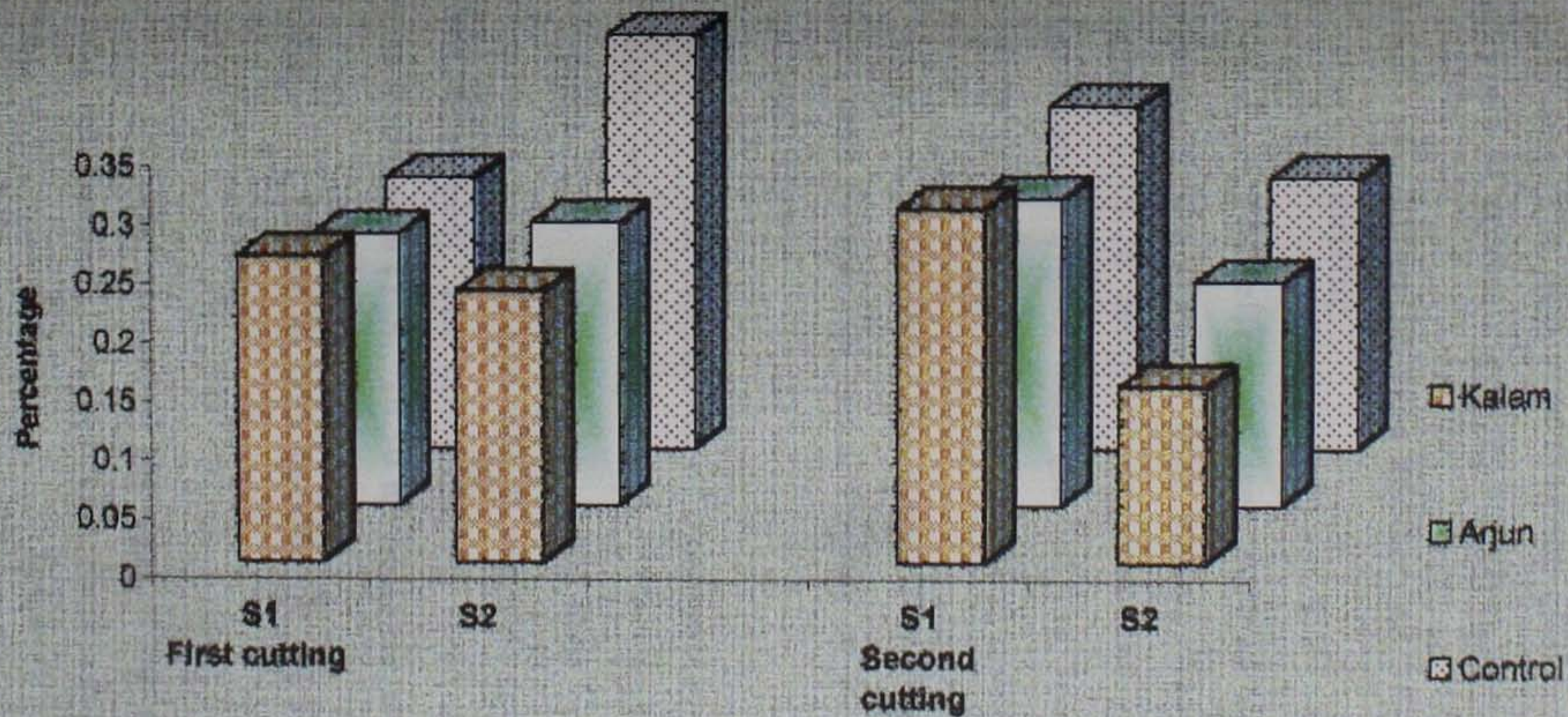


Fig. 2 : Oil content (per cent) of aromatic grasses at the time of first and second cuttings as influenced by forest tree species

4.6 Oil Yield (ml/plot)

The data regarding the effect of forest tree species on the oil yield of aromatic grasses are given in Table 4.6

4.6.1 Effect of tree species on oil yield at the time of first cutting

The effect of tree species on oil content of aromatic grasses at the time of first cutting was significant. Maximum oil content (115.26 ml/plot) was recorded in control (T_3), which was significantly higher than rest of the treatments. The minimum oil content (41.53 ml/plot) was recorded under Arjun tree (T_2).

Although Lemongrass registered 15.29 per cent higher oil yield than Palmarosa, the difference in oil content of two grasses was not significant.

The interaction of tree species and aromatic grasses on oil content was found significant. The maximum oil content (120.80 ml/plot) was found with treatment combination control with Lemongrass (T_3S_2) that was at par with control with Palmarosa (T_3S_1 , 109.73 ml/pot). The minimum oil yield was registered under Arjun with Palmarosa (T_2S_1 , 20.50 ml/plot) treatment combination.

4.6.2 Effect of tree species on oil yield at the time of second cutting

The perusal of the data of the effect of tree species on oil yield of aromatic grasses and their interactions are presented in Table 4.5

Table 4.6 : Oil Yield (ml/plot) of aromatic grasses at the time of first and second cuttings as influenced by forest tree species

Tree species	First cutting			Second cutting		
	Palmarosa (S ₁)	Lemongrass (S ₂)	Mean	Palmarosa (S ₁)	Lemongrass (S ₂)	Mean
Kalam (T ₁)	62.00	43.53	52.76	92.00	57.91	74.95
Arjun (T ₂)	20.50	62.56	41.53	50.33	54.75	52.54
Control (T ₃)	109.73	120.80	115.26	238.33	113.36	175.85
Mean	64.07	75.63		126.88	75.34	
Anova						
Source	S.E.m ±	C.D. at 5%	C.V.%	S.E.m. ±	C.D. at 5%	C.V.%
T	3.010	11.820	10.56	6.376	25.031	15.45
S	3.776	NS	16.22	2.911	10.076	8.64
T x S	6.540	22.633	-	5.043	17.453	-

The effect of tree species on oil content was found significant. Maximum oil content (175.85 ml/plot) was obtained in control (T_3), which was significantly higher as compared to the rest of treatments, the minimum oil content (52.54 ml/plot) was obtained under Arjun tree (T_2).

Among the aromatic grasses, maximum (126.88 m/plot) oil yield was recorded in Palmarosa (S_1) while minimum (75.34 ml/plot) in Lemongrass (S_2)

The interaction between tree species and aromatic grasses was found to be significant. The treatment combination control with Palmarosa (T_3S_1) gave maximum (238.33 ml/plot) oil yield which was significantly higher as compared to rest of the treatments. While minimum oil yield was recorded by Arjun with Palmarosa (T_2S_1 , 50.33 ml/plot) treatment combination that was at par with Arjun with Lemongrass (T_2S_2 , 54.75 ml/plot) and Kalam with Lemongrass (T_1S_2 , 57.91 ml/plot).

4.7 Total oil content first + second cutting (ml/plot)

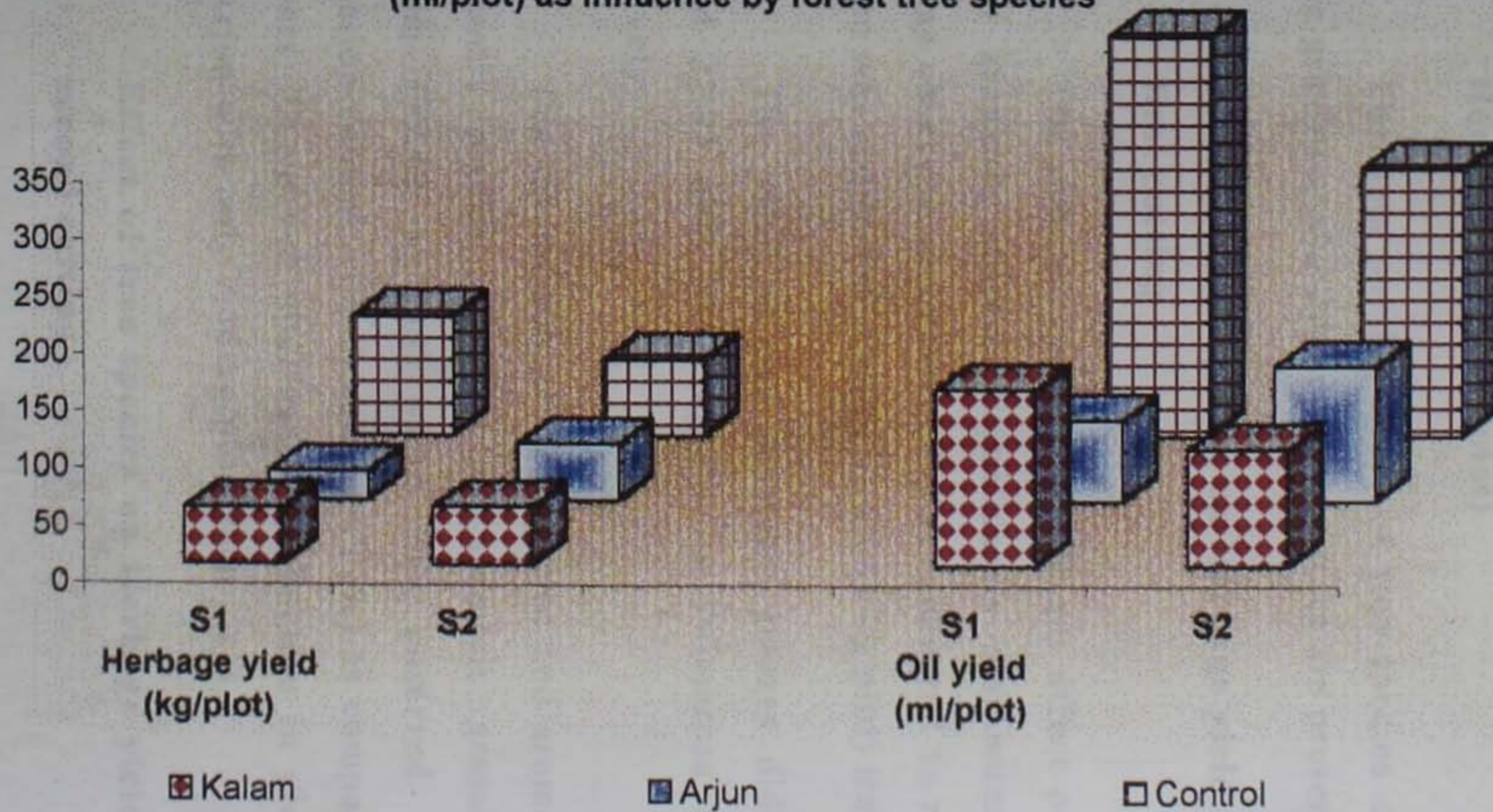
The data presented in Table 4.7 on total oil content of aromatic grasses was found significant. The maximum oil content (29.11 kg/plot) was recorded under control which was significantly higher than treatments. The minimum (44.07 kg/plot) yield was obtained under Arjun (T_2) trees. Among two grasses, Palmarosa recorded significantly higher total oil content as compared to Lemongrass.

The interaction effect of tree species and aromatic grass was significant. Significantly maximum (348.06 ml/plot) yield was

Table 4.7 : Total oil Yield (ml/plot) (first cutting + second cutting) of the aromatic grasses as influenced by forest tree species

Tree species	First + second cutting		
	Palmarosa (S ₁)	Lemongrass (S ₂)	Mean
Kalam (T ₁)	154.00	101.45	127.72
Arjun (T ₂)	70.83	117.31	94.07
Control (T ₃)	348.06	234.16	291.11
Mean	190.96	150.97	
ANOVA			
Source	S.Em. \pm	C.D. at 5%	C.V.%
T	8.558	33.600	12.26
S	4.196	14.522	7.36
T x S	7.268	25.153	-

Fig. 3: Total Herbage yield (1st + 2nd cutting) (kg/plot) and oil content (1st + 2nd cutting) (ml/plot) as influence by forest tree species



recorded in treatment combination control with Palmarosa (T_3S_1) and minimum (70.83 ml/plot) in Arjun with Palmarosa (T_2S_1).

4.8 Herbage Yield (kg/plot)

The data on the effect of tree species on fresh yield of aromatic grasses at the time of first cutting are presented in Table 4.8

4.8.1 Effect of tree species on Herbage yield of at the time of first cutting

The results revealed significant effect of tree species on yield of aromatic grasses. Significantly maximum (33.20 kg/plot) yield was observed in control (T_3) as compared to rest of treatments minimum was registered Arjun (T_2 , 15.41 kg/plot) trees.

The yield of two aromatic grasses did not differ and recorded 22.91 and 22.72 kg/plot in Palmarosa and Lemongrass, respectively.

The interaction of tree species and aromatic grasses gave significantly results on yield of aromatic grasses. Significantly maximum (39.40 kg/plot) yield was observed under treatment combination control with Palmarosa (T_3S_1) as compared to rest of the treatments. There was considerable reduction in yield of Palmarosa under Arjun with only 7.66 kg/plot fresh yield.

4.8.2 Effect of tree species on Herbage yield at the time of second cutting

The data presented in Table 4.8 gave significant effect of tree species on Herbage yield of aromatic grasses.

Table 4.8 : Herbage yield (kg/plot) of aromatic grasses at the time of first and second cuttings as influenced by forest tree species

Tree species	First cutting			Second cutting		
	Palmarosa (S ₁)	Lemongrass (S ₂)	Mean	Palmarosa (S ₁)	Lemongrass (S ₂)	Mean
Kalam (T ₁)	21.66	18.00	19.83	28.00	32.66	30.33
Arjun (T ₂)	7.66	23.16	15.41	17.16	26.16	21.66
Control (T ₃)	39.40	27.00	33.20	46.66	40.00	52.33
Mean	22.91	22.72		36.61	32.94	
Anova						
Source	S.E.m ±	C.D. at 5%	C.V.%	S.E.m. ±	C.D. at 5%	C.V.%
T	0.784	3.080	8.42	1.484	5.827	10.46
S	0.865	NS	11.38	0.792	2.742	6.84
T x S	1.499	5.187	-	1.372	4.750	-

The data revealed the significant effect on Herbage yield of aromatic grasses as influenced by tree species. Significantly maximum (52.33 kg/plot) yield was recorded in control as compared to rest of the treatments, while minimum (21.66 kg/plot) under Arjun.

The two aromatic grasses recorded significant difference on yield of grasses. Maximum (36.61 kg/plot) yield was noticed in Palmarosa while minimum (32.94 kg/plot) yield in Lemongrass (S_2).

The interaction between tree species and aromatic grasses was found to be significant. Maximum (64.66 kg/plot) yield was recorded in treatment combination control with Palmarosa that was significantly higher as compared to rest of treatments. The minimum (17.66 kg/plot) yield was noticed in treatment combination Arjun with Palmarosa (T_2S_1).

4.9 Total herbage yield first + second cutting (kg/plot)

The data presented in Table 4.9 on total yield of aromatic grasses was found significant. The maximum yield (86.20 kg/plot) was recorded under control, which was significantly higher than the rest of treatments. The minimum (37.08 kg/plot) yield was obtained under (T_2) tress. Among the two grasses, Palmarosa recorded significantly higher total yield as compared to Lemongrass

The interaction effect of tree spacing and aromatic grasses was significant. The maximum (105.06 kg/plot) yield was recorded in treatment combination control with Palmarosa (T_3S_1) and minimum (24.83 kg/plot) Arjun with Palmarosa (T_2S_1).

Table 4.9 : Total yield (kg/plot) (first cutting + second cutting) of the aromatic grasses as influenced by forest tree species

Tree species	First + second cutting		
	Palmarosa (S ₁)	Lemongrass (S ₂)	Mean
Kalam (T ₁)	49.66	50.66	50.16
Arjun (T ₂)	24.83	49.33	37.08
Control (T ₃)	105.06	67.33	86.20
Mean	59.85	55.77	
ANOVA			
Source	S.Em. \pm	C.D. at 5%	C.V.%
T	2.357	9.254	9.99
S	0.972	3.366	5.05
T x S	1.684	5.830	-

4.10 Herbage Yield: (kg/ha)

The data on effect of tree species on fresh yield (kg/ha) of weight of aromatic grasses in at time of first cutting are presented in Table. 4.10

4.10.1 Effect of tree species on Herbage yield (kg/ha) at the time of first cutting

The result revealed significant effect of tree species on yield of aromatic grasses. Significantly maximum (8364.2 kg/ha) yield was observed in control (T_3) as compared to rest of treatments, minimum was being registered in Arjun (T_2 , 3884.26 kg/ha) trees.

The yield of two aromatic grasses did not differ and recorded 5772.51 and 5724.92 kg/ha in Palmarosa and Lemongrass, respectively.

The interaction of tree species and aromatic grass gave significant result on yield of aromatic grasses. Significantly maximum (9926.93 kg/ha) yield was observed under treatment combination control with Palmarosa (T_3S_1) as compared to rest of the treatments. There was considerable reduction in yield recorded of Palmarosa under Arjun with only (1931.63 kg/ha) fresh yield.

4.10.2 effect of tree species on Herbage yield (kg/ha) at the time of second cutting

The data presented in Table 4.10 gave significant effect of tree species on yield of aromatic grasses.

Table 4.10 : Yield (kg/ha) of aromatic grasses at the time of first and second cutting as influenced by forest tree species

Tree species	First cutting			Second cutting		
	Palmarosa (S ₁)	Lemongrass (S ₂)	Mean	Palmarosa (S ₁)	Lemongrass (S ₂)	Mean
Kalam (T ₁)	5458.96	4535.14	4997.05	7054.67	8230.44	7642.55
Arjun (T ₂)	1931.63	5836.90	3884.26	4325.27	6592.75	5459.01
Control (T ₃)	9926.93	6802.71	8364.82	16292.93	10078.10	13185.51
Mean	5772.51	5724.92		9224.29	8300.43	
Anova						
Source	S.Em ±	C.D. at 5%	C.V.%	S.Em. ±	C.D. at 5%	C.V.%
T	197.670	776.02	8.42	374.021	1468.356	10.46
S	218.048	NS	11.38	199.686	691.031	6.84
T x S	377.670	1306.96	-	345.867	1196.902	-

The data revealed the significant effect on yield of aromatic grasses influenced by tree species. Significantly maximum (13185.51 kg/ha) yield was recorded in control as compared to rest of the treatments, while minimum (5459.01 kg/ha) under Arjun.

The two aromatic grasses recorded significant difference on yield of grasses. Maximum (9224.29 kg/ha) yield was noticed under Palmarosa while minimum (8300.43 kg/ha) under Lemongrass (S₂).

The interaction between tree species and aromatic grasses was found to be significant. Maximum Herbage (16292.93 kg/ha) yield was recorded in treatment combination control with Palmarosa that was significantly higher as compared to rest of treatments. The minimum Herbage (4325.27 kg/ha) yield was noticed in treatment combination Arjun with Palmarosa (T₂S₁).

4.11 Light intensity (klux)

The data on effect of tree species on light intensity reaching the aromatic grasses during day time at three different timing viz.; 8:00 a.m., 12:00 noon and 4:00 p.m. are furnished in Table 4.11, 4.12 and 4.13, respectively.

4.11.1 Light intensity at 8:00 a.m.

4.11.1.1 Tree species

The influence of forest tree species on light intensity was found significant. The maximum (407.06 klux) light was found under Kalam (T₁) compared to Arjun (T₂, 350.35 klux) tree at just before first cutting stage. On the other hand, just before second cutting stage,

Table 4.11 : Light intensity (klux) at 8.00 am. as influenced by forest tree species at the time of first and second cuttings

Tree species	First cutting				Second cutting			
	Distance				Distance			
	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean
Kalam (T ₁)	245.03	472.46	503.70	407.06	280.83	266.76	376.30	307.96
Arjun (T ₂)	360.93	237.93	505.20	350.35	251.96	303.60	367.60	307.72
Mean	276.48	355.20	504.45		266.40	285.18	371.95	
Anova								
Source	S.E.m ±	C.D. at 5%	C.V.%	S.E.m. ±	C.D. at 5%	C.V.%		
D	9.506	37.319	6.15	9.430	37.021	7.50		
T	3.850	13.325	3.05	9.893	NS	9.64		
D x T	6.669	23.081	-	17.135	NS	-		

Where, D₁ = 1m distance form tree base line

D₂ = 3m distance form tree base line

D₃ = 5m distance form tree base line

light intensity (307.96 klux) reaching aromatic grasses under both the tree species was nearly the same with non-significant difference between them.

4.11.1.2 Distance from the tree

The data furnished in Table 4.9 further indicated that the effect of forest tree species on light intensity at different distance from the tree base line was significant. Light intensity increased as the distance from the tree base line increased and maximum light intensity was recorded at 5 m (D_3) distance that was significantly higher than other distances at both the stage i.e., just before first cutting and just before second cutting.

The interaction effect of tree species and distance was found significant at just before first cutting stage. Significantly maximum (505.20 klux) light intensity was recorded in treatment combination Arjun with distance 5m from the tree base line (T_2D_3) that was at par with Kalam with distance 5m from the tree base line (T_1D_3 , 503.70 klux). The minimum light intensity was recorded under Kalam with distance 3 m from the tree base line (T_2D_2 , 237.93 klux). The interaction effect of tree species and distance was found to be non-significant at just before second cutting stage.

4.12 Light intensity at 12.00 noon. (klux)

4.12.1 Tree species

In contrast to light intensity recorded at 8.00 am, there was significant difference in light intensity on aromatic grasses under two different trees at two different cutting i.e., just before first cutting

and second cutting stage. In just before first cutting the light intensity in Kalam (T_1) (931.52 klux) was higher than Arjun (T_2) (887.80 klux) tree while just before second cutting, tree species was found to be non-significant.

4.12.2 Distance form the tree

The data given in Table 4.12 indicated that the effect of the forest tree species on light intensity 12.00 noon was significant just before first cutting and just before second cutting. In first cutting light intensity was maximum with distance (D_3) 5m while the distance D_1 (791.75 klux) registered minimum light intensity which was followed by distance D_2 (3m) while in second cutting, maximum light intensity was recorded distance D_3 (5m) and minimum in D_1 (1m).

Interaction effect of tree species and distance was found significant on light intensity at 12.00 noon both the cutting i.e., just before first cutting and just before second cutting. The maximum light intensity was recorded under the treatment combination Kalam with distance 5 m from the tree base line (T_1D_3 , 1122.73 klux and T_2D_3 , 821.33 klux) respectively under just before first and second cutting stage. On the other hand, just before second cutting stage it was at par with Arjun with distance 3m from tree base line (T_2D_2 , 815.16 klux) while in both the cutting minimum (776.23 klux and 678.56 klux) light intensity was recorded under just before first and second cutting respectively.

Table 4.12 : Light intensity (klux) at 12.00 noon as influenced by forest tree species at the time of first and second cuttings

Tree species	First cutting				Second cutting			
	Distance				Distance			
	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean
Kalam (T ₁)	776.23	895.60	1122.73	931.52	778.20	779.93	783.20	780.44
Arjun (T ₂)	807.26	866.80	990.33	887.80	678.56	815.16	821.33	771.68
Mean	791.75	880.70	1065.53		728.38	797.55	802.26	
Anova								
Source	S.Em ±	C.D. at 5%	C.V.%		S.Em. ±	C.D. at 5%	C.V.%	
D	9.792	38.444	2.64		5.878	23.076	1.86	
T	7.160	24.780	2.36		3.442	NS	1.33	
D x T	12.403	42.921	-		8.965	20.643	-	

Where, D₁ = 1m distance form tree base line
D₂ = 3m distance form tree base line
D₃ = 5m distance form tree base line

4.13 Light intensity at 4.00 p.m. (Klux)

4.13.1 Tree species

The data presented in Table 4.13 showed the effect of light intensity at 4.00 p.m. just before and second cutting stage respectively. The maximum light intensity (390.96 Klux) in first cutting was recorded in Kalam while in second cutting light intensity was found to be non-significant.

4.12.2 Distance from the tree

Data on light intensity furnished in Table 4.11 further revealed the effect of light intensity recorded at different distance from the tree species was found significant in just before first and just before second cutting. In first cutting stage maximum light intensity (541.66 klux) was recorded at distance D_3 (5m) as compared to (316.56 klux), (292.73 klux) at distance D_1 (1m) and distance D_2 (3m) respectively. On the other hand just before second cutting stage maximum light intensity of (508.71 klux) was recorded at distance D_3 (5m) as compared to (273.91 klux), (256.74 klux).

The interaction effect of the tree species and distance from the light intensity at 4.00 p.m. The interaction effect was found significant in just before first and cutting. The maximum (564.80 klux) and (511.70 klux) light intensity was recorded under treatment combination Kalam with distance 5 m from the tree base line (T_1D_3) Kalam with distance 5 m from tree base line (T_1D_3) respectively just before first cutting and second cutting. In just before second cutting stage was at par with treatment combination Arjun with distance (5m) tree from the base line (T_2D_3 , 505.73 klux). The minimum (282.71 klux) and (257.46 klux) light intensity was recorded under treatment combination Kalam with distance (3m) form the tree base line and

Table 4.13 : Light intensity (klux) at 4.00 pm. as influenced by forest tree species at the time of first and second cuttings

Tree species	First cutting				Second cutting			
	Distance				Distance			
	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean
Kalam (T ₁)	325.37	282.71	564.80	390.96	267.52	274.02	511.70	351.08
Arjun (T ₂)	307.75	302.75	519.53	376.34	280.30	257.46	505.73	347.82
Mean	316.56	292.73	541.66		273.91	265.74	508.71	
Anova								
Source	S.Em ±	C.D. at 5%		C.V.%	S.Em. ±	C.D. at 5%		C.V.%
D	21.077	82.747		13.46	11.089	43.534		7.77
T	3.782	13.089		2.96	2.332	NS		2.00
D x T	6.551	22.672		-	4.039	13.977		-

Where, D₁ = 1m distance form tree base line
D₂ = 3m distance form tree base line
D₃ = 5m distance form tree base line

treatment combination Arjun with distance (3m) form the tree base line just before fist and second cutting stage respectively.

DISCUSSION

V DISCUSSION

The agroforestry experiment was conducted to study the growth and production of aromatic grasses viz; Lemongrass (*Cymbopogon flexuosus*) and Palmarosa (*Cymbopogon martini*). The main object of this research was to examine whether, in this agri-silvicultural system, tree species have complementary or competitive effects and if it is competitive, than to what extent the competition is present. The observations on plant growth, yield and oil production were recorded and analysed. The results recorded are discussed in this chapter. It is contemplated to discuss the variations noticed in growth, yield and oil yield of aromatic grasses under the influence of *Terminalia arjuna* and *Mitragyna parvifolia*. The associated reasons and possible explanations with observed variations 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.

An examination of the meteorological data given in Table: 3.1 for different parameters indicated that, in general, the weather was favorable for growth and productions of aromatic grasses (intercrops) throughout the investigation period. Moreover, standard cultural practices were follow for each crop and other conditions were similar to all the crops, except for the treatments. The variations observed in the experimental results were hence, considered to be due to the response of treatment exercised in the present investigation.

Trees and aromatic grasses compete with each other for moisture, nutrients, lights and space. The above ground competition takes place for light and space and the underground competition for moisture, nutrients and space. The light intensity is reduced beneath the tree shades and has the suppressing effect on growth attributes of aromatic grasses.

Janardhan and Murthy (1980) demonstrated that low light intensity adversely affect various physiological parameters such as relative growth rate (RGR), dry matter accumulation and net assimilation rate (NAR) due to low rate of photosynthesis. This has bearing on growth and yield of agricultural crops. On the other hand, the extents of lateral development of tree roots compete with aromatic grasses for moisture, nutrients and space and ultimately affects the growth and production of aromatic grasses.

In the present investigation, the growth measured in terms of height, number of tiller per plant, fresh weight and dry weight of plant of both the aromatic grasses was suppressed due to forest tree species; the effect was more pronounced in case of Arjun trees as compared to Kalam trees.

In general, it is realized that when not limited by water, temperature and pest-disease problems, the growth and productivity of crop plants are influenced mainly by solar radiation. The aromatic grasses were irrigated and no pest-disease problem was noticed. Though, nutrient competition may be present, it may be suggested that the suppressive effect due to forest tree species on growth of aromatic grasses might be due to low light intensity reaching the aromatic grasses below tree species. The differential performance of various

aromatic grasses may be attributed to their differential requirement of light intensity for growth.

Another reason for growth suppression may be realised in under-ground competition for nutrients between aromatic grasses and forest tree species as well as toxic substances (allelochemicals) released by tree roots and decomposing fallen aerial parts in the soil.

In general, variable response was noticed in case of plant height. Kalam trees supported more light than Arjun trees at second cutting stage and vice versa at first cutting stage. The reduction in Palmarosa height over the control was observed under Kalam trees only at first cutting stage. On the other hand, Lemongrass performed better than control under both the trees at both the cuttings stage. Yadava and Singh (1996) also reported the variable response at different cuttings in height of grasses in poplar-Lemongrass based agroforestry. Stansel et al. (1965) reported taller plants under low light intensity conditions in rice cultivars. However, there are several reports of reduction in height under low light intensity conditions (Sundarmoorthy and Karla, 1991; Singh and Kohli 1992; Sharma, 1992). There are three possibilities of effect of tree species on height of aromatic grasses. First, it may be influenced by allelochemicals leached by tree roots; second, decrease in light intensity due to tree canopy and, third, competition for water and nutrients. The variable response noticed in the present investigation may be visualized as variable interactions between these factors in case of height. The effect of Arjun was more pronounced than Kalam at light intensity reaching aromatic grasses under Arjun was considerably less than that of Kalam. Moreover, Arjun's allelopathic effect may be stronger than

Kalam considering presence of tannin in Arjun's bark (Anonymous, 1976).

Significant higher number of tiller per plants of aromatic grasses was recorded in control as compared to Kalam and Arjun at the both the cutting stages. Under Arjun, significantly lower number of tillers was recorded in both the aromatic grasses as compared to Kalam.

The higher number of tillers in control might be due to more light intensity received in control than under Arjun or Kalam trees. Also, there might be relatively less competition excreted for nutrients and water in control as compared to grasses grown under forest tree species. This, in turn might have enhanced the vegetable growth primarily through inducing more number of tillers. Pareek and Gupta (1985) in consonance with those report these results in case of Lemongrass in coconut gardens.

In effect of Arjun was more pronounced than Kalam possibly because of low light intensity received by inter crops (Lemongrass and Palmarosa) under Arjun throughout the growth period. Moreover, Arjun's allelopathic effect may be stronger than Kalam considering presence of tannin (Anonymous, 1976) in Arjun's bark.

Forest tree species under investigation had significantly influenced fresh and dry weights of aromatic grasses. The maximum fresh and dry weights were recorded in control (open field) plants which were followed by crops under Kalam while, crops under Arjun recorded minimum fresh as well as dry weights at both the cutting

stages. Though, aromatic grasses were irrigated and fertilized, as per recommendation, tree species were not given any additional nutrients or water. Obviously, this might have resulted in competition for water and nutrients between aromatic grasses and tree species as compared to aromatic grasses grown in open field. Moreover, under the trees, light intensity was low throughout growth period of aromatic grasses, which might have limited production of photosynthates. This, in turn, resulted in low accumulation of fresh and dry weight under the influence of tree shade. These results are not without precedence. Venkteswarlu and Srinivasan (1978) and Janardhand and Murthy (1980) in rice have reported adverse effect of shade on dry matter accumulation. Tanaka et al. (1964) also reported lower dry matter accumulation under shaded conditions. Eze (1987) reported reduced dry matter accumulation in case of *Amaranthus* in shaded condition.

The results clearly indicated that Lemongrass does not tolerate the tree effect at both the cutting stages in case of per cent oil in the foliage. On the other hand, the per cent oil in Palmarosa was not adversely affected by tree shade. However, total oil per plant or per plot was drastically reduced under both the tree species; the effect was more pronounced under Arjun as compared to under Kalam trees. Pareek and Gupta (1985) reported reduction in Lemongrass oil when it was grown as intercrop in coconut gardens. The attributed the effect mainly to diffused light conditions. Similarly, Singh *et al.* (1989) observed significant reduction in oil yield of Palmarosa or Lemongrass under either poplar or *Eucalyptus tereticornis* trees. Considering less effect of tree species on per cent oil content, except in case of Lemongrass, over the control the effect on reduction of

total oil content may be visualized as the effect of tree species on total herbage yield.

The maximum herbage yield in both aromatic grasses was observed in control. This may be due to favourable light condition coupled with lack of competition from tree crop under open field condition resulting better synthesis of the food material. The data on fresh weight, dry weight and light intensity recorded in the present study also favour the increase the yields of inter crops when revised in open field crops. These results are in conformity of similar result reported by Bordoloi *et al.* (1985), George and Nair (1987), Singh *et al.* (1989), Patel (1996), Chauhan *et al.*(1997), and Mahajan (2001). The allelopathic effect and competition for water and nutrients may also be responsible for reduction in yield under tree species. Though, no work has been reported on the allelopathic effect of Arjun and Kalam, it is presumed that allelochemicals released by those tree species through roots as well as added by decomposition of above ground parts have suppressive effect of these tree species; the effect of Arjun was more pronounced than Kalam. It may further be presumed that competitive, allelopathic and shading effects of Arjun was more than Kalam in the present investigation.

The low light intensity under Arjun may be due spreading of branches and higher crown diameter of Arjun compared to that of Kalam (Tabel-3.3) light intensity beneath Arjun indicated poor light conditions for the growth of aromatic grasses beneath the tree canopy. This shading effect declined with increased distance from tree base line in case of both, Arjun and Kalam trees. This is obvious owing to less number of branches with reduction in crop canopy.

SUMMARY AND CONCLUSIONS

VI SUMMARY AND CONCLUSION

Though, a multitude of benefits has been attributed to the land use system of agroforestry, most farmers are yet hesitant to integrate trees in the farming system owing primarily to the yield reductions trees imposing on the crops. The magnitude of yield reduction imposed by trees on agricultural crops in the land use system of agroforestry will depend on a number of factors such as competition for water and nutrients, availability of light, release of phototoxic substances by trees, change of micro-environment by tree, etc. Thus, while identifying suitable plants for agroforestry system of farming, efforts should be made to select the tree species, which impose least reduction in yield as well as releasing minimum phytotoxic substance in soil. This investigation was aimed at to identify suitable tree species and aromatic grasses in agri-silvicultural agroforestry system.

To achieve this objective, six treatment combinations comprising of two forest tree species viz., *Terminalia arjuna* Bedd. and *Mitragyna parvifolia* Korth. With one control in open field and two aromatic grasses viz., (*Cymbopogon flexuosus*) var. OD-19 and (*Cymbopogon martini*) var. OD-29 were examined in an agri-silvicultural agroforestry system.

The results presented and discussed in the preceding chapters are summarized below.

1. Growth measured in terms of height, number of tillers per plant, fresh weight and dry weight of both the aromatic grasses, was adversely affected by the trees species; except height of grasses

under Arjun trees at the time of first cutting and under Kalam trees at the time second cutting. At first cutting, height of aromatic grasses was maximum under Arjun trees while at second cutting, it was maximum under Kalam trees.

2. The number of tillers per plant was maximum in control plants and minimum under the Arjun trees in both the cutting stages.
3. Maximum per cent oil of aromatic grasses was noticed in control (open field) while it was least under Arjun trees at both the cutting stages. However, no significant difference was noticed in oil content under the influence of tree species at second cutting stage.
4. The oil yield of aromatic grasses per plot (115.26 ml/plot) and (175 ml/plot) were significantly highest in control (open field) at first and second cutting stages, respectively. This was followed by oil content under Kalam trees.
5. Herbage yield (kg/plot and kg/ha) of both the aromatic grasses showed the similar trend having the maximum fresh herbage yield in control (T_3) and the minimum under Arjun (T_2) trees at both the first and second cutting stages.
6. The interaction between forest tree species and aromatic grasses was found significant in affecting the height of grasses, number of tillers per plant, dry weight fresh weight, per cent oil and total oil content as well as Herbage yield of grasses (kg/plot and kg/ha) at both the cutting stages.
7. Comparing the light under Kalam and Arjun trees, maximum light intensity (931.52 and 780.44 klux) was recorded at 12.00 noon

under Kalam at both the cutting stages. No significant difference between these two tree species was noted in the light intensities recorded at 8.00 a.m. and 4.00 p.m. at first as well as second cutting stages.

8. Light intensity recorded at various distances from the tree base line was significantly maximum under Kalam trees as compared to that under Arjun trees. Significant reduction in light intensity was observed at D_1 (1m away from the free base line) followed by D_2 (3m) as compared to D_3 (5m) distance from the tree base line.

Conclusion

From the results of present investigation following conclusion may be drawn.

Arjun(*Terminalia arjuna*) caused significant reduction in plant growth attributes except plant height at first cutting stage. Reduction in oil yield and fresh herbage yield of aromatic grasses was also significantly high under Arjun trees as compared to Kalam trees as well as open field. Similarly, light intensity reaching the ground level under Arjun trees was much less than under Kalam trees at all the distances from the tree base line and at both the cutting stages.

Thus, as far as the present investigation concerned, Kalam (*Mitragyna parvifolia*) exhibited less competitive agroforestry system with both the aromatic grasses (Palmarosa, Lemongrass) and proved to be a better agri-silvicultural system than Arjun combining with these aromatic grasses.

However, the investigation does not suffice to conclude that the aromatic grasses may perform with the same consistency in the system tested. Much more research work is needed such as allelopathic effect of these trees, water and nutrient requirements etc. Moreover, Palmarosa and Lemongrass being perennial grasses data on higher and oil yield over the years are required for precise conclusion. In depth studies may change the less competitive agri-silviculture system i.e. Kalam with Palmarosa and Lemongrass to be a complementary system. Therefore, a thorough investigation on these aspects should be made before this tree grass mixture could be recommended for an agro-silvicultural system for sustainable land use and higher fresh herbage yield and higher oil production.

REFERENCES

REFERENCES

- *Adkins, R.V.C. (1988). Intercropping firewood trees with essential oil plants. *Banko Janakari*, 2 (1) : 52-55.
- Anonymous (1976). The wealth of India.(Ed. Chadha,Y.R).Publication and information direcrorate, CSIR, New Delhi. Vol.X: 161.
- Bordoloi, D.N; Borah, U.C. and Baruah, J.N. (1985). Aromatic plants development at RPL Jorhat. *Indian perfumer*, 29 (1-2): 67-74.
- Brahaman, M.; Pillai, S.S.K. and Patil, U.K. (1997). Influence of rubber (*Hevea brasiliensis*) on growth performance and seed yield of pigeonpea intercrop. *Indian Journal of Forestry*, 20 (2): 181-182.
- Chandramala, M.S.; Palchamy, A. and Mark Davasagayam, M. (1996). Effect of alley width and intergrated nitrogen management on *Cenchrus glaucus* in *Leucaena leucocephala* alley under rainfed condition. *Forage Research*, 22 (2-3) : 139-146.
- Chauhan, H.S.; Kamala Singh and Patra, D.D. (1997). Performance of aromatic crops in *Eucalyptus* based agroforestry system. *J. of Medicinal and Aromatic Plant Science*, 19 (3) : 724-728.

- Chauhan, H.S.; Kamla Singh; Patra, D.D. and Singh, K. (1997). Studies on litter production, nutrient recycling and yield potential under (5-6 year old) poplar (*P. deltoides*) and Eucalyptus (*E. hybrid*) interplanted with aromatic crops in Tarai region of Uttar Pradesh. *J. of Medicinal and Aromatic Plant Sci.*, **19** (4): 1034-1038.
- Cooper, S. and Qualls, M. (1967). Morphology and chlorophyll content of shade and some leaves of two legumes. *Crop Sci.*, **7**: 672-674.
- Crookston, R.K.; Treharne, J.; Ludford, P. and Ozbun, J.L. (1975). Response of beans to shading. *Crop Sci.*, **7**: 675-680.
- Dastnagir, M.G. and Suresh, K.K. (1991). Forage production under silvipastoral system. *Journal of Tropical Forestry*, **7** (3) : 206-209.
- Dolan Desmond, D. (1972). Temperature, photoperiod and light intensity effect on growth of *Pisium sativum* L. *crop Sci.*, **12** : 60-62.
- Ella, A; Stur, W.W; Blair, G. J. and Jacobsen, C.N. (1991). Effect of plant density and cutting frequent on the yield of four tree legumes and interplanted *Panicum Maximum* cv. Riversdal. *Tropical grasslands*, **25** (3) 281-286.
- Eze, J.M.O (1987). Effect of bund planting of *Eucalyptus* on Agricultural crop. Paper presented in Seminar on *Eucalyptus*. FRI, Dehra Dun.

- Faiz Mohsini; Singh, R.P.; Singh, K.; and Mohsin, F. (1996). Nutrient cycling of Eucalyptus plantation in relation to stand age in agroforestry system. *Indian forester*, **122** (1): 69-75.
- Faiz, M. Singh, P.R.; Singh, K. and Mohsin, F. (1996). Growth and biomass production by *Populus deltoides* under agroforestry in Tarai of Kumaun Region, U.P. *Indian Forester*, **122** (7): 631-636.
- Faiz, M. Singh, P.R.; Singh, K. and Mohsin, F. (1996). Nutrient cycling of poplar plantation in relation to stand age in agroforestry system. *Indian J. of Forestry*, **19** (4) : 302-310.
- George, S.; Nair, Vikraman, R. (1987). Effect of shade on growth nodulation and yield of cowpea (*Vigna unguiculata* (L.) Wal p.). *Agriculture Research Journal of Kerala*, **25** (2): 281-284.
- Gill, A.S.; Deb Roy, R. and Bajpai, C.K. (1997). Agril-silviculture studies forage yield from *Leucaena leucocephala*. *Forage Research*, **23** (1-2): 17-23.
- Hazra, L.R. and Tripathi, S.B. (1996). Herbage productivity of different winter maize varieties under three tree species. *Forage Research*, **22** (2-3) : 71-75.
- Horne, P.M. and Blair, G.J. (1991). Forage tree legumes. IV. Productivity of *Leucaena*/grass mixtures. *Australian Journal of Agricultural Research*, **42** (7) : 1231-1250.

- Janardhan, K.V. and Murty, K.S. (1980). Effect of low light during vegetative stage on photosynthesis and growth attributes in rice. *Indian Journal of Plant physiology*, **23** (2): 156-162.
- Janardhan, K.V.; Murty, K.S. and Dash, N.B. (1980). Effect of low light during ripening period on grain yield and translocation of assimilates in rice varieties. *Indian Journal of Plant Physiology*, **23** (2): 163-168.
- *Jayachandran, B.K.; Meerabai, M.; Abdulsalam, M; Mammen, M.K. and Kanjammapp, M. (1991). Performance of Ginger under shade and open conditions. *Indian Coca, Areca nut and spices Journal*, NARD (SS). Kollarakkara, Kerala, **15** (2) : 40-41.
- Johan Jacob and Nair, M.A. (1999). Light-A limiting factor in coconut based home garden. *Indian Coconut Journal*, **30** (8) : 1-3.
- Kamla, Singh; Virendra, Singh; Husain, A; Kothari, S.K; Singh. K. and Singh, V. (1990). Aromatic plants as efficient intercrops under poplars (*Populus deltoides*). *Indian Forester*, **116** (3) : 189-193.
- *Knight, R.H. (1935). The effect of shade on American cotton empire. *Journal Expt. Agriculture*, **3** : 31-40.
- *Loomis, R.S. and Whitman, C.E. (1983). System analysis in production ecology. In Huxley, P.A. (Ed.). *Plant Research and Agroforestry*, ICRAF, Kenya : 209-220.

- Mahajan, V.(2001). Effect of Different spacements and pruning intensities of *Casuarina L.* on growth and yield of *Trigonella* grown as intercrop. M.Sc. (forestry) thesis submitted to the G.A.U, S.K.Nagar.
- Maheshwari, S.K. Sharma, R.K. and Gangrade, S.K. (1997). Performance of palmarosa and pigeopea intercropping under different planting geometries. *Indian J. Agron.*, 42 (3) : 425-428.
- Maheshwari, S.K.; Sharma, R.K. and Gangrade, S.K. (1995). Effect of spatial arrangement on performance of palmarosa pigeonepea intercropping on black cotton soil (Vertisol). *Indian J. Agron.* 40 (2): 181-185.
- Maheshwari, S.K.; Sharma, R.K. and Gangrade, S.K. (1996). Spatial arrangement in palmarosa red gram intercropping system. *Crop Res. Hissar*, 11 (2) : 141-144.
- *Mathew, T; Kumar, B.M; Babu, K.V.S; and Umamaheswaran, K. (1992). Comparative performance of four multipurpose trees associated with four grass species in the humid regions of southern India. *Agroforestry systems*, 17 (3) : 205-218.
- *Mayers, N. (1980). The conversion of tropical forest. *Environment*, 22 : 6-13
- Meera bai, M.; Lakshmi, S.; Saraswathy, P. and Rughavan Pillai. (1992). Effect of nitrogen levels and cutting intervals on

fodder production of congosignal grass intercropped in coconut garden. *Forage Research*, **18** (2) : 88-92.

Misra, K.K. and Rai, P.N. and Jaiswal, H.R. (1996). Effect of spacing and plant density on the growth of poplar. *Indian Forester*, **122** (1) : 65-68.

Muthana, K.D. and Shankarnaryan, K. A. (1978). The scope of silvi-pastoral management in arid regions. *Arid Zone research in India* : 84-89

Naik, S.K. and Murty, K.S. (1980). Effect of varying light intensities on yield and growth parameters in rice. *Indian Journal of Plant physiology*, **23** : 309-316.

Opitz, Von Boberfeld. W. and Seemer .H. (1986). Management of grass pasture under double utilization with forest based on the example of Ruraue. *Zeitschrift far Kulturtechnik and flurbereinigung*, **27** (4) : 225-232.

Pareek, S.K. and Gupta, R.(1985).On the status of agronomic research in *Cymbopogon* grasses in India with projection on future work. *Indian Perfumer*,**29**:215-224.

Patel, K.B. (1996). Growth and productivity of agricultural crops in agri-silvicultural system, M.Sc. (Agroforestry) thesis submitted to G.A.U., S.K. Nagar.

Pillai, K.P. (1961). Lemongrass in India. *Farm Bull.* **16**. Ministry of food and Agriculture, New Delhi : 26.

- Prakasa, Rao. E.V.S; Singh, M; Ganesha Rao. R. S; Rao R.S.G. and Rao. E.V.S.P. (1988). Intercropping studies in Java citronella (*Cymbopogon winterianus*). *Field crops Research*, **18** (4) : 279-286.
- Premi, O.P.; Sood, B.R.; Katoch, B.S. and Dogra, K.K. (1998). Production potential, quality and carrying capacity of improved grassland vis-a-vis silvipastoral system. *Forage Research*, **23** (3-4): 193-195.
- Rai, R.N. (1987). Effect of grasses and legumes of terrace risers on yields of rice and Indian mustard of adjoining terraces in northeastern hills region. *Indian Journal of Agricultural Science*, **57** (10) : 719-722.
- Rai, R.S.V. and Suresh, K.K. (1988). Agrosilvi-cultural studies-optimum species combination. *International tree crops journal*, **5** (1-2) : 1-8.
- Rao, D.V.M. and Singh, S.P. (1980). Studies on the effect of defoliation and shading on grain yield and its components in Bajara. *Indian Journal of Plant physiology*, **23** : 181-184.
- Ravindran, K.C. and Kulandaivall, G. (1998). Effect of light intensity on growth and yield of cardamom (*Elettaria cardamom*). *Journal of Plantation Crops*, **26** (1): 87-88.
- Sharma, K.K.(1992).Wheat cultivation in association with *Acacia niloticã*. (1) Wild ex. Del. Field bund Plantation a case study. *Agroforestry system*, **17**:43-51.

- Shinde, S.B. (2001). Effect of forest tree species on the growth and production of forage crops. M.Sc. (Agroforestry) thesis submitted to G.A.U., S.K. Nagar.
- Singh, A.; Singh, M. and Singh, K. (1998). Productivity and economic viability of palmarosa-pigeonpea intercropping system in the subtropical climate of north India. *J. of Agricultural Sci.*, **130** (2) :149-154.
- Singh, D. (1986). Effect of low light intensity on growth and the yield of rainfed cotton. *Indian Journal of Plant physiology*, **29** : 230-236.
- Singh, D. and Kohli, R.K. (1992). Impact of *Eucalyptus tereticornis* S.M. Shelterbelts on crops. *Agroforestry system*, **20**:253-266.
- Singh, K.; Chauhan, H. S; Rajput, D.K. and Singh, D.V. (1989). Report of 60 month study on litter production, changes in soil chemical properties and productivity under *Poplar* and *Eucalyptus* interplanted with aromatic grasses. *Agroforestry system*, **9**(1): 37-45.
- Singh, K; and Ram, P. (1991). Production potential in intercropping of *Citronella Java* with cowpea and Mint species. *Annals of agricultural Research*, **12** (2): 128-133.
- Singh, M. and Shivaraj, B. (1998). Intercropping studies in lemongrass (*Cymbopogon flexuosus*). *J. Agron. and Crop Sci.*, **180** (1) : 23-26.

- Singhal, R.M.; Yadava, A.K. and Yadav, A.K. (1994). Intercropping of aromatic plants with poplar (*Populus deltoides*, G-3). *Van Vigyan*, **32** (4) : 108-111.
- Stansel, J.W.; Bollich, C.N. and Thysell, J.R. (1965). The influence of light intensity and nitrogen fertility on rice and components of yield. *Rice J.*, **68**: 34-35.
- Sundaramoorthy, S. and Karla Anju (1991). Allelopathy and Vegetation in *Acacia tortilis* Plantation in Indian desert. *Annals of Arid Zone*, **30**(3): 259-266.
- Tanaka, A.; Navasero, S.A.; Garica, C.V.; Parora, F.T. and Ramirez, E. (1964). Growth habit of rice plant in the tropics and its effect on nitrogen response. *Tech. Bull. IRRI*, Philippines, **3** : 45-47.
- Tripathi, S.B. and Hazra, C.R. (1994). Forage yield and soil fertility as influenced by nitrogen application under agroforestry production system. *Forage Research*, **20** (4) : 265-271.
- Troup, R.S. (1986). The silviculture of Indian Trees. FRI publication, Dehradun, Vol-II.
- Venkateswarlu, B.; Prasad, V.V.S.S. and Rao, A.V. (1977). Effects of low light intensity on different growth phases in rice (*Oryza sativa* L.). *Plant and Soil*, **47**: 37-47.
- Venkateswarlu, B. and Srinivasan, T.E. (1978). Influence of low light intensity on growth and productivity in relation to population pressure and varietal reaction in irrigated rice

(*Oryza sativa* L.). *Indian Journal of Plant physiology*, **21**: 162-170.

Vinod Shankar, Dadhich, N.K. and Saxena, S.K. (1976). Effect of Khejri tree (*Prosopis cineraria*) on the productivity of forage grasses growing in its vicinity. *Forage Research*, **2**: 91-96.

Wattal, P.N. and Asana, R.D. (1974). Response of tall and dwarf varieties of wheat to light intensities. *Indian Journal of Agriculture Science*, **44** (11): 707-711.

*Wood, P.J. (1988). Agroforestry and decision making in rural development. *Forest Ecology Management*, **24** : 191-201.

Yadava, A. (2001). Cultivation of Lemongrass (*C. flexuosus*, 'CKP-25') under poplar Based Agroforestry System. *Indian Forester*, : 231-223.

Yadava, A.K. and Singh, K. (1996). Performance of the lemongrass under poplar based agroforestry systems. *Journal of Medicinal and Aromatic Plant Science*, **8**:290-294.

* Original not seen

APPENDICES

Appendix - 1 silvicultural information of two forest tree species

	<i>Terninalia arjuna</i> Bedd.	<i>Mitragyna parvifolia</i> Korth.
1. Family	Combretaceae	Rubiaceae
2. Local name	Arjun, Sadada	Kalam, kaim
3. Origin	India and Burma	Himalayan region
4. Climate requirements		
(i) Temperature (Max.)	25°C to 35°C	37°C to 47°C
(Min.)	15°C to 20°C	-1.1°C to 1.7°C
(ii) rainfall (cm)	80 to 150	88 to 325
5. Distribution	Common throughout the greater part of the Indian peninsula along rivers, streams, ravines and dry water courses.	Throughout the greater part of India and Burma ascending to 4,000 ft. in the outer Himalaya. Also found in Ceylon.
6. Soil	Grows well on a fertile alluvial loam.	Sandy loam, deep clay and well drained soil.
7. Growth habit	It is a tall evergreen or almost evergreen tree with a broad crown and drooping branchlets. Stem is generally buttressed and often fluted. Bark is smooth, exfoliating in thin irregular. Sheets, green when newly exposed.	It is large deciduous tree with a rounded crown and a bole often short, fluted and buttressed. The bark is upto 0.8 inch thick, grey, smooth and exfoliated in scales which leaves shallow depressions.
8. Phenology		
(i) Leaf shedding	Just before or during the summer season, evergreen or almost evergreen	February-March
(ii) Leaf renewal	All around the year	May-June
(iii) Flowering time and inflorescence type	April-May and upto July/spike	April-August/head
(iv) fruiting time and fruit type	Flowering Feb-May/Drupe	November-March/Capsule
9. Silvicultural characteristics		
(i) Light	Light demander, able to grow fairly well in conditions of shade.	Initially requires shade, afterwards light demander.
(ii) Drought	Tender to conditions of drought	Moderately drought hardy
(iii) Frost	Sensitive to forest	Sensitive to frost
(iv) Coppicing/pollarding	Well	Coppices well upto a moderate size

Contd...

10. Natural regeneration	Generation occurs at the onset of rainy season after seed fall	Seeds dispersal occurs in the hot season and germination occurs in the rainy season
11. Artificial regeneration	It may be carried out by direct sowing, seedling, Air-layering is also possible. Stum-planting also successful	2 to 3 months old seedling are transplanted.
12. no. of seeds/kg	775	10,00/gm
13. Pre-sowing treatment	Alternate wetting and drying	Not required
14. Sowing/plant season	April-May/June-July	Feb-March/June-July
15. Germination	50-60	30-50
16. Silvicultural system	Clear felling followed by artificial regeneration with teak and other species	Clear felling followed by artificial regeneration or simple coppice system
17. Uses	It is used for building agricultural implements, carts, boats, pit-props, water-troughs, plywood and other domestic purposes. The bark is used for tanning. Leaves are used for tasar silk	The wood is commonly used for building, furniture, agricultural implements and such purposes as toy making, turnery and the manufacture of combs, cups, platters, bowls, frames, walking sticks handles. It is recommended for certain types of bobbins, pen holders and mathematical instruments
18. Other information		
Calorific value calories/g		4.086

Appendix-II Some necessary information on package of practices of both the aromatic grasses


Agronomical practices	Aromatic grasses	
	Lemongrass	Palmarosa
1. Time of sowing	May, June, and July best season	Nursery in May by sowing seed, slip transplanting in June
2. Ploughing	Drilled by deshi plough followed by planking	Drilled by deshi plough followed by planking
3. Seed rate (kg/ha)	Nursery in 10 1,48 148 slips/ha	Nursery in 10 1,48 148 slips/ha
4. Spacing (cm)	15 cm x 45 cm 1,48,148 slips/ha (one to two slips/hole)	15 cm x 45 cm 1,48,148 slips/ha (one to two slips/hole)
5. Fertilizer dose (NPK) (kg/ha)	N 100 - 3 split, P 50 K 50	N 100 - 3 split, P 50 K 50
6. Number of irrigations	Summer 10 days interval Winter 1 or 2 irrigation/month	10-12 days interval Winter 1 or 2 irrigation/month
7. Number of weedings	3, hand weeding	3, hand weeding
8. Days of maturity	90-120	90-120
9. Yield (kg/ha)	Forage yield-68 tonnes/ha in 4 cuttings Oil-0.28 % Aprox. 190 kg oil/ha/year	Forage yield 45 tonnes/ha in 4 cuttings Oil-0.38 % Aprox. 170 kg oil/ha/year
10. Improved variety	Lemongrass (Cital) Rosha grass (Geraniol) Citronella.	Palmarosa, Sofia
11. Harvesting	Sep, Dec, March, June	Nursery in May by sowing seed Slips transplanting in June

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 : February, 2002.



(A.D. Chavda)