

**STUDIES ON ALLEY CROPPING AND
AGROSILVICULTURE SYSTEMS IN BLACK SOILS
UNDER DRYLAND AGRICULTURAL CONDITIONS**

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**DEPARTMENT OF AGRONOMY
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MARCH, 1992

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**STUDIES ON ALLEY CROPPING AND
AGROSILVICULTURE SYSTEMS IN BLACK SOILS
UNDER DRYLAND AGRICULTURAL CONDITIONS**

**Thesis Submitted to the
University of Agricultural Sciences, Dharwad
in partial fulfilment of the requirements for the
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in

AGRONOMY

By

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MARCH, 1992

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CERTIFICATE

This is to certify that the thesis entitled "**STUDIES ON ALLEY CROPPING AND AGROSILVICULTURE SYSTEMS IN BLACK SOILS UNDER DRYLAND AGRICULTURAL CONDITIONS**" submitted by **Mr. G.R. KORWAR** for the degree of **DOCTOR OF PHILOSOPHY IN AGRONOMY**, of the University of Agricultural Sciences, Dharwad, is a record of research work done by him during the period of his study in the University, under my guidance and supervision and the thesis has not previously formed the basis of the award for any degree, diploma, associateship, fellowship or other similar titles.

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INTRODUCTION

I INTRODUCTION

Semi-arid tropics (SAT) covers a geographical area of 2 billion hectares lying between 35° N and 35° S latitudes. It covers most of western, eastern and south-central Africa; most of India, north-eastern Burma, north-eastern Thailand; and northern Australia; most of Mexico; and large parts of eastern and central South America. It is home to over 700 million people, nearly half of them being in India. Dryland agriculture is the predominant form of land use in this region, which is characterized by a low standard of living and poor and unstable crop yields due to deficient, strongly seasonal and usually undependable precipitation.

In India, a sizable cropped area (92 million hectares) comprising 64 per cent of country's cropped land (143 million hectares) lies in SAT region. The SAT environment is characterized by high atmospheric water demand, high mean annual temperature (> 18° C), and low, variable annual rainfall. Rainfall (P) exceeds potential evapotranspiration (PE) from 2-4.5 months in a year in dry and 4.5-7 months in wet-dry tropics. The coefficient of variability of annual rainfall in SAT is 20 to 30 per cent, while it varies from 10 to 20 per cent in humid tropics.

Population explosion in India has increased pressure on forests and forest products. The area under forests is shrinking year by year, and the demand for forest products is ever increasing. A huge gap between deforestation and afforestation exists. If this continues, fuelwood shortage may become more serious problem than food. A study group of planning commission, Government of India estimated that, to meet the fuelwood demand by 2000 AD, at least three million hectares need to be planted every year with fast growing fuelwood tree species (Swaminathan, 1987). It is also estimated that only two-third of the total fodder

required for providing adequate nutrition to present livestock population is produced in the country. To overcome these deficits enormous efforts are being made. One of them is to increase area under forest. This led to the planting of trees in lands available for tree production. But this alone with existing forest cannot meet the requirements of forest products. Agricultural land cannot be diverted to forest as it is already under pressure. Under these circumstances, proper integration of trees with field crops seems to be better alternative to meet the growing needs.

Improved crop production technology using improved seeds, fertilizers, pesticides and irrigation water has increased crop production and income in irrigated areas. Significant increases in yield through use of improved seed, small dose of fertilizer and improved management have been demonstrated in dryland agriculture as well. However, owing to undependable monsoon, dryland farmers whose resource base is poor and are risk-averse dare not to use cash inputs, particularly the nitrogenous fertilizers, though it demands only a small capital investment. In the face of such reluctance, advantage may still be got of the crop response to nitrogen generated *in-situ* through a low cost system such as alley cropping. Further, most drylands are unfertile, degraded, marginal and low in productivity. The crop yields are not sustainable as their productivity is depleting year by year. Traditional arable cropping enterprise in these lands is unstable and often unremunerative.

Arable crops grown on most of these regions cover the land generally for one season of about three to four months duration. Rainfall occurring during the uncropped period goes unutilized because of the absence of any crop/vegetation, often causing serious soil erosion. For these areas, a

land use system which includes a perennial component would be most appropriate. Agroforestry systems such as alley cropping and agrosilviculture have been reported as viable alternatives to shifting cultivation and as sustainable agriculture systems in the humid tropics (Lal, 1989c). In agroforestry systems, while leguminous shrubs and trees may improve soil's nitrogen capital, their deep and extensive root systems and tall canopy compete with arable crop for water and nutrients reserves, and solar radiation. While competing for space, trees and shrubs can also provide additional products for the farm household such as fuel, fodder, mulch, staking material and other minor products.

In black soils erosion is a serious problem. Mechanical soil conservation structures which are commonly used in India are not stable, and often land is lost for these structures. Hedgerows of trees and shrubs when properly aligned can help in soil conservation. Further, they supply either valuable nitrogen to crop when the prunings from these hedgerows are returned to the soil or fodder. They also provide fuelwood from the sticks.

Earlier work on alley cropping with *Leucaena* under *rabi* situations at Bijapur has shown significant yield reduction even when prunings were returned to the plot, in alley cropped *rabi* sorghum (AICRPDA, 1988). This is probably due to competition for soil moisture. Interestingly, work at Solapur, under *rabi* situations has shown increase in yield of alley cropped *rabi* sorghum when prunings from the *Leucaena* hedgerows were returned to the soil (Narkhede and Ghugare 1987b). Similar positive effects of *Leucaena* hedgerows on *kharif* sorghum and pearl millet were observed at CRIDA, Hyderabad. Significant yield advantages from hedgerow intercropping have been reported from studies in different parts of the world

(Ssekabembe, 1985). Hence, it should be possible to increase yield from alley cropping by root pruning of *Leucaena* through cultivation and by canopy management through regulation of shoot pruning.

Trees are integral part of dryland agriculture. More generally, trees give stability to dryland agriculture in the long run. But, trees are known to affect crops by competing with them for soil moisture and light. However, some work done at CRIDA has shown that with appropriate canopy management it is possible to raise successful intercrops with trees like *Leucaena* and eucalyptus.

In black soils many trees are native, viz., neem, *Acacia nilotica*. They are commonly noticed on drylands. Among the native species trees that are fast growing and having least effect on the undercrops have to be identified. In dryland agriculture especially in low productive, eroded soils growing trees plus crops would be better suited than trees or crops alone.

Crops differ in their compatibility for intercropping with different tree species. Screening of different arable crops for their suitability for intercropping with different tree species is also important. In view of the above, the present investigation was planned with the following objectives:

1. To reduce the competition of *Leucaena* hedgerows with *rabi* sorghum through root pruning and canopy management of *Leucaena* hedgerows in alley cropping system.
2. To assess the *Leucaena* - sorghum alley cropping system vis-a-vis sole sorghum cropping.

3. To identify suitable tree species for low rainfall and eroded black soil areas for agrosilviculture system.
4. To reduce competition of trees with intercropped *rabi* sorghum in agrosilviculture system.
5. To screen *rabi* crops suitable for intercropping with different tree species in agrosilviculture system.
6. To study the interaction between hedgerows/tree species and crops in alley cropping and agrosilviculture systems.

REVIEW OF LITERATURE

II REVIEW OF LITERATURE

Literature on different aspects of alley cropping and agrosilviculture are reviewed in this chapter. In alley cropping, choice of tree species for alley cropping, alley width, height and frequency of pruning, time and methods of applying prunings, competition between tree species on the hedgerow and the arable crop; and benefits for crop production are covered. In agrosilviculture, positive and negative; above and below ground interactions between tree and crop species, effect of root pruning and canopy management on these interactions; and comparative performance of different crops with tree species are dealt with.

2.1 Alley Cropping

Alley cropping is an agroforestry practice in which arable crops are grown between managed, perennial hedgerows spaced at regular intervals. It is also called by the name hedgerow intercropping. The hedgerows are cut back at planting and kept pruned during cropping to reduce competition with crops. When there are no crops, the hedgerows are allowed to grow freely to cover the land. The prunings can be used as a mulch or removed for use as fodder, as fuelwood, or for other purposes. Alley cropping retains some of the main advantages of shifting cultivation, viz., regenerating soil fertility, providing green manure, fuelwood and stakes, and suppressing weeds (Kang *et al.*, 1981). The addition of green manure through alley cropping is very valuable, especially in the tropics where most of the plant nutrients are derived from mineralising organic matter and yet the soils are often deficient in the same. The important aspects to be studied in alley cropping are choice of tree species, alley width, height and frequency of pruning, time and method of prunings application and their interactions; and benefits for crop production.

2.1.1 Choice of tree species for hedgerow

The basic characteristics required for an alley cropping tree species are, easy establishment, deep root system, fast growth, tolerance to repeated pruning, ability to coppice vigorously and high forage productivity (Kang *et al.*, 1984). Further, nitrogen-fixing ability, coupled with a high foliar N content and rapid decomposition rate are other characteristics highly desirable for soil fertility maintenance. With livestock integration, the tree species should have good fodder value and should be capable of producing good quality fodder throughout the year. Toxins and other antinutritional substances should be absent or very low in foliage (Kang *et al.*, 1990).

A number of tree and shrub species are potentially suitable for alley cropping system, but only few have received research attention. *Leucaena* and *Gliricidia* were found best performing hedgerow species for alley cropping in humid and subhumid low-land tropical region of south-western Nigeria (Reynold and Atta-krah, 1989). Wijewardene and Waidyanatha (1984) also obtained good results with these tree species under similar agro-ecological conditions in Sri Lanka. Duguma *et al.* (1988) showed that *Leucaena* performed better than *Gliricidia* for alley cropping with food crops, while *Sesbania grandiflora* performed poorly because it could not withstand repeated pollarding. Over a six-month period, a monthly pruning killed 100 per cent of *S. grandiflora* trees and 25 percent of *Gliricidia*, but the mortality rate in *Leucaena* was insignificant. Yamoah *et al.* (1986 a) working in south-western Nigeria observed that *Gliricidia* coppiced faster and had higher biomass and N yields than either *Flemingia congesta* or *Cassia siamea*.

The emergence of psyllid pest (*Heteropsylla cubana*) and its widespread devastation of *Leucaena* trees in Asia, the Pacific and Australia has given impetus to the promotion of *Gliricidia*. *Gliricidia* has been found to be the most promising hedgerow species in the psyllid infested area. (International Development Research Centre, IDRC, 1988). Studies at Philippines (Friday and Friday, 1990) also revealed that *Gliricidia* performs as well or better than *Leucaena* as far as quantity and N content of green manure, the choice between the two species probably depends more on seed availability than on growth performance. Based on pot culture work in Hawaii, Gutteridge (1990) reported that, release of N from leaf mulches of *Sesbania sesban*, *Gliricidia* and *Leucaena* provided reasonable source of N for maize or other crops. The release of N from the leaf of *Calliandra calothyrsus*, *Acacia cunninghamii* and *A.fimbriata* however, did not suffice the demands of crop. High (11%) tannin content of *C. calothyrsus* was responsible for inhibition of microbial decomposition.

For the humid highlands of Costa Rica, Kass (1985) reported the beneficial effect of alley cropping food crops with *Erythrina poeppigiana*. Addition of prunings of *E.poeppigiana* increased crop yields.

Results of trials carried out at Kagasa, Rwanda, showed that *Cassia spectabilis* produced the highest N yield compared to *Calliandra*, *Leucaena* and *S.sesban*. Alley cropping with *C. spectabilis* also gave the highest maize, bean and sorghum yields (IITA, 1986). For the highland region of Rwanda, *S.sesban* was reported (Yamoah and Bureleigh, 1990) to be another promising N-fixing tree for alley cropping. Gichuru and Kang (1989) reported that the performance of *Calliandra* is comparable with that of *Leucaena* which has been widely shown effective in alley cropping systems of south-western Nigeria.

On acid soils, Kang *et al.* (1990) reported good yields of cassava when alley cropped with *Cassia* and *Acioa*. Hedgerows of *Gmelina arborea* significantly reduced cassava yield due to aerial and subterranean root competition. Szott *et al.* (1991) reported the potential of *Inga edulis* for alley cropping on acid soils. The potential of alley cropping with *Sesbania rostrata* in wetlands has been assessed. Addition of *S.rostrata* prunings increased rice straw and grain yields and N uptake (Kang *et al.*, 1990).

Sheelavantar (1990) reported that, growing rice and *Sesbania rostrata* in 6:1 proportion and incorporating at 55 days after planting (DAP) resulted in higher yields than that of sole rice at low fertility levels (0-50 kg N/ha). And at high fertility levels (100 kg N/ha) 2:1 row proportion of rice and *S.rostrata* incorporated at 55 DAP was superior to sole rice.

Chandrasekharaiah (1986) obtained higher yields of hedgerows of *Leucaena* than that of *Desmanthus virgatus*, *Pennisetum massaicum* and *Medicago sativa*. In *kharif* the yield of alley cropped maize was maximum with *Leucaena*, followed by that with *M.sativa*, *D.virgatus*, *P.massaicum*, while in *rabi*, yield of alley cropped safflower was highest with *M.sativa* (6.04 q/ha) followed by *D.virgatus* (5.31 q/ha) *Leucaena* (5.29 q/ha) and *P.massaicum* (5.10 q/ha). However, sole crops out-yielded the alley crops in both the seasons.

Itnal (1987) observed higher yield of hedgerows of *Leucaena* than *Sesbania* and *P.massaicum*. Whereas the yield of alley cropped *rabi* sorghum decreased to a greater extent with *Leucaena* hedgerows than with *Sesbania* and *P.massaicum*.

In the semi-arid tropical regions of India, so far *Leucaena* has been the alley cropping tree species (Singh *et al.*, 1989c). *Leucaena* once established has proven to be quite adapted, to even extreme drought conditions. Hence, *Leucaena* has been preferred by researchers and eventually by the farmers in agroforestry systems in the dryland regions of India.

2.1.2 Alley width

Food production is the major aim of subsistence farmers. The introduction of hedgerow intercropping system on arable land will reduce the area of land available for cropping. The land 'lost' for annual crop production depends on alley width, i.e., the distance between two hedgerows (Ssekabembe, 1985). At IITA, a higher quantity of biomass per unit area was obtained from 2 m alley width than from 4 m spaced alley, because of higher tree population, although with periodic pruning of trees there was no significant difference in maize yield (IITA, 1983). Chandrasekharaiah (1986) observed decrease in the production of *Leucaena*, *P.massaicum*, *D.virgatus* and *M.Sativa* hedgerows with increase in alley width from 3.6 to 10.8 m. The grain yield of alley cropped maize followed the opposite trend. Similar decrease in production of hedgerows (*Leucaena*, *Sesbania grandiflora* and *Pennisetum massaicum*) with increase in alley width from 4.05 to 8.1 m to 12.15 m was observed by Itnal (1987). While the trend in grain yield of the alley sorghum was in the opposite direction. Macklin *et al.* (1988) reported superiority of 2 m wide alleys over 8 m in producing maize grain yield and fuelwood yield of *Leucaena* in Kenya receiving 1000-1100 mm annual rainfall. Similarly, Yamoah and Burleigh (1990) working in highland region of Rwanda reported that bean yield in 6 m

alleys was about twice than that observed in 2 m alleys and maize yield in 8 m alleys was about 4 times compared to 2 m spaced alleys in alley cropping of maize and beans with *S.sesban*.

At ICRISAT, Hyderabad sorghum/pigeonpea intercrop (1:1) was tested as an alley crop in *Leucaena* hedgerows in a systematic design, with alley widths increasing by 0.9 m from 1.95 m to 5.55 m, on a shallow Vertic Inceptisol (ICRISAT, 1987). The crop yields were compared with sole crops. In the first year of *Leucaena* (1984), sorghum yields were relatively unaffected by hedgerow spacing, however, they were 45 to 62 per cent of sole sorghum. In next two years, the grain yield of sorghum decreased drastically at the two lowest spacings. In 1984, pigeonpea yield in agroforestry treatments were unaffected by presence of *Leucaena*, but, in 1985, pod yield declined dramatically (from 50 to 4% of sole crop yield) as hedgerow spacing decreased and the decrease was still higher in 1986. Economic comparison revealed that the best alley crop treatments were the widest spacings tested, namely 5.4 m for Alfisol and 5.55 m for Vertic Inceptisol (ICRISAT, 1989).

Lal (1989a) worked on alley cropping of maize and cowpea and *Leucaena* and *Gliricidia* hedgerows in Ibadan. Averaged over 6 years, both in *Leucaena* and *Gliricidia*, wide (4 m) and narrow (2 m) alleys did not vary appreciably in their effect on maize grain yield. But, during a below-normal rainfall year, wider alley was superior and *Gliricidia* had more drastic effect on yield of alley crop than *Leucaena*. Cowpea yield was reduced more than sorghum in narrower alleys and the effect was seen more in *Leucaena*.

In alley cropping studies carried out at different centres of All India Coordinated Research Project on Dryland Agriculture (AICRPDA), even at 2 years the pearl millet yield decreased systematically with decreasing alley width from 7.8 m to 2.0 m. This decrease was more or less independent of

rainfall. At CRIDA, Hyderabad in the 1st year, pearl millet grown in 3.6 m wide alleys (cut at 60 cm height) produced 83 per cent grain yield of sole pearl millet. By the 5th year, however this ratio decreased to 26 per cent. Yield in wider alleys (7.8 m) reduced from a high of 93 per cent of sole crop in the 2nd year to 60-65 per cent in years 3-5 (Singh *et al.*, 1989c). At Bijapur, *rabi* sorghum yields were 10 and 48 per cent of sole crop in 3.6 m and 6.6 m wide alleys respectively at 2 years age of hedgerows when the rainfall was poor. At age 4 of the hedgerows when the rainfall was better, the yields were 51 and 72 per cent (AICRPDA, 1988).

In areas with little rainfall wider alleys were found necessary in order to avoid competition for moisture between the hedgerows and the interplanted crops (Ssekabembe, 1985). Singh *et al.* (1989c) concluded that selection of alley width is much more important in the semi-arid tropics than in the sub-humid and humid tropics. Even greater widths (e.g. 15-20 m) must be examined for their effect on crop production. It is expected that farmers may not tolerate large decreases in grain and stover yield from alley crops despite the offsetting value of the prunings. In deciding the exact alley width, the working of farm machineries for tillage and sowing or drill widths for sowing should be kept in mind so that the alley-width matches with the number of passes with bullock drawn/*tractor* drawn seed drill and also the tillage equipment. If more than one crop is sown (rotation) spacing requirement of both the crops has to be kept in mind. Further, if the arable crops are intercropped, the row-ratios and the spacings should be taken into account while arriving at exact hedgerow spacing.

2.1.3 Height and frequency of pruning

Height of hedgerows at initial and subsequent pruning, and frequency of pruning are important aspects of hedgerow management. In Hawaii, *Leucaena glauca* harvested when 4 months old (after having attained a height of 120-150 cm) gave best forage yields; there was a progressive decrease in yield as the height of cutting was increased and cutting delayed (Takahashi and Ripperton, 1949). In Philippines, it was suggested that *Leucaena* plants should be allowed to grow at least 6 months before its initial harvesting (Ssekabembe, 1985). The above two examples come from high rainfall areas where growth of *Leucaena* is rapid. In semi-arid areas, *Leucaena* may need a much longer time to acquire a harvestable growth. Experience in India shows that initial pruning of *Leucaena* after one year's growth is optimum (Korwar, 1992).

Pruning height is another important aspect of hedgerow management. Obviously, a low cutting height of 15-30 cm would be desirable because it would avoid shading the crop, especially the short statured ones, such as cowpea. In Hawaii, yield data on *Leucaena glauca* over a 2 year period from plots cut at 7.5-90 cm heights, showed that the lowest cutting heights appeared best in terms of yield and quality of forage. However, Getahun (1980) has discouraged such a low cutting height because it may reduce yield. In the Philippines a cutting height of 30-40 cm is generally used (Ssekabembe, 1985). Vonk (1983) working in the semiarid Machakos district in Kenya reported that a low cutting (20-40 cm) for *Leucaena* caused its wood to split easily, leading to easy attack by insects including termites. Vergara (1982) also reported that although the trees survived with as short as 7.5 cm stumps, their herbage yields were greater when stumps were taller. But the medium height makes it convenient for the farmer to

perform the cutting operation with hand knives or machetes. Jama and Nair (1989) from Kenya also reported higher green manure production in *Leucaena* hedgerows at a medium cutting height of 60 cm than 30 or 90 cm.

At Bangalore, *Leucaena* strips maintained at 1.5 m height affected the growth and yield of fingermillet crop considerably. The yield reduction was 32 to 39 per cent as compared to that of sole fingermillet. In *Leucaena* strips of 30 cm height the yield reduction was 12 to 18 per cent. In the former case the rows near to *Leucaena* strips on either side were very much affected. In the latter case, the rows near to *Leucaena* gave higher yield as *Leucaena* did not offer any competition (AICRPDA, 1983). Palled (1985) reported reduced TDM production, grains per ear and grain weight per ear of sorghum when grown with *Leucaena* cut at 100 cm height as compared with 50 and 5 cm height. He also observed high correlation between sorghum grain yield with stem girth, dry matter per plant and grains per panicle.

Work at Gujarat revealed that a low (25 cm) cutting height as compared with high (90 cm) reduced the competitive effects of *Leucaena* hedgerows on alley cropped groundnut (AICRPDA, 1971b). Similarly work at Hyderabad showed that low cutting height (10-15 cm) of *Leucaena* hedgerows did not cause any competition with sorghum or pearl millet, while a high cutting height (60 cm) resulted in 50 per cent reduction in sorghum and pearl millet yields (Korwar, 1992). In Nigeria, three cutting heights (20, 50 and 100 cm) were tested in three hedgerow species (*Leucaena*, *Gliricidia* and *S.grandiflora*) with alley crops of maize and cowpea (Duguma *et al.*, 1988). Biomass, dry wood and nitrogen yield from hedgerow prunings increased with increasing pruning height. However, higher maize and cowpea yields were obtained with decreasing pruning height. Field and OeMaton (1990) observed higher maize yield with 10 cm cutting height of *Leucaena* hedgerows than 100 cm. *Leucaena* yields were highest at 100 cm cutting height.

Gaddanakeri (1991) obtained higher *Leucaena* dry matter (16.5 q/ha) at 90 cm cutting height than cutting close to ground (12.39 q/ha). The grain yield of sorghum was 16 q per ha in the former case and 22.3 q per ha in the latter case.

These findings indicate that lower pruning heights of the hedgerows reduced competition with arable crop and favoured their production at the cost of hedgerows. In semiarid areas where severe competition for moisture between hedgerows and crops is likely to occur, low cutting heights should be adopted.

The pruning frequency also has to be adjusted according to the growth rate of the tree species in a given area. If the frequency is too high, the trees may be killed and if it is too low the trees may develop into tall hedges that may shade the alley crops and reduce their yield. In some trials in the philippines, 2 to 3 months interval was found suitable (Vergara, 1982). Fast growing plants such as *Leucaena* and *Gliricidia* required pruning every 5-6 weeks during cropping period. Too low and too frequent pruning of the hedgerows should be avoided as it resulted in die back (Kang *et al.*, 1984). However, frequent pruning and lower pruning height reduced the shading effect of the hedgerows on the accompanying crops and favoured crop productivity (Kang *et al.*, 1984; Palled, 1984; Duguma *et al.*, 1988). Ezenwa *et al.* (1990) found in Nigeria that pruning *Leucaena* and *Gliricidia* at 8 or 12 weeks frequency was better than that at 4 weeks or no pruning with respect to leaf dry matter production and nodulation. However, highest root dry matter was observed in unpruned hedgerows. Field and OeMaton (1990) based on their work at Indonesia reported that 2 m spaced *Leucaena* hedgerows produced higher maize yield when pruned once 25 days after planting (DAP) maize in addition to the pruning before maize planting, as compared with no pruning during maize

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cropping period. Comparing interaction of pruning height with frequency it was observed that at 10 cm cutting height even the one pruning at 25 DAP was not required, but with 100 cm it was required. Highest *Leucaena* yields were obtained at 100 cm cutting height and no pruning and lowest with 10 cm height and 3 prunings.

Under Indian conditions for *kharif* season it has been observed that one cutting at planting and subsequent cuts at one month's interval during the cropping period was satisfactory. However, for *rabi* season the information on cutting frequency is not available. During off-season there is no need to cut the hedgerows unless fodder demands necessitate the same. VanDen-Beldt (1990) opined that the future role of alley cropping in the semi-arid tropics (SAT) will depend on the development of management methods to control sources of competition between hedgerows and crops. Among options that need to be examined are more frequent and severe loppings during the cropping season, wider hedgerow spacings emphasizing soil conservation with live bunding, and hedgerow species screening.

2.1.4 Time and method of prunings application

The time when prunings are applied on arable area is influenced by the frequency of cutting. Ssekabembe (1985) reported that for upland rice application of *Leucaena* prunings during land preparation, 25 days before seeding was superior to applying either at seeding or 25 days after seeding. Guevara (1976) reported higher maize yield when *Leucaena* was cut and applied at early stage of maize growth than at later stages.

Incorporation of fresh prunings produced higher N uptake by maize and higher grain yields than when applied as mulch, although it was not the case when dry leaves were used (IITA, 1982). In Hawaii, it was reported that incorporation of *Leucaena* green leaf manure was 62.7 per cent and

surface mulching only 41.2 per cent as efficient compared to urea as source of N, in supplying N to maize (Ssekabembe, 1985).

Atta-Krah (1983) suggested that incorporation of prunings in the soil would involve dislodging *Leucaena* roots and hence minimise its competition on associated agricultural crop. In another alley cropping trial with cowpea as the test crop, dry matter and seed yield were higher from tilled than from no-till treatment, and the lower cowpea yields in the no-till treatments were attributed to more root competition with *Leucaena* (IITA, 1982). These findings are an indication of the effect of tillage on reducing competition from roots of hedgerows on the arable crops, but deep tillage may be difficult to accomplish with light tillage.

2.1.5 Competition between tree species of the hedgerow and arable crop

Competition between tree species and annual crops has been well studied (Steiner, 1982). The competition is mainly for light, nutrients, space and moisture. In Nigeria, Kang *et al.* (1981) attributed the low yield from maize rows adjacent to the hedgerows to shade from the *Leucaena* hedges cut at 1-1.5 m height. Similar yield reductions were reported for cowpeas grown in 2 m alleys, yield reduction was maximum with *Gliricidia*, followed by *Leucaena*, *Alchornea cordifolia* and *Acioa barterii* which is more or less in line with size and leafiness of the tree (IITA, 1983). Yamoah and Burleigh (1990) reported reduction in height of maize adjacent to *S.sesban* hedgerows.

Lal (1989a) also reported suppressed growth and yield of maize in the vicinity of the hedgerows. During normal rainfall years, the reduced growth near hedgerows was due to shading rather than competition for moisture. Whereas during a low rainfall year, which experienced prolonged

dry spell after sowing, the suppression might be due mainly to competition for soil moisture. Average yield of maize in alleys was about 10 per cent lower than that of control. This reduction in maize yield was almost proportional to the actual area planted to hedgerows in the alley cropping system. There was apparently no border effects in maize-*Leucaena* or maize-*Gliricidia* systems. In contrast with maize, alley cropping system drastically suppressed cowpea grain yield. The average cowpea yield in alley cropping was 30 to 50 per cent of the control. The severe reduction in cowpea yields was attributed to competition between root systems (for nutrients such as P and possibly water) and for light between shoot systems.

Balasubramanian (1983) attributed the reduction in yam yield in alley cropping to shade from *Leucaena* hedgerows which were managed as livestock stakes for yams. This effect could however, be reduced by ringing *Leucaena* stems at the base or cutting and using it as dead stakes. Similarly, Ssekabembe (1985) reported that the yield of cassava intercropped with *Leucaena* was more affected by shading and competition for space rather than competition for or lack of nutrients. Benge (1977) reported from the Philippines that *Leucaena* spaced at 1 m resulted in competition for available light with intercropped cassava. In order to avoid this and maintain a vigorous stand of *Leucaena* for pruning, he suggested planting bands of *Leucaena* 10 m wide alternating with 10 m alleys in which agricultural crops could be planted. Getahun (1981) reported that in Nigeria the growth of cassava after 5 months affected the growth of young *Gmelina arborea* trees through shading. However, the shading was reduced by side-pruning of the cassava after it had started tuber-bulking, and the problem was eliminated with the cassava harvest. Gichuru and Kang (1989) observed reduced yield of cowpea rows adjacent to *Calliandra* hedgerows due to shading.

It appears that competition for light is the most widely observed form of competition in alley cropping in humid tropics, and can be effectively minimised with proper management (Kang *et al.*, 1985; Getahun and Jama, 1986). In the semi-arid tropics, this competition is more difficult to manage. Hedgerows are generally competitive with most crops, even with intensive and frequent hedgerow pruning, and crop yield reduction is probably due to root competition for soil moisture. At ICRISAT centre polythene root barrier separating the hedge and crop to a depth of 50 cm effectively eliminated yield reductions in the cereal crop (VanDenBeldt, 1990).

Srivastava (1986) observed decrease in yield of *rabi* sorghum, safflower and chickpea when grown with *Leucaena* hedgerows spaced 4.5 m apart. Row-wise competition studies revealed maximum yield reduction in chickpea (50%), followed by safflower (31%) and sorghum (28%). This was reported to be due to competition for light and moisture (Srivastava and RammohanRao 1989).

Many crops have been tested in alley cropping trials in the Indian semi-arid tropics, and all suffer in varying degrees from the competitive effects of hedgerows. Generally, during *kharif* season cereal crops (sorghum and pearl millet) were found most tolerant, with yield reductions averaging about 25 per cent in wide alleys across various sites and years (Singh *et al.*, 1989c). This is due to shallow (< 60 cm) aggressive rooting pattern and relatively short growing season of cereals which compete favourably with *Leucaena* for available moisture. Oilseed crops including sunflower, groundnut and castor were intermediate in tolerance.

In a study at ICRISAT, sunflower yields were reduced by 50 per cent in 5.4 m alley width (ICRISAT, 1986). Few pulse crops, with the exception of pigeonpea have been tested in the alley cropping trials in India. Pigeonpea often failed when rainfall was low and alley width was narrow.

Growth and yield of crops declined from 150 to 30 per cent of sole crop as the distance from the hedge-cum-pole row decreased from 5 to 0.3 m. The presence of polythene root barrier between *Leucaena* rows and field crops had a marked effect on crop growth and it completely eliminated any reduction in crop yield, although shading by the hedge cum pole rows reached 30 to 85 per cent of full sunlight. These results clearly showed that alley cropping in the semi-arid tropics induced competition for moisture between the trees and the field crops which severely reduced crop yield (Singh *et al.*, 1989b). Gaddanakeri (1991) obtained highest *rabi* sorghum grain yields (23.4 q/ha) when *Leucaena* live bunds were trenched, which was 18 and 28 per cent increase over polythene barrier and untrenched treatments. The competitive effects of hedgerows on seasonal crops were also reported by many researchers (Hoeskstra, 1983; Randhawa and Venkateshwarlu, 1986).

In semi-arid tropics under post-rainy cropping situation (*rabi* season) where crops are grown under receding soil moisture, higher magnitude of competition was noticed. Results of a study carried over a period of 4 years at Bijapur showed mean yields of 39 and 56 per cent of sole sorghum in 3.6 m and 6.6 m alley widths respectively (AICRPDA, 1988). The alley crop yields were still lower in years with below normal rainfall. All these studies indicate that in the semi-arid tropics the main competition between the hedgerows and arable crops is for moisture and to some extent for light and space.

2.1.6 Effect of alley cropping on soil and crop

Several authors have reviewed potential of agroforestry, including alley cropping, for soil conservation and for maintenance of soil fertility (Young, 1989). Lal (1989c) after a series of experiments concluded that alley cropping has potential as a sustainable alternative to shifting cultivation. Alley cropping allows for (1) longer cropping period, with increased land use intensity, (2) rapid and effective soil fertility regeneration by inclusion of selective multipurpose tree species (MPTs) and (3) more intensive cropping with reduced requirements for external inputs.

2.1.6.1 Erosion control

Sufficient soil cover with plant residue under conditions of erosive rains in the humid and subhumid tropics, can effectively reduce runoff and soil erosion. In addition, contour hedgerows of woody species that can form a solid barrier will help in soil and water conservation (Lal, 1975). Results of observations made in different parts of the tropics have shown that hedgerows of woody species reduce soil erosion and runoff (Lal 1987). Hedgerow intercropping with mulching has recommended as a means to tackle severe erosion problem in Haiti (Zimmerman, 1986). *Leucaena* hedgerow plants were very effective in controlling seasonal runoff and erosion on a shallow Alfisol of ICRISAT (ICRISAT,1989). Lal (1989 b) working at Nigeria also found contour hedgerows of *Leucaena* quite effective in reducing water runoff and controlling soil erosion. Results of trials conducted at Bijapur district of Karnataka showed that growing of *Leucaena* on contour bunds has a beneficial effect on the crop yield and adds to income. It increases the moisture availability in the soil by reducing soil surface runoff water loss and moisture evaporation due to wind break and shade in the fields. The live contour bunds will also increase the organic matter availability due to leaf litter (Hegde, 1986). *Leucaena*, *khus*, weeping

love grass and mechanical barrier of rubbles at 0.3 m vertical interval reduced runoff and soil loss over control by 29.7, 53.9, 28.3 and 52 per cent respectively on deep black soils of Bijapur. *Leucaena* caused maximum adverse border effect on associated *rabi* sorghum and *khus* had minimum effect (Patil, 1990). Large-scale demonstrations by University of Agricultural Sciences at Bijapur have indicated that *Leucaena* can make effective live vegetative bund when established at regular wide intervals on the contour in Vertisols and Vertic Inceptisols. Crop losses from competition are offset by less soil erosion and increased fodder production (VanDenBeldt, 1990).

In a study at Los Banos, Philippines runoff and soil erosion were controlled to a great extent in alley cropping treatments using 1 m wide hedgerows strips of the shrub legume *Desmanthus virgatus* intercropped with maize in the 5 m wide alleys. The soil loss decreased from 127 t per ha in control to 41 t per ha in alley crop, mulching the prunings further reduced the soil loss to 3 t per ha. Similarly, the runoff, which was 347 mm in control reduced to 183 mm in alley cropping and 75 mm in alley cropping with mulching of the prunings (Paningbatan Jr., 1990).

2.1.6.2 Effect on crop yield

Leaf litter and prunings from hedgerows when returned to the alleys can provide large amounts of organic matter and increase nutrient levels. Although prunings from some woody leguminous species yield sizeable quantities of N, the efficiency of N use by associated crop is low and is affected by the composition and decomposition rate of the prunings, timing of pruning in relation to crop growth, and placement method (Guevara, 1976; Kang and Duguma, 1985; Read *et al.*, 1985; Wilson *et al.*, 1986; IITA 1986). Guevara (1976) estimated that the efficiency of N contribution from

Leucaena prunings by a maize crop was about 36 per cent. The effective N contribution from *Leucaena* and *Gliricidia* hedgerows to alley cropped maize was estimated by Kang (1987) at about 40 kg N ha⁻¹.

Results of a long-term alley farming trial conducted in southern Nigeria on sandy soil have shown that with addition of *Leucaena* prunings soil even without N application, maize yields sustained at a reasonable level of about 2 t ha⁻¹. However, to obtain high maize yield *Leucaena* prunings must be supplemented with fertilizer N because of the low direct contribution of the prunings (Kang *et al.*, 1981). Investigations with *Gliricidia* hedgerows also showed that even partial removal of the prunings lowered maize yield, though application of inorganic N can compensate. Nutrients removed from the farm in fodder harvests should be returned to the soil through the manure or fertilizer; or through a short fallow to ensure sustainability of crop yields (Kang *et al.*, 1990).

A primary purpose of alley cropping in the humid tropics is the green manure benefit from prunings application. Data from various studies in semi-arid tropics on effect of prunings application in alley cropping appear somewhat contradictory. In a two-year study at Solapur application of *Leucaena* prunings significantly increased grain yield of *rabi* sorghum by 74 and 26 per cent at 0 and 25 kg N ha⁻¹ levels respectively. No beneficial effect of prunings application occurred at 50 kg N ha⁻¹. Mere association of *Leucaena* showed 12-17 per cent reduction in yield of sorghum compared with control (Narkhede and Ghugare, 1987b). Studies at CRIDA, Hyderabad (Korwar, 1992) over 2 years on *kharif* sorghum showed an yield increase of 18 and 3 per cent by prunings application in pearl millet and sorghum respectively over sole crops.

But, at ICRISAT incorporation of 3-10 t ha⁻¹ of prunings per annum had negligible effect on crop production (ICRISAT, 1989). In a study with fingermillet at Bangalore, *Leucaena* prunings application did not improve ragi yields, however reduction of cutting height from 1.5 m to 0.3 m had a marked effect on improvement of crop yield (AICRPDA, 1987a). Prakash and Bhushan (1987) from Agra reported 15 to 23 per cent improvement in wheat yield by incorporation of *Leucaena* leaves before sowing in *Leucaena*+wheat system. Studies at Bijapur (AICRPDA, 1988) over 4 years show a mean response of 8 and 19 per cent on *rabi* sorghum grain yield with prunings application in 3.6 and 6.6 m alleys respectively.

In Hawaii maize yield of 5 t ha⁻¹ were reported with prunings application as compared to 0.4 t ha⁻¹ where no prunings were applied (Ssekabembe, 1985). Rosecrance and Kuo (1989) reported increased grain yields of maize due to alley cropping in all the 9 tree species tested, the highest increase was with *S.sesban* and lowest with *Cassia siamea*. Studies at Nigeria have shown that maize alley cropped with *Gliricidia* met its N requirement through *Gliricidia* prunings. Grain cowpea following maize as alley crop with *Gliricidia* required no fertilizer application (Kang *et al.*, 1981). Gichuru and Kang (1989) got increased yields in maize by prunings application, but cowpea did not respond to the same when alley cropped with *Calliandra* hedgerows. Lal (1989a), based on his 6 years study at Nigeria reported decrease in maize grain yield by 10 per cent on an average when alley cropped with *Leucaena* or *Gliricidia* and prunings applied as compared with monoculture. In contrast to maize, cowpea yield decline was 50-70 per cent. Macklin *et al.* (1988) reported 60 and 80 per cent yield increase in alley cropped maize in 1985 and 1986 respectively with dense (2 m x 0.5 m) spaced *Leucaena* hedgerows as compared with sole crop. This increase was mainly through green manure application at the rate of 28 and 30 t ha⁻¹ (on wet basis) in 1985 and 1986 respectively.

Though prunings application had been quite promising under humid tropics, but under semi-arid tropics it is not yet clear. Green manures have little residual effect in continuous cropping situations. Yield increases from *in-situ* production and incorporation of green manures is more due to the "legume effect" (the enhanced production of a grain crop planted after a legume fallow or crop) than to the incorporated green manure *per se* (Singh, 1965).

The variability in response to prunings application in alley cropping under semi-arid tropical conditions prevents any definitive recommendation. Green fodder of the quality of *Leucaena* is a valuable commodity in both rural and urban India, it is unlikely that the use of prunings from hedgerows as green manure can be extended to the farm unless there are clear and consistent advantages in crop yield (Singh *et al.*, 1989b).

2.1.7 Economics

Economic evaluation is obviously an important tool to assess a technology. Agronomic experiments conducted on small plots do not provide adequate information on economic feasibility of a highly labour-intensive system such as alley cropping (Lal, 1989c).

Verinumbe *et al.* (1984) using a linear programming model, indicated that *Leucaena* - maize alley farming was economically attractive. Although more labour was required to prune trees but less fertiliser and herbicides were needed. The authors concluded that under severe cash constraint and where hired labour was available at relatively low cost, a *Leucaena* - maize alley cropping was most promising system.

In Kovilpatti, it was found that returns from *Leucaena* + sorghum alley cropping were 10 to 13 thousand rupees per hectare. The returns were only 3.25 to 7.2 thousand in sole sorghum (AICRPDA, 1984c).

On black soil at Bellary alley cropping system of *Leucaena* + rabi sorghum gave Rs.4,600 while sole sorghum gave only Rs.2,100 per hectare when the alley width was 4.2 m (Srivastava, 1986).

In low rainfall areas like Ananthapur (A.P.), *Leucaena* grown in alley width of 2 m with groundnut as intercrop gave the highest monetary returns of Rs.6,489 per hectare while the return from groundnut crop were Rs.5,330 per hectare. Similarly, the monetary returns from the pure stand of pearl millet, pigeonpea and *Leucaena* were Rs.300, Rs.616 and Rs.6,117 per hectare respectively, while with alley cropping the returns were Rs.4,172, and Rs.4,449 per hectare for *Leucaena* + pearl millet and *Leucaena* + pigeonpea alley cropping respectively (AICRPDA, 1986).

Economic comparison of the most remunerative alley and annual crops over a wide range of prices for *Leucaena* dry fodder for both Alfisol and Vertic Inceptisol was carried out at ICRISAT (ICRISAT, 1989). Both trials revealed that the economic superiority of alley cropping was small and was confined to the price range of Rs 0.8 - 1.6 kg⁻¹. Below this range annual crops gave the best economic returns, and sole *Leucaena* dominated above Rs 1.6 kg⁻¹. The poor performance of alley cropping on the Alfisol was partly due to lack of response to mulching.

Lal (1989c) concluded that net returns per hectare was in the following order: alley cropping 2 m with herbicides < traditional system < alley cropping 2 m < no - till < alley cropping with 4 m. The return per unit of labour, however, was in the order of alley cropping 2 m with

herbicides < alley cropping 2 m < alley cropping 4 m with herbicides < alley cropping 4 m < traditional system < no-till system. Korwar (1992) also reported economic advantage of alley cropping over sole cropping of pearl millet or sorghum.

2.2 Agrosilvicultural system

Agrosilviculture, the practice of growing arable crops and trees together is an age old practice among farmers all over the world. It is also referred to as parkland system or two-tiered system. A mixture of annual and perennial plants in an agrosilvicultural system interact. Sometimes these interactions are masked or overlooked. There could be positive and negative economic and/or physical interactions that offset one another. The interaction could be below-ground and/or above ground. A mixture of trees and crops could be located in a resource-rich environment where the various components each have sufficient light, nutrients and/or water. Or, perhaps, the system under observation is simply too complex to separate interactions and site effects of the individual components. Further, different arable crops perform differently when grown mixed with different tree species.

2.2.1 Positive interactions

There are many examples of positive interactions between tree and crop components in an agrosilvicultural system. The *Faidherbia albida* (Syn. *Acacia albida*) - grain system of West Africa has been much studied over the past 20 years (Felker, 1978). Many authors have shown an enhanced effect of this tree on crops growing underneath. The *Prosopis cineraria* - millet mixtures of eastern Rajasthan, India has also received much attention (Mann and Saxena, 1980).

Dancette and Poulain (1969) compared sorghum planted away and under *A.albida* with and without fertilizer. Sorghum yield was double and groundnut yielded nearly 30 per cent more under the trees. Similar results were reported by Charreau (1974) for millet; crops grown under acacia canopies produced 150 per cent more yield than crops grown in open space. More recently Poschan (1986) has shown yield increases of 76 per cent for maize and 36 per cent for sorghum grown under *A.albida*. Examination of the yield components showed higher 1000 grain weight, and more grains per plant for the crops grown under *A.albida*. It showed that water availability was greater under trees during anthesis and grain filling (Poschan, 1986) because of improvement of soil water holding capacity, reduced evapotranspiration or other related factors.

Many soil parameters are improved under *A.albida* trees. Dancette and Poulain (1969), confirming earlier reports found 40 per cent more organic carbon and nitrogen, 42 per cent more exchangeable calcium and moderate increases in P and K in soils under *A.albida* compared to soils away from the trees. They concluded that green manure additions of over 100 t per ha would be necessary to provide equivalent soil improvement. Obviously, the improved soil conditions under *A.albida* trees are the result of nutrient and organic matter accumulation over long periods of time.

Although there are no comparative yield data for cereal/*Prosopis cineraria* associations in Rajasthan, India; many authors state that grain yields are higher when grown under it (Singh and Lal 1969; Leakey and Last, 1979; Mann and Saxena, 1980). There is evidence that the tree is not competitive with crops. Soil under *P.cineraria* trees is generally higher in organic carbon, total nitrogen, phosphorus and potassium than elsewhere in the field and under other tree species (Singh and Lal, 1969). In addition,

the tree is believed to have a rather unique rooting pattern, which does not seem to compete with crop growth. Muthana *et al.* (1984) excavated a 20 year old *P.cineraria* tree to a rooting depth of 7.5 m. Horizontal extension of lateral roots of this specimen was less than 1 m from the trunk. The local practice of annually lopping the trees for the highly valued fodder soon after crop harvest ensures that the canopy never gets large enough to shade subsequent crops.

In *A.albida* the annual shedding of leaves at the outset of the rainy season is widely known (Wickens, 1969). The tree would be practically leafless during arable cropping period. Although the cause of this shedding is not known, the end result of it is to provide litter fall to the soil underneath, at the same time allowing light to penetrate to the crop canopy. Since the active growth phase is in dry season, the tree is believed to obtain water (and thus nutrients) beyond the crop root zone, which is depleted of water during the dry season. Root depths of 15-20 m are believed to exist (Charreau, 1974).

Kulkarni *et al.* (1970) found that growth and yield of *rabi* sorghum and cotton grown in association with *P.cineraria* were better than crops grown away from tree in black soils of Karnataka. Intercropping of *Leucaena* with sorghum and pearl millet produced significantly higher green forage yield compared to sole crops and this was attributed to positive interaction between *Leucaena* and sorghum, and pearl millet (Gill *et al.*, 1982).

In silvipastoral system of *Hardwickia binata* and grasses, biomass production of the tree component was not adversely affected due to the presence of grasses but in the case of *Albizia amara* grasses significantly reduced the biomass production of the tree at Jhansi (Deb Roy, 1989) so,

H.binata has better compatibility with under-storey vegetation. Muthana and Harsh (1985) observed after seven years growth, higher height increment (73.5 cm/year) in *H.binata* than many other species including *Leucaena* (32 cm) at Jodhpur. In the initial stages of growth (at 31.5 months/age). *H.binata* was found slow growing (140 cm height and 0.73 cm DBH) as compared to *Leucaena* (223 and 2.8) and neem (221 and 2.13) at Urlikanchan near Pune (Relwani and Gandhe, 1989).

Temporal interactions were also found important in agroforestry. Agricultural fields fallowed to perennial vegetation invariably improve site to the benefit of subsequent agricultural crops (Young, 1989). Similar effects were noticed in parklands and rangelands; felled trees leave behind "islands of fertility" where grasses and crops thrive on accumulated nutrients and organic matter. These islands of fertility disappear with time (Tiedeman and Klemmedson, 1986).

2.2.2 Negative interactions

Negative interactions between trees and crops are usually the result of direct and strong competition for limiting resources. Despite, the positive benefits from trees like *F.albida* in parklands, other species are clearly detrimental to crop and grass production (VanDenBeldt, 1990).

Prajapati *et al.* (1971) studied the effect of *Prosopis juliflora* trees growing near a cropped field in black soils of Bellary (Karnataka) and observed that the yields of rabi sorghum were reduced to a considerable extent upto a distance of 28 m from the tree row. Roots of the trees extend to 30 m into the field, reducing sorghum yields by 80 per cent over this range. This was attributed to competition of *P.juliflora* with sorghum for moisture and nutrients.

The competition between trees and crops increased with increase in tree population. A trial at ICRISAT Hyderabad showed the effect of tree population on grain yield of millet. Low population (400-1300 trees/ha) of young *Leucaena* trees lopped twice at 3 m height during the cropping season had little effect on crop yield. However, competition increased linearly with increasing tree population. At the highest tree population tested (10,000 trees per hectare), yield reduction was about 30 per cent (VanDenBeldt, 1990).

Eucalyptus planted on field boundaries reduced the production of arable crops (wheat, rice and mustard). The average loss in annual crop production was estimated at 12, 16 and 20 per cent respectively with rotation age of 8, 9 and 10 years (Ahmed, 1989). In the 9th and 10th years, the losses were as high as 46 and 49 per cent respectively, indicating strong competitive effects of eucalyptus with increasing age.

2.2.3 Below ground interaction

Conventional belief suggests that trees and crops are complementary because they exploit moisture and nutrients from different soil depths. This portrays trees as ideal "nutrient pumps" and complementary, uncompetitive extractors of water from the soil profile. Recent evidence indicated that trees aggressively exploit the crop root zone for nutrients and water.

A recent study of five common agroforestry tree species with maize as intercrop showed that a majority of their fine (<2 mm) roots occurred in the top layers of the soil (Jonsson *et al.*, 1988). This is also true with trees in rangelands (Belsky *et al.*, 1989). The primary effects of this is

competition with crop roots for nutrients and water. Allelopathic interactions in this root zone milieu has been proposed by several authors, but clear evidence is lacking.

There is substantial evidence that the presence of trees does, in many cases positively affect soil nutrient status (Young, 1989), and several of these - shifting cultivation systems, alley cropping and soil enrichment of parkland species - have been cited. However, these examples are not universally applicable. Nitrogen - Fixing Trees (NFTs) are promoted as superior contributors of soil fertility in agroforestry systems. The fact that a species may nodulate does not necessarily mean that it aggressively fixes N in the field. Also, NFTs may not be better always in enhancing soil fertility over the long term than non-NFTS (Beer, 1988).

Chandrasekharaiah (1986) reported decrease in available phosphorus under *Leucaena*, eucalyptus and teak as compared with control. However, available P_2O_5 increased under casuarina, *D.sissoo* and Bamboo. The soil organic carbon and available K_2O increased by the influence of all the tree species tested.

Itnal (1987) observed decrease in available phosphorus of soil under *Leucaena* as compared with control. Organic carbon, available phosphorus and available potash increased due to presence of tree species like Teak, *Dalbergia sissoo*, Eucalyptus, *Acacia catechu*, *A.nilotica*, Casuarina, *Acacia auriculiformis* and *Albizia lebbeck*. Under *Leucaena* organic carbon and available potash increased.

Depletion in available P_2O_5 and available K_2O was observed with tree species (*A.auriculiformis*, *Dalbergia latifolia*, *D.sissoo*, Eucalyptus, *Leucaena* and Teak) as compared to non-tree control. However, organic

carbon increased by 50-200 per cent with tree species. Organic carbon, available P_2O_5 and available K_2O levels in soils immediately adjacent to the tree line were less than those observed at 2.7 and 5.4 m distance from the tree line (Nadagoud, 1990).

Direct competition for soil water has been demonstrated in windbreaks in both temperate (Kort, 1988) and semi-arid (VanDenBeldt, 1990) regions. Recent evidence for competitive extraction of water has been suggested for agroforestry parklands and rangelands (Belsky *et al.*, 1989). In pastures, increasing tree population decreased evapotranspiration of forage component but increased overall pasture evapotranspiration (Eastham and Rose, 1988).

Various agroforestry studies involving mixtures of trees and crops either as spatial mixed or spatial zoned indicated competition between the tree and the crop component. The competition was more near the tree and decreased with increasing distance from the tree. All the tree species tested competed with the crop, but, the degree of competition varied with tree species. *Leucaena* competed least among the tree species tested (Chandrasekharaiah, 1986; Itnal, 1987 and Bhat, 1988).

Reports exist of phreatiphytic trees in arid zones exuding excess water through their roots at night to the surface soil layer to the benefit of shallow rooted species growing nearby (Mooney *et al.*, 1980).

2.2.3.1 Effect of root pruning on below ground interaction

Root pruning at relatively shallow depths (< 1 m) has been suggested as a method of removing underground competition between trees and crops. Kort (1988) cited numerous examples from studies with temperate windbreaks demonstrating the cost-effectiveness of this practice.

Singh and Dayal (1974) studied the effect of trench dug along the field boundary of a 15 year old plantation of *Dalbergia sissoo* and *Acacia nilotica*. Elimination of *D.sissoo* roots from the crop zone increased the yield of cotton from 956 to 1950 kg ha⁻¹ and that of tobacco from 1206 to 1859 kg ha⁻¹ by pruning root of *Acacia nilotica*.

Verinumbe and Okali (1985) reported that elimination of roots alone by trenching (30 cm deep) did not have a significant effect on maize height, growth, total dry matter population, grain yield, number of cobs per plant, average cob weight and weight of grains per cob of maize intercropped with coppiced teak spaced 1.8 m x 1.8 m.

Dadhwal *et al.* (1986) reported the beneficial effect of trenching on the arable crops. A trench (0.5 m wide and 1m deep) dug out by the side of eucalyptus trees minimized the root effect to some extent on *rabi* crops. With increase in distance from the tree line, surface soil moisture (0-15 cm) did not change appreciably. Relatively higher moisture was observed in trenched plots compared to non-trenched plots. Similarly near the tree line, moisture was higher in trenched than non-trenched plots. *Kharif* maize yields were not affected appreciably by trenching. In *rabi* wheat the effect of trenching was found to be quite pronounced. Yield did not change appreciably in trenched plots, but, considerable increase in yield was recorded in non-trenched plots away from the tree line. The lesser root effect in *kharif* than *rabi* can be explained by better rainfall in the former case. Therefore, it is inferred that the ill effect of boundary trees roots on the *rabi* crops can be reduced by trenching.

2.2.4 Above ground interaction

The presence of trees in croplands can have profound effects on the micro-climatic environment that can either promote or inhibit growth and

yield of the crop. Above ground influences depend on the agroforestry system under investigation, the age of the system and the environment where it exists. Radiation a major energy input into the system will be affected to a great extent.

The amount of light intercepted by an agroforestry system depends on the amount of incident light and the fraction of light intercepted through the system to the soil surface. Shading affected under-storey crops by reducing temperature and the amount (and quality) of light. When competition for water or light favours the tree component, the tree canopy may suppress the crop canopy and reduce the crop light interception and productivity (Monteith *et al.*, 1989). Shading has been reported to cause crop losses in pastures (Somarriba, 1988).

Shade may be beneficial when it reduced soil temperature during crop germination and establishment in hot climate. Cereal germination and plumule extension were reduced and even arrested by high soil temperature found in semi-arid areas during periods of crop establishment (Ong and Monteith, 1984). Soil temperature under *F.albida* trees in the Sahel have been shown to be 8°C cooler than unsheltered soil. Shade has also been attributed to increased N content of pasture grasses (Wilson *et al.*, 1986). In arid areas shade benefited crops. In Kandi area of Punjab, crop yields were studied in association with *Acacia nilotica* trees scattered in fields (Singh *et al.*, 1989 a). The crop yields were good in shaded area (the area North to trunk which is shaded almost whole day), poor in exposed area (area South to trunk which is exposed to sun) and medium in open area (where there is no shade). The average yields of gram, wheat and taramira were 7.7, 25.3, 10.4 q ha⁻¹ in shaded area; 3.1, 9.9, 7.2 q ha⁻¹ in exposed area; and 5.8, 14.4 and 9 q ha⁻¹ respectively in open area.

Total annual light interception for tree-crop combinations are likely to be higher than for sole crops (Ong *et al.*, 1989). In an agroforestry system with annual crops, trees maintain a canopy throughout the year, and thereby light interception by the system increases. This is probably the case with *F.albida* system, where the tree is leafless through much of the cropping season, but is foliated in the dry season.

In agrosilvicultural studies involving different tree species and arable crops in semi-arid tropics it was observed that light transmission ratio (LTR) in the mixture was lower as compared with no-tree control. It was observed in all the tree species, though the degree of reduction varied with tree species. Among the tree species highest LTR was observed in teak followed by eucalyptus, *Leucaena*, and casuarina (Chandrasekharaiah, 1986; Bhat 1988). Nadagoud (1990) also observed maximum LTR in teak and the minimum in *D.sissoo* and *A.auriculiformis*. The LTR was higher on southern side of the trees as compared to Northern side. Further, LTR was lowest near the tree line and increased gradually with increasing distance from tree line.

2.2.4.1 Effect of canopy management on above ground interaction

Canopy management can decrease the above ground competition between trees and crops. Mann and Saxena (1980) stated that a six-fold increase in mungbean (*Vigna radiata*) was obtained when grown under 12 year old *Acacia tortilis* spaced 4 x 4 m when the trees were pruned. Pruning also suppressed the spreading habit of the tree by encouraging erect and rapid growth.

Verinumbe and Okali (1985) reported that in a coppiced teak intercropped with maize, competition for light was a more critical limiting factor than root competition, because teak was planted at close (1.8 x 1.8 m)

spacing. Reduced light severely limited photosynthesis, caused etiolated height growth and lowered production of maize. The above-ground competition between teak and maize was removed by decoppicing the teak shoots. Combined with shading, root competition of teak appreciably reduced total dry matter yield and average cob weight of maize.

Muthana and Arora (1977) also reported the beneficial effect of canopy management of eight year old *Holoptelia integrifolia* tree on intercropped guar.

Pollarding at two metres height, effectively removed the strong competitive effect of dense canopy of 2 x 8 m spaced four year old *Leucaena* trees on intercropped *kharif* sorghum. Pollarding produced 50 per cent grain yield of sole sorghum. Light and heavy lopping respectively produced 3 and 10 per cent yield of sole sorghum. (Singh et al., 1989c).

Some lopping of *A.albida* for wood and fodder is practiced traditionally in the semi-arid tropics of Africa (Miehe, 1986). Poschan (1986) opined that this is important because crops grown under young or low-branched trees can suffer, presumably because of light competition. In matured trees, the effect of lopping is mimicked phenologically through annual leaf fall at the outset of rainy season. However, in recent studies by Jama and Getahun (1991) leaf shedding was not observed in young trees (upto 5 yrs age) of *Acacia albida*. The shade adversely affected intercrops of maize and cowpea. They stressed the need to understand mechanism of leaf-fall/retention in this species.

2.2.5 Comparative performance of crops with tree species in mixtures

Crops differ in their compatibility with different tree species. Different crops may respond in different way in association with different species of trees with respect to their growth and yield.

Reduction in maize yield was 30 per cent in *Leucaena*, 58 in *sesbania*, 30 in *casuarina*, 56 in *Melia azedarach*, 44 in *Acacia* and 27 per cent in *eucalyptus* when four rows of crops on either side of the tree species were harvested separately to study effect of tree species on the yield of maize (AICRPDA, 1984a).

At Bellary (AICRPDA, 1984b) *A.nilotica* caused greater yield reduction in *rabi* sorghum and safflower than *eucalyptus* and *neem*. The reduction, which was attributed to competition for moisture increased with age. Chandrasekharaiah (1986) observed that *A.nilotica* and *bamboo* had more adverse effect on yield of intercropped maize and safflower. Among the tree species tested, *Leucaena* (local) had the lowest adverse effect. In another study made at Bellary, it was observed that sorghum and safflower varied in their yield reduction in association with *A.nilotica*, *neem* and *eucalyptus* (Srivastava, 1986). In *rabi* sorghum and safflower yields were reduced by 3 to 8 and 13 to 18 per cent respectively due to *neem* and *eucalyptus*, while *Acacia nilotica* reduced the yield by 42 and 46 per cent in *rabi* sorghum and safflower respectively. Hence, it was concluded that *A.nilotica* was most competitive and sorghum was less affected as compared with safflower.

Sheikh and Haq (1986) based on their studies in Thar desert of Pakistan concluded that tree species like *D.sissoo*, *Tamarix aphylla* and *Populus deltoides* were not different in their yield depressing effect on crops. Crop yields reduced upto 3 m with *eucalyptus* and upto 2 m only with *casuarina* (AICRPDA, 1987a).

Rice yields reduced by 0 to 52 per cent in association with *eucalyptus*, *casuarina* and *Albizia molucana*, but, *Dalbergia sissoo* and *teak* has no adverse effect on the yield of rice at Prabhunagar, Dharwad (Nadagoudar, et al., 1988).

Itnal (1987) observed varying degrees of influence of strip plantations of different tree species on the growth and yield of *rabi* sorghum grown by the side of the strip in black soils under rainfed conditions. While all the tree species reduced the yield, maximum yield reduction was observed with eucalyptus, lowest reduction was observed with *Leucaena* and teak. The yield suppression effect decreased with increasing distance from the tree strip. These findings suggest that strip plantation had adverse effect on the crop growing in its vicinity. Lowest runoff was collected through the strips of teak, casuarina and *Leucaena*.

Bhat (1988) observed in a sunflower-pigeonpea intercrop interplanted with tree species that, bamboo caused more yield reduction in sunflower than the other tree species tested. *Leucaena* affected the yield least, the yield of pigeonpea reduced to a great extent with eucalyptus and *D.sissoo*. Pigeonpea yields were affected least with *Leucaena* as compared with other species. Though *Leucaena* in full tree form (unpruned and unlopped) is reported to be quite competitive with crops, especially under rainfed conditions (Singh *et al.*, 1989 b), in this study it was found least competitive probably because native species was grown in this study while Hawaiian giant was grown in other studies.

Nadagoud (1990) reported higher adverse effect of eucalyptus than *Leucaena*, *A.auriculiformis* and casuarina on associated groundnut crop under irrigated conditions. Among the five crops tested viz., maize, groundnut, pearl millet, pigeonpea and cotton, the yield reduction was highest in maize and lowest in cotton and was in the above order. However, the economic analysis revealed that highest net income was realized with cotton followed by pigeonpea and least in groundnut.

The above studies indicate that, among the various tree species tested *A.nilotica* and eucalyptus were most competitive with crops. Among *kharif* crops cotton was least affected and among *rabi* crops sorghum was least affected.

MATERIALS AND METHODS

III MATERIALS AND METHODS

Details of materials used and techniques adopted in the present investigation are described in this chapter.

3.1 Location

The following four field experiments were carried out for two years (1989-90 and 1990-91) at the Regional Research Station (RRS), Bijapur, which is located in the Northern dry zone (zone-3) of Karnataka state. Bijapur is situated at 16°49'N latitude, 75°42'E longitude and at an altitude of 593.8 m above MSL.

S.No.	Title	Experiment site (Block No)
1.	Influence of root pruning and cutting interval of <i>Leucaena</i> hedgerows on alley cropped <i>rabi</i> sorghum	VIII
2.	Evaluation of effects of N and <i>Leucaena</i> prunings application to alley cropped <i>rabi</i> sorghum	VIII
3.	Effect of tree species and their management on intercropped <i>rabi</i> sorghum	J
4.	Screening of <i>rabi</i> crops for intercropping with different tree species.	J

3.2 Climate

The data on climatic parameters, viz., rainfall, maximum and minimum temperature, relative humidity, open pan evaporation and number of rainy days recorded at meteorological observatory, RRS Bijapur during cropping period and the mean of past 50 years (1939-1988) are presented in Appendix-I and figures 1, 2 and 3.

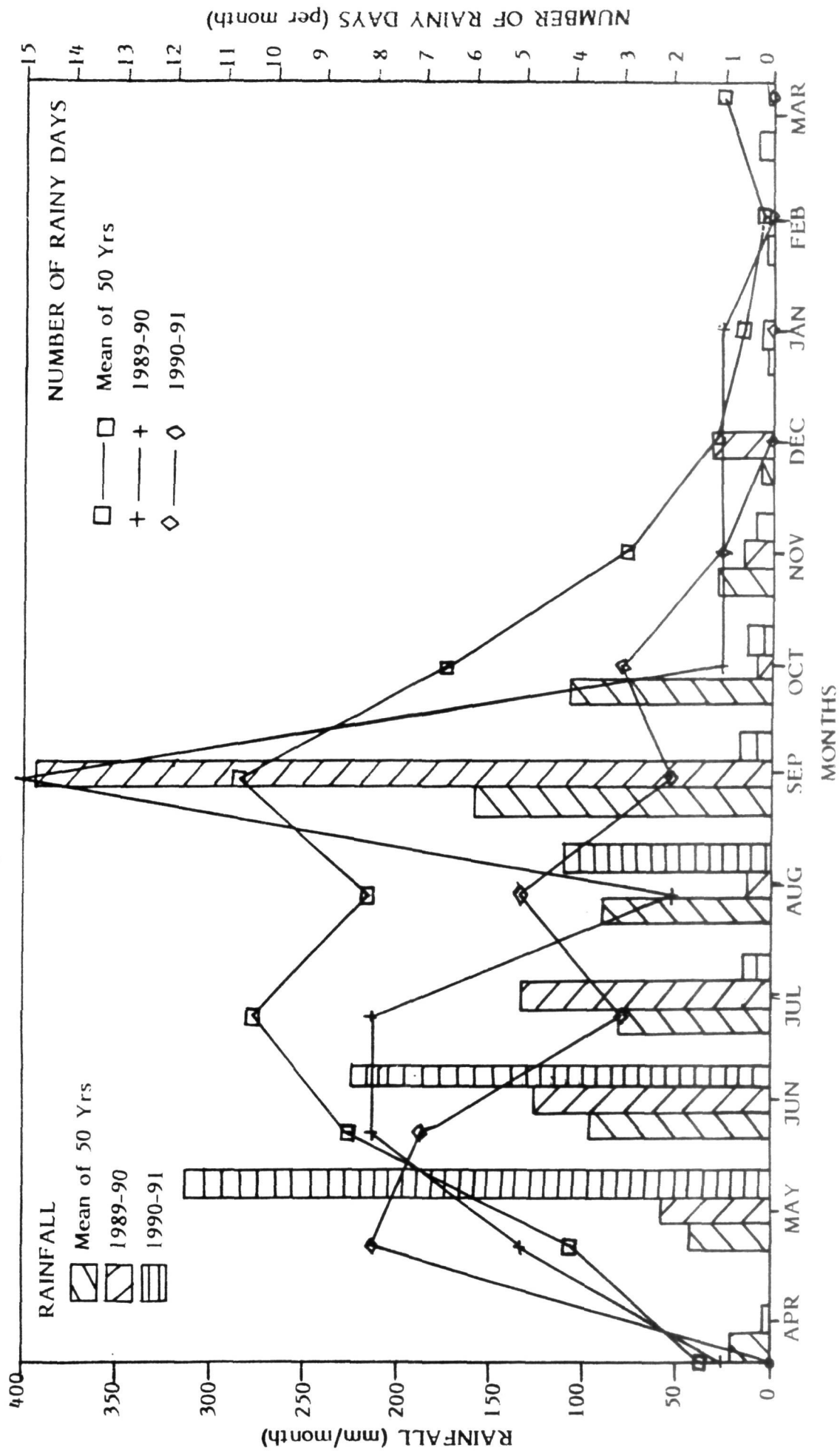


Fig.1. MONTHLY RAINFALL AND NUMBER OF RAINY DAYS AT REGIONAL RESEARCH STATION, BIJAPUR

The mean annual rainfall for the past 50 years at RRS, Bijapur was 643.6 mm distributed over 55.4 rainy days. Maximum rainfall (157.5 mm) was received in 10.4 rainy days in September, followed by October (106.9 mm) in 8.1 rainy days. Of the total rainfall about 41.6 per cent was received during *kharif* season (June-August), 47 per cent during *rabi* season (September-February), and 11 per cent during summer season (March-May). The highest mean monthly maximum temperature (38.5°C) and the lowest mean monthly minimum temperature (15.3°C) were observed in May and December months respectively. Mean monthly maximum relative humidity (80.1%) was observed for July, August and September months, and minimum (45.2%) for March month. The highest (399.9 mm) open pan evaporation was recorded during May and minimum during November (146.5 mm).

Total rainfall of 788.3 mm and 703.1 mm was received during 1989-90 and 1990-91 respectively which was 22 and 9 per cent excess compared to normal rainfall during 1989-90 and 1990-91 respectively. Though the total rainfall during both the years was higher than that of 50 years average, the number of rainy days were only 43 and 29 during 1989-90 and 1990-91 respectively as compared to 55.4 rainy days per year for 50 years average. The per cent distribution of rainfall during 1989-90 and 1990-91 in summer (March-May), *kharif* (June-August) and *rabi* (September-February) seasons was 8 and 44.8; 34.8 and 49.8; and 57.2 and 5.4, respectively. The rainfall distribution during 1989-90 was favourable for growth of *rabi* crop. However, during 1990-91 it was erratic. In the month of May 313.1 mm (44.8% of year's total) rainfall was received, which was not useful to arable crops (as they were not sown). However, *Leucaena* hedgerows and trees were benefited by this rain. Further, rainfall during September was only 16.6 mm (2.4% of total) and against 393.4 mm (50% of total) in 1989-90 and 157.5 mm (25% of total) during past 50 years. Hence, the *rabi* crops were adversely affected.

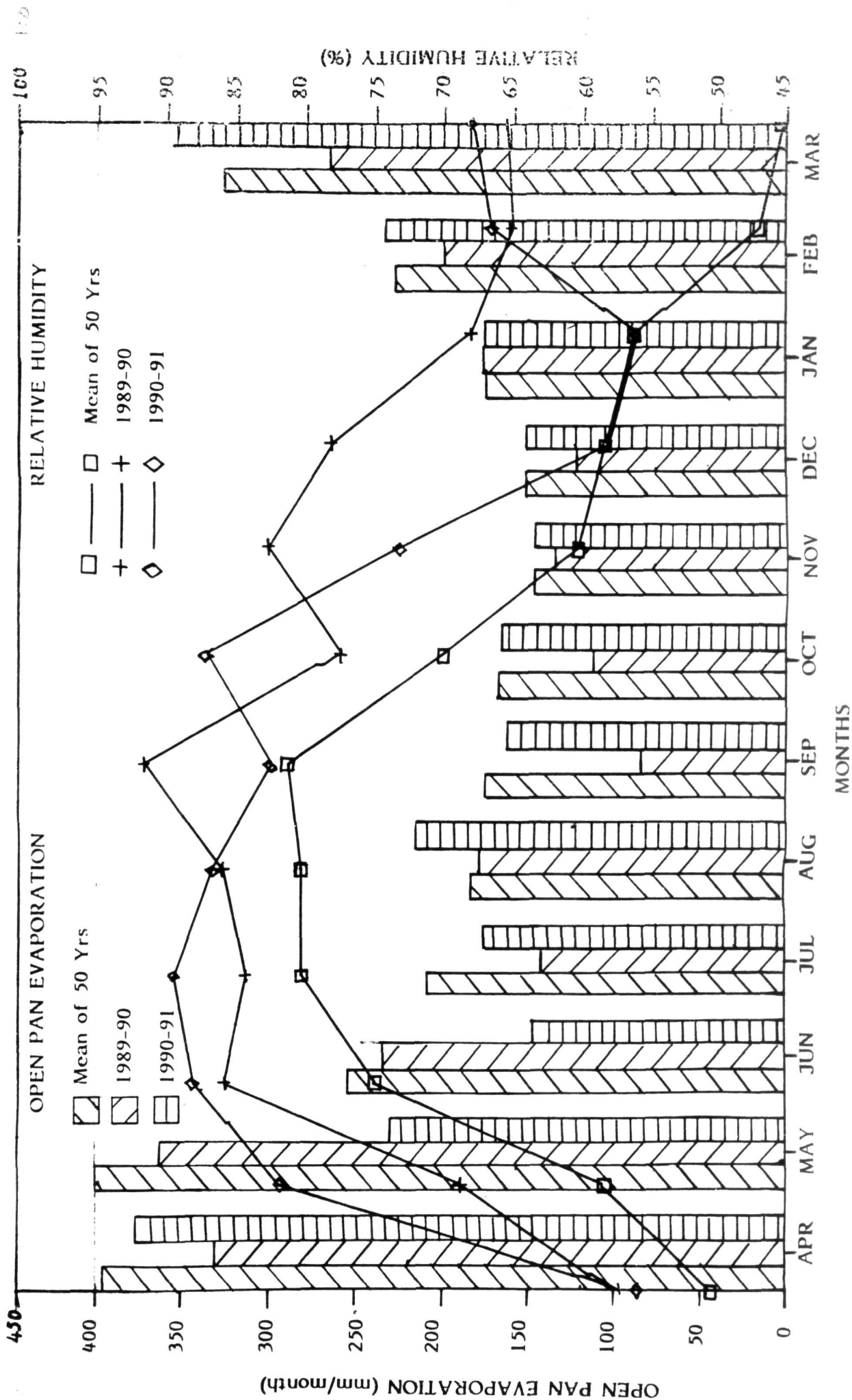


Fig.2. OPEN PAN EVAPORATION AND RELATIVE HUMIDITY AT REGIONAL RESEARCH STATION, BIJAPUR

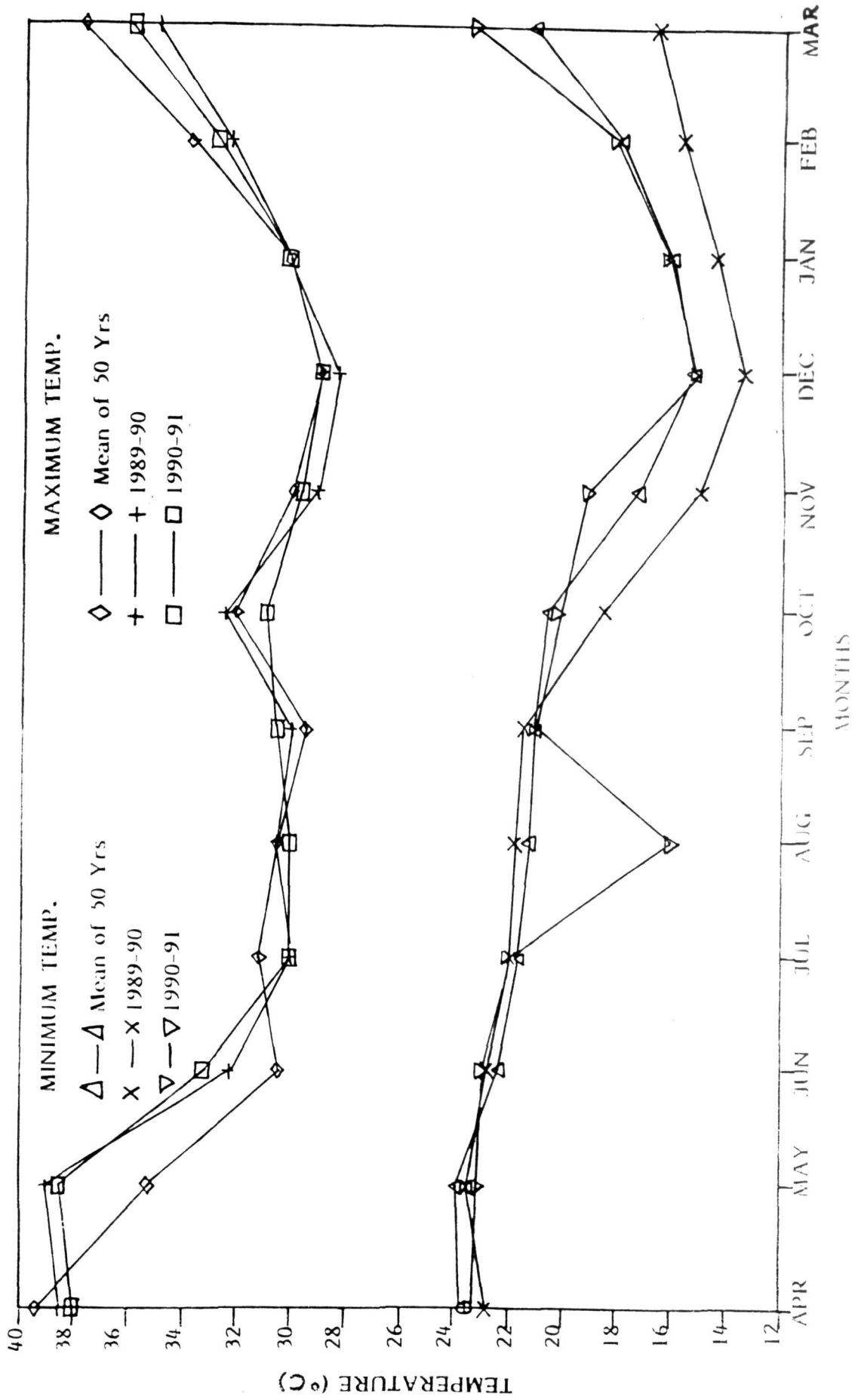


Fig. 3. MONTHLY MEAN MINIMUM AND MAXIMUM TEMPERATURES AT REGIONAL RESEARCH STATION, BEAPUR

During 1989-90, the highest mean monthly maximum temperature was observed in May (39°C) and the lowest minimum temperature in December (13.4°C). The maximum relative humidity (91.4%) was observed in September and minimum (57%) in April. The monthly open pan (USWB class A) evaporation was maximum (362.1 mm) in May and minimum (84.7 mm) in September.

During 1990-91, the highest mean monthly maximum temperature was observed in May (39.4°C) and the lowest minimum temperature (15.2°C) in December. The highest relative humidity (89.3%) was observed in July and lowest (55.8 %) in April. Monthly open pan evaporation was highest (375.9 mm) in April and lowest (146.4 mm) in November.

3.3 Soils

Experiments 1 and 2 were conducted on a deep (> 90 cm) black soil (Managoli series), classified as fine, montmorillonitic isohyperthermic family of Typic Chromusterts. Experiments 3 and 4 were conducted on shallow (< 30 cm) black soil (Telagi series), classified as fine montmorillonitic family of Vertic Ustocrepts. Composite soil samples were collected from 0 to 30 cm soil depth from each experimental site before initiation of the experiments. The soil samples were air dried, powdered and allowed to pass through 2 mm sieve and were analyzed for physical and chemical properties (Table 1).

3.4 Previous crops grown on the experimental area

On sites of experiment 1 and 2, *rabi* sorghum crop was grown with recommended package of practices during 1987-88, and during 1988-89 it was fallow. On sites of experiment 3 and 4 *Cenchrus ciliaris* grass was grown during the preceding years.

Table 1 : Physical and chemical properties of the soils of the experimental site

Properties	Block VIII	Block J	Method
I. Physical properties			
Sand (%)	21.0	60	Hydrometer method (Piper, 1966)
Silt (%)	17.5	12	Hydrometer method (Piper, 1966)
Clay (%)	59.0	27	Hydrometer method (Piper, 1966)
Loss of solution (%)	2.5	1	
Maximum water holding capacity (%)	55.0	35	Field method (Piper, 1966)
Bulk Density (Mg m ⁻³)			Core Sampler method (Black, 1965)
0 - 15 cm	1.28	1.42	
15 - 30 cm	1.30	1.45	
30 - 60 cm	1.32	-	
60 - 90 cm	1.32	-	
Moisture content at:			
1/3 bar (%)	35.0	20.1	Pressure membrane apparatus (Black, 1965)
15 bar (%)	16.2	12.5	Pressure membrane apparatus (Black, 1965)
II. Chemical properties			
p ^H	8.5	8.2	1:2.5 (Richards, 1954)
E.C (DS/m)	0.48	0.36	Richards (1954)
Organic carbon (%)	0.60	0.52	Walkely and Black's wet oxidation method
Available P ₂ O ₅ (kg/ha)	8.30	15.0	Olsen's method (Jackson, 1967)
Available K ₂ O (kg/ha)	570.0	300	Ammonium acetate method (Black, 1965)

3.5 Experimental details

The details of treatments included in these 4 field experiments are furnished below. The other details in respect of variety, spacing, fertilizer, date of sowing and date of harvesting are furnished in Table 2. All the experiments were conducted for two years (1989-90 and 1990-91).

3.5.1 Experiment 1: Influence of Root Pruning and Cutting Interval of *Leucaena* Hedgerows on Alley cropped Rabi sorghum

Leucaena leucocephala (K8) hedgerows established in 1984 were used in this experiment. The paired (60 cm) hedgerows were spaced 6.6 m apart and were regularly cut to a height of 10-15 cm till initiation of this experiment. Last pruning was done in March 1989.

3.5.1.1 Treatments : There were 3 main plot and 4 sub plot treatments

A. Main plots (Root pruning)

1. *Leucaena* hedgerows - roots unpruned + *Rabi* sorghum (RP₀)
- *2. *Leucaena* hedgerows - roots pruned + *Rabi* sorghum (RP₁)
3. Sole *Leucaena* (SL) without root pruning

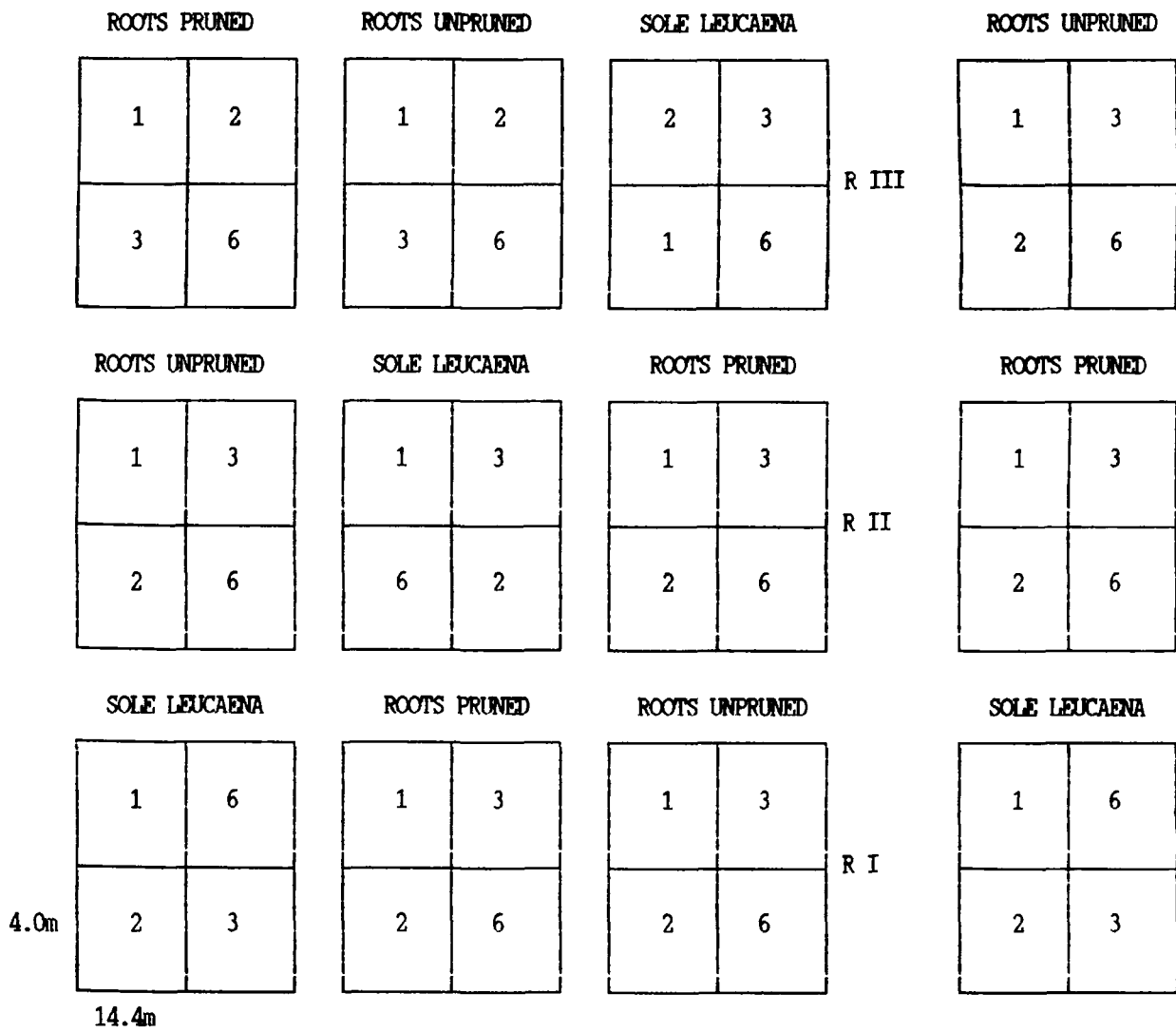
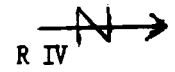
B. Sub-plots (cutting interval)**

1. 1 month
2. 2 months
3. 3 months
4. 5 months

* Achieved by ploughing to a depth of 30 cm on either side of paired hedgerows with a country plough during mid-*kharif* season (August month).

Table 2 : Other Experimental Details

Details	Experiment 1	Experiment 2	Experiment 3	Experiment 4
Crop	Rabi Sorghum	Rabi Sorghum	Rabi Sorghum	Safflower Sunflower
Variety	M35-1	M35-1	M35-1	A-1
Spacing (cm)	60 x 15	60 x 15	60 x 15	60 x 30
Fertilizer (N, P ₂ O ₅ , K ₂ O kg/ha)	25-25-0	*-25-0 (* N as per treatment)	50-25-0	37.5-37.5-12.5
Date of Sowing				
1989-90	16-9-89	16-9-89	7-9-89	7-9-89
1990-91	9-10-90	9-10-90	8-10-90	8-10-90
Date of Harvesting				
1989-90	10-2-90	10-2-90	18-1-90	18-1-90
1990-91	18-2-91	18-2-91	5-2-91	5-2-91
				14-12-89
				8-1-91



CUTTING INTERVAL OF *LEUCAENA*

- 1 = 1 month interval
- 2 = 2 months interval
- 3 = 3 months interval
- 6 = 6 months interval

FIG. 4 LAYOUT PLAN OF EXPERIMENT 1



A



B

Plate 1. Root pruning of Leucaena hedgerows (Expt. 1)
A. Front view B. Rear view



Plate 2. Leucaena roots pruned by the root pruning operation (Expt. 1)

** One common cutting of *Leucaena* was done in all the treatments during mid-August, and from then onwards the above cutting interval was followed till harvest of *rabi* sorghum. The next cutting in all the treatments was the common cut in mid-August. The prunings of the hedgerows from the common mid-August cutting were applied to their respective alleys. After leaf-shedding the woody portion (sticks) of the prunings was removed from the plot for use as fuelwood. The later harvested prunings from hedgerows and all prunings from sole *Leucaena* were removed from the plots for use as fodder/fuelwood. A low cutting height of 10-15 cm was adopted at each cutting.

3.5.1.2 Design, Layout and Replications

The experiment was laid out in split-plot Design (Fig.4) with root pruning in main plots and pruning frequency in sub-plots. For analysing yield of *Leucaena* all the 3 main plots were considered and for analysing sorghum growth and yield only the first two main plots were considered as sorghum crop was not grown in third main plot which was sole *Leucaena*. The treatments were replicated four times.

3.5.1.3 Plot size

Gross : 14.4 x 4 m

Net : 7.2 x 3 m

3.5.2 Experiment 2 : Evaluation of Effects of N and *Leucaena*

Prunings Application to Alley Cropped *Rabi* Sorghum

Leucaena leucocephala (K8) hedgerows established in 1984 were used in this experiment. The paired (60 cm) hedgerows were spaced 6.6 m apart and were regularly cut to a height of 10-15 cm till initiation of this experiment. Last cutting was in done in March 1989.



A



B

Plate 3 Luxuriant growth of Leucaena before mid-August cutting (Expt. 1)

A. Sole Leucaena B. Leucaena hedgerows

3.5.2.1 Treatments: This experiment had 3 main plot and 4 sub-plot treatments.

A. Main plot (Prunings Application) - PA

1. Alley cropped *rabi* sorghum without prunings application (PA₀)
- *2. Alley cropped *rabi* sorghum with prunings application (PA₁)
3. Sole sorghum (SS)

B. Sub-plots (N levels/ha)

1. 0 kg N
2. 12.5 kg N
3. 25 kg N
4. 50 kg N

* One cutting of *Leucaena* hedgerows was done in mid-August. Prunings obtained from this cutting were applied to the alleys. After leaf-shedding woody portion (sticks) of the prunings were removed from the plots for use as fuelwood. After the mid-August cutting, regular cutting was done in all the plots at 2 months interval till harvest of *rabi* sorghum. After this the next cutting was in mid-August. The prunings from the mid-August cutting in no prunings application treatments (PA₀), and the latter harvested prunings from all the treatments were removed from the plots for use as fodder/fuelwood.

3.5.2.2 Design, Layout and Replications

The experiment was laid out in split-plot Design (Fig.5), with prunings application in main plots and N levels in subplots. The treatments were replicated four times.

3.5.2.3 Plot size

Gross : 14.4 x 4 m

Net : 7.2 x 3 m



R IV

SOLE SORGHUM

100	0
50	25

PRUNINGS NOT APPLIED

50	0
100	25

PRUNINGS APPLIED

0	100
25	50

R III

PRUNINGS NOT APPLIED

50	0
25	100

PRUNINGS NOT APPLIED

25	50
100	0

PRUNINGS APPLIED

25	0
50	100

SOLE SORGHUM

25	0
50	100

R II

SOLE SORGHUM

0	50
25	100

PRUNINGS APPLIED

0	50
100	25

SOLE SORGHUM

0	100
25	50

PRUNINGS NOT APPLIED

25	0
100	50

R I

PRUNINGS APPLIED

0	25
100	50

4.0m

14.4m

N LEVELS

0 - 0 kg N/ha

25 - 12.5 kg N/ha

50 - 25 kg N/ha

100 - 50 kg N/ha

FIG. 5 LAYOUT PLAN OF EXPERIMENT 2



Plate 4. Leucaena prunings applied alley plot (Expt.2)

3.5.3 Experiment 3: Effect of Tree Species and Their Management on Intercropped *Rabi* Sorghum

Tree species planted in 1983 at 5 x 2 m spacing were used in this experiment.

3.5.3.1 **Treatments:** Four tree species and a sole crop (no trees) in combination with 4 levels of tree management were tested.

A. Horizontal Factor (Tree species)

1. *Eucalyptus tereticornis* (Eucalyptus)
2. *Azadirachta indica* (Neem)
3. *Dalbergia sissoo* (Sissoo)
4. *Hardwickia binata* (Anjan)
5. Sole crop (No trees)

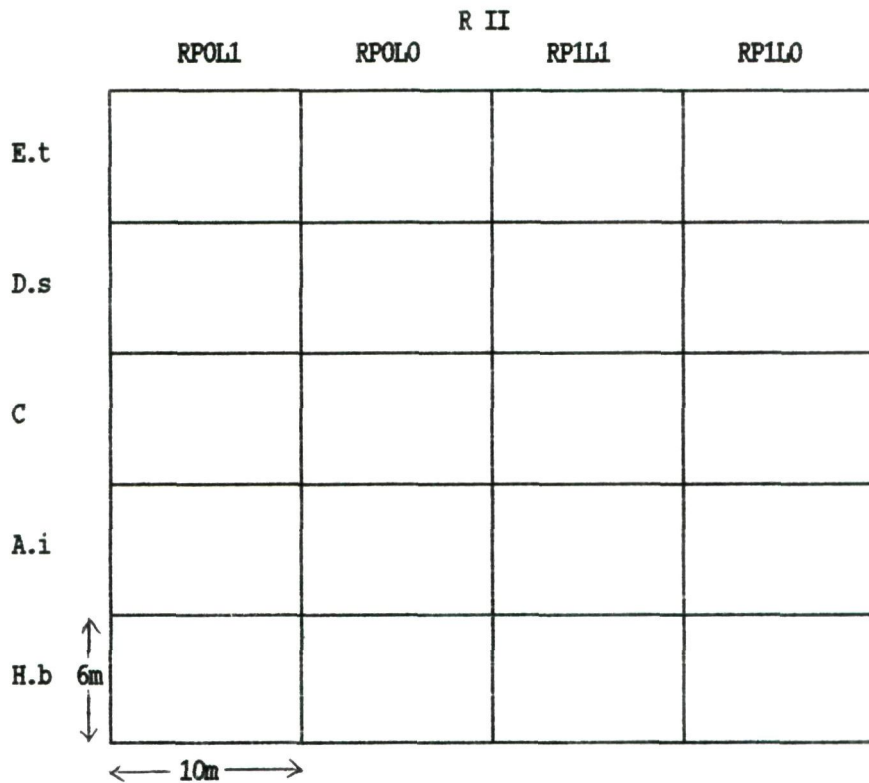
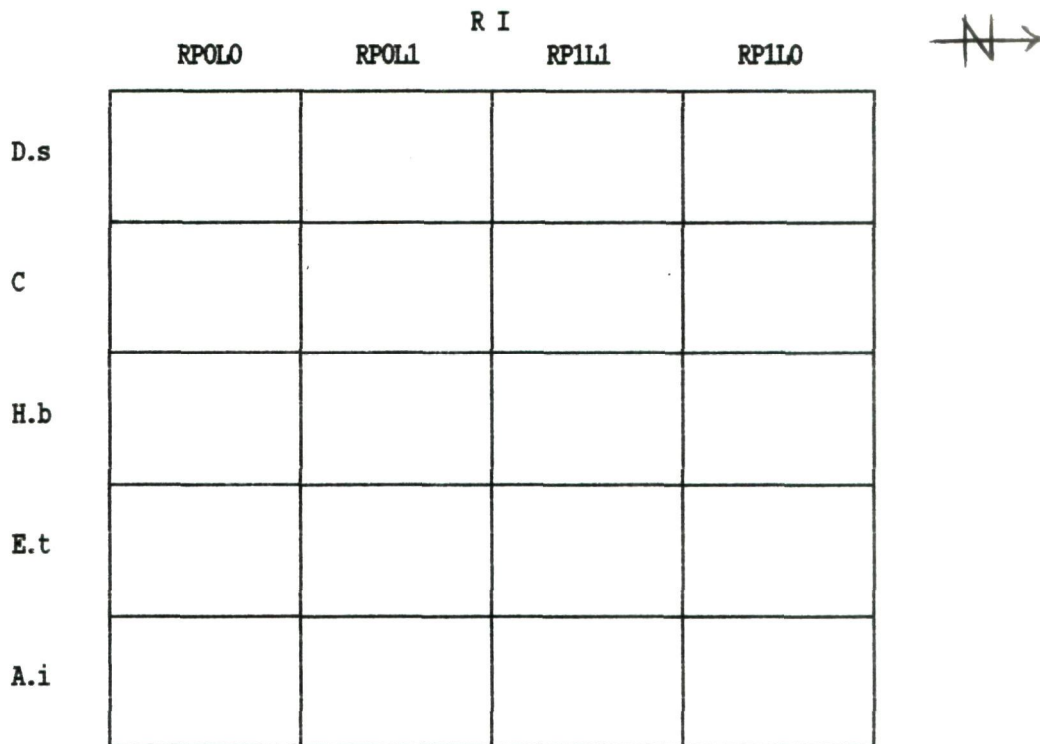
B. Vertical factor (Tree Management) *

1. Control (unmanaged - no root pruning and tree lopping)
2. Root pruning with no lopping of trees
3. No root pruning with lopping of trees
4. Root pruning with lopping of trees

* Root pruning done by ploughing close to tree rows on either side to 30 cm depth with tractor drawn MB plough during mid-*kharif* season (in root pruning treatment). Twigs from each tree were lopped upto 2/3 height from the base of the tree before sowing of *rabi* sorghum (in lopping treatment).

3.5.3.2 Design, Layout and Replications

The experiment was laid out (Fig.6) in strip plot design. Tree species formed horizontal treatments and tree management formed vertical treatments. They were replicated two times.



Tree species

- A.i - *Azadirachta indica*
- D.s - *Dalbergia sissoo*
- E.t - *Eucalyptus tereticornis*
- H.b - *Hardwickia binata*
- C - Sole crop (no trees)

Tree management

- RPOLO - Control trees (unmanaged)
- RP1LO - Root pruning with no lopping of trees
- RPOL1 - No root pruning with lopping of trees
- RP1L1 - Root pruning with lopping of trees

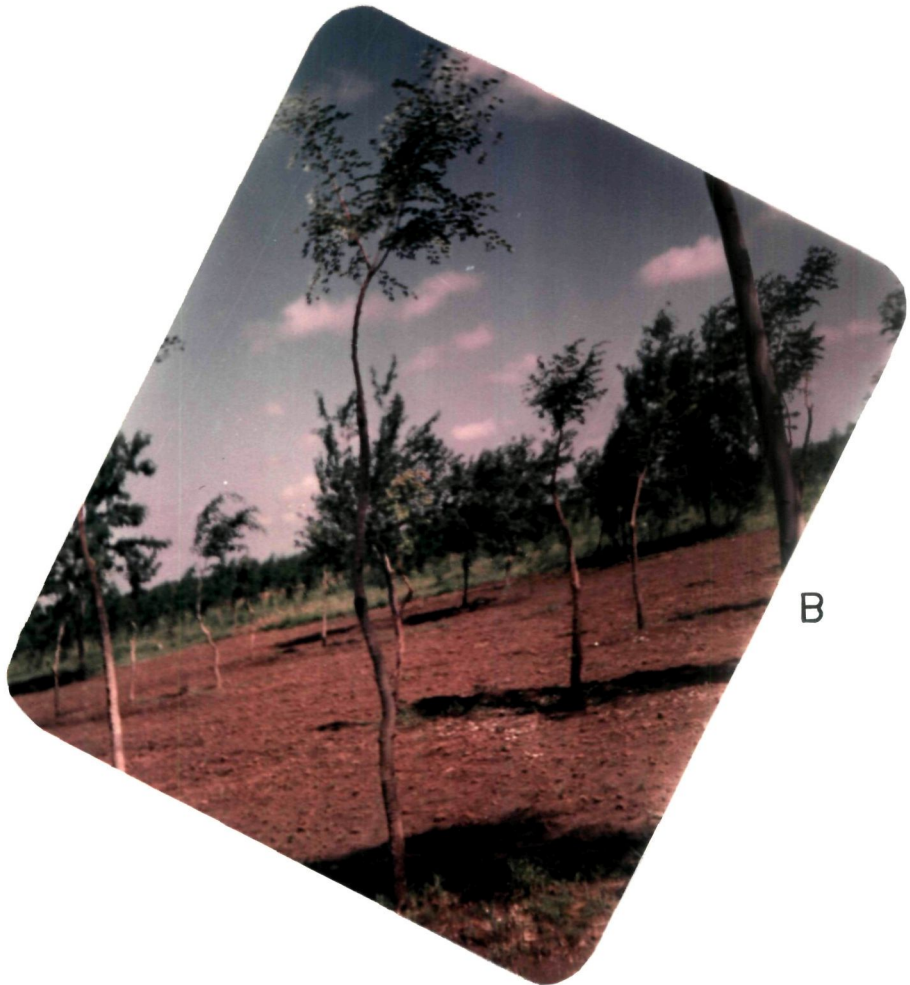
FIG. 6. LAYOUT PLAN OF EXPERIMENT 3



Plate 5. Tree roots pruned by the root pruning operation (Expt. 3)



A



B

Plate 6. Hardwickia binata (Anjan) trees (Expt.3)
A. Control trees B. Lopped trees

3.5.3.3 Plot size

Gross : 60 m²

Net : 10 m²

3.5.4 Experiment 4: Screening *Rabi* Crops For Intercropping with Different Tree Species

Tree species planted in 1983 at 5 x 2 m spacing were used in this experiment.

3.5.4.1 Treatments: Three crops were tested with four tree species and as well as sole crop (no trees).

A. Horizontal Factor (Tree species)

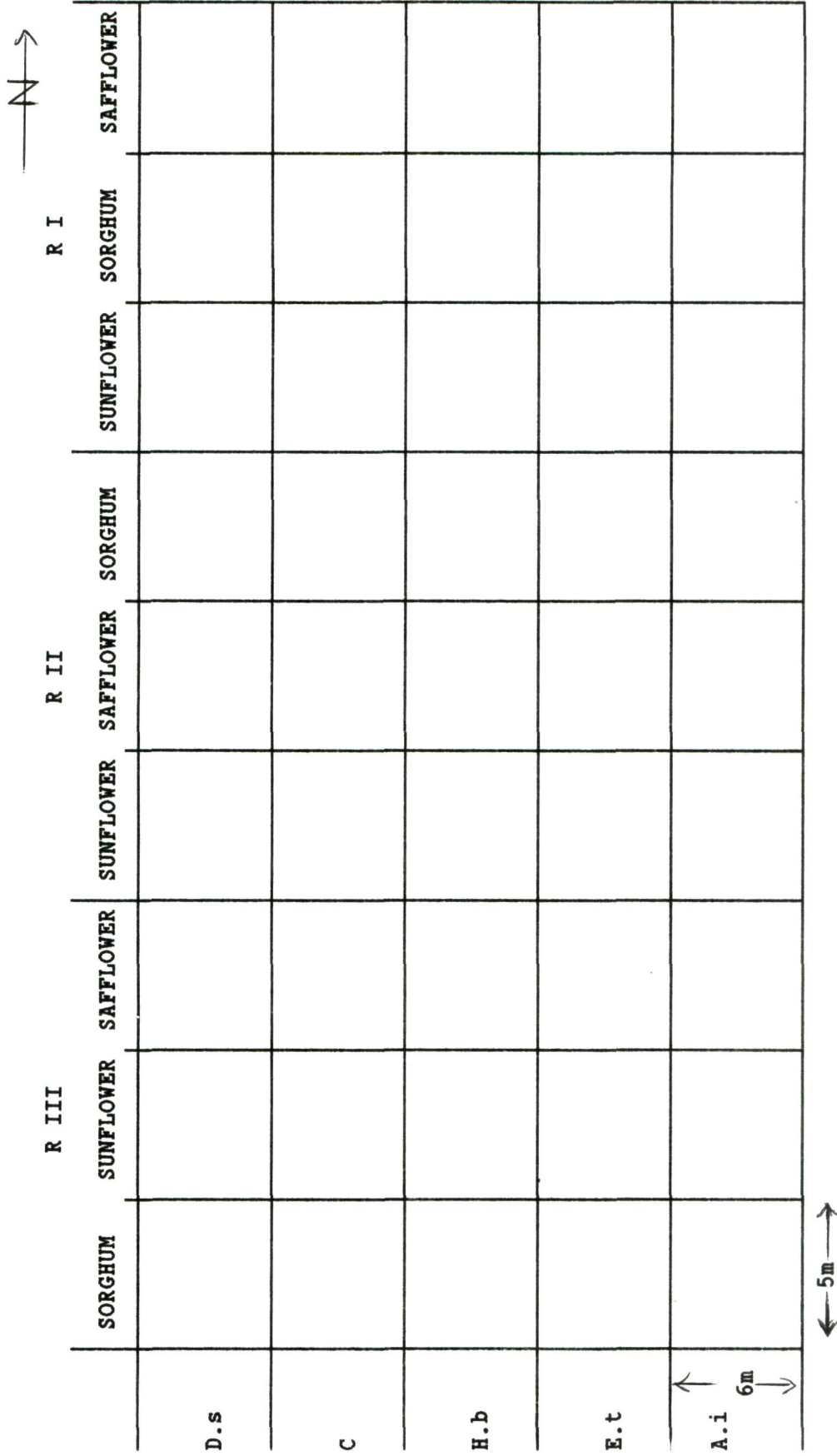
1. *Eucalyptus tereticornis* (Eucalyptus)
2. *Azadirachta indica* (Neem)
3. *Dalbergia sissoo* (Sissoo)
4. *Hardwickia binata* (Anjan)
5. Sole crop (No trees)

B. Vertical Factor (crops grown in *rabi* season)

1. Safflower
2. Sorghum
3. Sunflower

3.5.4.2 Design, Layout and Replications

The experiment was laid out (Fig.7) in strip-plot design. Tree species formed horizontal treatments and crops formed vertical treatments. They were replicated three times.



A.i - *Azadirachta indica*

D.s - *Dalbergia sissoo*

E.t - *Eucalyptus tereticornis*

H.b - *Hardwickia binata*

C - Sole crop (no trees)

FIG. 7 LAYOUT PLAN OF EXPERIMENT 4

3.5.4.3 Plot size

Gross : 30 m²

Net : 10 m²

3.6 Cultural operations

Experiments 1 and 2 were situated side by side in the same field and similarly experiment 3 and 4 were situated side by side in the same field. To utilize sole *Leucaena* yield of experiment 1 for calculation of land equivalent ratio (LER) in experiment 2, and sole sorghum yield of experiment 2 for calculation of LER in experiment 1, experiments 1 and 2 were treated as single unit for the purpose of carrying out different cultural operations. Similarly, experiments 3 and 4 were treated as single unit.

3.6.1 Land preparation

During each year land was ploughed once during summer, followed by harrowing twice. Later, the clods were crushed to prepare a fine seed bed. Harrowing was done once again before sowing.

3.6.2 Irrigation

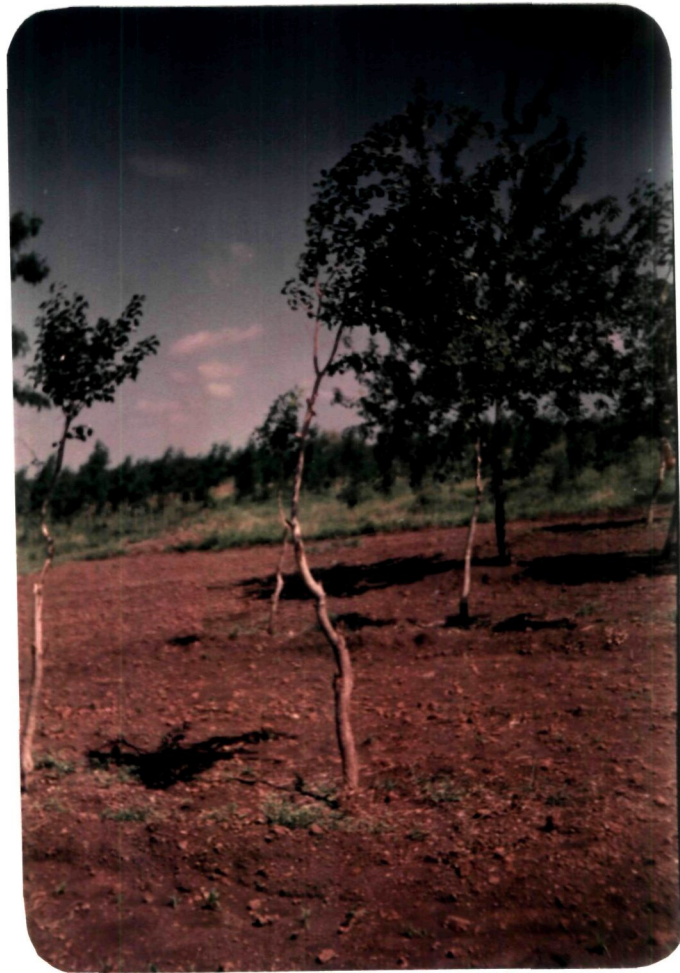
In 1990-91 season at the time of sowing of *rabi* crop, surface soil was dry, while the sub-surface soil had enough moisture. This was because of failure of rains in September. To ensure uniform germination, a light irrigation (of 10 cm depth) was given after sowing in all the 4 experiments.

3.6.3 Application of fertilizer

In experiment 1, 50 per cent of recommended N and full dose of recommended P₂O₅; in experiment 2, N as per treatment, and recommended dose



A



B

Plate 7. Dalbergia sissoo (Sissoo) trees (Expt.3)
A. Control trees B. Lopped trees



A



B

Plate 8. Neem trees (Expt. 3)

A. Control trees

B. Lopped trees

of P_2O_5 (Table 2) were applied in small furrows opened manually and mixed well before dibbling of sorghum seeds. In experiments 3 and 4 recommended dose of fertilizer (Table 2) was applied at sowing with bullock-drawn seed-cum-fertilizer drill.

3.6.4 Seed treatment and sowing

Sorghum seeds were treated with sulphur @ 2 g kg^{-1} against smut. In experiment 1 and 2 shallow furrows were opened and the seeds were hand-dibbled as per the spacing (Table 2). In an alley 10 rows of sorghum at 60 cm row spacing were accommodated. The first row of sorghum in the alley was 60 cm away from the hedgerow. Two to three seeds were dibbled per hill. In experiments 3 and 4 sowing was done with drill at the recommended row spacing (Table 2). Between 2 tree rows 5 crop rows at 60 cm row spacing were accommodated. The first crop row was about 1.3 m away from the tree row.

3.6.5 Aftercare

Thinning was carried out in all the experiments 15 days after sowing to maintain required plant population (Table 2). Two intercultivations and one hand weeding was done in all the experiments. Endosulfan (2 ml/litre of water) was sprayed once both on sorghum and *Leucaena* in experiments 1 and 2 to control aphids and psyllid bugs. In experiment 3 endosulfan was sprayed once on sorghum, and in experiment 4 endosulfan was sprayed once on sorghum and safflower to control aphids.

3.6.6 Harvesting

Harvesting of the crops was done after complete maturity as per dates shown in Table 2. First, the border plants were harvested and removed from the plot and then the net plot crop was harvested. The plants were



A



B

PLate 9. Eucalyptus trees (Expt.3)
A. Control trees B. Lopped trees

cut close to the ground and heads were separated from the stalk. The heads were dried in sun for 5 days and then threshed. Similarly the stalks were dried to constant weight and then weighed.

3.7 Collection of Data

Observations recorded on growth and yield of hedgerows, tree species and crops are given below.

3.7.1 Hedgerows - Yield of Prunings

The prunings obtained from the *Leucaena* hedgerows from the net plot area at each cutting were separated into leaf (leaf + stem with < 0.5 cm diameter) and wood (stem with > 0.5 cm diameter) and fresh weight recorded. Samples (500 g each) were taken from leaf and wood and the dry matter percentage was estimated by oven-drying the samples at 70°C to constant weight. The yield from different cuttings were summed up to obtain yield per year. The yield was expressed in terms of kilograms per hectare on oven dry weight basis as leaf, wood and total (leaf + wood) biomass. In the plots with prunings application treatment the leafy portion returned to the plot was not considered as yield. Only the material removed from the plot (net biomass harvest) was considered as yield (Net biomass harvest = Total biomass - leaf biomass applied to the alleys).

3.7.2 Trees

In each net plot, two central trees were used for recording observations viz., yield of loppings, height and diameter at breast height (DBH).

3.7.2.1 Tree height

The tree height was measured in June 1989 i.e. before initiation of the experiment and then once in a year (in June month). It was measured from the base of the tree to tip of the main stem and expressed in metres.

3.7.2.2 Diameter at breast height (DBH)

Diameter of the main stem was recorded in June 1989 and then once in a year (in June month) at 1.3 m height from the base of the tree and expressed in centimeters.

3.7.2.3 Weight of loppings

After lopping of trees in the lopping treatment, loppings were separated into leaf (leaf plus twigs with <0.5 cm diameter) and wood (twigs and branches with > .5 cm diameter) and their fresh weight was recorded. Samples (500 g each) were oven dried at 70°C to constant weight and per cent dry matter was determined. The loppings yield was expressed as leaf, wood and total biomass yield kg per tree on dry weight basis.

3.7.2.4 Dry matter accumulation in trees

In experiments 3, two trees with same height and DBH in each species, and each management treatment were tagged before initiation of experiment in June 1989. One set of trees was harvested that time, separated into stem, branches and leaves, and their fresh weight was recorded. A sample of 500 g each from stem, branches and leaves was oven dried to constant weight at 70°C. Thus, the dry weight of stem, branches, leaves and total was estimated at the initiation of the experiment. The second set of trees was cut in June 91 i.e. after 2 years of the experimentation and the dry

matter was recorded. The difference between the two dry matter readings was taken as dry matter accumulated over the two year period, and the annual dry matter accumulation was obtained by dividing this value by two.

3.7.3 Rabi sorghum

In experiments 1 and 2, five plants (one plant per row, from line no. 1 to line no. 5 from southern side of the alley to centre of alley) were selected per plot at random and tagged. In experiments 3 and 4 one plant per row was selected at random, thus a total of 5 plants were selected per plot and tagged. The observations on plant height and yield components were made on these plants.

3.7.3.1 Plant height

Height of the five plants was measured from base of the plant to base of the topmost fully opened leaf, upto heading and from base to tip of earhead after heading. The average height per plant was worked out and expressed in cm. The plant height was measured at 30, 60 and 90 days after sowing (DAS) and at harvest.

3.7.3.2 Dry matter

Above ground dry matter of 5 sorghum plants selected at random (as explained in 3.7.3) was determined by cutting the plants close to ground and drying them at 70°C to a constant weight. From this average dry matter per plant was calculated and expressed in g. The dry matter was recorded at 30, 60, 90 DAS, and at harvest.

3.7.3.3 Plant population at harvest

Row-wise count of the plant population at harvest in the net plot was done and expressed on hectare basis (area occupied by hedgerows/trees was included)

3.7.3.4 Number of ear bearing plants (effective population)

Ear bearing plants at harvest were counted row-wise in the net plot and expressed per hectare basis (area occupied by hedgerows/trees was included).

3.7.3.5 Ear weight per plant

Ears from the five tagged plants (3.7.3) were dried to constant weight and per plant ear weight was calculated and expressed in g.

3.7.3.6 Grain weight per plant (ear)

Grain weight from the ears of above 5 plants was recorded after threshing, grain weight per ear was calculated and expressed in g.

3.7.3.7 Grain number per ear

Grain number per ear was calculated from the grain weight per ear and the corresponding 1000 grain weight as follows.

$$\text{Grain number per ear} = \frac{\text{Grain weight per ear}}{1000 \text{ grain weight}} \times 1000$$

3.7.3.8 1000-grain weight

The weight of 1000 grains drawn from the grain yield of net plot was recorded and expressed in g.

3.7.3.9 Ear weight per hectare

Ears harvested row-wise from the net plot were dried to constant weight and their weight was recorded. From this, ear weight per hectare was calculated (area occupied by hedgerows/trees was included).

3.7.3.10 Grain, stover and biomass yield

The dried ears from each net plot were threshed row-wise and the grain weights were recorded and totaled to get net plot yield. From this per hectare grain yield was calculated (area occupied by hedgerows/trees was included). Similarly the row-wise stalk weight was recorded after drying them to constant weight, the weight of chaff (ear weight - grain weight) was added to this and was recorded as stover weight. From this per hectare stover yield was calculated. The sum total of grain and stover yield was calculated as biomass yield.

3.7.3.11 Harvest index

Harvest index was calculated as follows:

$$\text{Harvest index} = \frac{\text{Grain yield}}{\text{Biomass yield}}$$

3.7.4 Safflower

From each row one plant was selected at random, thus a total of 5 plants were selected per plot and tagged.

3.7.4.1 Plant height

Height of the 5 tagged plants was recorded as the length from the base of the plant to top of apical bud, average plant height was calculated and expressed in cm. The plant height was recorded at 30, 60 and 90 DAS.

3.7.4.2 Dry matter

At 60 days after sowing, in each plot 5 plants were cut at random @ one plant per row, their oven dry weight was recorded and per plant dry matter was calculated and expressed in g.

3.7.4.3 Grain weight per plant

Grain weight from the above five tagged plants (3.7.4) was recorded after threshing, grain weight per plant was calculated and expressed in g.

3.7.4.4 1000 grain weight

Thousand grains were counted from the net plot grain yield and their weight was expressed in g.

3.7.4.5 Grain yield

After drying the plants from the net plot were threshed row-wise and grain weights were recorded and totaled to get net plot yield. From net plot yield (including area occupied by trees) the grain yield per hectare was calculated.

3.7.4.6 Crop equivalent yield

Crop equivalent yield was calculated as the product of crop yield and price of the crop divided by the price of standard crop. *Rabi sorghum* was taken as a standard crop for calculating the crop equivalent yield per hectare.

$$\text{Crop equivalent yield} = \frac{\text{Crop yield} \times \text{Price of the crop}}{\text{Price of a standard crop}}$$

3.7.5 Sunflower

At random five plants were selected per plot @ one plant per row and they were tagged.

3.7.5.1 Plant height

Height of the 5 tagged plants was recorded as the length from the base of the plant to apical bud, average plant height was calculated and expressed in cm. The plant height was recorded at 30, 60 and 90 DAS.

3.7.5.2 Dry matter

At 60 days after sowing, in each plot 5 plants were cut at random ● one plant per row, their over dry weight was recorded, per plant dry matter was calculated and expressed in g.

3.7.5.3 Grain weight per plant

Grain weight from the above five tagged plants (3.7.5) was recorded after threshing and weight per plant was calculated and expressed in g.

3.7.5.4 1000 Grain weight

Thousand grains drawn from the net plot grain yield were weighed and expressed in g.

3.7.5.5 Grain yield

After drying, the plants from the net plot were threshed row-wise and grain weights were recorded and totaled to get net plot yield. The per hectare grain yield was calculated from net plot (including area occupied by trees)

3.7.5.6 Crop equivalent yield

This was worked out similar to the crop equivalent yield of safflower (3.7.4.6).

3.7.6 Other observations

Other observation made in addition to growth and yield of hedgerows, trees and crops are given below.

3.7.6.1 Light transmission ratio (LTR)

Light intensity was measured at noon time at crop canopy level using a Lux meter. In experiments 1 and 2, one observation was made at crop canopy level at a spot between the hedgerow and first crop line and another

observation was made at centre of the alley at crop canopy level and the average of these two readings was taken. Similarly in experiments 3 and 4, one reading taken near tree line and another at the centre of two tree lines and average was worked out. LTR was worked out by using the following formula (Yoshida *et al.*, 1972) and expressed in percentage.

$$\text{LTR}(\%) = \frac{\text{Light intensity in alley/under tree canopy but over sorghum/safflower/sunflower crop}}{\text{Light intensity over sorghum/safflower/sunflower in the absence of hedgerows/trees}} \times 100$$

3.7.6.2 Land equivalent ratio (LER)

Land equivalent ratio was calculated in experiments 1 and 2 as follows:

$$\text{LER} = \frac{\text{Grain yield of sorghum in Alley cropping}}{\text{Grain yield of sole sorghum}} + \frac{\text{Net biomass harvest of } Leucaena \text{ in alley cropping}}{\text{Net biomass harvest of sole } Leucaena}$$

In LER calculations, only the prunings removed from the plots (net biomass harvest) were considered as yields not the prunings returned to the alleys. While calculating LER in expt. 1, sole sorghum yield of expt. 2 receiving 25 kg N per ha (which is same level of management) was considered (as suggested by Willey, 1979). Similarly, while calculating LER in expt. 2 sole *Leucaena* yields of expt. 1 cut at 60 days interval was considered.

3.7.6.3 Soil moisture studies

Soil moisture was determined gravimetrically, at sowing, flowering and harvest stage of *rabi* sorghum in experiments 1 and 2. The samples were taken from 0-15, 15-30, 30-60 and 60-90 cm depth at two spots in each treatment. One spot was near the hedgerow and other was in the centre of the hedgerow. The average of these two spots is reported. In experiments 3 and 4, samples were taken at sowing, flowering and harvest stages of crops

from 0-15 and 15-30 cm depths at two spots in each treatment. One spot was near the tree line and other midway between the two (tree) lines. The average of these two spots is reported.

3.7.6.4 Determination of soil available N and organic carbon

Soil samples were collected in each plot from 0-15 cm soil layer at the time of sowing and harvest of *rabi* sorghum in experiment 2. In each plot 3 samples were taken (2 near the hedgerows and one in centre of alley) and mixed well. The soil samples were air-dried, lightly crushed and passed through a 2 mm sieve.

Available nitrogen was determined in the soil samples using the method advocated by Subbaih and Asija (1956). Organic carbon was determined in the soil samples by Walkley and Black wet oxidation method (Jackson, 1967).

3.7.6.5 Plant nitrogen analysis

Five plants @ 1 plant per row were collected from all plots of experiment 2 at the time harvest. The plants were partitioned into grains, leaves (with leaf sheath) and stem (including chaff) and were oven dried. The percentage of these parts viz., grain, leaf and stem in the total dry matter was worked out. The oven-dried samples were ground in a Willey mill to pass through 40 mesh sieve and analysed for nitrogen. The nitrogen was analysed by modified micro Kjeldal method (Jackson, 1967) using Tecater Kjeltac Auto 1030 analyser. The nitrogen concentration was multiplied with biomass yield and percentage of the components (viz., grain, stem and leaf) to obtain per hectare uptake of N in different parts.

The sum total of uptake in different parts was calculated as the total N uptake per hectare. Protein content of grains was worked out by multiplying the nitrogen percentage in grain with a factor 6.25 (Dubetz and Wells, 1968).

3.7.6 Economics

The cost of inputs and the price of outputs in the local market (Appendix II) and cost of cultivation (Appendix III) were considered, and net returns per hectare were computed. In experiment one and two, in the treatments where prunings were applied to the plots, that portion of prunings were not considered as outputs. Only the prunings removed from the plots (net biomass harvest) were considered as outputs, because only this portion was salable.

In experiment 3 the dry matter accumulated in the trees during that year only was considered as output for that year. Similarly the cost of cultivation for the particular year only. Annual dry matter accumulated in unmanaged treatment in a tree species of experiment 3 was taken as output for the respective tree species in experiment 4 for calculation of net returns.

3.8 Statistical analysis and interpretation of data

The data recorded on various characters were subjected to Fisher's method of analysis of variance and interpretation of data as given by Snedecor and Cochran (1967). The level of significance used in F and t-tests was $P=0.05$. Critical difference values were calculated wherever the 'F' test was significant. Correlation analysis was carried out to study the nature and degree of relationship between growth components and yield; and,

yield components and yield. Further, regression analysis was done to study the pattern of response of *Leucaena* to cutting intervals and response of sorghum to N application. In case of quadratic regression equation, $Y = a + bN + cN^2$, where Y is yield of sorghum; N is nitrogen level; and, a, b and c are constants, optimum N (N_{opt}) was estimated as $N_{opt} = -b/2c$.

EXPERIMENTAL RESULTS

IV EXPERIMENTAL RESULTS

Results of the four experiments, viz., 1. Influence of root pruning and cutting interval of *Leucaena* hedgerows on alley cropped *rabi* sorghum; 2. Evaluation of effects of nitrogen and *Leucaena* prunings application to alley cropped *rabi* sorghum; 3. Effect of different tree species and their management on intercropped *rabi* sorghum, and 4. Screening of *rabi* crops for intercropping with different tree species, conducted at Regional Research Station, Bijapur during 1989-90 and 1990-91 are presented in this chapter.

4.1 Influence of root pruning and cutting interval of *Leucaena* hedgerows on alley cropped *rabi* sorghum

The effect of three main plot treatments, viz., *Leucaena* hedgerows (roots unpruned), *Leucaena* hedgerows (roots pruned) and sole *Leucaena*; at four levels of cutting interval (1,2,3 and 6 months) of *Leucaena* on *rabi* sorghum and *Leucaena* was evaluated during 1989-90 and 1990-91.

4.1.1 *Rabi* Sorghum

4.1.1.1 Plant height (cf. Table 3, Fig.8)

30 DAS

At 30 days after sowing (DAS) plant height of *rabi* sorghum did not vary significantly due to root pruning, cutting interval and their interactions during both the years.

60 DAS

During the second year, root pruned hedgerows resulted in significantly more height of sorghum plants than root unpruned. During the first year also root pruning of hedgerows increased sorghum plant height but, the increase was statistically not significant. Mean data for the two

Table 3 : Plant height (cm) of sorghum at different growth stages as influenced by root pruning and cutting intervals of *Leucaena* hedgerows

Treatment	30 DAS			60 DAS			90 DAS			Harvest	
	1989-90	1990-91	Mean	1989-90	1990-91	Mean	1989-90	1990-91	Mean	1989-90	1990-91
	Mean	SEM ±	CD 5%	Mean	SEM ±	CD 5%	Mean	SEM ±	CD 5%	Mean	SEM ±
Root Pruning (RP)											
Roots unpruned	13.7	16.5	15.1	74.5	81.1	77.8	98.8	137.5	118.2	109.1	137.7
Roots pruned	14.1	16.5	15.3	83.3	90.7	87.0	110.8	152.9	131.9	122.9	153.1
SEM ±	0.14	0.24		2.34	2.04		3.77	3.06		3.60	3.07
CD 5%	NS	NS		NS	9.19	NS	NS	13.77		NS	13.8
Cutting Interval (CI)											
1 month	13.7	16.5	15.1	84.3	90.1	87.2	123.1	165.3	144.2	136.3	166.4
2 months	14.1	16.5	15.3	84.1	88.1	86.1	112.3	164.9	138.6	124.9	165.0
3 months	13.8	16.5	15.2	73.4	82.9	78.2	96.1	143.3	119.7	106.4	143.4
6 months	14.0	16.4	15.2	73.9	82.4	78.2	87.6	107.5	97.6	9.6	107.8
SEM ±	0.44	0.61		1.99	2.32		2.9	4.92		2.81	4.88
CD 5%	NS	NS		5.92	NS		8.6	14.61		8.36	14.51
Interaction											
CI at same RP	0.63	0.87		2.82	3.28		4.1	6.96		3.98	6.91
CD 5%	NS	NS		NS	NS		NS	NS		NS	NS
RP at same or different CI	0.56	0.79		3.38	3.50		5.17	6.76		4.98	6.77
CD 5%	NS	NS		NS	NS		NS	NS		NS	NS

DAS = Days after sowing

years showed that plant height of sorghum in root pruned plots was 12 per cent higher than that in roots unpruned (77.8 cm).

In the first year sorghum plant height in one and two months cutting intervals was significantly more than that in three and six months intervals. The same trend was seen during the second year also, however, the cutting intervals did not vary significantly. Mean data of the two years showed 12 and 10 per cent more height in one and two months intervals respectively over three (78.2 cm) or six (78.2 cm) months intervals. The interaction between root pruning and cutting intervals was not significant.

90 DAS

During the second year root pruned hedgerows produced significantly taller sorghum plants than root unpruned. During the first year also height was more in root pruned than root unpruned. However, they were statistically at par. Mean data of the two years indicated that plant height in root pruned plots was 12 per cent higher than that in root unpruned (118.2 cm).

Cutting intervals influenced plant height significantly during both the years. In the first year height increased significantly with decrease in cutting intervals from six to one month. In the second year one and two months were at par, and were significantly superior to three months. Three months was significantly superior to six months interval. Mean data of the two years showed that plant height was 48, 42 and 23 per cent higher in one, two and three months intervals than in six months (97.6 cm). The interaction between root pruning and cutting interval was not significant.

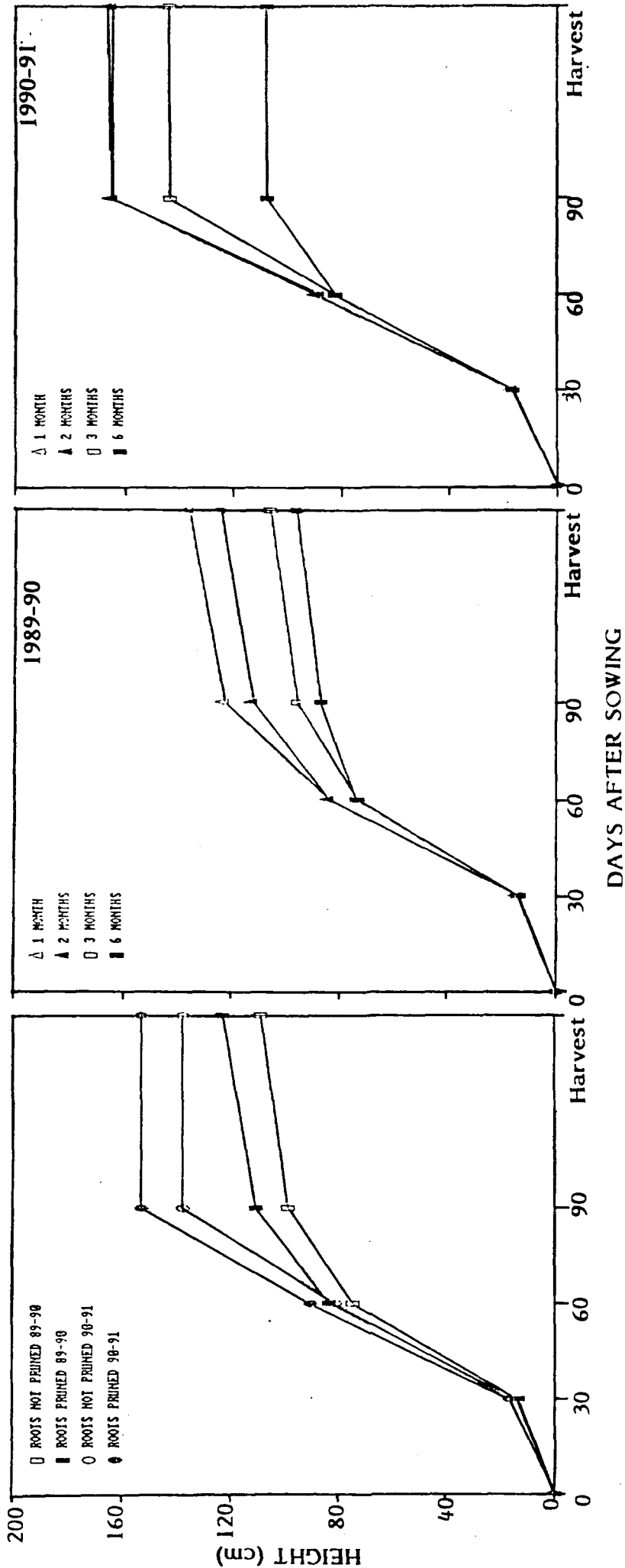


Fig. 8. SORGHUM HEIGHT AT DIFFERENT STAGES OF GROWTH AS INFLUENCED BY ROOT PRUNING AND CUTTING INTERVAL OF LEUCAENA HEDGEROWS

Harvest

Root pruning increased plant height significantly during the second year. Though the increase was seen during the first year also it was not significant statistically. Mean data of the two years showed 12 per cent increase in sorghum plant height due to root pruning of *Leucaena* hedgerows.

During both the years cutting intervals influenced sorghum plant height significantly. In the first year, plant height increased significantly with decrease in cutting intervals from six to one month. In the second year one and two months were at par, and were significantly superior to three months. Three months was significantly superior to six months interval. Mean data of the two years showed that plant height in one, two and three months intervals was 48, 42 and 22 per cent higher respectively over six months interval (102.2 cm).

4.1.1.2 Dry matter production per plant (cf. Table 4, Fig.9)

30 DAS

Dry matter production (g/plant) in *rabi* sorghum did not vary significantly due to root pruning, cutting intervals and their interaction at 30 DAS during both the years.

60 DAS

During both the years root pruning increased dry matter of sorghum significantly. Mean data of the two years showed that dry matter in sorghum plants growing in association with root pruned hedgerows was 19 per cent higher than that with root unpruned hedgerows (10.2 g/plant).

Cutting intervals influenced dry matter production significantly during both the years. One and two months were on par, and were superior to three and six months intervals which were also on par. Mean data of the two years showed that dry matter in sorghum plants was higher by 39, 34 and 1

Table 4 : Dry matter (g/plant) in sorghum at different growth stages as influenced by root pruning and cutting interval of *Leucaena* hedgerows

Treatment	30 DAS			60 DAS			90 DAS			Harvest		
	1989-90	1990-91	Mean	1989-90	1990-91	Mean	1989-90	1990-91	Mean	1989-90	1990-91	Mean
Root Pruning (RP)												
Roots unpruned	3.1	3.6	3.4	9.3	11.1	10.2	28.1	28.3	28.2	34.9	32.8	33.9
Roots pruned	3.2	3.6	3.4	11.4	12.8	12.1	33.8	33.1	33.5	43.3	41.0	42.2
SEm ±	0.04	0.09		0.27	0.33		0.71	0.76		0.71	0.79	
CD 5%	NS	NS		1.23	1.47		3.19	3.41		3.20	3.57	
Cutting Interval (CI)												
1 month	3.2	3.6	3.4	12.4	13.8	13.1	38.5	39.5	39.0	50.0	47.6	48.8
2 months	3.2	3.7	3.5	11.7	13.5	12.6	37.7	37.2	37.5	48.3	44.5	46.4
3 months	3.2	3.6	3.4	8.6	10.3	9.5	25.6	26.6	26.1	31.7	31.2	31.5
6 months	3.1	3.5	3.3	8.7	10.1	9.4	22.2	19.6	20.9	26.3	24.5	25.4
SEm ±	0.3	0.32		0.72	0.72		1.84	1.27		1.39	1.27	
CD 5%	NS	NS		2.12	2.15		5.46	3.77		4.13	3.78	
Interaction												
CI at same RP	SEm ±	0.42	0.46	1.01	1.02		2.60	1.79		1.97	1.80	
	CD 5%	NS	NS	NS	NS		NS	NS		NS	NS	
RP at same or different CI	SEm ±	0.37	0.40	0.92	0.94		2.36	1.73		1.85	1.75	
	CD 5%	NS	NS	NS	NS		NS	NS		NS	NS	

DAS = Days after sowing

per cent with one, two and three months respectively over six months interval (9.4 g/plant). The interaction between root pruning and cutting interval was not significant.

90 DAS

During both the years root pruning of *Leucaena* hedgerows resulted in significantly higher dry matter. Mean data of the two years showed 19 per cent increase in dry matter due to root pruning over the unpruned treatment (28.2 g/plant).

Cutting intervals significantly influenced dry matter in sorghum plant during both the years. In 1989-90 one and two months were on par and, were significantly superior to three and six months, which were also at par. In 1990-91 one and two months were on par, and were significantly superior to three months. Three months was significantly superior to six months. Mean data of the two years showed higher dry matter in one, two and three months intervals by 87, 79 and 25 per cent respectively than that in six months interval (20.9 g/plant). The interaction between root pruning and cutting interval was not significant.

Harvest

Dry matter in sorghum plant at harvest increased significantly due to root pruning during both the years. Mean data of the two years showed 24 per cent increase over root unpruned (42.2 g/plant).

During both the years dry matter at harvest in sorghum plant varied significantly due to cutting intervals of *Leucaena* hedgerows. During 1989-90 one and two months were on par, and were significantly superior to three months. Three months was significantly superior to six months interval. During 1990-91 one and two months were on par, and were significantly superior to three months. Three months was significantly

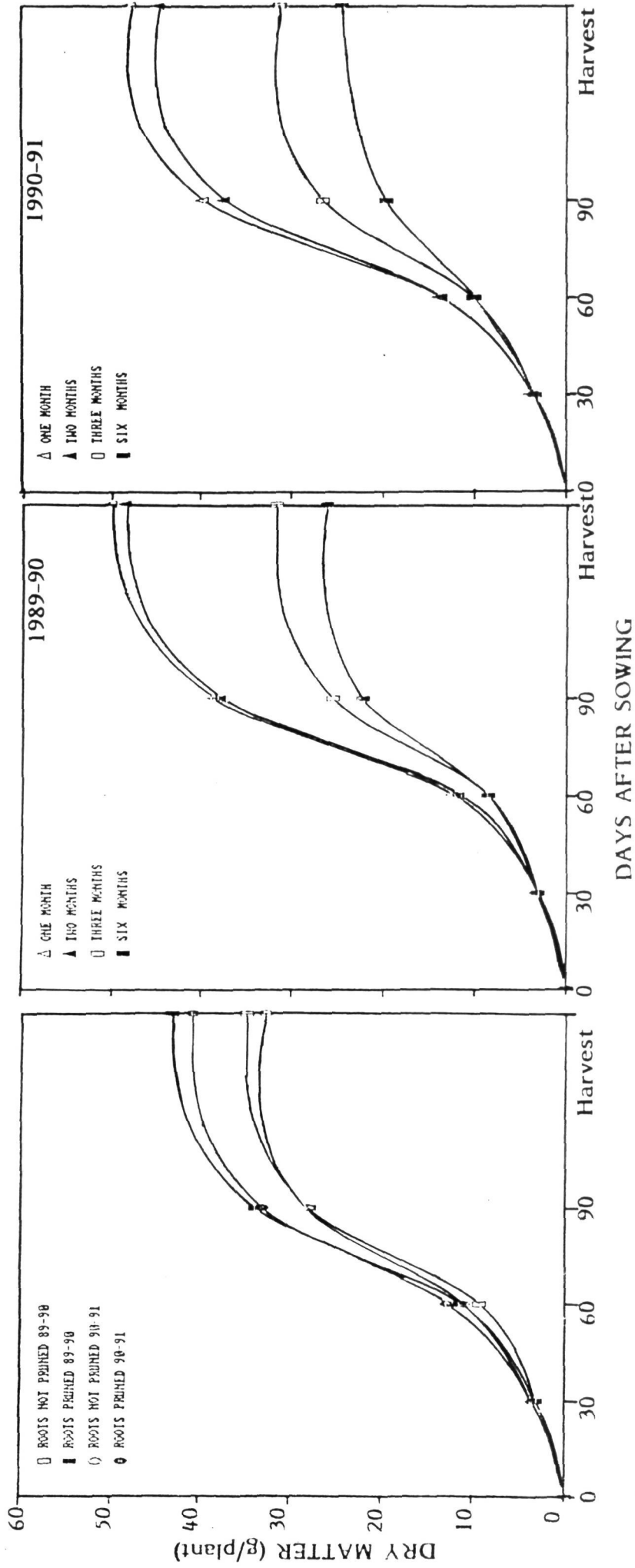


Fig.9. DRY MATTER IN SORGHUM PLANT AT DIFFERENT STAGES OF GROWTH AS INFLUENCED BY ROOT PRUNING AND CUTTING INTERVAL OF LEUCAENA HEDGEROWS

superior to six months. Mean data of the two years indicated 92, 83 and 24 per cent increase in dry matter with one, two and three months cutting intervals respectively over six months (25.4 g). The interaction between root pruning and cutting interval was not significant during both the years.

4.1.1.3 Light transmission ratio (cf. Table 5)

Light transmission ratio (LTR) in the centre of the alley did not vary due to different treatments during both the years, it was 100 per cent at all the stages. In the following paragraphs LTR near the hedgerows only is quoted.

30 DAS

During both the years LTR did not vary due to root pruning of *Leucaena* hedgerows. LTR varied due to cutting intervals of *Leucaena* during both the years. Mean data of the two years showed higher LTR (90.8%) in one month interval than that in other cutting intervals, where similar (84.3, 84.8 and 84.9%) LTR was recorded.

60 DAS

During both the years LTR did not vary due to root pruning of *Leucaena* hedgerows. LTR varied due to cutting interval of *Leucaena* hedgerows during both the years. Mean data of the two years showed higher LTR (94.6 and 94.7%) in one and two months interval than three and six months (80.7 and 80.8%).

90 DAS

During both the years LTR did not vary due to root pruning. LTR varied due to *Leucaena* cutting intervals during both the years. Mean data of the two years showed higher (98.2, 96.2 and 98.4%) LTR in one, two and three months intervals than in six months (71%).

Table 5 : Light Transmission Ratio (%) at different growth stages of sorghum as influenced by root pruning and cutting intervals of *Leucaena* hedgerows

		1990-91																		
		1989-90						MEAN												
Cutting Interval	E C E C E C E C	Roots unpruned			Roots pruned			Mean			Roots unpruned			Roots pruned			Mean			
		E C E C E C E C	E C E C E C E C	E C E C E C E C	E C E C E C E C	E C E C E C E C	E C E C E C E C													
30 DAS																				
1 month	90.5	100	91	100	90.8	100	91	100	90.5	100	90.8	100	90.8	100	90.8	100	90.8	100	90.8	100
2 months	84.5	100	84	100	84.3	100	84	100	84.5	100	84.3	100	84.3	100	84.3	100	84.3	100	84.3	100
3 months	84	100	85	100	84.5	100	85	100	85	100	85	100	84.5	100	85	100	84.5	100	85	100
6 months	85	100	84.5	100	84.8	100	85	100	85.5	100	85	100	85	100	85	100	84.8	100	84.9	100
Mean	86	100	86.1	100	86.1	100	86.3	100	86.3	100	86.3	100	86.2	100	86.2	100	86.2	100	86.2	100
60 DAS																				
1 month	94	100	94.5	100	94.3	100	94.5	100	95	100	94.8	100	94.3	100	94.8	100	94.8	100	94.6	100
2 months	95	100	94	100	94.5	100	95	100	94.5	100	94.8	100	95	100	94.3	100	94.3	100	94.7	100
3 months	80	100	80.5	100	80.3	100	81	100	81	100	81	100	80.5	100	80.8	100	80.8	100	80.7	100
6 months	81	100	80.5	100	80.8	100	81.5	100	80	100	80.8	100	81.3	100	80.3	100	80.3	100	80.8	100
Mean	87.5	100	87.4	100	87.5	100	88	100	87.6	100	87.8	100	87.8	100	87.5	100	87.5	100	87.7	100
90 DAS																				
1 month	98	100	98.5	100	98.3	100	98	100	98	100	98	100	98	100	98.3	100	98.3	100	98.2	100
2 months	96	100	95.5	100	95.8	100	97	100	96	100	96.5	100	96.5	100	95.8	100	95.8	100	96.2	100
3 months	98	100	97.5	100	97.8	100	98.5	100	98	100	98.3	100	98.3	100	97.8	100	97.8	100	98.4	100
6 months	70	100	71	100	70.5	100	71	100	72	100	71.5	100	70.5	100	71.5	100	71.5	100	71	100
Mean	90.5	100	90.6	100	90.6	100	91.1	100	91	100	91.1	100	90.8	100	90.8	100	90.8	100	90.9	100
120 DAS																				
1 month	99.5	100	99	100	99.3	100	99	100	99	100	99	100	99.3	100	99	100	99.2	100	99.2	100
2 months	98.5	100	98	100	98.3	100	98	100	98	100	98	100	98.3	100	98	100	98.2	100	98.2	100
3 months	96.5	100	96	100	96.3	100	96	100	96	100	96	100	96.3	100	96	100	96.2	100	96.2	100
6 months	63.5	100	65.5	100	64.5	100	65	100	67	100	66	100	64.3	100	66.3	100	65.3	100	65.3	100
Mean	89.5	100	89.6	100	89.6	100	89.5	100	90	100	89.8	100	89.5	100	89.8	100	89.7	100	89.7	100

DAS = Days after sowing E = near hedgerows C = centre of alley

120 DAS

At this stage also LTR did not vary due to root pruning of *Leucaena* hedgerows during both the years. During both the years LTR decreased with increasing cutting interval. Mean data of the two years showed LTR values of 99.2, 98.2, 96.2 and 65.3 per cent in one, two, three and six months cutting intervals respectively.

Mean data of the two years showed that in one month cutting interval, the LTR increased from 90.8 per cent at 30 DAS to 94.6 per cent at 60 DAS to 98.2 per cent at 90 DAS and to 99.2 per cent at 120 DAS. In two months cutting interval the values were 84.3, 94.7, 96.2 and 98.2 per cent respectively. In three months interval the values were 84.8, 80.7, 98.4 and 96.2 per cent. In six months interval the LTR decreased gradually from 84.9 per cent at 30 DAS to 80.8 at 60 DAS, 71 at 90 DAS and 65.3 per cent at 120 DAS.

4.1.1.4 Plant population at harvest (cf. Table 6)

Root pruning and cutting intervals of *Leucaena* did not cause any significant change in sorghum plant population at harvest during both the years. However, mean data for the two years showed higher plant population in root pruned (54,000/ha) than root unpruned plots (51,500/ha). Similarly highest plant population (54,400/ha) was observed in one month cutting interval, and the lowest (50,100/ha) in six months cutting interval.

4.1.1.5 Effective population (ear bearing plants)

Per hectare (cf. Table 7)

During both the years effective population of *rabi* sorghum was significantly higher in root pruned plots. Mean data of the two years showed 13 per cent increase in effective population with root pruning over root unpruned hedgerows (41,600/ha).

Table 6 : Plant population of sorghum at harvest as influenced by root pruning and cutting intervals of *Leucaena* hedgerows

Cutting Interval	Plant population at harvest (' 000/ha)										
	1989-90					1990-91					MEAN
	Roots unpruned	Roots pruned	Mean	Roots unpruned	Roots pruned	Roots unpruned	Roots pruned	Mean	Roots unpruned	Roots pruned	
1 month	56.3	58.8	57.5	50.2	52.4	51.3	53.3	55.6	54.4		
2 months	55.3	59.0	57.2	49.7	52.8	51.2	52.5	55.9	54.2		
3 months	54.1	56.7	55.4	48.3	50.2	49.3	51.2	53.5	52.4		
6 months	51.9	55.1	53.4	46.4	47	46.7	49.2	51	50.1		
Mean	54.4	57.4	55.9	48.6	50.6	49.6	51.5	54	52.8		

For comparing means of :

	S.Em±	CD 5%	SEm±	CD 5%
Root Pruning (RP)	1.83	NS	2.43	NS
Cutting Interval (CI)	1.35	NS	1.44	NS
CI at same RP	1.92	NS	2.03	NS
RP at same or diff. CI	2.47	NS	3.00	NS

Table 7 : Effective plant population per hectare of sorghum as influenced by root pruning and cutting intervals of *Leucaena* hedgerows

Interval	Effective population (' 000/ha)								
	Roots unpruned	Roots pruned	Mean	Roots unpruned	Roots pruned	Mean	Roots unpruned	Roots pruned	Mean
1 month	52.3	55.2	53.8	46.1	48.3	47.2	49.2	51.8	50.5
2 months	51.3	55.1	53.2	46.3	48.3	47.3	48.8	51.7	50.3
3 months	37.0	44.7	40.9	33.1	44.1	38.6	35.1	44.4	39.8
6 months	36.0	40.4	38.2	30.3	40.7	35.5	33.2	40.6	36.9
Mean	44.2	48.8	46.5	38.9	45.4	42.1	41.6	47.1	44.3

For comparing means of:

	S.Em±	CD 5%	SEM±	CD 5%
Root Pruning (RP)	0.98	4.43	0.84	3.77
Cutting Interval (CI)	1.38	4.09	0.94	2.78
CI at same RP	1.95	NS	1.32	3.93
RP at same or diff. CI	1.95	NS	1.42	4.97

Cutting intervals caused significant differences in effective plant population during both the years. In the first year, one and two months cutting intervals were on par, and were significantly superior to three and six months, which were also at par. In the second year one and two months were on par, and were significantly superior to three months. Three months was significantly superior to six months. Mean data of the two years showed that effective population was higher by 37, 36 and 8 per cent in one, two and three months cutting intervals respectively over that in six months interval (36,900/ha.)

The interaction between root pruning and cutting interval was significant during 1990-91. The reduction in effective population with increasing cutting interval was more drastic in root unpruned hedgerows than root pruned hedgerows. In root unpruned hedgerows effective population in six months interval was 65 per cent of one month interval (46,100/ha). In root pruned plots it was 85 per cent of one month interval (48,300/ha.).

Per row effective population (cf. Table 8)

During both years per row effective population (number/10 m row length) increased in all five rows due to root pruning, however, the increase was significant in rows one and two only. Mean data of the two years showed that per row effective population of rows 1,2,3,4 and 5 in root pruned plots was higher than that of the respective rows in root unpruned plots by 36, 24, 10, 13 and 11 per cent respectively.

Cutting intervals produced significant difference in per row effective population in rows 1,2,4 and 5 during 1989-90 and in rows one and two during 1990-91. During 1989-90 per row effective population of rows 1,2,3,4 and 5 at one and two months cutting interval was on par, and was

Table 8 : Effective plant population per row (number/10 m row length) of sorghum as influenced by root pruning and cutting intervals of *Leucaena* hedgerows

Treatment	1990-91										MEAN					
	1989-90					1990-91										
	1	2	3	4	5	1	2	3	4	5		1	2	3	4	5
Root Pruning (RP)																
Roots unpruned	18.2	28.4	33.8	38.8	40.4	10.8	24.0	31.6	37.2	37.2	14.5	26.2	32.7	38.0	38.8	
Roots pruned	22.6	35.8	38.7	43.8	43.8	16.7	29.2	33.2	42.1	42.0	19.7	32.5	36.0	42.9	42.9	
SEM ±	0.78	0.67	1.68	1.89	1.47	0.72	0.28	1.51	1.26	2.43						
CD 5%	3.49	3.03	NS	NS	NS	3.25	1.27	NS	NS	NS						
Cutting Interval (CI)																
1 month	28.5	16.7	16.7	45.8	46.7	18.1	11.1	14.0	42.9	41.7	21.4	15	15.4	44.4	44.2	
2 months	25.0	37.5	37.5	45.0	46.7	18.3	32.5	34.8	42.4	41.5	21.7	35	36.2	43.7	44.1	
3 months	15.2	28.3	36.5	37.5	38.3	10.0	22.5	31.7	37.5	37.5	12.6	25.4	34.1	37.5	37.9	
6 months	12.9	26.0	34.2	36.7	36.7	8.3	17.9	29.2	35.8	37.5	10.6	22	31.7	36.3	37	
SEM ±	2.05	2.17	1.61	2.38	2.81	1.46	1.71	1.56	3.38	3.37						
CD 5%	6.09	6.45	NS	7.07	8.35	4.33	5.07	NS	NS	NS						
Interaction																
CI at same RP	2.90	3.07	2.28	3.37	3.98	2.06	2.42	2.21	4.78	4.77						
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS						
RP at same or different CI	2.63	2.74	2.59	3.48	3.52	1.92	2.11	2.44	4.32	4.79						
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS						

significantly superior to three and six months, which were also at par. During 1990-91 per row effective population of rows 1 and 2 in one and two months cutting interval were on par, and were superior to three and six months cutting intervals, which were also at par. Mean data of the two years showed that per row effective population in rows 1,2,3,4 and 5 of one month cutting interval was higher than that in the respective rows of six months interval by 121, 59, 17, 22 and 19 per cent respectively.

4.1.1.6 Ear yield per hectare (cf. Table 9)

Ear yield increased significantly due to root pruning during both the years. Mean data of the two years showed 30 per cent increase in ear yield due to root pruning of *Leucaena* hedgerows over root unpruned (880 kg/ha).

Ear yield also differed significantly due to cutting intervals of *Leucaena* hedgerows during both the years. One and two months cutting intervals were on par, and were significantly superior to three and six months, which were also at par. Mean data of the two years showed that ear yield in one, two and three months cutting intervals was higher than that in six months interval (726 kg/ha) by 74, 67 and 17 per cent respectively.

4.1.1.7 Ear weight per plant (cf. Table 9)

During both the years ear weight per plant increased significantly due to root pruning of *Leucaena* hedgerows. Mean data of the two years showed that ear weight in root pruned plots was 17 per cent higher than that in root unpruned plots (25.4 g/plant).

During both the years per plant ear weight of *rabi* sorghum differed significantly due to cutting intervals of *Leucaena* hedgerows. In 1989-90 one and two months cutting interval were at par, and were significantly superior to 3 and six months intervals, which were at par with each other.

Table 9 : Ear yield and yield components of sorghum as influenced by root pruning and cutting intervals of *Leucaena* hedgerows

Treatment	Ear yield (kg/ha)		Ear weight per plant (g)		Grain weight per plant (g)		Grain number per ear		1000 Grain weight (g)						
	1989-90	1990-91	Mean	1989-90	1990-91	Mean	1989-90	1990-91	Mean	1989-90	1990-91	Mean			
	Mean	SEm ±	CD 5%	Mean	SEm ±	CD 5%	Mean	SEm ±	CD 5%	Mean	SEm ±	CD 5%			
Root Pruning (RP)															
Roots unpruned	883	877	880	24.3	26.6	25.4	17.5	18.4	17.9	542	500	521	30.9	27.2	29.1
Roots pruned	1131	1160	1146	28.6	30.5	29.6	21.5	21.8	21.7	668	591	630	31.0	27.0	29.0
SEm ±	37.3	39.6		0.94	0.80		0.76	0.44		27.8	11.0		0.43	0.20	
CD 5%	167.8	178.3		4.24	3.62		3.41	1.97		125	49.4		NS	NS	
Cutting Interval (CI)															
1 month	1239	1291	1265	29.8	33.3	31.6	22.5	23.4	23.0	715*	647	681	31.8	27.6	29.7
2 months	1181	1239	1210	28.8	31.8	30.3	21.5	22.6	22.1	675	613	644	31.4	27.2	29.3
3 months	857	845	851	24.3	26.5	25.4	17.7	18.4	18.0	535	498	517	30.3	27.1	28.7
6 months	752	700	726	22.8	22.7	22.8	16.2	16.1	16.2	495	424	460	30.4	26.4	28.4
SEm ±	36.5	57.8		1.28	1.05		1.11	0.74		30.5	22.8		0.40	0.25	
CD 5%	108.5	171.5		3.81	3.12		3.30	2.20		90.4	67.7		1.20	0.74	
Interaction															
CI at same RP	51.6	81.7		1.82	1.48		1.57	1.05		43.1	32.2		0.57	0.35	
CD 5%	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	
RP at same or different CI	58.2	81.1		1.84	1.52		1.56	1.01		37.3	30.0		0.66	0.36	
CD 5%	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	

In 1990-91 one and two months were on par, and were significantly superior to three months. Three months was significantly superior to six months interval. Mean data of the two years showed that per plant ear weight in one, two and three months intervals was higher by 39, 33 and 11 per cent respectively than that in six months interval (22.8 g/plant).

4.1.1.8 Grain weight per plant (cf. Table 9)

Grain weight per plant increased significantly due to root pruning of *Leucaena* hedgerows during both the years. Mean data of the two years showed that grain weight per plant in root pruned hedgerows was higher than that in root unpruned (17.9 g/plant) by 21 per cent.

Cutting intervals also produced significant differences in grain weight per plant of *rabi* sorghum during both the years. In 1989-90 one and two months intervals were on par, and were significantly superior to three and six months, which were also on par. In 1990-91 one and two months intervals on par, and were significantly superior to three months. Three months was significantly superior to six months interval. Mean data of the two years indicated that grain weight per plant in one, two and three months cutting intervals was higher than that in six month interval (16.2 g/plant) by 42, 36 and 11 per cent respectively.

4.1.1.9 Grain number per ear (cf. Table 9)

Grain number per ear in *rabi* sorghum increased significantly due to root pruning of *Leucaena* hedgerows during both the years. Mean data of the two years showed that root pruned hedgerows resulted in 21 per cent higher grain number than root unpruned (521/ear).

During both the years grain number differed significantly due to cutting intervals of *Leucaena* hedgerows. In 1989-90 one and two months intervals were on par and, were significantly superior to three and six months which

were also on par. In 1990-91 one and two months were on par, and were significantly superior to three months. Three months was significantly superior to six months cutting interval. Mean data of the two years showed that, grain number in one, two and three months cutting intervals was higher than that in six months interval (460/ear) by 48, 40 and 12 per cent respectively.

4.1.1.10 Thousand grain weight (cf. Table 9)

Root pruning did not have any significant influence on 1000 grain weight of *rabi* sorghum during both the years. Thousand grain weight of *rabi* sorghum differed significantly due to cutting intervals of *Leucaena* hedgerows during both the years. In 1989-90 one month interval was on par with two months, and was significantly superior to three and six months. Two, three and six months intervals were on par. During 1990-91 one month was on par with two and three months intervals and was significantly superior to six months interval. Two, three and six months intervals were at par. Mean data of the two years showed that thousand grain weight in one, two and three months was higher than that in six months interval (28.4 g) by 4,3 and 1 per cent respectively.

4.1.1.11 Grain yield

Grain yield per row (cf. Table 10)

During both the years per row grain yield of *rabi* sorghum increased significantly due to root pruning of *Leucaena* in all the five rows. Mean data of the two years showed that grain yield of *rabi* sorghum in root pruned plots was higher than that in root unpruned by 63,21,44,34 and 25 per cent in rows 1,2,3,4 and 5 respectively.

Table 10 : Grain yield per row (g/10 m row length) of sorghum as influenced by root pruning and cutting intervals of *Leucaena* hedgerows

Treatment	1989-90										1990-91					MEAN					
	1989-90					1990-91					1990-91										
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5						
Root Pruning (RP)																					
Roots unpruned	213.4	423.0	493.8	631.4	668.9	91.7	356.3	448.0	589.7	735.6	152.6	389.7	470.9	610.6	702.3						
Roots pruned	279.2	499.1	748.1	829.3	858.5	218.8	445.9	604.3	810.6	896.0	249.0	472.5	676.2	820.0	877.3						
SEm ±	4.23	5.78	14.70	21.71	12.51	2.82	13.32	13.11	22.42	30.22											
CD 5%	19.05	26.03	66.16	97.73	56.29	12.7	59.93	59.02	100.9	136.0											
Cutting Interval (CI)																					
1 month	449.9	618.9	708.5	871.0	887.7	200.0	591.8	708.5	904.3	937.7	325.0	605.4	708.5	887.7	912.7						
2 months	354.2	587.6	716.8	866.8	866.8	183.4	570.9	662.6	862.7	896.0	268.8	579.3	689.7	864.8	881.4						
3 months	108.1	375.1	525.1	658.5	675.1	141.7	229.2	404.2	604.3	746.0	124.9	302.2	464.7	631.4	710.6						
6 months	72.9	262.6	533.4	525.1	625.1	95.9	212.5	329.2	429.3	683.5	84.4	237.6	431.3	477.2	654.3						
SEm ±	13.95	20.71	34.12	42.91	56.01	14.12	28.95	35.03	43.42	39.33											
CD 5%	41.44	61.51	48.26	127.4	166.35	41.92	85.97	104.04	128.95	116.8											
Interaction																					
CI at same RP	SEm ±	19.73	29.29	48.26	60.68	79.21	19.96	40.94	49.55	61.40	55.62										
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	182.4	165.18								
RP at same or different CI	SEm ±	17.60	26.02	44.30	56.86	69.73	17.52	37.87	44.87	57.70	56.86										
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	184.70	193.44								

Table 10 a : Grain yield per row (g/10 m row length) as influenced by root pruning x cutting intervals of *Leucaena* hedgerows

Treatment	Row 4 - 1990-91						Row 5 - 1990-91						
	Cutting Interval (CI) in months			Cutting Interval (CI) in months			Cutting Interval (CI) in months			Cutting Interval (CI) in months			
	1	2	3	4	5	6	1	2	3	4	5	6	
Roots unpruned	830.2	850.2	425.1	233.4	589.7	916.9	883.5	633.5	508.4	735.6			
Roots pruned	958.5	875.2	783.5	625.1	810.6	958.5	908.5	858.5	858.5	896.0			
Mean	904.3	862.7	604.3	429.3		937.7	896.0	745.9	683.5				
For comparing:	SEm±	CD 5%	SEm±	CD 5%	SEm±	CD 5%							
CI at same RP	61.4	182.4	55.62	165.18									
RP at same or different CI	57.7	184.7	56.86	193.44									

During both the years per row grain yield differed significantly due to cutting intervals in all the five rows. Decreasing cutting interval from six to one month significantly increased the grain yield in all the five rows. Mean data of the two years showed that grain yield of first row, in one, two and three months cuttings intervals was higher than that in six months by 285, 218 and 48 per cent respectively. In second row it was 155, 144 and 27 per cent; in third row it was 64, 60 and 8 percent; in fourth row it was 86, 81 and 32 percent and in fifth row it was 39, 35 and 9 per cent respectively.

The interaction between root pruning and cutting interval was significant in rows 4 and 5 (Table 10a) during 1990-91. In row four of root pruned plots two and three months, and three and six months cutting intervals were at par. But, in root unpruned plots 2 months interval was significantly superior to three months. Three months was significantly superior to six months. In the fifth row, all the cutting intervals were at par in root pruned plots, but in root unpruned plots one and two months were on par, and were significantly superior to three and six months cutting intervals, which were also on par.

Grain yield per hectare (cf. Table 11, Fig.10)

During both the years root pruning of *Leucaena* hedgerows significantly increased grain yield of *rabi* sorghum growing in its association. Mean data of the two years showed that grain yield of *rabi* sorghum grown in association with root pruned hedgerows was higher than that with root unpruned hedgerows (646 kg/ha) by 33 per cent.

Grain yield of *rabi* sorghum differed significantly due to varying cutting intervals of *Leucaena* hedgerows during both the years. During 1989-90 one and two months were on par and were significantly superior to three months



A



B

PLate 10. Sorghum in association with :
A. Roots unpruned Leucaena hedgerows
B. Roots pruned Leucaena hedgerows
(Expt. 1)

Table 11 : Grain yield per hectare (kg/ha) of sorghum as influenced by root pruning cutting intervals of *Leucaena* hedgerows

Cutting Interval	1989-90				1990-91				MEAN	
	Roots unpruned	Roots pruned	Mean unpruned	Mean pruned	Roots unpruned	Roots pruned	Mean unpruned	Mean pruned		
1 month	904	1061	983	857	881	993	925	881	1027	954
2 months	864	1019	941	828	846	936	882	846	978	912
3 months	507	792	649	460	484	743	592	484	768	626
6 months	423	700	561	324	374	649	487	374	674	524
Mean	674	893	784	617	646	826	721	646	860	754

For comparing means of :

	SEm±	CD(5%)	SEm±	CD(5%)
Root pruning (RP)	27.9	125.7	31.8	143.1
Cutting interval(CI)	28.6	85.0	42.9	127.5
CI at same RP	40.5	NS	60.7	NS
RP at same or different CI	44.8	NS	61.4	NS

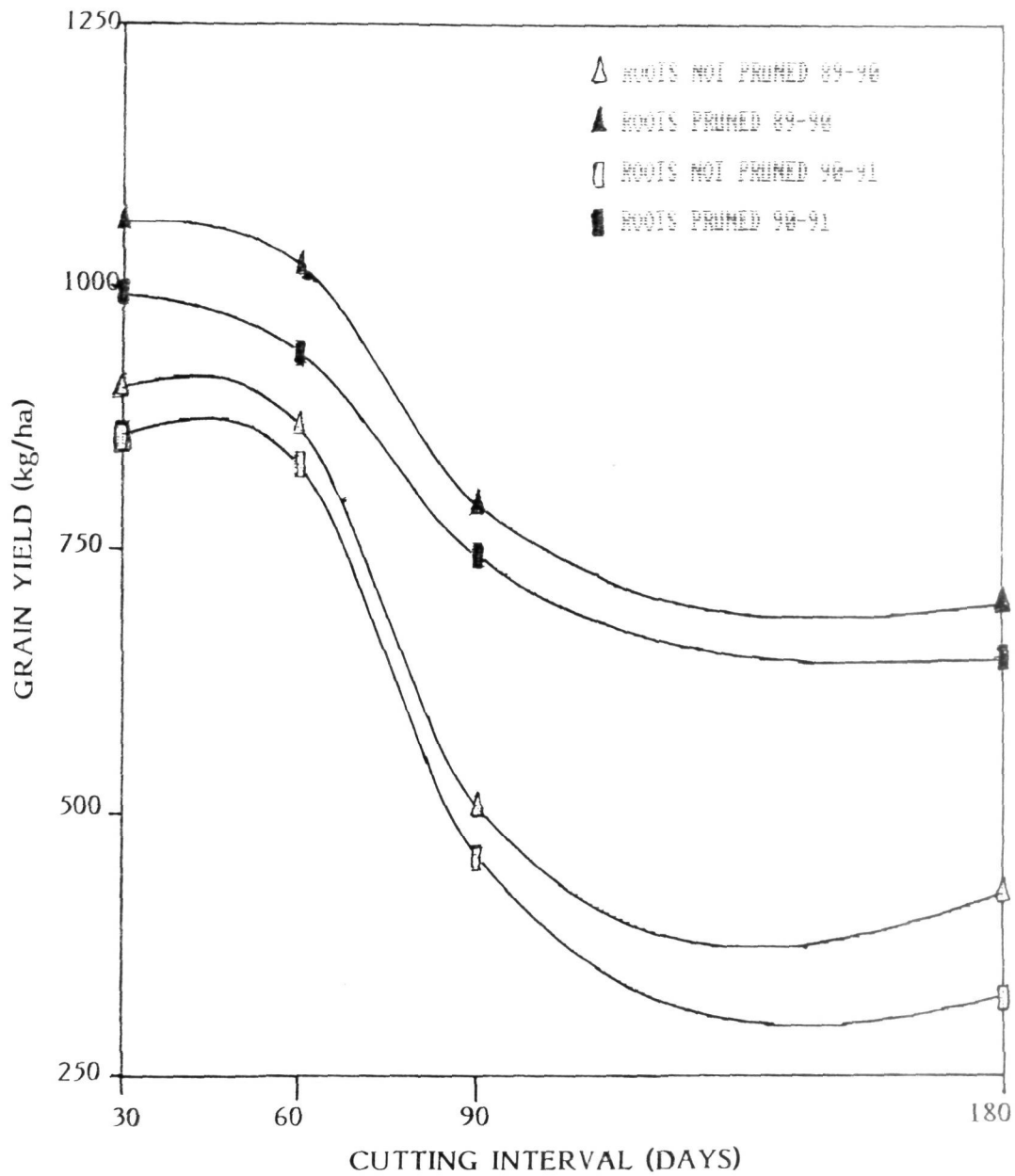


Fig.10. GRAIN YIELD OF SORGHUM AS INFLUENCED BY ROOT PRUNING AND CUTTING INTERVAL OF LEUCAENA HEDGEROWS



A



B

Plate 11. Sorghum in association with:

- A. Leucaena hedgerows cut at six-months interval
- B. Leucaena hedgerows cut at one-month interval

(Expt. 1)

which was significantly superior to six months cutting interval. During 1990-91 one and two months were on par and significantly superior to three and six months which were also on par. Mean data of the two years indicated that grain yield in one, two and three months cutting intervals was higher than that in six months cutting interval (524 kg/ha) by 82, 74 and 19 per cent respectively. Grain yield decreased with increasing cutting interval from one to six months. Considering grain yield in one month interval as 100 per cent it was 96, 65 and 55 percent in two, three and six months cutting intervals respectively.

Grain yield of sorghum and cutting interval of *Leucaena* hedgerows had a sigmoid relationship (Fig. 10), both in root pruned and root unpruned hedgerows during both the years. The shape of the curve was like the mirror image of 'S'.

4.1.1.12 Stover yield

Stover yield per row (cf. Table 12)

During both the years per row stover yield of *rabi* sorghum increased significantly due to root pruning in all the five rows. Mean data of the two years showed that the increase due to root pruning was 23, 19, 17, 22 and 9 per cent in rows 1, 2, 3, 4 and 5 respectively.

Decreasing cutting intervals from six to one month significantly increased per row stover yield of *rabi* sorghum in all the five rows during both the years. Mean data of the two years showed that the increase was 166, 128, 70, 58 and 49 per cent in rows 1, 2, 3, 4 and 5 respectively.

The interaction between root pruning and cutting interval was significant (Table 12 a) for rows 2 and 3 during 1990-91. In the second row at one and two months cutting intervals, root pruned and root unpruned hedgerows were at par, while at three and six months intervals root pruned

Table 12 : Stover yield per row (g/10 m row length) of sorghum as influenced by root pruning and cutting intervals of *Leucaena* hedgerows

Treatment	1989-90					1990-91					MEAN				
	ROW					ROW									
	1	2	3	4	5	1	2	3	4	5					
Root Pruning (RP)															
Roots unpruned	358.4	606.8	861.8	972.3	1005.6	308.4	643.0	775.7	972.6	1204.9	333.4	624.9	818.8	972.5	1105.3
Roots pruned	409.2	751.4	939.8	1186.1	1160.2	408.9	736.1	976.2	1180.4	1248.7	409.1	743.8	958.0	1183.3	1204.5
SEM ±	6.77	16.24	19.81	11.58	12.19	6.46	17.53	15.03	14.22	17.16					
CD 5%	30.45	73.10	NS	52.10	54.88	29.09	78.92	67.65	64.01	NS					
Cutting Interval (CI)															
1 month	607.6	826.8	995.2	1351.9	1334.4	502.2	946.0	1235.7	1318	1388.8	554.9	886.4	1115.5	1335.0	1366.6
2 months	489.3	873.5	991.0	1131.9	1215.2	444.9	921.4	1087.7	1271.1	1333.6	467.1	897.5	1039.4	1201.5	1274.4
3 months	245.9	617.6	849.3	917.7	895.2	262.6	512.6	637.6	946	1228.4	254.2	565.1	743.5	931.9	1061.8
6 months	192.5	398.4	767.7	915.2	876.8	225.0	378.2	542.8	771	954.4	208.8	388.3	655.3	843.1	915.6
SEM ±	32.59	40.88	42.45	47.96	47.10	33.61	34.96	42.93	40.70	35.95					
CD 5%	96.79	121.41	126.07	142.43	139.88	99.83	103.84	127.49	120.88	106.76					
Interaction															
CI at same RP	SEM ±	46.09	57.81	60.03	67.82	66.61	47.54	49.45	60.71	57.56	50.84				
	CD 5%	NS	NS	NS	NS	NS	NS	146.84	180.30	NS	NS				
RP at same or different CI	SEM ±	40.49	52.64	55.63	59.87	58.96	41.67	46.27	54.68	51.84	47.25				
	CD 5%	NS	NS	NS	NS	NS	NS	147.60	168.70	NS	NS				

Table 12 a : Stover yield per row (g/10 m row length) of sorghum as influenced by root pruning x cutting intervals of *Leucaena* hedgerows

Root Pruning (RP)	Row 2 - 1990-91						Row 3 - 1990-91					
	Cutting Interval (CI) in months						Cutting Interval (CI) in months					
	1	2	3	6	Mean	Mean	1	2	3	6	Mean	
Roots unpruned	925.2	963.5	412.6	270.9	643.0	643.0	1158.6	1116.9	454.3	373.0	775.7	
Roots pruned	966.9	879.3	612.6	485.5	736.1	736.1	1312.8	1058.5	821.0	712.6	976.2	
Mean	946.0	921.4	512.6	378.2	1235.7	1235.7	1087.7	637.6	542.8			
For comparing:	SEM±	SEM±	SEM±	SEM±	SEM±	SEM±	SEM±	SEM±	SEM±	SEM±	SEM±	
CI at same RP	49.45	49.45	146.84	146.84	60.71	60.71	180.3	180.3				
RP at same or different CI	46.27	46.27	147.6	147.6	54.68	54.68	168.7	168.7				

Table 13 : Stover yield per hectare (kg/ha) of sorghum as influenced by root pruning and cutting intervals of *Leucaena* hedgerows

Cutting Interval	1989-90				1990-91				MEAN	
	Roots unpruned	Roots pruned	Mean unpruned	Mean pruned	Roots unpruned	Roots pruned	Mean unpruned	Mean pruned		
1 month	1360	1487	1424	1448	1448	1548	1498	1404	1518	1461
2 months	1278	1335	1306	1417	1417	1395	1406	1348	1365	1356
3 months	847	1112	980	854	854	1139	997	850	1126	989
6 months	739	1010	875	618	618	978	798	679	994	837
Mean	1056	1236	1146	1085	1085	1265	1175	1070	1251	1161

For comparing means of :

	SEM±	CD(5%)	SEM±	CD(5%)
Root pruning (RP)	29.6	133.3	35.4	159.5
Cutting interval (CI)	45.2	134.2	51.1	151.8
CI at same RP	63.9	NS	72.3	NS
RP at same or different CI	62.8	NS	71.9	NS

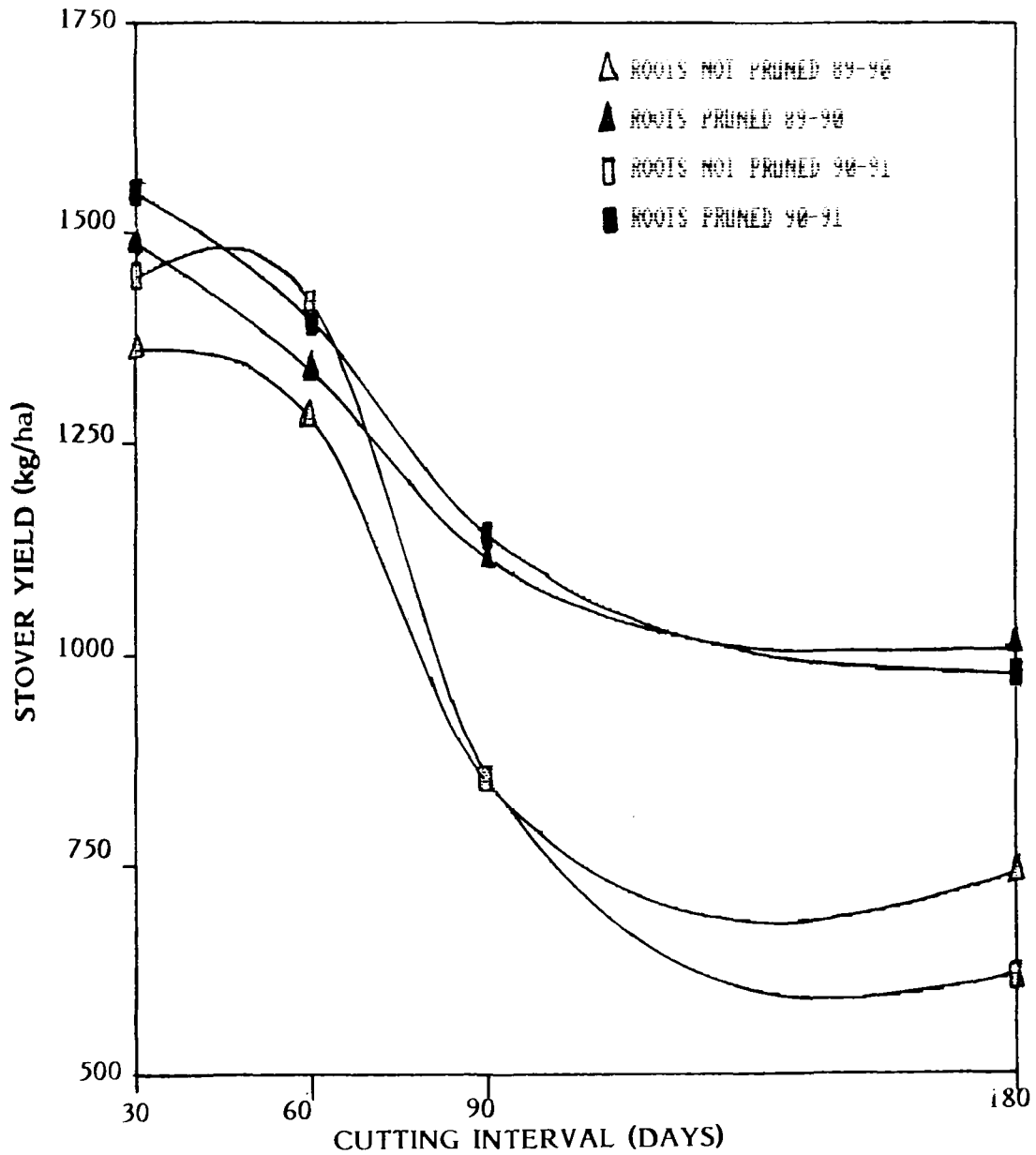


Fig.11. STOVER YIELD OF SORGHUM AS INFLUENCED BY ROOT PRUNING AND CUTTING INTERVAL OF LEUCAENA HEDGEROWS

hedgerows were significantly superior to root unpruned. In the third row root pruned and unpruned hedgerows were at par at one and two months cutting intervals, but at three and six months intervals root pruned hedgerows were significantly superior to root unpruned hedgerows.

Stover yield per hectare (cf. Table 13, Fig.11)

During both the years stover yield of *rabi* sorghum increased significantly due to root pruning. Mean data of the two years showed that sorghum stover yield in root pruned plots was higher than that in root unpruned (1071 kg/ha) by 17 per cent.

Cutting intervals influenced sorghum stover yield significantly during both the years. In 1989-90 one and two months intervals were at par, and were significantly superior to three and six months, which were also at par. In 1990-91 one and two months were on par, and were significantly superior to three months. Three months was significantly superior to six months cutting interval. Mean data of the two years showed that stover yield in one, two and three months intervals was higher than that in six months (837 kg/ha) by 75, 62 and 18 per cent respectively.

4.1.1.13 Biomass yield (cf. Table 14, Fig.12)

Sorghum biomass yield increased significantly due to root pruning of hedgerows during both the years. Mean data of the two years showed that sorghum biomass yield in root pruned hedgerows was higher than that in root unpruned hedgerows (1716 kg/ha) by 17 per cent.

During both the years sorghum biomass yield differed significantly due to cutting intervals. One and two months were on par, and were significantly superior to three months. Three months was significantly superior to six months cutting interval. Mean data for the two years indicated that

Table 14 : Biomass yield (kg/ha) and harvest index of sorghum as influenced by root pruning and cutting intervals of *Leucaena* hedgerows

Treatment	Biomass yield (kg/ha)			Harvest Index		
	1989-90	1990-91	Mean	1989-90	1990-91	Mean
Root Pruning (RP)						
Roots unpruned	1730	1702	1716	0.385	0.357	0.371
Roots pruned	2129	2090	2110	0.419	0.396	0.408
SEm ±	52.1	65.8		0.007	0.004	
CD 5%	234.6	1296.3		0.03	0.02	
Cutting Interval (CI)						
1 month	2406	2423	2415	0.410	0.379	0.395
2 months	2247	2288	2268	0.418	0.385	0.402
3 months	1629	1588	1609	0.396	0.369	0.383
6 months	1436	1285	1361	0.385	0.371	0.378
SEm ±	59.5	85.1		0.013	0.012	
CD 5%	176.8	252.8		NS	NS	
Interaction						
CI at same RP	SEm ±	84.2	120.4	0.018	0.017	
	CD 5%	NS	NS	NS	NS	
RP at same or different CI	SEm ±	89.6	123.3	0.017	0.015	
	CD 5%	NS	NS	NS	NS	

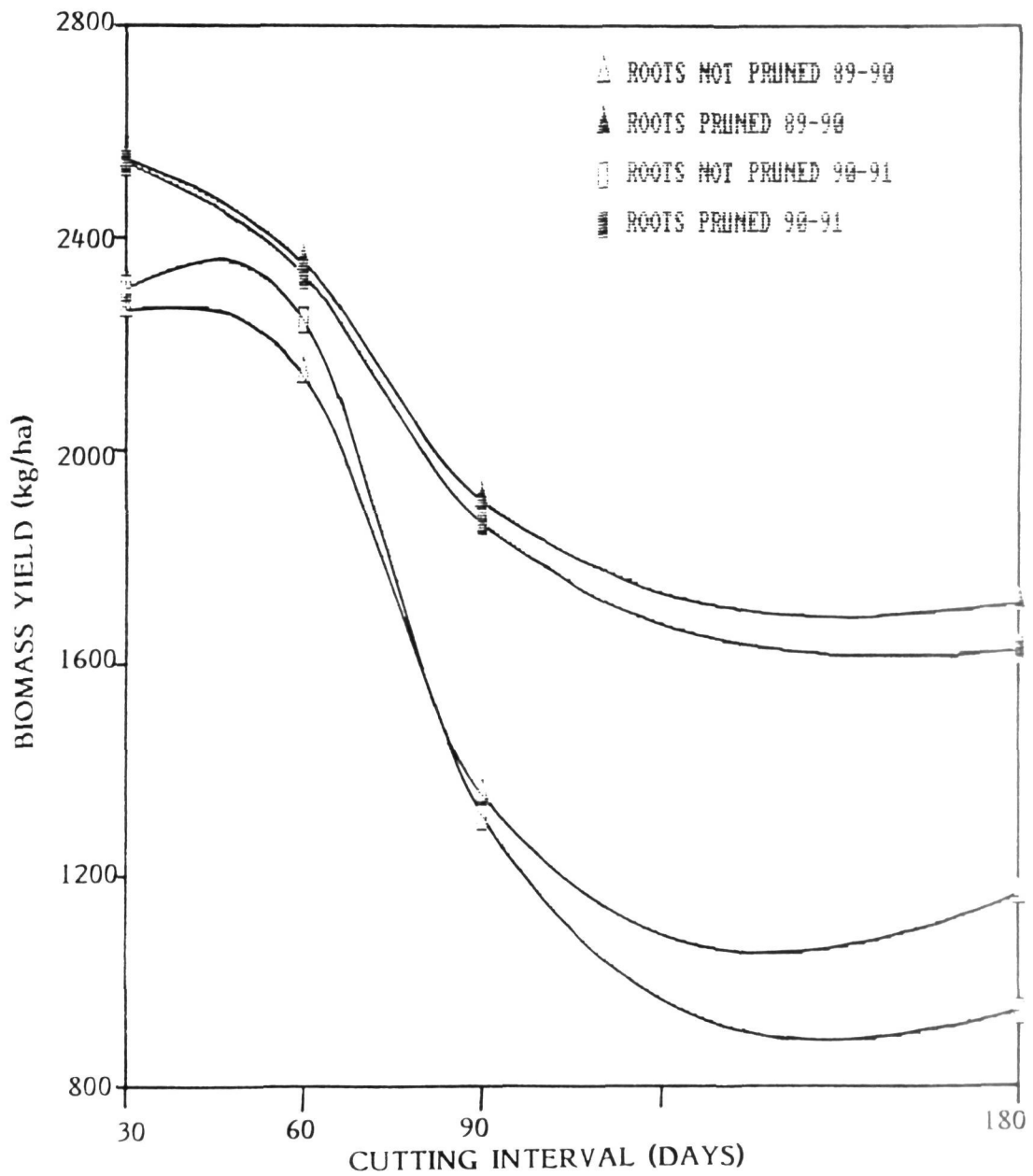


Fig.12. BIOMASS YIELD OF SORGHUM AS INFLUENCED BY ROOT PRUNING AND CUTTING INTERVAL OF LEUCAENA HEDGEROWS

sorghum biomass yield in one, two and three months cutting intervals was higher than that in six months (1361 kg/ha) by 77, 67 and 18 per cent respectively.

4.1.1.14 Harvest index (cf. Table 14)

Harvest index of *rabi* sorghum increased significantly by root pruning of *Leucaena* hedgerows during both the years. Mean data of the two years showed that harvest index in root pruned plots was higher than that in root unpruned (0.371) by 10 per cent.

Cutting intervals of *Leucaena* hedgerows did not have any significant influence on harvest index in either of the two years. However, mean data of the two years indicated that harvest index in one, two and three months cutting intervals was higher than that in six months (0.378) by 4,6 and 1 per cent respectively.

4.1.2 *Leucaena*

4.1.2.1 *Leucaena* leaf biomass production (cf. Table 15)

During both the years *Leucaena* leaf biomass production was significantly higher in sole *Leucaena* than root pruned and unpruned hedgerows which were at par. Mean data of the two years showed that *Leucaena* leaf biomass production in root unpruned as well as in root pruned hedgerows was 44 per cent of sole *Leucaena* (6049 kg/ha).

Cutting intervals of *Leucaena* produced significant difference in its leaf biomass production during both the years. In first year highest leaf biomass was produced in two months interval followed by three, one and six months respectively, and they differed from each other significantly. In second year lowest leaf biomass was produced in one month interval and the highest in six months interval. Two, three and six months intervals were

Table 15 : *Leucaena* leaf biomass production (kg/ha) as influenced by its cutting intervals

Cutting Interval	1989-90				1990-91				MEAN			
	Roots unpruned	Roots pruned	Sole <i>Leucaena</i>	Mean	Roots unpruned	Roots pruned	Sole <i>Leucaena</i>	Mean	Roots unpruned	Roots pruned	Sole <i>Leucaena</i>	Mean
1 month	1874	1917	4919	2903	2629	3002	6263	3964	2252	2460	5591	3464
2 months	2394	2256	5465	3372	3106	3140	7339	4528	2750	2696	6402	3950
3 months	2351	2195	4919	3155	3270	3427	7599	4765	2811	2811	6259	3960
6 months	2221	1848	4069	2712	3522	3626	7816	4988	2872	2737	5943	3850
Mean	2210	2054	4843	3036	3122	3299	7254	4562	2671	2677	6049	3799

For comparing means of : SEM± CD(5%) SEM± CD(5%)

Root pruning (RP) 113 392 105 363

Cutting interval (CI) 65 187 229 665

CI at same RP 112 324 397 NS

RP at same or different CI 149 480 360 NS

on par, and were significantly superior to one month interval. Mean data of the two years indicated that *Leucaena* leaf biomass production in two, three and six months interval was higher than that in one month (3,434 kg/ha) by 15,15 and 12 per cent respectively.

The interaction between main plots and cutting intervals was significant during 1989-90. In root unpruned hedgerows two, three and six months intervals were on par, and were significantly superior to one month interval. In root pruned hedgerows two months interval was significantly superior to six months. One, three and six months intervals were on par. In sole *Leucaena* two months cutting interval produced significantly higher biomass than other intervals it was followed by one and three months which were on par, and were significantly superior to six months interval.

4.1.2.2 *Leucaena* wood biomass production (cf. Table 16)

During both the years *Leucaena* wood biomass production in sole *Leucaena* was higher than that in root pruned or unpruned hedgerows which were on par. Mean data of the two years showed that wood biomass production both in root unpruned and pruned hedgerows was only 47 per cent of that in sole *Leucaena* (3,974 kg/ha).

Cutting intervals produced significant difference in *Leucaena* wood biomass production during both the years. In 1989-90 six months was significantly superior to the rest, it was followed by 3 months. Three months was significantly superior to one and two months cutting intervals, which were on par. In 1990-91 six months cutting interval was on par with three months, and significantly superior to two and one months. Three months was on par with two months and was significantly superior to one month. One and two months cutting intervals were at par. Mean data of the

Table 16 : *Leucaena* wood biomass production (kg/ha) as influenced by its cutting intervals

Cutting Interval	1989-90					1990-91					Mean	
	Roots unpruned	Roots pruned	Sole <i>Leucaena</i>	Mean	Roots unpruned	Roots pruned	Sole <i>Leucaena</i>	Mean	Roots unpruned	Roots pruned		Sole <i>Leucaena</i>
1 month	1067	1093	2117	1426	1683	2039	3999	2574	1375	1566	3058	2000
2 months	1067	1032	2117	1405	1969	2089	4875	2976	1518	1557	3496	2191
3 months	1770	1596	3383	2250	2368	2516	5205	3363	2069	2056	4294	2807
6 months	2238	1882	4155	2759	2750	2811	5942	3834	2494	2347	5049	3297
Mean	1535	1401	2943	1960	2193	2362	5005	3186	1864	1882	3974	
For comparing means of :												
Root pruning (RP)		92		318	120	414						
Cutting interval (CI)		52		150	187	543						
CI at same RP		89		260	324	NS						
RP at same or different CI		120		388	305	NS						

two years indicated that *Leucaena* wood biomass production in two, three and six months intervals was higher than that in one month interval (2,000 kg/ha) by 10, 40 and 65 per cent respectively.

The interaction between main plots and cutting intervals was significant during 1989-90. In root pruned hedgerows three and six months intervals were at par, but, in root unpruned hedgerows and sole *Leucaena*, six months interval was superior to three months cutting interval.

4.1.2.3 *Leucaena* total biomass production (cf. Table 17, Fig.13)

During both the years sole *Leucaena* produced significantly higher biomass than root pruned or unpruned hedgerows, which were at par. Mean data of the two years showed that *Leucaena* total biomass production in root unpruned as well as root pruned hedgerows was only 45 per cent of sole *Leucaena* (10,026 kg/ha).

Cutting intervals produced significant differences in total biomass production of *Leucaena* during both the years. In 1989-90 three and six months were on par, and were significantly superior to two months. Two months was significantly superior to one month. In 1990-91 six months was on par with 3 months but was superior to one and two months, cutting intervals. Three months interval was on par with two months, and was superior to one month. One and two months cutting intervals were at par. Mean data of the two years showed that *Leucaena* total biomass production in two, three and six months intervals was higher than that in one month (5,434 kg/ha) by 13, 24 and 32 per cent respectively.

Table 17 : *Leucaena* total biomass production (kg/ha) as influenced by its cutting intervals

Cutting Interval	1989-90					1990-91					MEAN		
	Roots unpruned	Roots pruned	Sole <i>Leucaena</i>	Mean	Roots unpruned	Roots pruned	Sole <i>Leucaena</i>	Mean	Roots unpruned	Roots pruned		Sole <i>Leucaena</i>	Mean
	1 month	2941	3002	7035	4326	4311	5049	10263	6541	3626		4026	8649
2 months	3451	3279	7582	4774	5066	5222	12223	7504	4264	4251	9903	6139	
3 months	4112	3791	8311	5405	5639	5934	12796	8123	4876	4863	10554	6764	
6 months	4459	3730	8224	5471	6272	6437	13767	8825	5366	5084	10996	7149	
Mean	3743	3450	7788	4994	5322	5660	12262	7748	4533	4555	10026	6372	

For comparing means of : SEmt CD(5%) SEmt CD(5%)

Root pruning (RP)	200	691	220	761
Cutting interval (CI)	110	318	414	1201
CI at same RP	180	NS	717	NS
RP at same or different CI	259	NS	659	NS

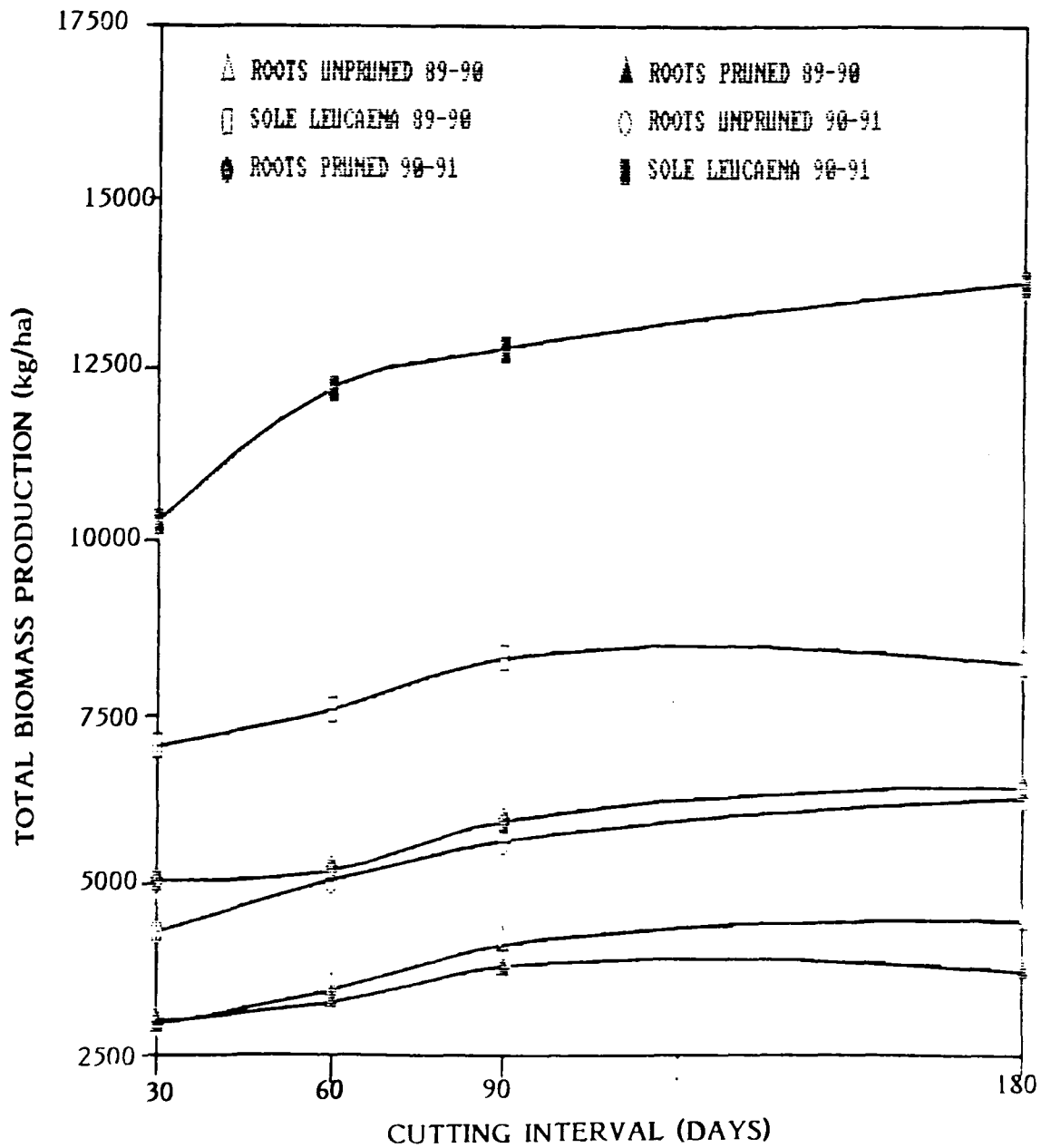


Fig.13. TOTAL BIOMASS PRODUCTION OF LEUCAENA AS INFLUENCED BY ITS ROOT PRUNING AND CUTTING INTERVAL

Table 18 : *Leucaena* net biomass harvest (kg/ha) as influenced by/its cutting intervals

Cutting Interval	1989-90					1990-91					MEAN	
	Roots unpruned	Roots pruned	Sole <i>Leucaena</i>	Mean	Roots unpruned	Roots pruned	Sole <i>Leucaena</i>	Mean	Roots unpruned	Roots pruned		Sole <i>Leucaena</i>
1 month	1796	1839	7035	3557	2229	2533	10263	5005	2013	2186	8649	4281
2 months	2308	2177	7582	4022	2629	2655	12223	5835	2469	2416	9903	4929
3 months	2793	2629	8311	4578	2845	3019	12796	6223	2819	2824	10554	5400
6 months	3140	2646	8224	4670	3262	3236	13767	6755	3201	2941	10996	5713
Mean	2509	2322	7788	4207	2741	2861	12262	5954	2625	2592	10026	5081

For comparing means of :

	SEmt	CD(5%)	SEmt	CD(5%)
Root pruning (RP)	119	411	166	576
Cutting interval (CI)	98	284	330	958
CI at same RP	169	NS	572	NS
RP at same or different CI	189	NS	522	NS

4.1.2.4 *Leucaena* net biomass harvest (cf. Table 18)

During both the years *Leucaena* net biomass harvest was significantly higher in sole *Leucaena* than root pruned and unpruned hedgerows which were on par. Mean data of the two years showed that *Leucaena* net biomass harvest in root unpruned as well as root pruned hedgerows was only 26 per cent of sole *Leucaena* (10,026 kg/ha).

Cutting intervals of *Leucaena* produced significant differences in *Leucaena* net harvest during both the years. In 1989-90 six and three months intervals were at par, and were significantly superior to three months which was significantly superior to one month interval. During 1990-91 six months interval was on par with two and three months and significantly superior to one month cutting interval. One and two months, and two and three months were at par. Mean data of the two years showed that *Leucaena* net biomass harvest in two, three and six months intervals was higher than that in one month (4,281 kg/ha) by 15, 26 and 33 per cent respectively.

4.1.3 Soil moisture (cf. Table 19)

At sowing

During both the years soil moisture content (cm water in 0-90 cm soil profile) in root pruned plots was higher than that in the root unpruned plots, both near the hedgerows and in the centre of the alley. Mean data of the two years showed that soil moisture in root pruned plots was higher by 7 per cent over root unpruned (26.7 cm) near the hedgerows, and in the centre of the alley the increase was 23 percent over root unpruned hedgerows (27.3 cm). Sole *Leucaena* recorded the lowest soil moisture (24.7 cm). Soil moisture did not vary much due to cutting intervals at this stage, both near the hedgerows and centre of the alley during either years.

Table 19 : Soil moisture content (cm water in 0-90 cm soil profile) in alley cropped sorghum and sole *Leucaena* at different stages of sorghum growth as influenced by cutting intervals of *Leucaena*

Cutting Interval	ALLEY CROPPED SORGHUM																		SOLE <i>LEUCAENA</i>		
	1989-90						1990-91						MEAN						1989-90	1990-91	Mean
	Roots unpruned		Roots pruned		Mean		Roots unpruned		Roots pruned		Mean		Roots unpruned		Roots pruned		Mean				
	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	
SOWING																					
1 month	30.2	30.4	32.0	37.8	31.1	34.1	23.0	23.8	25.4	29.8	24.2	26.8	26.6	27.1	28.7	33.8	27.7	30.5	29.1	20.1	24.6
2 month	30.2	30.6	32.1	37.8	31.2	34.2	23.1	24.0	25.2	28.8	24.2	26.4	26.7	27.3	27.6	33.3	27.2	30.3	29.2	20.3	24.8
3 month	30.3	30.5	32.2	37.7	31.3	34.1	23.2	24.0	25.5	29.7	24.4	26.5	26.8	27.3	28.9	33.7	27.9	30.5	29.0	20.5	24.8
6 month	30.2	30.5	32.1	37.8	31.2	34.2	23.2	24.2	25.3	29.2	24.3	26.7	26.7	27.4	28.7	33.5	27.7	30.5	29.1	20.4	24.8
Mean	30.2	30.5	32.1	37.8	31.2	34.2	23.1	24.0	25.4	29.4	24.3	26.7	26.7	27.3	28.5	33.6	27.6	30.5	29.1	20.3	24.7
FLOWERING																					
1 month	24.7	25.1	27.0	28.1	25.9	26.6	21.6	23.0	22.9	24.5	22.3	23.8	23.2	24.1	25.0	26.3	24.1	25.2	24.2	18.1	21.2
2 month	23.5	24.3	27.0	28.1	25.3	26.2	20.8	22.2	22.8	24.6	21.8	23.4	22.2	23.3	24.9	26.4	23.6	23.5	24.2	18.3	21.3
3 month	22.2	23.6	26.0	26.2	24.1	24.9	19.5	21.3	21.7	24.0	20.6	22.7	20.9	22.5	23.9	25.1	22.4	23.8	23.3	17.5	20.4
6 month	22.1	23.5	26.0	26.1	24.1	24.8	19.2	21.0	21.8	24.0	20.5	22.5	20.7	22.3	23.9	25.1	22.3	23.7	23.3	17.3	20.3
Mean	23.1	24.1	26.5	27.1	24.8	25.6	20.3	21.9	22.3	24.3	21.3	23.1	21.7	23.1	24.4	25.7	23.1	24.4	23.8	17.8	20.8
HARVEST																					
1 month	20.6	20.8	22.6	23.0	21.6	21.9	17.1	21.6	19.4	21.3	18.3	21.5	18.9	21.2	21.0	22.2	20.0	21.7	19.3	17.1	18.2
2 month	20.5	20.7	22.0	22.4	21.3	21.6	17.2	21.4	19.3	21.3	18.3	21.4	18.9	21.1	20.7	21.9	19.8	21.5	19.2	17.3	18.3
3 month	19.6	20.1	21.0	21.6	20.3	20.9	17.0	20.2	19.5	20.3	18.3	20.4	18.3	20.2	20.3	21.0	19.3	20.6	18.3	17.0	17.7
6 month	19.0	19.4	21.1	21.5	20.1	20.5	17.1	20.1	19.0	20.1	18.1	20.1	18.1	19.8	20.1	20.8	19.1	20.3	18.2	16.9	17.6
Mean	19.9	20.2	21.7	22.1	20.8	21.2	17.1	20.8	19.3	20.8	18.2	20.8	18.5	20.5	20.5	21.5	19.5	21.0	18.8	17.1	18.0

E = near the hedgerows C = centre of alley

Flowering stage

Soil moisture content (cm water in 0-90 cm soil profile) during both the years was higher in root pruned than root unpruned plots, both near the hedgerows and centre of the alley. The mean of the two years, showed that in root pruned plots near the hedgerow, the moisture was 16 per cent higher than that in root unpruned (21.7 cm), and in the centre of the alley it was 11 per cent higher than root unpruned (23.1 cm). At this stage also sole *Leucaena* recorded the lowest (20.8 cm) soil moisture.

Soil moisture reduced with increasing cutting interval during both the years. Mean data of the two years showed that it was 24.1 cm in one month, 23.6 cm in two, 22.4 cm in three and 22.3 cm in six months cutting interval near the hedgerows. In the centre of the alley the variation was less, the respective values for the centre of the alley were 25.2, 23.5, 23.8 and 23.7 cm.

At harvest stage

At this stage soil moisture content (in 0-90 cm soil profile) was higher in root pruned plots than root unpruned plots during both years, both near the hedgerows and centre of the alley. Mean data of the two years showed that in root pruned alley the soil moisture near the hedgerows was higher by 11 per cent than root unpruned (18.5 cm) and in the centre of the alley it was higher by 5 per cent than the root unpruned hedgerows (20.5 cm). Sole *Leucaena* recorded the lowest soil moisture (18 cm) at this stage as well.

Soil moisture reduced with increasing cutting interval during both the years, both near the hedgerows and at the centre of the alley. Mean data of the two years showed that near the hedgerows the soil moisture was 20,

Table 20 : Land equivalent ratio (LER) as influenced by root pruning and cutting intervals of *Leucaena* hedgerows

Cutting Interval	1989-90				1990-91				MEAN
	Roots unpruned	Roots pruned	Mean	Roots unpruned	Roots pruned	Mean	Roots unpruned	Roots pruned	
1 month	0.98	1.11	1.05	0.89	1.02	0.96	0.94	1.07	1.01
2 months	0.99	1.10	1.05	0.86	0.95	0.91	0.93	1.03	0.98
3 months	0.74	0.95	0.85	0.58	0.82	0.70	0.66	0.89	0.78
6 months	0.72	0.88	0.80	0.49	0.74	0.62	0.61	0.81	0.71
Mean	0.86	1.01	0.94	0.71	0.88	0.80	0.79	0.95	0.87

19.8, 19.3 and 19.1 cm in one, two, three and six months intervals respectively. The values for the centre of the alley were 21.7, 21.5, 20.6 and 20.3 cm respectively.

4.1.4 Land equivalent ratio (cf. Table 20)

During both the years Land equivalent ratio (LER) was higher in root pruned hedgerows than that in the root unpruned hedgerows. Mean data of the two years showed that LER in root pruned plots was higher by 20 per cent than that in root unpruned (0.79). However in both the cases LER was less than unity.

Land equivalent ratio decreased with increasing cutting intervals during both the years. Mean data of the two years showed that LER in one, two and three months intervals was higher than that in six months interval (0.71) by 42, 39 and 10 per cent respectively. However, the values in general were low.

4.1.5 Correlation studies (cf. Table 21)

Significant positive correlation was recorded during both the years between grain yield and soil moisture at flowering (0.82 in first, 0.87 in second year) and harvest (0.88, 0.87); dry matter in *rabi* sorghum at 60 DAS (0.98, 0.97), 90 DAS (0.95, 0.97) and harvest (0.97, 0.98); LTR at 60 DAS (0.83, 0.80) and 120 DAS (0.68 during second year only) and effective population (0.97, 0.99) and grain weight per plant (0.99, 0.99). The correlation between grain yield and soil moisture at sowing during both years, LTR at 90 DAS during both years and LTR at 120 DAS during first year though positive was not significant. *Leucaena* total biomass production had significant negative correlation with grain yield of alley cropped sorghum during both the years (-0.91, -0.68).

Table 21 : Correlation coefficient (r) between sorghum grain yield and other parameters

Parameter	1989-90	1990-91
Soil moisture at sowing	0.50	0.46
Soil moisture at flowering	0.82 **	0.85 **
Soil moisture at harvest	0.88 **	0.87 **
Dry matter at 60 DAS	0.98 **	0.97 **
Dry matter at 90 DAS	0.95 **	0.97 **
Dry matter at harvest	0.97 **	0.98 **
Light transmission ratio at 60 DAS	0.83 **	0.80 **
Light transmission ratio at 90 DAS	0.59	0.61
Light transmission ratio at 120 DAS	0.64	0.68 *
Effective population	0.97 **	0.99 **
Grain weight per plant	0.99 **	0.99 **
<i>Leucaena</i> total production	-0.91**	-0.68 *

* Significant at 5% level

** Significant at 1% level

4.1.6 Regression analysis (cf. Fig. 13)

Regression analysis for total biomass production of *Leucaena* showed that it had a quadratic relationship with cutting interval for all the treatments during both the years, except root pruned hedgerows in 1990-91, where it was linear. The equations are given below.

Roots unpruned 1989-90 :

$$Y = 2069.6 + 30.6067 I - 0.0961 I^2 \quad (R^2 = 0.989)$$

Roots pruned 1989-90 :

$$Y = 2353.6 + 22.4032 I - 0.0817 I^2 \quad (R^2 = 0.941)$$

Sole *Leucaena* 1989-90 :

$$Y = 5991.2 + 37.0285 I - 0.1365 I^2 \quad (R^2 = 0.971)$$

Roots unpruned 1990-91 :

$$Y = 3375.0 + 34.2167 I + 0.0302 I^2 \quad (R^2 = 1.000)$$

Roots pruned 1990-91 :

$$Y = 4805.3 + 9.5024 I \quad (R^2 = 0.915)$$

Sole *Leucaena* 1990-91 :

$$Y = 8444.6 + 72.3663 I - 0.2385 I^2 \quad (R^2 = 0.971)$$

where, Y = *Leucaena* total biomass production (kg/ha),

I = Cutting interval of *Leucaena* (days)

4.1.7 Net returns (cf. Table 22)

During both the years net returns (Rs/ha) differed significantly due to main plot treatments. In 1989-90 root pruned hedgerows and sole *Leucaena* were on par, and were significantly superior to root unpruned hedgerows. In the second year highest net returns were obtained from sole *Leucaena*, it was followed by root pruned and unpruned hedgerows, they differed from each other significantly. Mean data of the two years showed that net returns from root pruned hedgerows and sole *Leucaena* were higher than that from root unpruned (Rs.2,520/ha) by 26 and 91 percent respectively.

Cutting intervals produced significant differences in net returns during both the years. In first year, two and one month intervals were on par, and were significantly superior to three months. Three months was significantly superior to six months cutting interval. In the second year two months was significantly superior to other cutting intervals, which were at par. Mean data of the two years showed that net returns from two, one and three months cutting intervals were higher than that from six months (Rs.3,128/ha.) by 27, 14 and 7 per cent respectively.

The interaction between main plots and cutting intervals was significant during both the years. In both the years in root unpruned and root pruned plots, one and two months cutting intervals were at par, and were significantly superior to three and six months, which were at par. In sole *Leucaena* in 1989-90 three months was on par with 2 and 6 months, and was significantly superior to one month, and in 1990-91, 2,3 and 6 months were on par and, were significantly superior to one month interval.

Table 22 : Net returns (Rs/ha) from *Leucaena* - sorghum hedgerow intercropping system and sole *Leucaena* as influenced by cutting intervals of *Leucaena*

Cutting Interval	1989-90					1990-91					MEAN	
	Roots unpruned	Roots pruned	Sole <i>Leucaena</i>	Mean	Roots unpruned	Roots pruned	Sole <i>Leucaena</i>	Mean	Roots unpruned	Roots pruned		Sole <i>Leucaena</i>
1 month	3117	3631	3185	3311	3049	3532	4826	3802	3083	3582	4006	3557
2 months	3410	3782	3864	3685	3164	3416	6183	4254	3287	3599	5024	3970
3 months	2204	3091	3800	3032	1809	2747	6477	3678	2007	2919	5139	3355
6 months	1952	2647	3345	2648	1450	2488	6886	3608	1701	2568	5116	3128
Mean	2671	3288	3549	3169	2368	3046	6093	3836	2520	3167	4821	3503

For comparing means of : SEM± CD(5%) SEM± CD(5%)

Root pruning (RP)	89.0	162.8	308.0	563.4
Cutting interval (CI)	82.7	155.3	239.9	450.7
CI at same RP	143.2	269.0	415.6	780.6
RP at same or different CI	152.7	284.0	472.0	876.0

4.2 Evaluation of effects of Nitrogen and *Leucaena* prunings Application to Alley cropped *Rabi* sorghum

Three systems, viz., alley cropped *rabi* sorghum without *Leucaena* prunings application, with prunings application; and sole sorghum were evaluated at four N levels, viz., 0, 12.5, 25 and 50 kg N per ha.

4.2.1 *Rabi* sorghum

4.2.1.1 Plant height (cf. Table 23, Fig. 14)

30 DAS

Plant height (cm) of *rabi* sorghum did not vary significantly due to the systems in both the years. However, mean data of the two years indicated that sole sorghum maintained highest plant height (15.8 cm) and prunings unapplied alley sorghum the lowest (15.1 cm).

Nitrogen levels did not have significant influence on plant height in both the years. However, mean data of the two years indicated that plant height was maximum (15.9 cm) with 25 kg and the minimum (15 cm) at 0 kg N per ha.

60 DAS

Plant height of *rabi* sorghum differed significantly due to systems in both the years. Sole sorghum resulted in maximum plant height, followed by prunings applied and unapplied alley sorghum. Mean data of the two years showed that plant height in sole sorghum and prunings applied alley sorghum was higher than that in prunings unapplied (75.8) by 56 and 9 per cent respectively.

During both the years plant height of *rabi* sorghum increased significantly with increasing N level from 0 to 50 kg N per ha. In 1989-90 plant height increased significantly with increasing N level upto 25 kg N

Table 23 : Plant height (cm) of sorghum at different stages of growth as influenced by prunings application and N levels

N levels (kg/ha)	30 DAS						60 DAS						90 DAS						HARVEST							
	Prunings applied		Sole sorghum		Mean		Prunings applied		Sole sorghum		Mean		Prunings applied		Sole sorghum		Mean		Prunings applied		Sole sorghum		Mean			
	SEM±	CD(5%)	SEM±	CD(5%)	SEM±	CD(5%)	SEM±	CD(5%)	SEM±	CD(5%)	SEM±	CD(5%)	SEM±	CD(5%)	SEM±	CD(5%)	SEM±	CD(5%)	SEM±	CD(5%)	SEM±	CD(5%)	SEM±	CD(5%)		
1989-90																										
0	13.4	14.2	13.3	13.6	66.0	74.0	96.5	78.8	101.5	105.5	129.8	112.3	109.8	117.5	143.8	127.7										
12.5	14.0	14.9	14.4	14.4	70.0	81.0	104.3	85.1	103.3	107.3	133.8	114.8	115.5	118.8	147.8	127.3										
25	14.0	14.7	16.2	14.9	79.0	83.5	117.8	93.4	110.3	113.3	146.0	123.2	122.0	125.5	162.8	136.8										
50	14.0	14.2	15.1	14.4	88.0	90.5	118.3	98.9	117.0	122.5	140.5	126.7	130.5	135.5	161.8	142.6										
Mean	13.8	14.5	14.7	14.4	75.8	82.3	109.2	89.1	108.0	112.1	137.5	119.2	119.4	124.3	154.0	132.6										
1990-91																										
0	16.1	17.0	16.2	16.4	67.3	79.8	104.3	83.8	128.5	143.3	152.8	141.5	128.5	143.3	153.0	141.6										
12.5	16.3	16.9	16.8	16.6	77.0	82.0	126.3	95.1	131.5	150.3	170.3	150.7	131.5	150.3	170.3	150.7										
25	16.4	16.9	17.1	16.8	77.8	82.8	136.5	99.0	149.3	158.8	180.5	162.8	149.5	158.8	180.5	162.9										
50	16.3	16.8	17.1	16.7	81.5	88.0	139.5	103.0	156.8	168.5	183.8	169.7	156.8	168.8	184.0	169.8										
Mean	16.3	16.9	16.8	16.6	75.8	83.1	126.6	95.2	141.5	155.2	171.8	156.2	141.6	155.3	171.9	156.3										
MEAN																										
0	14.8	15.6	14.8	15.0	66.7	76.9	100.4	81.3	115.0	124.4	141.3	126.9	119.2	130.4	148.4	134.7										
12.5	15.2	15.9	15.6	15.5	73.5	81.5	115.3	90.1	117.4	128.8	152.1	132.8	123.5	134.6	159.1	139.0										
25	15.2	15.8	16.7	15.9	78.4	83.2	127.2	96.2	129.8	136.1	163.3	143.0	135.8	142.2	171.7	149.9										
50	15.2	15.5	16.1	15.6	84.8	89.3	128.9	101.0	136.9	145.5	162.2	148.2	143.7	152.2	172.9	156.2										
Mean	15.1	15.7	15.8	15.5	75.8	82.7	117.9	92.2	124.8	133.7	154.7	137.7	130.5	139.8	163.0	145.0										
For comparing 1989-90																										
means of: SEM±																										
CD(5%)																										
1990-91																										
SEM±																										
CD(5%)																										
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SEM±																										
CD(5%)																										
1990-91																										
SEM±																										
CD(5%)																										
Prunings application (PA)																										
0.355 NS																										
0.178 NS																										
1.86 NS																										
6.42 NS																										
1.68 NS																										
5.83 NS																										
2.94 NS																										
10.16 NS																										
2.78 NS																										
9.65 NS																										
2.46 NS																										
8.50 NS																										
2.77 NS																										
9.58 NS																										
N levels(N)																										
0.425 NS																										
0.386 NS																										
2.09 NS																										
6.06 NS																										
2.06 NS																										
5.99 NS																										
2.22 NS																										
6.44 NS																										
3.00 NS																										
8.71 NS																										
2.09 NS																										
6.05 NS																										
2.99 NS																										
8.66 NS																										
N at same PA																										
0.736 NS																										
0.669 NS																										
3.62 NS																										
10.37 NS																										
3.85 NS																										
5.20 NS																										
3.61 NS																										
5.17 NS																										
105 NS																										
PA same or diff. N																										
0.730 NS																										
0.606 NS																										
3.64 NS																										
10.66 NS																										
4.44 NS																										
5.20 NS																										
3.98 NS																										
5.26 NS																										

per ha, the increase with 50 over 25 kg N per ha was not significant. In 1990-91 the increase was significant upto 12.5 kg N, 25 kg N was on par with 12.5 kg, and 50 kg N was on par with 25, and was significantly superior to 12.5 kg N per ha. Mean data of the two years showed that plant height with application of 12.5, 25 and 50 kg N per ha was higher than that with no N application (75.8 cm) by 11, 18 and 24 per cent respectively.

The interaction between systems and N levels was significant in 1990-91. In prunings applied alley sorghum N application did not increase sorghum plant height significantly, but in prunings unapplied alley sorghum and sole sorghum, N application increased sorghum plant height significantly.

90 DAS

Plant height of *rabi* sorghum differed significantly due to systems in both the years. In 1989-90 sole sorghum recorded significantly higher plant height than prunings applied and unapplied alley sorghum, which were on par. In 1990-91 sole sorghum recorded maximum plant height followed by prunings applied and unapplied alley sorghum, which differed from each other significantly. Mean data of the two years indicated that plant height was more in sole sorghum and prunings applied alley sorghum than that in prunings unapplied (124.8 cm) by 24 and 7 per cent respectively.

Rabi sorghum plant height differed significantly due to N levels during both the years. In 1989-90, 50 and 25 kg N per ha were on par, and were significantly superior to 0 and 12.5 kg N per ha, which were on par with each other. In 1990-91, 50 and 25 kg N per ha were on par and were significantly superior to 12.5 kg N per ha, which was significantly superior to no N application. Mean data for the two years showed that

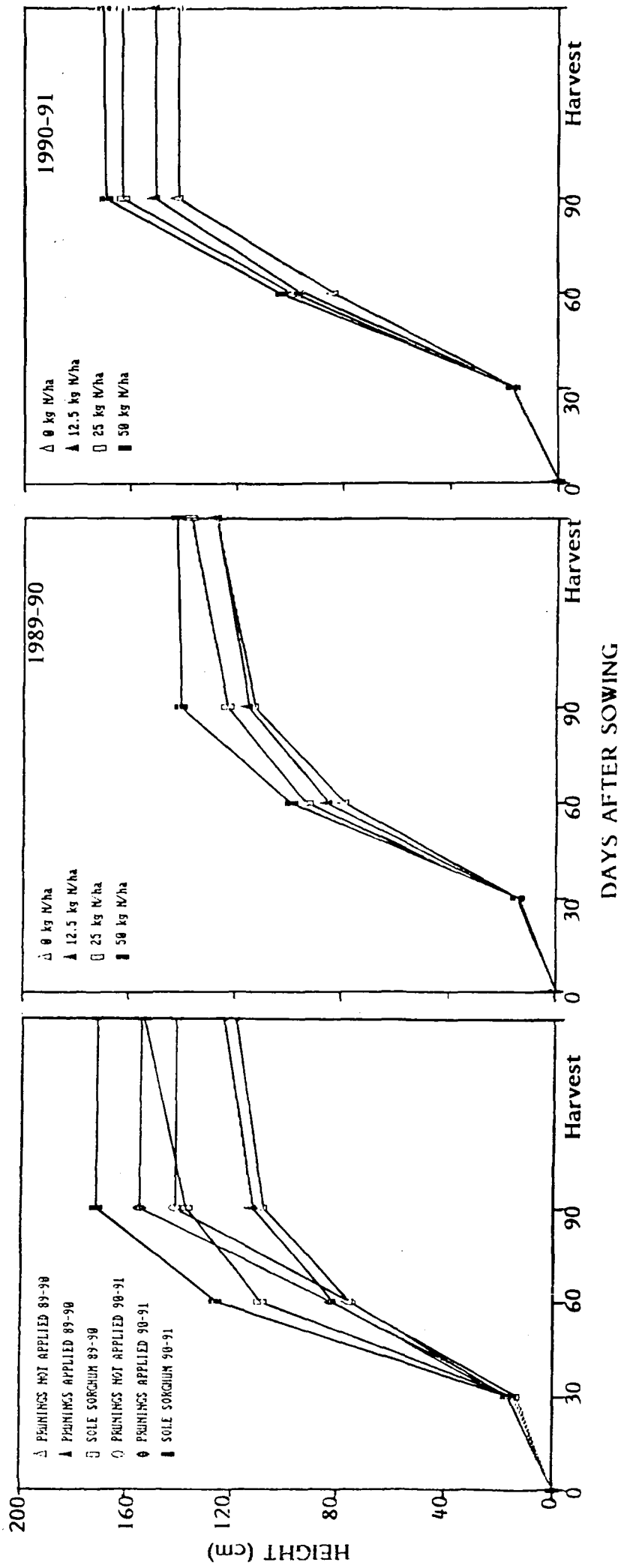


Fig.14. SORGHUM HEIGHT AT DIFFERENT STAGES OF GROWTH AS INFLUENCED BY LEUCAENA PRUNINGS APPLICATION AND N LEVELS

plant height with application of 12.5, 25 and 50 kg N per ha was higher than that with 0 kg N per ha (126.9 cm) by 5, 13 and 17 per cent respectively.

Harvest

During both the years plant height of sorghum at harvest differed significantly due to systems. In 1989-90 sole sorghum recorded maximum plant height, followed by prunings applied and unapplied alley sorghum, however the difference between prunings applied and unapplied alley sorghum was not significant. In 1990-91 sole sorghum recorded maximum plant height, followed by prunings applied and unapplied alley sorghum, they differed from each other significantly. Mean data of the two years indicated that plant height in prunings applied alley sorghum and sole sorghum was higher than that in prunings unapplied (130.5 cm) by 7 and 25 per cent respectively.

Rabi sorghum plant height increased significantly due to N application during both the years. In 1989-90, 50 and 25 kg N per ha levels were on par, and were significantly superior to 12.5 and 0 kg N per ha levels, which were on par. In the second year 50 and 25 kg N levels were on par, and were significantly superior to 12.5 kg N, which was significantly superior to 0 kg N per ha. Mean data of the two years indicated that plant height with application of 12.5, 25 and 50 kg N per ha was higher than that with no N application (134.7 cm) by 3, 11 and 16 per cent respectively.

4.2.1.2 Dry matter (cf. Table 24, Fig. 15)

30 DAS

At 30 DAS dry matter in sorghum (g/plant) did not vary significantly due to systems in both the years. Mean data of the two years showed that

Table 24 : Dry matter (g/plant) of sorghum at different stages of plant growth as influenced by prunings application and N levels

N levels (kg/ha)	60 DAS						90 DAS						HARVEST								
	30 DAS		60 DAS		90 DAS		30 DAS		60 DAS		90 DAS		Prunings applied		Prunings applied		Sole sorghum		Sole sorghum		
	Prunings unapplied	Prunings applied	Mean	SEm±	Prunings unapplied	Prunings applied	Mean	SEm±	Prunings unapplied	Prunings applied	Mean	SEm±	Prunings unapplied	Prunings applied	Mean	SEm±	Prunings unapplied	Prunings applied	Mean	SEm±	
1989-90																					
0	3.1	3.2	3.1	3.1	7.5	9.3	9.8	8.9	23.9	30.1	31.1	28.4	29.0	38.0	38.9	35.3					
12.5	3.1	3.3	3.2	3.2	9.3	10.5	14.0	11.3	31.1	33.8	44.8	36.5	39.1	42.1	55.2	45.6					
25	3.2	3.2	3.2	3.2	10.7	11.2	15.1	12.3	35.1	36.2	47.6	39.6	43.9	45.5	60.5	49.9					
50	3.1	3.3	3.3	3.3	11.3	12.2	20.1	14.5	36.9	40.7	55.4	44.3	45.3	50.2	70.0	55.2					
Mean	3.1	3.2	3.2	3.2	9.7	10.8	14.8	11.7	31.8	35.2	44.7	37.2	39.3	43.9	56.2	46.5					
1990-91																					
0	3.4	3.5	3.4	3.4	8.2	11.3	11.1	10.2	21.3	32.7	32.1	28.7	24.6	38.7	39.1	34.2					
12.5	3.5	3.6	3.6	3.6	11.1	12.1	16.0	13.1	30.1	34.4	44.1	36.2	35.8	40.1	52.6	42.8					
25	3.4	3.8	3.7	3.7	11.5	13.1	20.0	14.9	32.1	37.1	55.0	41.4	38.5	42.8	65.4	48.8					
50	3.5	3.7	3.6	3.6	13.2	15.1	21.1	16.4	37.0	41.1	60.2	46.1	44.5	49.0	70.9	54.8					
Mean	3.5	3.6	3.6	3.6	10.7	12.9	17.0	13.6	30.1	36.3	47.8	38.1	35.8	42.6	57.0	45.2					
MEAN																					
0	3.3	3.4	3.3	3.3	7.9	10.3	10.5	9.6	22.6	31.4	31.6	28.6	26.8	38.4	39.0	34.8					
12.5	3.3	3.5	3.4	3.4	10.2	11.3	15.0	12.2	30.6	34.1	44.5	36.4	37.5	41.1	53.9	44.2					
25	3.3	3.5	3.6	3.5	11.1	12.2	17.6	13.6	33.6	36.7	51.3	40.5	41.2	44.2	63.0	49.4					
50	3.3	3.5	3.5	3.5	12.3	13.7	20.6	15.5	37.0	40.9	57.8	45.2	44.9	49.6	70.5	55.0					
Mean	3.3	3.4	3.4	3.4	10.2	11.9	15.9	12.7	31.0	35.8	46.3	37.7	37.6	43.3	56.6	45.9					
For comparing 1989-90																					
means of : SEm±		1989-90		1989-91		1989-90		1989-91		1989-90		1989-91		1989-90		1989-91		1989-90		1989-91	
CD(5%)		NS		NS		0.06		NS		0.47		1.63		0.28		0.96		0.36		1.25	
Prunings application (PA)		0.12		NS		0.06		NS		0.47		1.63		0.28		0.96		0.36		1.25	
N levels(N)		0.17		NS		0.23		NS		0.57		1.65		0.63		1.82		1.25		3.62	
N at same PA		0.30		NS		0.40		NS		0.98		2.85		1.08		3.14		2.16		NS	
PA same or diff. N		0.28		NS		0.35		NS		0.97		2.95		0.98		3.14		1.90		NS	
								</													

dry matter in sole sorghum, prunings applied alley sorghum and prunings unapplied alley sorghum was 3.4, 3.4 and 3.3 g per plant respectively.

Nitrogen application also did not produce significant difference in dry matter in sorghum plant during both the years. Mean data of the two years showed dry matter values of 3.3, 3.4, 3.5 and 3.5 g per plant with application of 0, 12.5, 25 and 50 kg N per ha respectively.

60 DAS

At this stage dry matter in sorghum plant differed significantly due to systems in both the years. In 1989-90 highest dry matter was recorded in sole sorghum, followed by prunings applied and unapplied alley sorghum, however the difference between the latter two was not significant statistically. During 1990-91 also sole sorghum recorded highest dry matter, followed by prunings applied and unapplied alley sorghum, which differed from each other significantly. Mean data of the two years showed that dry matter in prunings applied alley sorghum and sole sorghum was higher than that in prunings unapplied (10.2 g/plant) by 17 and 56 per cent respectively.

Nitrogen application affected dry matter in sorghum significantly during both the years. During 1989-90 50 kg N per ha recorded the highest dry matter, followed by 25, 12.5 and 0 N levels. However, difference between 12.5 and 50 kg N per ha was not significant. During 1990-91 50 kg N per ha produced significantly highest dry matter, followed by 25, 12.5 and 0 kg N per ha. However, the differences between 12.5 and 25; and 25 and 50 kg N per ha were not significant. Mean data of the two years showed that dry matter in sorghum plants with 12.5, 25 and 50 kg N per ha was higher than that with 0 kg N (9.6 g/plant) by 27, 42 and 72 per cent respectively.

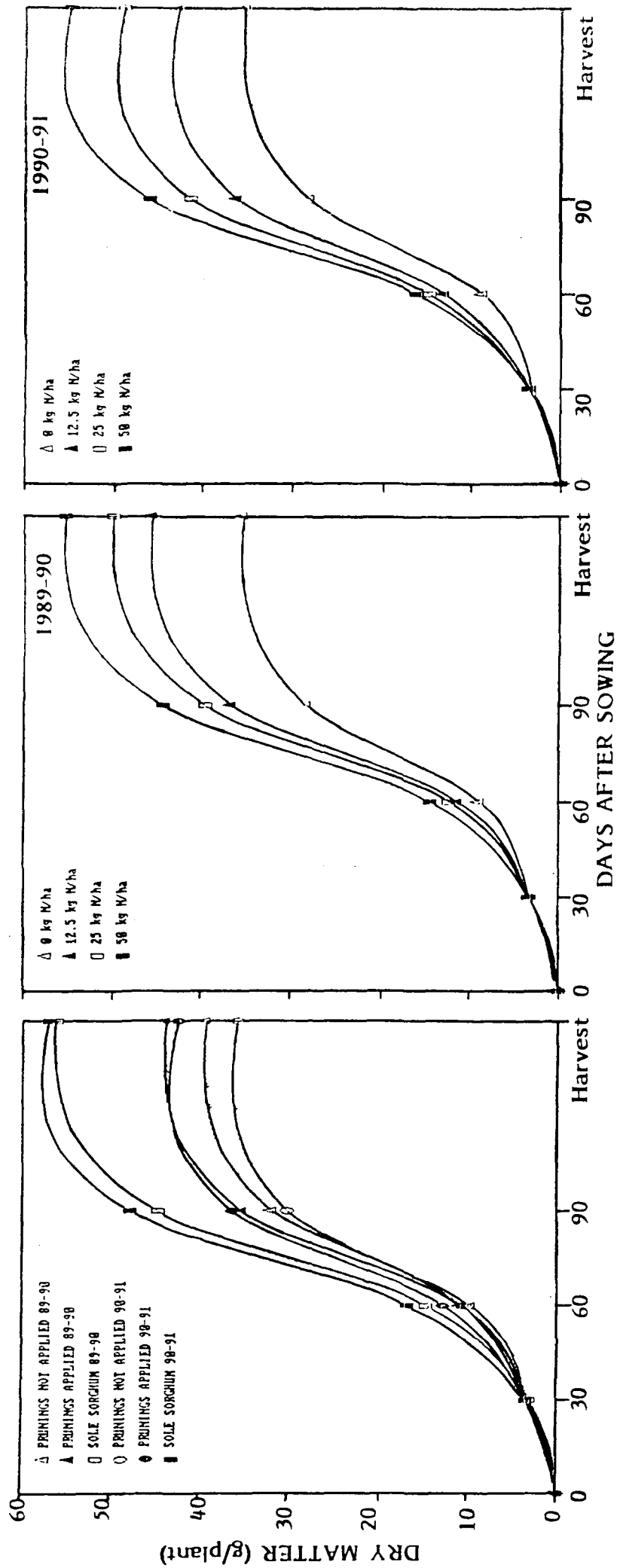


Fig.15. DRY MATTER IN SORGHUM PLANT AT DIFFERENT STAGES OF GROWTH AS INFLUENCED BY LEUCAENA PRUNINGS APPLICATION AND N LEVELS

The interaction between systems and N levels was significant in both the years. The rate of increase in dry matter of sorghum plant with increase in N level from 0 to 50 kg N per ha was highest in sole sorghum, followed by prunings unapplied and applied alley sorghum. The mean values of the two years were 96, 56 and 33 per cent in sole sorghum, prunings unapplied and prunings applied alley sorghum respectively.

90 DAS

During both the years dry matter in sorghum plant at 90 DAS differed significantly due to systems. Dry matter was highest in sole sorghum, followed by prunings applied and unapplied alley sorghum, and the differences were statistically significant during both the years. Mean data of two years showed that dry matter in prunings applied alley sorghum and sole sorghum was higher than that in prunings unapplied (31 g/plant) by 15 and 49 per cent respectively.

Dry matter in sorghum plant differed significantly due to varying N levels during both the years. In 1990-91 dry matter increased significantly with increasing N level from 0 to 50 kg N per ha. In 1989-90 also, though dry matter increased with increasing N level from 0 to 50 kg N per ha, 12.5 and 25 kg N per ha were at par. Mean data of the two years showed that dry matter in sorghum plant was higher with application of 12.5, 25 and 50 kg N per ha than that with 0 kg N (28.6 g/plant) by 27, 42 and 58 per cent respectively.

The interaction between systems and N levels was significant during 1990-91. The rate of increase in dry matter of sorghum plant with increase in N level from 0 to 50 kg N per ha was higher in sole sorghum (88%) than prunings unapplied (74%) and prunings applied (27%) alley sorghum.

Harvest

In both the years dry matter in sorghum plant was highest in sole sorghum, followed by prunings applied and unapplied alley sorghum, they differed from each other significantly. Mean data of the two years indicated that dry matter in sole sorghum and prunings applied alley sorghum was higher than that in prunings unapplied (37.6 g/plant) by 15 and 50 per cent respectively.

During both the years dry matter in sorghum plant increased significantly with increasing N level from 0 to 50 kg N per ha. Mean data of the two years indicated that dry matter in sorghum plant was higher with 12.5, 25 and 50 kg N per ha than 0 kg N (34.8 g/plant) by 27, 42 and 58 per cent respectively.

The interaction between systems and N levels was significant during both the years. Mean data of two years showed that the rate of increase in dry matter in sorghum plant with increased N application from 0 to 50 kg N per ha was higher in sole sorghum (81%) than prunings unapplied (68%) and prunings applied (29%) alley sorghum.

4.2.1.3 Light transmission ratio (cf. Table 25)

Light transmission ratio (LTR) at 30 DAS differed to some extent due to systems during both the years. Mean data of the two years showed that it varied from 90 per cent in prunings unapplied to 91 per cent in prunings applied and 100 per cent in sole sorghum.

At 30 DAS LTR did not vary much due to N levels during both the years. Mean data of the two years showed that LTR values varied from 93 to 94 per cent with different N levels. At later stages (60, 90 and 120 DAS), LTR did not differ markedly due to systems or N levels during both the years.

Table 25 : Light transmission ratio (%) at different stages of sorghum growth as influenced by prunings application and N levels

N levels (kg/ha)	1989-90				1990-91				MEAN				
	Prunings applied		Sole sorghum		Prunings applied		Sole sorghum		Prunings unapplied	Prunings applied	Sole sorghum	Mean	
	0	87	90	100	92	92	91	100	94	90	91	100	93
12.5	89	90	90	100	93	90	92	100	94	90	91	100	94
25	88	88	100	100	92	92	91	100	94	90	90	100	93
50	89	89	100	100	93	90	92	100	94	90	91	100	94
Mean	88	89	100	100	93	91	92	100	94	90	91	100	94
60 DAS													
0	100	100	100	100	100	99	99	100	100	100	100	100	100
12.5	100	100	100	100	100	98	97	100	98	99	99	100	99
25	99	100	100	100	100	98	99	100	99	99	100	100	100
50	100	100	100	100	100	100	100	100	100	100	100	100	100
Mean	100	100	100	100	100	99	99	100	99	100	100	100	100
90 DAS													
0	97	98	100	100	98	97	95	100	97	97	97	100	98
12.5	98	98	100	100	99	95	98	100	98	97	98	100	99
25	97	97	100	100	98	100	95	100	98	99	96	100	98
50	98	96	100	100	98	96	96	100	97	97	96	100	98
Mean	98	97	100	100	98	97	96	100	98	98	97	100	98
120 DAS													
0	98	98	100	100	99	98	97	100	98	98	98	100	99
12.5	98	97	100	100	98	97	99	100	99	98	98	100	99
25	98	97	100	100	98	100	97	100	99	99	97	100	99
50	98	98	100	100	99	98	98	100	99	98	98	100	99
Mean	98	97	100	100	99	98	98	100	99	98	98	100	99

4.2.1.4 Plant population at harvest (cf. Table 26)

During both the years per hectare plant population of sorghum at harvest differed significantly due to systems. Sole sorghum recorded significantly higher plant population than prunings applied and unapplied alley sorghum which were at par. Mean data of the two years showed that plant population in sole sorghum was higher than that in prunings unapplied (54,000/ha) or prunings applied (54,100/ha) alley sorghum by 27 per cent. Sorghum plant population at harvest did not vary significantly due to varying N levels during both the years.

4.2.1.5 Effective population (cf. Table 26)

During both the years effective (ear bearing) population per hectare differed significantly due to systems. Effective population in sole sorghum was significantly higher than that in prunings unapplied and prunings applied alley sorghum, which were at par. Mean data of the two years showed that effective population in sole sorghum was higher than that in prunings unapplied (50,000) and or applied alley sorghum (49,800) by 29 per cent. Effective population of *rabi* sorghum was not influenced significantly by varying N levels during both the years.

4.2.1.6 Ear yield (cf. Table 26)

During both the years ear yield differed significantly due to systems. In 1989-90 sole sorghum was significantly superior to prunings applied and unapplied alley sorghum, which were on par. In the second year highest ear yield was obtained in sole sorghum, followed by prunings applied and unapplied alley sorghum, which differed from each other significantly. Mean data of the two years indicated that ear yield in prunings applied alley sorghum and sole sorghum was higher than that in prunings unapplied (938 kg/ha) by 20 and 55 per cent respectively.

Table 26 : Plant population at harvest, effective population and ear yield of sorghum as influenced by prunings application and N levels

Treatment	Plant population at harvest (' 000/ha)			Effective population (' 000/ha)			Ear yield (kg/ha)		
	1989-90	1990-91	Mean	1989-90	1990-91	Mean	1989-90	1990-91	Mean
Prunings Application									
Prunings unapplied	56.4	51.5	54.0	52.8	47.1	50.0	1100	776	938
Prunings applied	56.1	52.1	54.1	52.0	47.5	49.8	1198	1059	1129
Sole sorghum	70.3	67.5	68.9	66.8	61.9	64.4	1508	1401	1455
SEmt	0.83	1.24		1.09	1.38		48.7	38.2	
CD 5%	2.87	4.31		3.79	4.76		168.7	132.2	
N levels (kg/ha)									
0	60.1	56.0	58.1	56.9	51.8	54.4	995	803	899
12.5	62.0	58.0	60.0	58.2	52.1	55.2	1215	1042	1129
25	61.5	57.5	59.5	57.9	52.4	55.2	1350	1204	1277
50	60.1	56.7	58.4	55.8	52.4	54.1	1512	1266	1389
SEmt	2.23	1.47		2.04	1.31		39.1	42.7	
CD 5%	NS	NS		NS	NS		113.4	123.9	
Interaction									
N at same PA	3.86	2.54		3.53	2.28		67.7	73.9	
CD 5%	NS	NS		NS	NS		196.4	214.7	
PA at same or different N	3.44	2.53		3.25	2.41		76.2	74.6	
CD 5%	NS	NS		NS	NS		238.6	227.4	

Table 26 a : Ear yield (kg/ha) as influenced by prunings application x N levels

N levels (kg/ha)	1990-91						MEAN		
	Prunings unapplied	Prunings applied	Sole sorghum	Prunings unapplied	Prunings applied	Sole sorghum			
0	891	1065	1030	451	995	961	671	1030	996
12.5	1100	1169	1377	787	1042	1296	944	1106	1337
25	1215	1215	1621	857	1097	1655	1156	1156	1638
50	1192	1343	2002	1007	1100	1690	1100	1222	1846
For comparing means of N at same PA	SEmt	67.7	196.4	SEmt	73.9	214.7			
PA at same or different N	SEmt	76.2	238.6	SEmt	74.6	227.4			

During both the years ear yield differed significantly due to varying N levels. In first year each increasing level from 0 to 50 kg N per ha significantly increased ear yield. In the second year also ear yield increased significantly upto 25 kg, the further increase with 50 kg N per ha over 25 kg N was statistically not significant. Mean data of the two years indicated that ear yield with 12.5, 25 and 50 kg N per ha was higher than that with 0 kg N (899 kg/ha) by 26, 42 and 55 per cent respectively.

The interaction between systems and N levels was significant during both the years (Table 26a). Mean data of the two years showed that the rate of increase in ear yield with increase in N level from 0 to 50 kg N per ha was higher in sole sorghum (85%) and prunings unapplied alley sorghum (64%) than that in prunings applied alley sorghum (19%).

4.2.1.7 Ear weight per plant (cf. Table 27)

During both the years ear weight per plant differed significantly due to systems. Sole sorghum and prunings applied alley sorghum were on par, and were significantly superior to prunings unapplied alley sorghum. Mean data of the two years showed that ear weight per plant in prunings applied alley sorghum and sole sorghum was higher than that in prunings unapplied alley sorghum (22.8 g) by 22 and 23 per cent respectively.

During both the years per plant ear weight differed significantly due to systems. Ear weight increased significantly with increasing N level from 0 to 50 kg N per ha, however, the difference between 12.5 and 25 kg N per ha was not significant. Mean data of the two years showed that ear weight per plant in 12.5, 25 and 50 kg N levels was higher than that in 0 kg N (20.5 g) by 23, 40 and 52 per cent respectively.

Table 27 : Yield components of sorghum as influenced by prunings application and N levels

Treatment	Ear weight per plant (g)		Grain weight per plant (g)		Number of grains per ear		1000 grain weight (g)					
	1989-90	1990-91	Mean 1989-90	1990-91	Mean 1989-90	1990-91	Mean 1989-90	1990-91				
Prunings Application												
Prunings not applied	25.8	19.8	22.8	19.3	15.3	17.3	583	428	506	30.4	28.1	29.3
Prunings applied	28.9	26.8	27.9	21.0	20.6	20.8	648	572	610	30.8	27.9	29.4
Sole sorghum	28.6	27.4	28.0	21.3	21.0	21.2	694	658	676	32.4	31.3	31.9
SEmt	0.77	0.99	0.69	0.71	0.71	0.71	22.7	16.4	0.40	0.40	0.60	0.60
CD 5%	2.68	3.42	NS	NS	2.47	2.47	78.5	56.7	1.38	1.38	2.07	2.07
N levels (kg/ha)												
0	22.3	18.7	20.5	16.1	14.1	15.1	498	416	457	31.0	29.3	30.2
12.5	26.5	24.0	25.3	19.8	18.4	19.1	602	537	570	30.4	29.3	29.9
25	28.7	27.2	28.0	21.1	21.0	21.1	659	613	636	31.3	29.0	30.2
50	33.6	28.7	31.2	25.2	22.3	23.8	808	644	726	32.1	28.8	30.5
SEmt	1.05	1.13	0.89	0.87	0.87	0.87	27.8	27.1	0.40	0.40	0.36	0.36
CD 5%	3.05	3.29	2.58	2.53	2.53	2.53	80.8	78.8	1.16	1.16	NS	NS
Interaction												
N at same PA	1.82	1.96	1.54	1.51	1.51	1.51	48.2	47	0.69	0.69	0.62	0.62
SEmt	NS	NS	NS	NS	NS	NS	NS	136.5	NS	NS	NS	NS
CD 5%	1.76	1.97	1.50	1.49	1.49	1.49	47.5	43.9	0.72	0.72	0.80	0.80
SEmt	NS	NS	NS	NS	NS	NS	NS	130.8	NS	NS	NS	NS
CD 5%												

Table 27 a : Number of grains per ear in 1990-91 as influenced by prunings application x N levels

N levels (kg/ha)	Prunings unapplied	Prunings applied	Sole sorghum
0	243	559	447
12.5	440	555	615
25	474	586	780
50	556	588	790

For comparing means of :
 N at same PA : 47 136.5
 PA at some or different N : 43.9 130.8

4.2.1.8 Grain weight per plant (cf. Table 27)

Grain weight per plant differed significantly due to systems in the second year, where prunings applied alley sorghum and sole sorghum were on par, and were significantly superior to prunings unapplied. During the first year though the grain weight per plant in prunings applied alley sorghum and sole sorghum was higher than that in prunings unapplied, the differences were statistically not significant. Mean data of the two years showed that grain weight per plant in prunings applied alley sorghum and sole sorghum was higher than that in prunings unapplied (17.3 g/plant) by 20 and 23 per cent respectively.

Grain weight per plant differed significantly due to varying N levels during both the years. In 1989-90 50 kg N per ha recorded significantly highest grain weight, followed by 25 and 12.5, which were on par and were significantly superior to 0 kg N. During 1990-91 50 kg N per ha recorded significantly highest grain weight, followed by 25, 12.5 and 0 kg N per ha. The difference between 50 and 25 kg N per ha was not significant statistically. Mean data of the two years showed that grain weight with 50, 25 and 12.5 kg N per ha increased over that with no N application (15.1 g/plant) by 26, 40 and 58 per cent respectively.

4.2.1.9 Grain number per ear (cf. Table 27)

Grain number per ear differed significantly due to systems during both the years. In the first year sole sorghum recorded significantly highest grain number, followed by prunings applied alley sorghum which ^{was} on par with the former and also prunings unapplied alley sorghum. In the second year again sole sorghum recorded significantly higher grain number, followed by prunings applied and unapplied alley sorghum, all the three systems

differed from each other significantly. Mean data of the two years showed that grain number in prunings applied alley sorghum and sole sorghum was higher than that in prunings unapplied alley sorghum (506/ear) by 21 and 34 per cent respectively.

Grain number per ear differed significantly due to varying N levels during both the years. During 1989-90 50 kg N per ha recorded significantly highest grain number per ear, followed by 25 and 12.5 kg N levels, which were on par with each other, and were significantly superior to no N application. In the second year also 50 kg N per ha recorded significantly highest grain number per ear, followed by 25, 12.5 and 0 kg N per ha levels. However, the differences between 12.5 and 25; and 25 and 50 were not significant. Mean data of the two years showed that grain number with application of 12.5, 25 and 50 kg N per ha was higher than that with no N application (457/ear) by 25, 39 and 59 per cent respectively.

The interaction between systems and N levels was significant during 1990-91 (Table 27a). With increase in N level from 0 to 50 kg N per ha the rate of increase in grain number was higher in prunings unapplied alley sorghum (129%) and sole sorghum (77%) than prunings applied alley sorghum (5%).

4.2.1.10 Thousand grain weight (cf. Table 27)

Thousand grain weight of *rabi* sorghum differed significantly due to systems during both the years. Sole sorghum recorded significantly higher 1000 grain weight than prunings applied and unapplied alley crops, which were on par. Mean data of the two years indicated that thousand grain weight of sole sorghum (31.9 g) was higher than that of prunings unapplied and applied alley crop by 9 per cent.

Thousand grain weight differed significantly due to N levels only during 1989-90, where application of 50 kg N per ha resulted in significantly higher 1000 grain weight than 12.5kg N per ha, all other N levels were at par.

4.2.1.11 Grain yield per hectare (cf. Table 28, Fig. 16)

Sorghum grain yield differed significantly due to systems during both the years. In the first year highest grain yield was produced in sole sorghum, followed by prunings applied and prunings unapplied alley sorghum, however the difference between the latter two was not significant. In the second year also sole sorghum produced significantly highest grain yield, followed by prunings applied and unapplied alley sorghum, they differed from each other significantly. Average data for the two years indicated that grain yield in prunings applied alley sorghum and sole sorghum was higher than that in prunings unapplied alley sorghum (712 kg/ha) by 22 and 57 per cent respectively.

Grain yield of *rabi* sorghum differed significantly due to varying N levels during both the years. In the first year grain yield increased significantly with increase in N levels from 0 to 50 kg N per ha. In the second year also grain yield increased significantly upto 25 kg N per ha, further increase with 50 kg N per ha, was not statistically significant. Mean data of the two years showed that grain yield with application of 12.5, 25 and 50 kg N per ha was higher than that with no N application (676 kg/ha) by 28, 45 and 59 per cent respectively.

The interaction between systems and N levels was significant during both the years. In first year at 0 kg N level prunings applied alley sorghum was superior to prunings unapplied alley sorghum and on par with sole sorghum; and sole sorghum was on par with prunings unapplied. At 50

Table 28 : Grain yield (kg/ha) of sorghum as influenced by prunings application and N levels

N levels (kg/ha)	1989-90				1990-91				MEAN			
	Prunings unapplied	Prunings applied	Sole sorghum	Mean	Prunings unapplied	Prunings applied	Sole sorghum	Mean				
0	656	813	777	749	324	757	723	602	490	785	750	676
12.5	841	891	1053	929	602	789	1000	797	722	840	1027	863
25	911	923	1255	1029	654	847	1277	926	783	885	1266	978
50	924	1046	1551	1174	782	856	1298	979	853	951	1425	1077
Mean	833	918	1159	970	591	813	1074	826	712	866	1117	898

For comparing means of : SEMt CD 5% SEMt CD5%

Prunings Application (PA) 33.7 123.7 28.4 98.2

Nitrogen levels (N) 30.6 88.8 32.8 95.1

N at same PA 53.0 153.7 56.7 164.7

PA at same or
different N 58.2 181.1 56.7 172.6

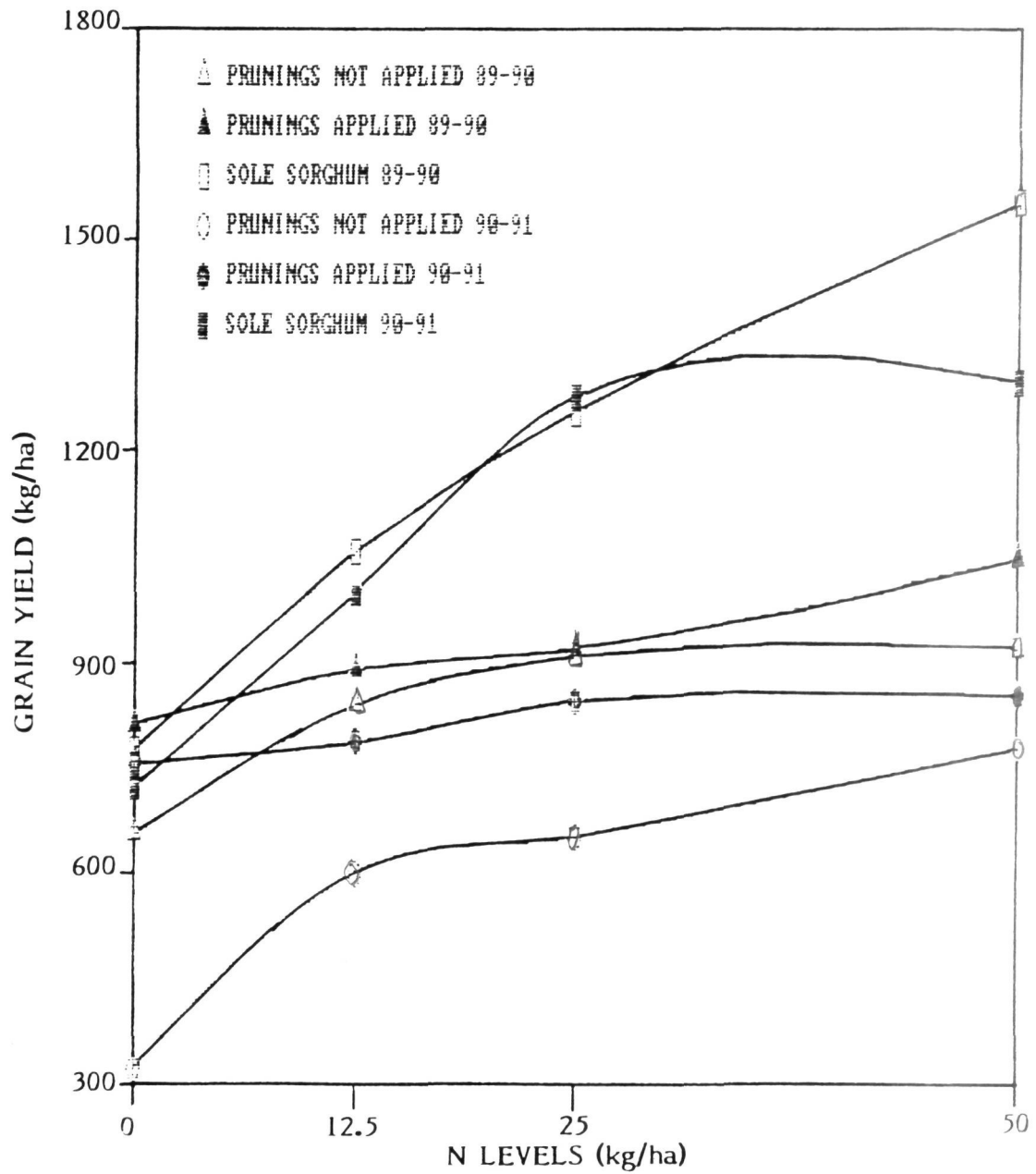


Fig.16. GRAIN YIELD OF SORGHUM AS INFLUENCED BY LEUCAENA PRUNINGS APPLICATION AND N LEVELS

kg N per ha sole sorghum was significantly superior to prunings applied and unapplied alley sorghum, which were on par. In second year all N levels were at par in prunings applied alley sorghum but in prunings unapplied alley sorghum and sole sorghum they differed significantly. At 0 kg N level, sole sorghum and prunings applied alley sorghum were on par, and were superior to prunings unapplied. At 50 kg N per ha sole sorghum was significantly superior to both alley sorghum treatments, which were at par. Average data for the two years showed that the rate of increase in grain yield of sorghum with increasing N level from 0 to 50 kg N per ha was higher in sole sorghum (90%) and prunings unapplied alley sorghum (74%) than prunings applied alley sorghum (21%).

4.2.1.12 Stover yield per hectare (cf. Table 29, Fig. 17)

Sorghum stover yield differed significantly due to systems during both the years. During first year sole sorghum yielded significantly highest stover yield, followed by prunings applied and unapplied alley sorghum treatments which were on par. During the second year also same ranking was observed and they differed from each other significantly. Mean data of the two years showed that stover yield in prunings applied alley sorghum and sole sorghum was higher than that in prunings unapplied alley sorghum by 18 and 71 per cent respectively.

Varying N levels affected sorghum stover yield significantly during both the years. During first year increasing N level from 0 to 50 kg increased stover yield significantly, during second year the increase was significant upto 25 kg N per ha, though, further increase was seen with 50 kg, it was statistically not significant. Mean data of the two years showed that stover yield increased by 23, 37 and 47 per cent over 0 N (1208 kg/ha) with application of 12.5, 25 and 50 kg N per ha respectively.

Table 29 : Stover yield (kg/ha) of sorghum as influenced by prunings application and N levels

N levels (kg/ha)	1989-90				1990-91				MEAN			
	Prunings unapplied	Prunings applied	Sole sorghum	Mean	Prunings unapplied	Prunings applied	Sole sorghum	Mean				
0	1115	1269	1307	1230	607	1221	1728	1185	861	1245	1518	1208
12.5	1322	1396	1675	1464	1031	1292	2220	1514	1177	1344	1948	1489
25	1454	1457	1864	1592	1126	1472	2559	1719	1290	1465	2212	1656
50	1461	1564	2232	1752	1351	1495	2568	1805	1406	1530	2400	1779
Mean	1338	1421	1769	1509	1029	1370	2269	1556	1184	1396	2019	1533

For comparing means of :	SEm±	CD 5%	SEm±	CD5%
Prunings Application (PA)	35.9	124.3	60.8	210.4
Nitrogen levels (N)	37.9	110.0	34.8	101.1
N at same PA	65.7	190.5	60.3	175.1
PA at same or different N	67.3	205.9	80.2	232.6

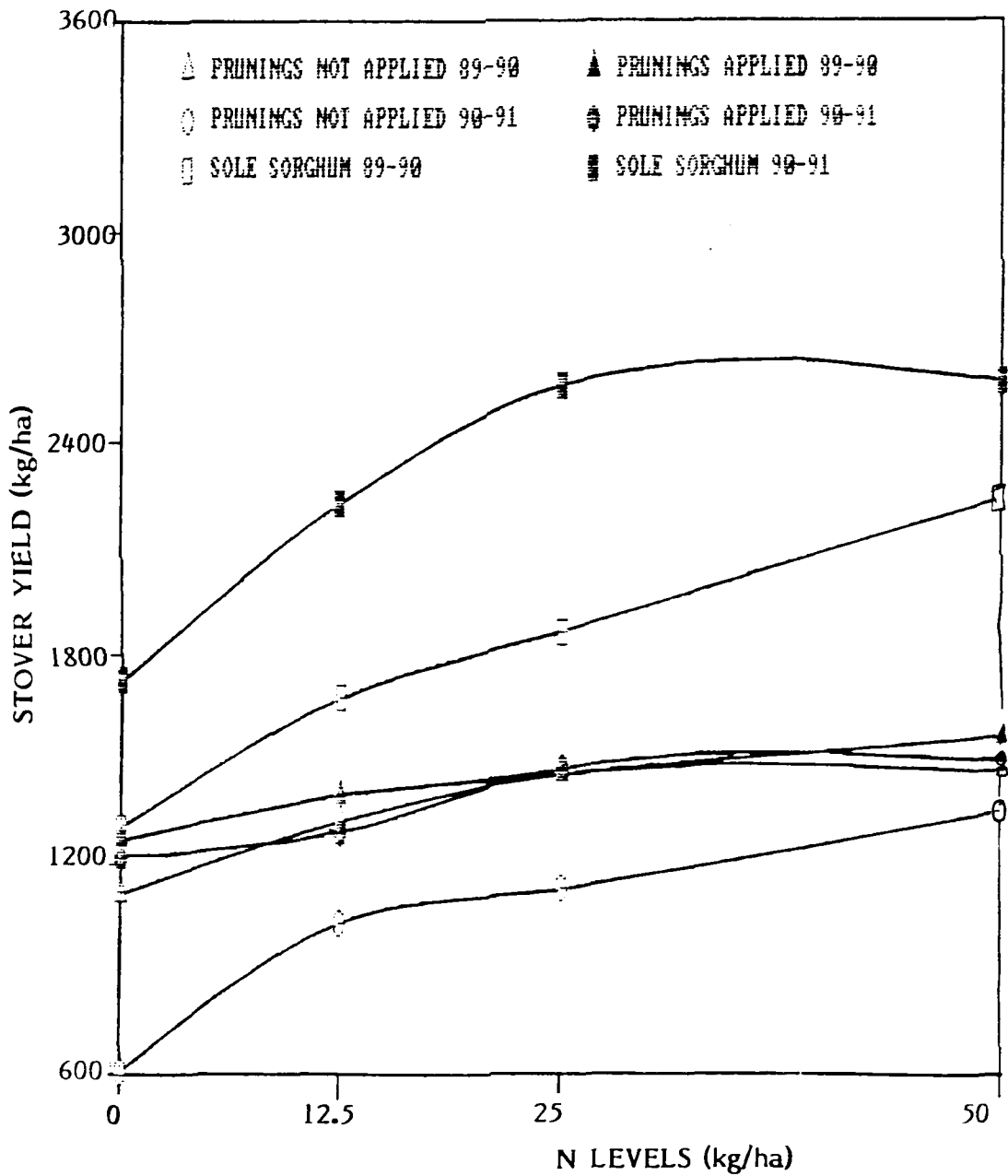


Fig.17. STOVER YIELD OF SORGHUM AS INFLUENCED BY LEUCAENA PRUNINGS APPLICATION AND N LEVELS

The interaction between systems and N levels was significant during both the years, like grain yield the rate of increase in stover yield with increased N application from 0 to 50 kg N per ha was higher in sole sorghum (71%) and prunings unapplied (31%) than prunings applied alley sorghum (23%).

4.2.1.13 Sorghum biomass yield (cf. Table 30, Fig. 18)

During both the years, sorghum biomass yield differed significantly due to systems. In the first year sole sorghum produced significantly higher biomass yield, followed by prunings applied alley sorghum and prunings unapplied alley sorghum, however the latter two were at par. In 1990-91 also similar ranking was observed, but, the treatments differed from each other significantly. Mean data of the two years showed that sorghum biomass yield in prunings applied alley sorghum and sole sorghum was higher than that in prunings unapplied (1894 kg/ha) by 19 and 66 per cent respectively.

Sorghum biomass yield increased significantly with increasing N levels during both the years. In 1989-90 the increase was significant upto 50 kg N per ha. In 1990-91 the increase was significant upto 25 kg N only, the further increase with 50 kg N per ha was not significant. Mean data of the two years showed that sorghum biomass yield with application of 12.5, 25 and 50 kg N per ha was higher than that with 0 kg N (1883 kg/ha) by 25, 40 and 52 per cent respectively.

The interaction between systems and N levels was significant during both the years. Mean data of the two years showed that the rate of increase in sorghum biomass yield with increasing N level from 0 to 50 kg N per ha was higher in sole sorghum (69%) and prunings unapplied alley sorghum (67%) than prunings applied alley sorghum (22%).

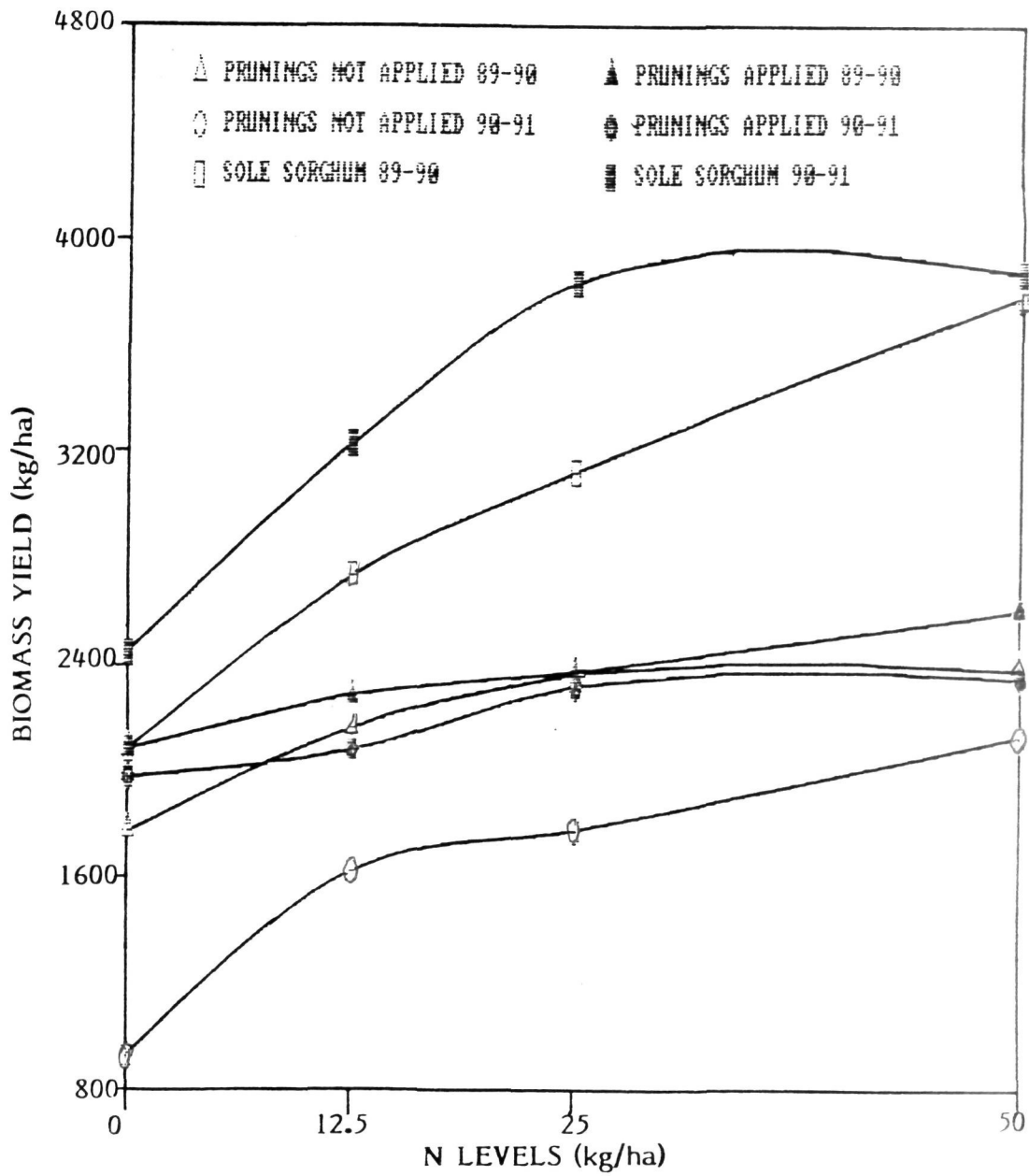


Fig.18. BIOMASS YIELD OF SORGHUM AS INFLUENCED BY LEUCAENA PRUNINGS APPLICATION AND N LEVELS

4.2.1.14 Harvest index (cf. Table 31)

Harvest index of *rabi* sorghum differed significantly due to systems during 1990-91, where prunings applied and unapplied alley sorghum were on par, and recorded significantly higher harvest index than sole sorghum. In 1989-90 harvest index did not vary significantly due to systems. Mean data of the two years showed that harvest index in prunings unapplied and prunings applied alley sorghum was higher than that in sole sorghum (0.355) by 5 and 8 per cent respectively.

Harvest index of *rabi* sorghum differed significantly due to N levels during 1989-90, where N application increased harvest index significantly upto 12.5 kg N per ha, though further increase was seen upto 50 kg N per ha it was not significant. During 1990-91 the variation in harvest index due to varying N levels was not significant. Mean data of the two years showed that harvest index with application of 12.5, 25 and 50 kg N per ha was higher than that with 0 kg N (0.359) by 3, 4 and 5 per cent respectively.

4.2.1.15 N concentration in leaf (cf. Table 32)

During both the years leaf N concentration was significantly higher in prunings applied alley sorghum, followed by prunings unapplied alley sorghum and sole sorghum respectively, they differed from each other significantly. Mean data of the two years showed that leaf N concentration in prunings applied alley sorghum and prunings unapplied alley sorghum was higher than that in sole sorghum (0.386%) by 22 and 15 per cent respectively.

Leaf N concentration increased significantly due to increasing N level from 0 to 50 kg N per ha in both the years. Mean data of the two years indicated an increase of 15, 32 and 46 per cent over 0 kg N (0.514%) with 12.5, 25 and 50 kg N per ha respectively.

Table 31 : Harvest index of sorghum as influenced by prunings application and N levels

N levels (kg/ha)	1989-90				1990-91				MEAN			
	Prunings unapplied	Prunings applied	Sole sorghum	Mean	Prunings unapplied	Prunings applied	Sole sorghum	Mean	Prunings unapplied	Prunings applied	Sole sorghum	Mean
0	0.370	0.391	0.371	0.377	0.349	0.383	0.291	0.341	0.360	0.387	0.331	0.359
12.5	0.389	0.390	0.386	0.388	0.373	0.378	0.308	0.353	0.381	0.384	0.347	0.371
25	0.385	0.387	0.403	0.391	0.368	0.365	0.333	0.355	0.377	0.376	0.368	0.373
50	0.387	0.400	0.410	0.399	0.369	0.364	0.336	0.357	0.378	0.382	0.373	0.378
Mean	0.383	0.392	0.392	0.389	0.365	0.373	0.317	0.351	0.374	0.383	0.355	0.370
For comparing means of :												
Prunings Application (PA)		SEm±	CD 5%		SEm±	CD5%						
		0.004	NS		0.013	0.045						
Nitrogen levels (N)		0.004	0.013		0.007	NS						
N at same PA		0.008	NS		0.013	NS						
PA at same or different N		0.008	NS		0.017	NS						

Table 32 : N concentration (%) in leaf of sorghum at harvest as influenced by prunings application and N levels

N levels (kg/ha)	1989-90				1990-91				MEAN			
	Prunings unapplied	Prunings applied	Sole sorghum	Mean	Prunings unapplied	Prunings applied	Sole sorghum	Mean	Prunings unapplied	Prunings applied	Sole sorghum	Mean
0	0.379	0.424	0.323	0.375	0.350	0.323	0.313	0.329	0.365	0.374	0.318	0.352
12.5	0.433	0.490	0.347	0.423	0.406	0.421	0.329	0.385	0.420	0.456	0.338	0.404
25	0.472	0.528	0.396	0.465	0.469	0.547	0.387	0.467	0.471	0.538	0.392	0.466
50	0.526	0.528	0.515	0.523	0.500	0.535	0.480	0.505	0.513	0.532	0.498	0.514
Mean	0.452	0.492	0.395	0.447	0.431	0.456	0.377	0.422	0.442	0.474	0.386	0.435
For comparing means of :												
Prunings Application (PA)	SEm±	CD 5%	SEm±	CD 5%	SEm±	CD 5%						
	0.010	0.035	0.003	0.012								
Nitrogen levels (N)	0.013	0.038	0.004	0.012								
N at same PA	0.023	NS	0.007	0.020								
PA at same or different N	0.022	NS	0.007	0.020								

The interaction between systems and N levels was significant during 1990-91. The rate of increase in leaf N concentration with increasing N level from 0 to 50 kg N per ha was higher in prunings applied alley sorghum (66%) than sole sorghum (53%) and prunings unapplied alley sorghum (43%).

4.2.1.16 N Concentration in stem (cf. Table 33)

In both the years N concentration in stem was significantly higher in prunings applied alley sorghum, followed by prunings unapplied alley sorghum and sole sorghum crop, they differed from each other significantly. Mean data of the two years showed that N concentration in stem was higher in prunings applied alley sorghum and prunings unapplied alley sorghum than sole crop (0.175%) by 52 and 21 per cent respectively.

Increasing level of N application from 0 to 50 kg N per ha significantly increased N concentration in stem during both the years. Mean data of the two years showed that stem N concentration was higher with application of 12.5, 25 and 50 kg N per ha than that with 0 kg N (0.176) by 10, 40 and 115 per cent respectively.

The interaction between systems and N levels was significant during both the years. Mean data of the two years showed that the rate of increase in stem N concentration with increasing N application from 0 to 50 kg N per ha was low in prunings unapplied alley sorghum (23%) as compared with prunings applied alley sorghum (53%) and sole sorghum (64%).

4.2.1.17 N Concentration in Grain (cf. Table 34)

Grain N concentration differed significantly due to systems during both the years. During 1989-90 prunings applied alley sorghum recorded highest N concentration, followed by prunings unapplied alley sorghum and sole sorghum, they differed from each other significantly. During 1990-91 also

Table 33 : N concentration (%) in stem of sorghum at harvest as influenced by prunings application and N levels

N levels (kg/ha)	1989-90				1990-91				MEAN			
	Prunings unapplied	Prunings applied	Sole sorghum	Mean	Prunings unapplied	Prunings applied	Sole sorghum	Mean	Prunings unapplied	Prunings applied	Sole sorghum	Mean
0	0.197	0.210	0.134	0.180	0.184	0.200	0.130	0.172	0.191	0.205	0.132	0.176
12.5	0.210	0.244	0.150	0.201	0.197	0.211	0.146	0.185	0.204	0.228	0.148	0.193
25	0.218	0.315	0.207	0.246	0.218	0.325	0.195	0.246	0.218	0.320	0.201	0.246
50	0.239	0.304	0.229	0.257	0.231	0.321	0.204	0.252	0.235	0.313	0.217	0.255
Mean	0.216	0.268	0.180	0.221	0.207	0.264	0.169	0.213	0.212	0.266	0.175	0.218

For comparing means of : SEM± CD 5% SEM± CD5%

Prunings Application (PA) 0.004 0.015 0.005 0.016

Nitrogen levels (N) 0.005 0.014 0.002 0.007

N at same PA 0.008 0.024 0.004 0.012

PA at same or different N 0.009 0.027 0.006 0.013

Table 34 : N concentration (%) in grain of sorghum at harvest as influenced by prunings application and N levels

N levels (kg/ha)	1989-90						1990-91					
	Prunings unapplied	Prunings applied	Sole sorghum	Mean	Prunings unapplied	Prunings applied	Sole sorghum	Mean	Prunings unapplied	Prunings applied	Sole sorghum	Mean
0	1.154	1.230	0.882	1.089	1.095	0.963	0.894	0.984	1.125	1.097	0.888	1.037
12.5	1.193	1.308	0.985	1.162	1.119	1.018	0.940	1.026	1.156	1.163	0.963	1.094
25	1.331	1.404	1.039	1.258	1.194	1.323	0.992	1.170	1.263	1.364	1.016	1.214
50	1.397	1.447	1.232	1.358	1.223	1.351	1.056	1.210	1.310	1.399	1.144	1.284
Mean	1.269	1.347	1.035	1.217	1.158	1.164	0.970	1.097	1.214	1.256	1.003	1.157
For comparing means of :												
Prunings Application (PA)	SEm±	CD 5%	SEm±	CD 5%	SEm±	CD 5%	SEm±	CD 5%	SEm±	CD 5%	SEm±	CD 5%
Nitrogen levels (N)	0.015	0.051	0.017	0.060	0.028	0.081	0.048	0.140	0.036	NS	0.034	NS
N at same PA	0.021	0.061	0.028	0.081	0.048	0.140	0.034	NS	0.034	NS	0.045	0.130
PA at same or different N	0.036	NS	0.048	0.140	0.034	NS	0.045	0.130	0.034	NS	0.045	0.130

similar ranking was observed, however difference between the two alley crop treatments was not significant statistically. Mean data of the two years showed that grain N concentration in prunings applied alley sorghum and prunings unapplied alley sorghum was higher than that in sole sorghum (1.003%) by 25 and 21 per cent respectively.

Increasing N level from 0 to 50 kg N per ha increased N concentration in grain significantly during both the years. In 1989-90 all the levels differed from each other significantly. In 1990-91, 25 and 50 kg N per ha levels were at par. Mean data of the two years showed that N concentration with application of 12.5, 25 and 50 kg N per ha was higher than that with 0 kg N (1.037%) by 5, 17 and 24 per cent respectively.

The interaction between systems and N levels was significant during 1990-91. The rate of increase in grain N concentration with increasing N level from 0 to 50 kg N per ha was higher in prunings applied alley sorghum (40%) than prunings unapplied alley sorghum (12%) and sole sorghum (18%).

4.2.1.18 Grain Protein (cf. Table 35)

Grain protein differed significantly due to systems during both the years. The trend was same as that for grain N concentration. Mean data of the two years showed that grain protein in prunings applied alley crop and prunings unapplied alley crop was higher than that in sole sorghum (7.59%) by 25 and 21 per cent respectively.

Grain protein differed significantly due to N levels during both years. The variation in grain protein due to varying N levels was similar to that of grain N concentration. Mean data of the two years showed that grain protein with application of 12.5, 25 and 50 kg N per ha was higher than that with 0 kg N (6.48%) by 5, 17 and 24 per cent respectively.

The interaction between systems and N levels was significant in 1990-91. The rate of increase in grain protein with increasing N level from 0 to 50 kg N per ha was higher in prunings applied alley sorghum (40%) than prunings unapplied alley sorghum (12%) and sole sorghum (18%).

4.2.1.19 N uptake through leaf (cf. Table 36)

Nitrogen uptake through leaf differed significantly due to systems during both the years. In 1989-90, significantly higher N uptake was observed in prunings applied alley sorghum than prunings unapplied sorghum and sole sorghum which were on par. In 1990-91, uptake in sole sorghum was highest, followed by prunings applied and unapplied, all the treatments differed from each other significantly. Mean data of the two years showed that N uptake through leaf was higher in sole sorghum and prunings applied alley sorghum than that in prunings unapplied sorghum (1.33 kg/ha) by 20 and 32 per cent respectively.

N uptake through leaf increased significantly due to increasing N level during both the years. Mean data of the two years showed that N uptake through leaf was higher with application of 12.5, 25 and 50 kg N per ha than 0 kg N (1.1 kg/ha) by 28, 56 and 83 per cent respectively.

The interaction between systems and N levels was significant during both the years. Mean data of the two years showed that the rate of increase in N uptake through leaf with increase in N level from 0 to 50 kg N per ha was higher in sole sorghum (94%) and prunings unapplied (84%) than prunings applied sorghum (68%).

4.2.1.20 N uptake through stem (cf. Table 37)

During both the years N uptake through stem differed significantly due to systems. In 1989-90 prunings applied alley sorghum recorded highest stem N

Table 36 : N uptake (kg/ha) through leaf by sorghum at harvest as influenced by prunings application and N levels

N levels (kg/ha)	1989-90				1990-91				MEAN			
	Prunings unapplied	Prunings applied	Sole sorghum	Mean	Prunings unapplied	Prunings applied	Sole sorghum	Mean	Prunings unapplied	Prunings applied	Sole sorghum	Mean
0	1.18	1.36	1.04	1.19	0.63	0.91	1.48	1.01	0.91	1.14	1.26	1.10
12.5	1.46	1.74	1.29	1.50	1.03	1.22	1.69	1.31	1.25	1.48	1.49	1.41
25	1.76	1.89	1.51	1.72	1.21	1.85	2.09	1.72	1.49	1.87	1.80	1.72
50	1.90	2.00	2.18	2.03	1.44	1.83	2.70	1.99	1.67	1.92	2.44	2.01
Mean	1.58	1.75	1.50	1.61	1.08	1.45	1.99	1.51	1.33	1.60	1.75	1.56
For comparing means of :												
	SEmt	SEmt	CD 5%	SEmt	SEmt	CD5%						
Prunings Application (PA)	0.046	0.046	0.161	0.054	0.054	0.185						
Nitrogen levels (N)	0.062	0.062	0.181	0.040	0.040	0.117						
N at same PA	0.108	0.108	0.310	0.070	0.070	0.203						
PA at same or different N	0.105	0.105	0.320	0.081	0.081	0.255						

Table 37 : N uptake (kg/ha) through stem by sorghum at harvest as influenced by prunings application and N levels

N levels (kg/ha)	1989-90				1990-91				MEAN			
	Prunings unapplied	Prunings applied	Sole sorghum	Mean	Prunings unapplied	Prunings applied	Sole sorghum	Mean	Prunings unapplied	Prunings applied	Sole sorghum	Mean
0	1.58	2.00	1.33	1.64	0.78	1.88	1.64	1.43	1.18	1.94	1.49	1.54
12.5	2.07	2.55	1.95	2.19	1.54	2.12	3.09	2.25	1.81	2.34	2.52	2.22
25	2.36	3.45	3.07	2.96	1.87	3.69	3.94	3.17	2.12	3.57	3.51	3.07
50	2.64	3.61	4.13	3.46	2.45	3.70	4.09	3.41	2.55	3.66	4.11	3.44
Mean	2.16	2.90	2.62	2.56	1.66	2.85	3.19	2.57	1.91	2.88	2.91	2.57
For comparing means of :												
Prunings Application (PA)			SEm±	CD 5%			SEm±	CD5%				
			0.068	0.234			0.135	0.468				
Nitrogen levels (N)			SEm±	CD 5%			SEm±	CD 5%				
			0.094	0.272			0.073	0.212				
N at same PA			SEm±	CD 5%			SEm±	CD 5%				
			0.163	0.472			0.126	0.367				
PA at same or different N			SEm±	CD 5%			SEm±	CD 5%				
			0.156	0.469			0.174	0.564				

uptake, followed by sole sorghum and prunings unapplied, they differed from each other significantly. In 1990-91 prunings applied alley sorghum and sole sorghum were at par, and were significantly superior to prunings unapplied. Mean data of the two years showed that stem N uptake was higher in prunings applied alley sorghum and sole sorghum than prunings unapplied (1.91 kg/ha) by 51 and 52 per cent respectively.

Stem N uptake increased significantly with increasing N level in both the years. Mean data of the two years showed that N uptake with application of 12.5, 25 and 50 kg N per ha was higher than that with 0 kg N (1.54 kg/ha) by 44, 99 and 125 per cent respectively.

The interaction between systems and N levels was significant during both the years. Mean data of two years showed that the rate of increase in stem N uptake with increase in N level from 0 to 50 kg N per ha was higher in sole sorghum (176%) and prunings unapplied alley sorghum (116%) than prunings applied alley sorghum (89%).

4.2.1.21 N uptake through grain (cf. Table 38)

During both the years N uptake through grain differed significantly due to systems. In 1989-90 prunings applied alley sorghum and sole sorghum were on par, and were significantly superior to prunings unapplied alley sorghum. In 1990-91 sole sorghum recorded highest grain N uptake followed by prunings applied and unapplied alley crops, they differed from each other significantly. Mean data of the two years showed that N uptake through grain was higher in prunings applied alley crop and sole crop than prunings unapplied (8.78 kg/ha) by 25 and 30 per cent respectively.

Nitrogen uptake through grain increased significantly with increasing N level during both the years. In 1989-90 the response was significant upto 50 kg N per ha while in 1990-91 it was significant upto 25 kg N per ha.

Table 38 : N uptake (kg/ha) through grain by sorghum at harvest as influenced by prunings application and N levels

N levels (kg/ha)	1989-90				1990-91				MEAN			
	Prunings unapplied	Prunings applied	Sole sorghum	Mean	Prunings unapplied	Prunings applied	Sole sorghum	Mean	Prunings unapplied	Prunings applied	Sole sorghum	Mean
0	7.55	9.96	6.86	8.12	3.54	7.28	6.45	5.76	5.55	8.62	6.66	6.94
12.5	10.05	11.63	10.38	10.69	6.72	8.03	9.44	8.06	8.39	9.83	9.91	9.38
25	12.12	12.97	13.02	12.70	7.86	11.26	12.64	10.58	9.99	12.12	12.83	11.64
50	12.91	15.14	19.09	15.71	9.49	11.59	13.68	11.59	11.20	13.37	16.39	13.65
Mean	10.66	12.43	12.33	11.81	6.90	9.54	10.55	9.00	8.78	10.99	11.44	10.40
For comparing means of :												
Prunings Application (PA)	SE _{mt}	CD 5%	SE _{mt}	CD 5%	SE _{mt}	CD 5%	SE _{mt}	CD 5%				
Nitrogen levels (N)	0.390	1.349	0.409	1.188	0.278	0.964	0.409	1.186				
N at same PA	0.709	2.057	0.708	NS								
PA at same or different N	0.727	2.226	0.674	NS								

Mean data of the two years showed that N uptake in grain was higher with 12.5, 25 and 50 kg N per ha application than with 0 kg N (6.94 kg/ha) by 35, 68 and 97 per cent respectively.

The interaction between systems and N levels was significant during 1989-90. Mean data of the two years showed that the rate of increase in grain N uptake with increase in N level from 0 to 50 kg N per ha was higher in sole sorghum (146%) and prunings unapplied alley sorghum (102%) than prunings applied alley sorghum (55%).

4.2.1.22 Total N uptake (cf. Table 39)

Total N uptake differed significantly due to systems during both the years. In 1989-90 prunings applied alley sorghum and sole sorghum were on par, and were significantly superior to prunings unapplied. In 1990-91 total N uptake was highest in sole sorghum, followed by prunings applied and unapplied alley sorghum, they differed from each other significantly. Mean data of the two years showed that total N uptake was higher in sole sorghum and prunings applied alley sorghum than in prunings unapplied (12.02 kg/ha) by 29 and 34 per cent respectively.

During both the years total N uptake increased significantly with increasing N application upto 50 kg N per ha. N uptake with application of 12.5, 25 and 50 kg N per ha was higher than that with 0 kg N (9.58 kg/ha) by 36, 72 and 99 per cent respectively.

The interaction between systems and N levels was significant in 1989-90. Mean data of the two years showed that the rate of increase in N uptake with increase in N level from 0 to 50 kg N per ha was higher in sole sorghum (144%) and prunings unapplied alley sorghum (102%) than prunings applied alley sorghum (62%).

4.2.2 *Leucaena*

4.2.2.1 *Leucaena* leaf, stem and total biomass production (cf. Tables 40, 41 and 42)

Leucaena leaf, stem and total biomass production was not influenced either by systems (prunings application) or by N application to *rabi* sorghum during both the years. Between the year comparison showed that, during 1990-91 mean leaf biomass production was higher by 30 per cent over that in 1989-90 (2379 kg/ha). Similarly stem and total biomass production were higher by 81 and 46 per cent in 1990-91 compared to 1989-90 (1115 kg and 3994 kg/ha).

4.2.2.2 *Leucaena* net biomass harvest (cf. Table 43)

During both the years net biomass harvest in prunings unapplied alley cropping system was significantly higher than that in prunings applied. Data for the two years showed a mean increase of 63 per cent over prunings applied system (2538 kg/ha). Nitrogen application to sorghum at varying levels did not have any significant influence on *Leucaena* net biomass harvest.

4.2.3 Soil organic carbon (cf. Table 44)

At sowing

During both the years soil organic carbon (%) at sowing was significantly higher in prunings applied than prunings unapplied alley cropping system and sole sorghum system. Mean data of the two years showed higher organic carbon in prunings applied and unapplied alley system by 25 and 17 per cent over sole sorghum system (0.528%). Nitrogen application to sorghum at varying levels did not influence soil organic carbon significantly during both the years.

Table 40 : *Leucaena* leaf biomass production (kg/ha) as influenced by prunings application and N levels

N levels (kg/ha)	1989-90				1990-91				MEAN
	Prunings unapplied	Prunings applied	Mean	Prunings unapplied	Prunings applied	Mean	Prunings unapplied	Prunings applied	
0	2360	2386	2373	2906	3340	3123	2633	2863	2748
12.5	2394	2420	2407	3028	3106	3067	2711	2763	2737
25	2325	2412	2368	2837	3192	3015	2581	2802	2692
50	2360	2377	2368	2889	3427	3158	2625	2902	2763
Mean	2360	2399	2379	2915	3266	3090	2638	2833	2735
For comparing means of :									
Prunings Application (PA)	SEM±	56.3	CD 5%	NS	SEM±	114.8	CD5%	NS	
Nitrogen levels (N)	SEM±	41.4	CD 5%	NS	SEM±	67.1	CD5%	NS	
N at same PA	SEM±	58.5	CD 5%	NS	SEM±	94.9	CD5%	NS	
PA at same or different N	SEM±	57.7	CD 5%	NS	SEM±	141.0	CD5%	NS	

Table 41 : *Leucaena* wood biomass production (kg/ha) as influenced by prunings application and N levels

N levels (kg/ha)	1989-90				1990-91				MEAN
	Prunings unapplied	Prunings applied	Mean	Prunings unapplied	Prunings applied	Mean	Prunings unapplied	Prunings applied	
0	1119	1093	1106	1917	2195	2056	1518	1644	1581
12.5	1128	1154	1141	1961	2013	1987	1545	1584	1564
25	1093	1128	1110	1856	2073	1965	1475	1601	1538
50	1136	1067	1101	1865	2256	2060	1501	1662	1581
Mean	1119	1110	1115	1900	2134	2017	1510	1622	1566

For comparing means of : SEM± CD 5% SEM± CD5%

Prunings Application (PA) 7.90 NS 78.0 NS

Nitrogen levels (N) 26.5 NS 49.2 NS

N at same PA 37.5 NS 69.6 NS

PA at same or different N 33.4 NS 78.0 NS

Table 42 : *Leucaena* total biomass production (kg/ha) as influenced by prunings application and N levels

N levels (kg/ha)	1989-90				1990-91				MEAN
	Prunings unapplied	Prunings applied	Mean	Prunings unapplied	Prunings applied	Mean	Prunings unapplied	Prunings applied	
0	3487	3470	3479	4806	5535	5170	4147	4503	4325
12.5	3531	3574	3352	4988	5118	5053	4260	4346	4303
25	3418	3539	3479	4685	5266	4975	4052	4403	4227
50	3496	3435	3466	4745	5682	5213	4121	4559	4340
Mean	3483	3505	3494	4806	5400	5103	4145	4453	4299

For comparing means of :

	SEm±	CD 5%	SEm±	CD5%
Prunings Application (PA)	61.6	NS	195	NS
Nitrogen levels (N)	69.2	NS	117	NS
N at same PA	97.9	NS	166	NS
PA at same or different N	105.0	NS	196	NS

Table 43 : *Leucaena* net biomass harvest (kg/ha) as influenced by prunings application and N levels

N levels (kg/ha)	1989-90				1990-91				MEAN
	Prunings unapplied	Prunings applied	Mean	Prunings unapplied	Prunings applied	Mean	Prunings unapplied	Prunings applied	
0	3487	2308	2897	4806	2811	3808	4147	2560	3353
12.5	3531	2342	2936	4988	2637	3813	4260	2490	3375
25	3418	2334	2876	4685	2698	3691	4052	2516	3284
50	3496	2299	2897	4745	2871	3808	4121	2585	3353
Mean	3483	2321	2902	4806	2754	3780	4145	2538	3341

For comparing means of :

	SEmt	CD 5%	SEmt	CD5%
Prunings Application (PA)	81.2	365.9	187.6	844.2
Nitrogen levels (N)	44.4	NS	97.9	NS
N at same PA	62.8	NS	138.4	NS
PA at same or different N	97.7	NS	222.0	NS

At Harvest

Soil organic carbon at harvest differed significantly due to systems during both the years. In 1989-90 both the alley crop treatments were on par, and were significantly superior to sole sorghum. In 1990-91 prunings applied alley crop treatment resulted in highest soil organic carbon at harvest, followed by prunings unapplied and sole crop treatments, they differed from each other significantly. Mean data for the two years showed that soil organic carbon was higher in prunings applied and unapplied alley crop treatments than sole sorghum treatment (0.533%) by 10 and 8 per cent respectively. During both the years soil organic carbon at harvest did not vary significantly due to N application to sorghum at varying levels.

4.2.4 Soil available N (cf. Table 44)

At sowing

During both the years highest soil available N was observed in prunings applied alley plot, followed by prunings unapplied alley and sole sorghum plots, they differed from each other significantly. Mean data of the two years showed that soil available N in prunings applied and unapplied alley plot treatments was higher than that in sole sorghum (183.7 kg/ha) by 27 and 10 per cent respectively. Soil available N at sowing was not significantly influenced by varying levels of N application to sorghum during both the years.

At harvest

During both the years prunings applied alley plot recorded highest soil available N, followed by prunings unapplied alley plot and sole sorghum, they differed from each other significantly. Mean data of the two years showed that soil available N in prunings applied and unapplied alley crop

treatments was higher than that in sole sorghum (167.7 kg/ha) by 6 and 16 per cent respectively. Soil available N at harvest was not significantly influenced by varying levels of N application to sorghum.

4.2.5 Soil moisture (cf. Table 45)

At sowing

During both the years soil moisture (cm water /0-90 cm soil profile) was highest in sole sorghum, followed by prunings applied and unapplied alley crop treatments. Mean data of two years showed that soil moisture in sole sorghum and prunings applied alley crop was higher than that in prunings unapplied (26.7 cm) by 7.4 cm and 0.5 cm respectively. Soil moisture did not vary much due to varying levels of N application to sorghum during both the years.

At flowering

Soil moisture at flowering was higher in sole sorghum than alley cropped sorghum during both the years. The two alley crop treatments did not vary much in their soil moisture at flowering. Mean data of the two years showed highest soil moisture in sole sorghum (26.3 cm) followed by prunings applied (22.9 cm) and unapplied (22.7 cm) alley crop treatments.

Soil moisture differed to some extent due to varying levels of N application to sorghum during both the years. Mean data of the two years shows higher soil moisture at 0 kg N (24.2 cm) than that at 12.5 (23.9 cm), 25 (23.9 cm) and 50 (23.7 cm) kg N per ha levels.

Table 45 : Soil moisture content (cm of water in 0-90 cm soil profile) as influenced by prunings application and N levels at sowing, flowering and harvest stages of sorghum

N levels (kg/ha)	1989-90						1990-91						MEAN					
	Prunings applied		Sole sorghum		Mean	Prunings unapplied	Prunings applied		Sole sorghum		Mean	Prunings unapplied	Prunings applied		Sole sorghum		Mean	
	0	25	50	Mean	0		25	50	Mean	0	25		50	Mean	0	25	50	Mean
SOWING																		
0	30.2	30.6	38.2	33.0	33.0	23.1	23.8	30.0	25.6	25.6	26.7	27.2	34.1	29.3				
12.5	30.0	30.4	38.1	32.8	32.8	23.2	23.7	29.9	25.6	25.6	26.6	27.1	34.0	29.2				
25	30.1	30.8	38.3	33.1	33.1	23.4	23.6	30.0	25.7	25.7	26.8	27.2	34.2	29.4				
50	30.0	30.5	38.0	32.8	32.8	23.1	23.6	29.8	25.5	25.5	26.6	27.1	33.9	29.2				
Mean	30.1	30.6	38.2	33.0	33.0	23.2	23.7	29.9	25.6	25.6	26.7	27.2	34.1	29.3				
FLOWERING																		
0	24.6	24.5	28.2	25.8	25.8	21.5	22.0	24.3	22.6	22.6	23.1	23.3	26.3	24.2				
12.5	23.9	23.7	28.0	25.2	25.2	21.4	21.9	24.3	22.5	22.5	23.7	22.8	26.2	23.9				
25	23.2	23.7	28.7	25.2	25.2	21.6	21.9	24.2	22.6	22.6	22.4	22.8	26.5	23.9				
50	23.3	23.6	28.1	25.0	25.0	21.4	21.8	24.1	22.4	22.4	22.4	22.7	26.1	23.7				
Mean	23.8	23.9	28.3	25.3	25.3	21.5	21.9	24.2	22.5	22.5	22.7	22.9	26.3	23.9				
HARVEST																		
0	21.0	21.1	22.5	21.5	21.5	19.2	19.5	21.0	19.9	19.9	20.1	20.3	21.8	20.7				
25	20.8	21.0	21.0	20.9	20.9	19.2	19.5	20.8	19.8	19.8	20.0	20.3	20.9	20.4				
12	20.3	20.5	21.5	20.8	20.8	19.0	19.4	20.5	19.6	19.6	19.7	20.0	21.0	20.2				
50	19.9	20.3	20.9	20.4	20.4	19.0	19.3	20.4	19.6	19.6	19.5	19.8	20.7	20.0				
Mean	20.5	20.7	21.5	20.9	20.9	19.1	19.4	20.9	19.7	19.7	19.8	20.1	21.2	20.3				

At harvest

During both the years soil moisture at harvest differed to some extent due to systems. Mean data of the two years showed that soil moisture in sole sorghum was higher (21.2 cm) than that in prunings applied (20.1 cm) and unapplied (19.8 cm) alley sorghum.

Varying levels of N application to sorghum also caused some variation in soil moisture at harvest during both the years. Mean data of the two years showed that soil moisture at 0 kg N (20.7 cm) was higher than that at 12.5 (20.4 cm), 25 (20.2 cm) and 50 kg N per ha levels (20 cm).

4.2.6 Land equivalent ratio (cf. Table 46)

During first year land equivalent ratio (LER) was higher in prunings applied (1.20) than prunings unapplied (1.13) alley treatment. During second year LER was higher in prunings unapplied (1.01) than prunings applied (0.93) alley plot treatment. Mean data of the two year showed same LER (1.07) both in pruning applied and unapplied alley crop treatments.

During both the years LER decreased with increasing level of N application to *rabi* sorghum. Mean data of the two years showed LER of values of 1.20, 1.11, 1.00 and 0.99 with application of 0, 12.5, 25 and 50 kg N per ha. In both the years at 0 kg N level LER in prunings applied alley treatment was higher than that in prunings unapplied, mean data of the two years showed LER values of 1.32 and 1.07 respectively.

4.2.7 Correlation analysis (cf. Table 47)

Correlation analysis showed that, during both the years grain yield of sorghum had a positive significant correlation with soil moisture at sowing (0.58 in first and 0.69 in second year); dry matter at 60 DAS (0.99 and

Table 46 : Land equivalent ratio (LER) as influenced by prunings application and N levels

N levels (kg/ha)	1989-90				1990-91				MEAN
	Prunings unapplied	Prunings applied	Mean	Prunings unapplied	Prunings applied	Mean	Prunings unapplied	Prunings applied	
0	1.30	1.35	1.33	0.84	1.28	1.06	1.07	1.32	1.20
12.5	1.27	1.15	1.21	1.01	1.00	1.01	1.14	1.08	1.11
25	1.18	1.04	1.11	0.89	0.88	0.89	1.04	0.96	1.00
50	1.06	0.98	1.02	0.99	0.89	0.94	1.03	0.94	0.99
Mean	1.20	1.13	1.17	0.93	1.01	0.97	1.07	1.07	1.07

Table 47 : Correlation coefficient (r) between sorghum grain yield and other parameters

Parameters	1989-90	1990-91
Soil moisture at sowing	0.58 *	0.69 **
Soil moisture at flowering	0.53	0.70 **
Soil moisture at harvest	-0.08	0.58 *
Dry matter at 60 DAS	0.99 **	0.97 **
Dry matter at 90 DAS	0.98 **	0.98 **
Dry matter at Harvest	0.82 **	0.98 **
Effective population	0.56 *	0.72 **
Grain weight per plant	0.87 **	0.91 **

* Significant at 5% level

** Significant at 1% level

0.97); dry matter at 90 DAS (0.98 and 0.98); dry matter at harvest (0.82 and 0.98), effective population (0.56 and 0.72) and grain weight per plant (0.87 and 0.91). There was significant positive correlation between grain yield of sorghum and soil moisture at flowering (0.70); and soil moisture at harvest (0.58) during the second year.

4.2.8 Regression analysis (cf. Fig.16)

During 1989-90 the grain yield response of sorghum to applied N was quadratic in prunings unapplied alley sorghum and it was linear in prunings applied alley sorghum and sole sorghum. In the second year the grain yield response to applied N was constant in prunings applied alley sorghum (where no significant response to applied N was observed as seen in 4.2.1.11 earlier), hence no equation was fitted. The response was quadratic in prunings unapplied alley sorghum and sole sorghum. The fitted equations are given below.

Prunings unapplied alley sorghum 1989-90 :

$$Y = 661.9 + 15.6742 N - 0.2095 N^2 \quad (R^2 = 0.991)$$

Prunings applied alley sorghum 1989-90 :

$$Y = 819.6 + 4.5097 N \quad (R^2 = 0.987)$$

Sole sorghum 1989-90 :

$$Y = 828.2 + 15.1223 N \quad (R^2 = 0.977)$$

Prunings unapplied alley sorghum 1990-91 :

$$Y = 343.1 + 19.2822 N - 0.2127 N^2 \quad (R^2 = 0.960)$$

Sole sorghum 1990-91 :

$$Y = 708.5 + 31.2694 N - 0.3876 N^2 \quad (R^2 = 0.988)$$

where, Y = Sorghum grain yield (kg/ha)

N = Nitrogen applied (kg/ha)

4.2.9 Net returns (cf. Table 48)

During both the years net returns differed significantly due to systems. During 1989-90 prunings unapplied alley crop system gave highest net returns, followed by prunings applied alley crop and sole crop treatments, they differed from each other significantly. In 1990-91 also prunings unapplied alley crop system topped, followed by sole sorghum and prunings applied alley crop system, the latter two treatments were at par. Mean data of the two years showed higher net returns from prunings unapplied alley crop and prunings applied alley crop systems than sole sorghum (Rs.3,176/ha) by 32 and 6 per cent respectively.

Net returns differed significantly due to varying levels of N application to sorghum during both the years. In 1989-90 net returns increased significantly upto 50 kg N per ha however 12.5 and 25 kg N per ha levels were at par. In 1990-91 net returns increased significantly upto 25 kg N per ha, the further increase with 50 kg N per ha was not significant. Mean data of the two years showed 22, 33 and 42 per cent increase over 0 kg N (Rs 2,889/ha.) with application of 12.5, 25 and 50 kg N per ha respectively.

The interaction between systems and N levels was significant during both the years. The increase in net returns with increase in N level from 0 to 50 kg N per ha was highest in sole sorghum (107%) followed by prunings unapplied alley sorghum (31%) and prunings applied alley sorghum (13%).

Table 48 : Net returns (Rs/ha) as influenced by prunings application and N levels

N levels (kg/ha)	1989-90				1990-91				MEAN			
	Prunings unapplied	Prunings applied	Sole sorghum	Mean	Prunings unapplied	Prunings applied	Sole sorghum	Mean	Prunings unapplied	Prunings applied	Sole sorghum	Mean
0	3772	3347	1983	3034	3228	3012	1992	2744	3500	3180	1988	2889
12.5	4388	3576	2896	3620	4303	3037	2954	3431	4346	3307	2925	3526
25	4523	3650	3512	3895	4253	3249	3856	3786	4388	3450	3684	3841
50	4499	3960	4420	4293	4667	3227	3794	3896	4583	3594	4107	4095
Mean	4295	3633	3203	3710	4113	3131	3149	3464	4204	3382	3176	3587
For comparing means of :												
Prunings Application (PA)			SEm±	CD 5%			SEm±	CD 5%				
			109	377			126.5	438.0				
Nitrogen levels (N)			105	304			111.3	322.9				
N at same PA			181	526			192.7	559.3				
PA at same or different N			161	496			209.5	650.5				

4.3 Effect of tree species and their management on *rabi* sorghum

In this experiment, four tree species, viz., *Eucalyptus tereticornis* (eucalyptus), *Azadirachta indica* (neem), *Dalbergia sissoo* (sissoo) and *Hardwickia binata* (Anjan) were tested under four levels of tree management, viz., control trees (without any management), root pruning only, lopping only and, root pruning plus lopping. *Rabi* sorghum was grown as test crop with these four tree species and as sole crop (no trees) during 1989-90 and 1990-91.

4.3.1 *Rabi* sorghum

4.3.1.1 Plant height

30 DAS (cf. Table 49)

During both the years sorghum plant height varied significantly with different tree species. Sorghum plant height was on par when grown with sissoo, anjan as sole crop, but was superior to neem and eucalyptus. The extent of reduction in plant height under neem and eucalyptus was 29 and 39 per cent as compared to sole sorghum (no trees plot).

In both the years root pruned plus lopped trees resulted in significantly more sorghum height than other three management treatments which were on par, plant height with control trees was the lowest. Root pruning coupled with lopping of trees resulted in maximum plant height (9.7 cm) which was 26 per cent more as compared to control trees.

During 1990-91 the interaction between tree species and their management was significant. In neem and eucalyptus root pruning plus lopping treatment was significantly superior to other management treatments, but, in the case of other tree species all management treatments were at par.

Table 49 : Sorghum plant height (cm) at 30 DAS as influenced by tree species and management

Species	1990-91										MEAN			
	1989-90													
	Control Trees	Root pruned	Lopped	Root pruned plus lopped	Mean	Control Trees	Root pruned	Lopped	Root pruned plus lopped	Mean	Control Trees	Root pruned	Lopped	Root pruned plus lopped
Eucalyptus	4.7	5.1	4.6	8.0	5.6	5.0	5.4	5.0	8.2	5.9	4.9	4.8	8.1	5.8
Neem	5.1	5.9	6.0	9.1	6.5	5.5	5.9	6.3	9.7	6.8	5.3	6.2	9.4	6.7
Sissoo	9.1	9.1	10.0	10.0	9.5	9.8	9.7	10.3	10.3	10.0	9.5	10.2	10.2	9.8
Anjan	9.3	9.7	10.1	10.9	10.0	9.5	10.1	10.2	11.1	10.2	9.4	10.2	11.0	10.1
Sole crop (No trees)	9.2	9.8	9.1	9.7	9.4	9.5	10.0	9.3	9.7	9.6	9.4	9.2	9.7	9.5
Mean	7.5	7.9	7.9	9.5	8.2	7.8	8.2	8.2	9.8	8.5	7.7	8.1	9.7	8.4

For comparing means of :

	SEmt	CD 5%	SEmt	CD 5%
Species (S)	0.31	1.23	0.32	1.27
Management (M)	0.23	1.04	0.18	0.83
S at same M	0.75	NS	0.50	1.73
M at same S	0.74	NS	0.44	1.51

60 DAS (cf. Table 50)

During both the years, sorghum height was significantly more in sole crop and in association with *anjan* and *sissoo* compared to its growth in association with *neem* and *eucalyptus*. The extent of reduction in sorghum plant height with *neem* and *eucalyptus* was 25 and 39 per cent compared to sole sorghum.

During 1989-90 root pruning plus lopping of trees resulted in significantly more sorghum plant height (20.4 cm) than the other three tree management treatments which were at par, control trees resulted in lowest height (16.7 cm). During 1990-91, root pruned plus lopped trees resulted in significantly more height (20.6 cm) than only lopped (18.2 cm) and only root pruned trees (18.2cm), which were superior to control trees (17.1 cm.).

The interaction between tree species and their management was significant during both years. During 1989-90 in *anjan* and *sissoo* all tree management treatments were at par, while in *eucalyptus* and *neem* root pruned plus lopped trees produced significantly more sorghum height than in other tree management treatments. During 1990-91 in *anjan* and *sissoo* all the management treatments were at par, but in *neem* and *eucalyptus* root pruned plus lopped trees were superior to control trees.

90 DAS (cf. Table 51)

During both the years, sole crop recorded maximum sorghum plant height, followed by *anjan*, *sissoo*, *neem* and *eucalyptus*. During 1989-90 sole crop and *anjan* were at par, and all other treatments differed significantly. During 1990-91 all the treatments differed from each other significantly.

Table 50 : Sorghum plant height (cm) at 60 DAS as influenced by tree species and management

Species	1989-90						1990-91						MEAN		
	Control Trees	Root pruned	Lopped	Root pruned plus lopped	Mean	Control Trees	Root pruned	Lopped	Root pruned plus lopped	Mean	Control Trees	Root pruned		Lopped	Root pruned plus lopped
Eucalyptus	10.9	11.2	11.0	18.0	12.8	11.3	11.3	11.4	18.5	13.1	11.1	11.3	11.2	18.2	12.9
Neem	12.1	15.2	15.2	20.2	15.6	12.1	15.9	15.8	20.2	16.0	12.1	15.6	15.5	20.2	15.9
Sissoo	20.2	19.9	21.2	19.9	20.3	20.8	20.5	21.9	20.3	20.8	20.5	20.2	21.6	20.1	20.6
Anjan	20.1	20.3	20.5	21.9	20.7	20.3	21.3	21.2	22.2	21.2	20.2	20.8	20.9	22.0	21.0
Sole crop (No trees)	20.2	21.8	19.4	22.2	20.9	21.3	22.1	20.6	21.7	21.4	20.8	21.9	20.0	22.0	21.2
Mean	16.7	17.7	17.4	20.4	18.0	17.1	18.2	18.2	20.6	18.5	16.9	18.0	17.8	20.3	18.3

For comparing means of :

	SEmt	CD 5%	SEmt	CD 5%
Species (S)	0.77	3.00	0.54	2.11
Management (M)	0.26	1.16	0.13	0.58
S at same M	0.98	3.53	0.93	3.12
M at same S	0.68	2.46	0.79	2.67

Table 51 : Sorghum plant height (cm) at 90 DAS as influenced by tree species and management

Species	1989-90						1990-91						MEAN		
	Control Trees	Root pruned	Lopped	Root pruned plus lopped	Mean	Control Trees	Root pruned	Lopped	Root pruned plus lopped	Mean	Control Trees	Root pruned	Lopped	Root pruned plus lopped	Mean
	20.0	26.0	26.0	58.0	32.5	20.5	25.0	25.0	25.0	31.9	20.3	25.5	25.5	25.5	32.2
Eucalyptus	20.0	26.0	26.0	58.0	32.5	20.5	25.0	25.0	25.0	31.9	20.3	25.5	25.5	25.5	32.2
Neem	46.5	48.5	54.5	65.0	53.6	51.5	50.0	59.0	66.0	56.6	49.0	49.2	56.8	65.5	55.1
Sissoo	63.0	60.0	63.5	62.5	62.3	65.5	62.0	65.0	62.5	63.8	64.3	61.0	64.3	62.5	63.0
Anjan	78.0	78.0	77.5	80.5	78.5	79.5	80.0	79.5	82.5	80.4	78.8	79.0	78.5	81.5	79.5
Sole crop (No trees)	85.0	91.5	83.0	84.0	85.9	87.0	91.5	84.5	87.5	87.6	86.0	91.5	83.8	85.8	86.8
Mean	58.5	60.8	60.9	70.0	62.6	60.8	61.7	62.6	71.1	64.1	59.7	61.3	61.8	70.6	63.3

For comparing means of :

	SEmt	CD 5%	SEmt	CD 5%
Species (S)	2.13	8.36	0.71	2.78
Management (M)	1.28	5.58	0.84	3.80
S at same M	3.62	12.21	2.26	7.15
M at same S	3.28	11.08	2.37	7.50

Mean data of the two years indicated that the extent of reduction in sorghum plant height under *anjan*, *sissoo*, *eucalyptus* and *neem* compared to sole sorghum was 8, 27, 37 and 63 per cent respectively.

During both the years root pruned plus lopped trees resulted in significantly more height than other management treatments, which were on par, control trees resulted in minimum (59.7 cm) height. The mean increase in plant height with root pruning coupled with lopping over control trees was 18 per cent.

During both the years interaction between tree species and their management was significant. In *anjan* and *sissoo* all management treatments were at par, while in *neem* and *eucalyptus* root pruning coupled with lopping of trees resulted in significantly more sorghum height.

Harvest (cf. Table 52)

During both the years sole crop resulted in maximum height of sorghum plants followed by *anjan*, *sissoo*, *neem* and *eucalyptus*, they differed from each other significantly. The mean reduction in sorghum plant height when grown in association with *anjan*, *sissoo*, *neem* and *eucalyptus* as compared to sole sorghum was 9, 26, 35 and 63 per cent respectively.

In both the years sorghum plant height under root pruned plus lopped trees was significantly higher than that in the other three tree management treatments which were at par. Control trees resulted in lowest plant height of sorghum (61.9 cm), root pruning coupled with tree lopping resulted in 18 per cent increase in plant height over this.

Table 52 : Sorghum plant height (cm) at harvest as influenced by tree species and management

Species	1990-91										Mean				
	1989-90					1990-91									
	Control Trees pruned	Root pruned plus lopped	Lopped	Mean	SEmt	Control Trees pruned	Root pruned plus lopped	Lopped	Mean	SEmt		Control Trees pruned	Root pruned plus lopped	Lopped	Mean
Eucalyptus	21.5	27.0	26.5	33.5	20.5	25.5	25.0	32.3	21.0	26.2	25.8	58.5	32.9		
Neem	52.0	52.5	60.5	58.6	51.5	51.0	59.5	57.3	51.8	51.7	60.0	68.3	58.0		
Sissoo	67.0	65.5	69.0	67.5	66.0	63.5	65.5	64.8	66.5	64.5	67.2	66.3	66.1		
Anjan	83.0	82.0	82.0	82.4	80.0	80.5	79.5	80.8	81.5	81.3	80.7	82.8	81.6		
Sole crop (No trees)	89.5	95.0	88.0	90.8	87.5	92.0	85.0	88.1	88.5	93.5	86.5	89.3	89.5		
Mean	62.6	64.4	65.2	66.6	61.1	62.5	62.9	64.6	61.9	63.4	64.0	73.0	66.6		

For comparing means of :

	SEmt	CD 5%	SEmt	CD 5%
Species (S)	2.11	8.27	0.71	2.80
Management (M)	1.14	5.12	1.11	5.01
S at same M	3.15	10.90	2.05	6.51
M at same S	2.68	9.26	2.27	7.23

The interaction between tree species and their management was significant during both the years. During 1989-90 in *anjan* and *sissoo* all management treatments were at par, but in *neem* and *eucalyptus* root pruned plus lopped trees were significantly superior to control trees. During 1990-91 in *anjan* and *sissoo* all management treatments were at par, while in *neem* and *eucalyptus* root pruning plus lopping increased plant height significantly over control trees.

4.3.1.2 Light transmission ratio

At 30 DAS (cf. Table 53)

During both the years highest light transmission ratio (LTR) was observed in sole crop (100%) followed by *anjan*, *eucalyptus* and *neem*. *Anjan* and no tree control, *sissoo* and *neem*, and *sissoo* and *eucalyptus* were at par during 1989-90, while *sissoo* and *eucalyptus* were on par during 1990-91.

During both the years LTR was highest in root pruned plus lopped trees followed by lopped, root pruned and control trees. Root pruned plus lopped and lopped as well as root pruned and control trees were at par during both the years.

The interaction between tree species and their management was significant during both the years. In *anjan* all the management treatments were at par, but, in other tree species lopping only or root pruning coupled with lopping treatments were superior to other two management treatments.

Table 53 : Light Transmission Ratio (%) at 30 DAS as influenced by tree species and management

Species	1990-91										MEAN				
	1989-90					1990-91									
	Control Trees	Root pruned	Lopped	Root pruned plus lopped	Mean	Control Trees	Root pruned	Lopped	Root pruned plus lopped	Mean		Control Trees	Root pruned	Lopped	Root pruned plus lopped
Eucalyptus	65.0	67.4	85.5	82.5	75.0	67.0	68.0	86.5	83.5	76.3	66.0	67.5	86.0	83.0	75.6
Neem	50.0	59.0	71.5	75.5	64.0	53.0	60.5	72.5	76.5	65.6	51.5	59.8	72.0	76.0	64.8
Sissoo	46.0	55.0	81.5	97.5	69.9	47.5	57.5	83.0	98.5	71.6	46.8	56.3	82.2	98.0	70.8
Anjan	91.0	89.0	94.5	93.5	92.0	92.5	89.0	94.5	92.5	92.1	91.8	89.0	94.5	93.0	92.1
Sole crop (No trees)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Mean	70.4	74.0	86.6	89.7	80.2	72.0	75.0	87.3	90.2	81.1	71.2	74.5	87.0	90.0	80.7
For comparing means of :															
Species (S)			2.43	9.56				1.56	6.14				1.56	6.14	
Management (M)			2.43	10.94				1.75	7.86				1.75	7.86	
S at same M			4.18	14.07				3.06	10.11				3.06	10.11	
M at same S			4.27	14.37				3.23	10.67				3.23	10.67	

60 DAS (cf. Table 54)

During both the years sole crop recorded highest LTR (100%), followed by *anjan*, eucalyptus, sissoo and neem. Sole crop and *anjan* were at par, and were significantly superior to eucalyptus and sissoo which were at par during both the years.

During both the years though higher LTR was observed in lopped and root pruned plus lopped trees than control and root pruned trees, all the management treatments were at par.

The interaction between tree species and their management was significant during both the years. During 1989-90 in *anjan* and eucalyptus all tree management treatments were at par, but in neem, root pruned plus lopped trees were superior to the rest; in sissoo, lopped, and root pruned plus lopped trees were superior to the rest. During 1990-91 in *anjan* all management treatments were at par, but in neem, root pruned plus lopped trees resulted in higher LTR.

90 DAS (cf. Table 55)

During both the years LTR differed significantly due to tree species. Highest LTR was observed in sole crop (100%) followed by *anjan*, eucalyptus, sissoo and neem. However, sole crop and *anjan*; *anjan* and eucalyptus; *anjan* and sissoo; and, neem and sissoo were at par during both the years.

LTR differed significantly due to management treatment during both the years, root pruned plus lopped and lopped trees were on par, and were significantly superior to root pruned and control trees. Mean data of the two years showed LTR values of 95.5, 93.7, 74.4 and 77.9 per cent in root pruned plus lopped, lopped, root pruned and control trees respectively.

Table 54 : Light Transmission Ratio (%) at 60 DAS as influenced by tree species and management

Species	1990-91										MEAN					
	1989-90					1990-91					Lopped	Root pruned plus lopped	Mean	Root pruned plus lopped	Mean	
	Control Trees	Root pruned	Lopped	Root pruned plus lopped	Mean	Control Trees	Root pruned	Lopped	Root pruned plus lopped	Mean						Control Trees
Eucalyptus	79.0	61.0	83.0	77.5	75.1	73.0	64.5	83.5	78.0	74.8	76.0	62.7	83.3	77.8	75.0	
Neem	50.0	50.0	64.5	87.0	62.9	52.0	46.0	65.5	87.5	62.8	51.0	48.0	65.0	87.3	62.8	
Sissoo	56.0	53.0	95.0	87.5	72.8	58.5	55.0	95.5	90.0	74.8	57.3	54.0	95.2	88.8	73.8	
Anjan	100.0	99.0	100.0	98.5	99.4	98.5	99.0	99.0	98.0	98.6	99.2	99.0	99.5	98.3	99.0	
Sole crop (No trees)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	
Mean	77.0	72.6	88.5	90.1	82.1	76.4	72.9	88.7	90.7	82.7	76.7	72.7	88.6	90.4	82.1	
For comparing means of :											SEmt	CD 5%				
Species (S)											2.44	9.57				
Management (M)											3.85	NS				
S at same M											6.13	19.59				
M at same S											7.04	22.49				

Table 55 : Light Transmission Ratio (%) at 90 DAS as influenced by tree species and management

Species	1990-91										Mean				
	1989-90					1990-91									
	Control Trees	Root pruned	Lopped	Root pruned plus lopped	Mean	Control Trees	Root pruned	Lopped	Root pruned plus lopped	Mean		Control Trees	Root pruned	Lopped	Root pruned plus lopped
Eucalyptus	70.5	72.5	96.5	91.0	82.6	73.0	75.5	94.5	93.5	84.1	71.8	74.0	95.5	92.3	83.8
Neem	69.5	56.0	82.0	92.0	74.9	70.0	58.5	82.0	92.0	75.6	69.8	57.2	82.0	92.0	75.3
Sissoo	65.5	55.0	97.5	98.5	79.1	67.0	57.0	97.0	98.0	79.8	66.2	56.0	97.2	98.3	79.5
Anjan	81.0	83.5	93.0	93.5	87.8	82.0	86.0	94.5	96.0	89.6	81.5	84.8	93.8	94.8	88.7
Sole crop (No trees)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Mean	77.3	73.4	93.8	95.0	84.9	78.4	75.4	93.6	95.9	85.8	77.9	74.4	93.7	95.5	85.4

For comparing means of :

	SEmt	CD 5%	SEmt	CD 5%
Species (S)	3.34	13.13	2.92	11.46
Management (M)	2.52	11.34	1.91	8.58
S at same M	7.27	NS	6.64	NS
M at same S	7.13	NS	6.44	NS

4.3.1.3 Effective (ear bearing) population (cf. Table 56)

Per row

During 1989-90 effective population (number/10 m row length) differed significantly due to tree species in rows one and two, whereas during 1990-91 effective plant population differed significantly due to tree species in rows one and three. In both the years, highest effective population was observed in row three of *anjan* and lowest in row one of eucalyptus. With increase in row distance from the tree line the effective population increased, the rate of increase was highest in eucalyptus and lowest in *anjan*. In all the three rows highest effective population was recorded in *anjan* and the lowest in eucalyptus. Mean data of two years showed that in *anjan* the effective population was higher than that in eucalyptus by 350, 133 and 69 per cent in rows 1, 2 and 3 respectively.

In both the years, tree management affected effective population significantly in all the three rows. The highest effective population was observed in row three of root pruned plus lopped trees and lowest in row one of control trees. With increase in row distance from tree line, per row effective population increased, the rate of increase was highest in control trees and lowest in root pruned plus lopped trees. The effective population increased by 144, 148 and 60 per cent in root pruned plus lopped trees compared to control trees in rows 1, 2 and 3 respectively. The interaction between tree species and their management was not significant during both the years in any of the rows.

Table 56 : Effective population per row and per hectare as influenced by tree species and management

Treatment	1989-90						1990-91						Per Hectare ('1000)	Per 10 m row length ROW 1	Per 10 m row length ROW 2	Per 10 m row length ROW 3	Per Hectare ('1000)	Per Hectare ('1000)
	Per 10 m row length			Per 10 m row length			Per 10 m row length			Per 10 m row length								
	ROW 1	ROW 2	ROW 3	ROW 1	ROW 2	ROW 3	ROW 1	ROW 2	ROW 3	ROW 1	ROW 2	ROW 3						
Tree species (S)																		
Eucalyptus	5.0	10.6	15.6	9.38	2.8	8.8	11.3	6.63	3.5	9.4	13.5	8.01						
Neem	7.2	12.5	15.6	11.00	5.0	10.9	14.4	9.25	6.1	11.7	15.0	10.13						
Sissoo	10.9	17.2	20.3	15.25	8.8	14.4	18.1	12.88	9.9	15.8	19.2	14.07						
Anjan	22.5	24.7	26.3	24.25	21.0	21.3	22.3	21.38	21.8	23.0	24.3	22.82						
Sole crop (No trees)				43.88				37.38				40.63						
SEm±	0.18	0.99	1.74	0.646	0.92	1.83	1.72	1.062				1.062						
CD5%	0.81	4.45	NS	2.537	4.14	NS	7.74	4.171				4.171						
Management (M)																		
Control Trees	7.5	10.0	15.3	17.0	5.6	8.1	12.8	13.90	6.6	9.1	14.1	15.45						
Root pruned	9.4	14.1	18.1	18.9	7.2	10.9	15.6	15.70	8.3	12.5	16.9	17.30						
Lopped	12.2	17.2	18.8	21.0	9.4	15.0	18.1	18.10	10.8	16.1	18.5	19.60						
Root pruned plus lopped	16.6	23.8	25.6	26.1	15.5	21.3	19.5	22.30	16.1	22.6	22.6	24.20						
SEm±	0.4	0.68	0.53	0.265	0.92	1.43	1.23	0.557				0.557						
CD5%	1.82	3.04	2.40	1.191	4.14	6.43	5.55	2.479				2.479						
Interaction																		
For comparing means of : S at same M																		
SEm±	1.775	2.39	3.565	2.291	1.75	2.65	3.31	1.928				1.928						
CD5%	NS	NS	NS	NS	NS	NS	NS	NS				NS						
M at same S																		
SEm±	1.847	2.16	2.690	2.426	1.75	2.39	2.85	1.751				1.751						
CD5%	NS	NS	NS	NS	NS	NS	NS	NS				NS						

Per hectare

During both the years effective population per hectare differed significantly due to tree species. Highest effective population was observed in sole crop followed by *anjan*, *sissoo*, *neem* and *eucalyptus*. *Neem* and *eucalyptus* were on par during both the years. Mean data of the two years showed that effective population per hectare decreased by 44, 65, 75 and 80 per cent as compared to sole crop in *anjan*, *sissoo*, *neem* and *eucalyptus* respectively.

Effective population per hectare differed significantly due to tree management treatments during both the years. Root pruned plus lopped trees resulted in highest effective population, followed by lopped, root pruned and control trees. However, the differences between control and root pruned trees as well as between root pruned plus lopped trees were not significant during 1990-91. Mean data of the two years showed that effective population increased by 12, 27 and 57 per cent over control trees with root pruning, lopping and root pruning plus lopping of trees. The interaction between tree species and their management was not significant during both the years.

4.3.1.4 Grain weight per plant (cf. Table 57)

During both the years significantly highest grain weight per plant was recorded in sole crop followed by *anjan*, *sissoo*, *neem* and *eucalyptus*. While sole crop, *anjan* and *sissoo* were on par in 1989-90, in 1990-91 all treatments differed significantly from each other. Mean data of two years showed that compared to *eucalyptus*, which recorded the lowest per plant grain weight (6.47 g), the per plant grain weight was higher in *sissoo*, *anjan* and sole crop by 168, 177 and 194 per cent respectively.

Table 57 : Grain weight per plant (g) and 1000 Grain weight (g) of sorghum as influenced by tree species and management

Treatment	Grain weight per plant (g)			1000 Grain weight (g)		
	1989-90	1990-91	Mean	1989-90	1990-91	Mean
Tree species (S)						
Eucalyptus	7.21	5.73	6.47	28.1	27.5	27.8
Neem	14.08	13.29	13.69	26.7	26.5	26.6
Sissoo	17.68	16.93	17.31	28.0	27.7	27.9
Anjan	17.99	17.85	17.92	30.9	30.1	30.5
Sole crop (No trees)	19.10	18.99	19.05	31.3	30.7	31.0
SEm±	0.701	0.255		1.05	0.93	
CD5%	2.751	1.001		NS	NS	
Management (M)						
Control Trees	12.74	11.89	12.32	28.3	27.9	28.1
Root pruned	13.51	13.23	13.37	29.0	28.4	28.7
Lopped	16.54	15.49	16.02	29.1	28.7	28.9
Root pruned plus lopped	18.01	17.61	17.81	29.6	29.1	29.4
SEm±	0.234	0.222		0.96	0.66	
CD5%	1.055	1.001		NS	NS	
Interaction						
For comparing means of :						
S at same M	SEm±	1.871	1.605	1.97	1.64	
	CD5%	NS	NS	NS	NS	
M at same S	SEm±	1.630	1.604	1.98	1.55	
	CD5%	NS	NS	NS	NS	

During both the years significantly highest grain weight per plant was recorded in sorghum growing in association with root pruned plus lopped trees, followed by lopped, root pruned and control trees. However, root pruned and control trees were at par during 1989-90. Mean data of the two years showed that grain weight per plant in root pruned, lopped and root pruned plus lopped trees was higher than in control trees (12.32 g/plant) by 9, 30 and 45 per cent respectively. During both the years interaction between tree species and their management was not significant.

4.3.1.5 Thousand grain weight (cf. Table 57)

Tree species and their management did not cause any significant variation in thousand grain weight of sorghum during both the years. However mean data of the two years indicated that, thousand grain weight was higher in sole crop (31 g) and *anjan* (30.5 g) than *sissoo* (27.9 g), *eucalyptus* (27.8 g) and *neem* (26.6 g). Root pruned plus lopped trees resulted in higher thousand grain weight (29.4 g) than control trees (28.1 g).

4.3.1.6 Grain yield (cf. Table 58, Fig. 19)

Yield per row

During both the years per row grain yield (g/10 m rowlength) of *rabi* sorghum differed significantly due to tree species in all the three rows. Highest grain yield was recorded in row three of *anjan* and lowest in row one of *eucalyptus*. With increase in row distance from the tree line, per row grain yield increased, the rate of increase was highest in *eucalyptus* and lowest in *anjan*. In all the three rows highest yield was obtained in

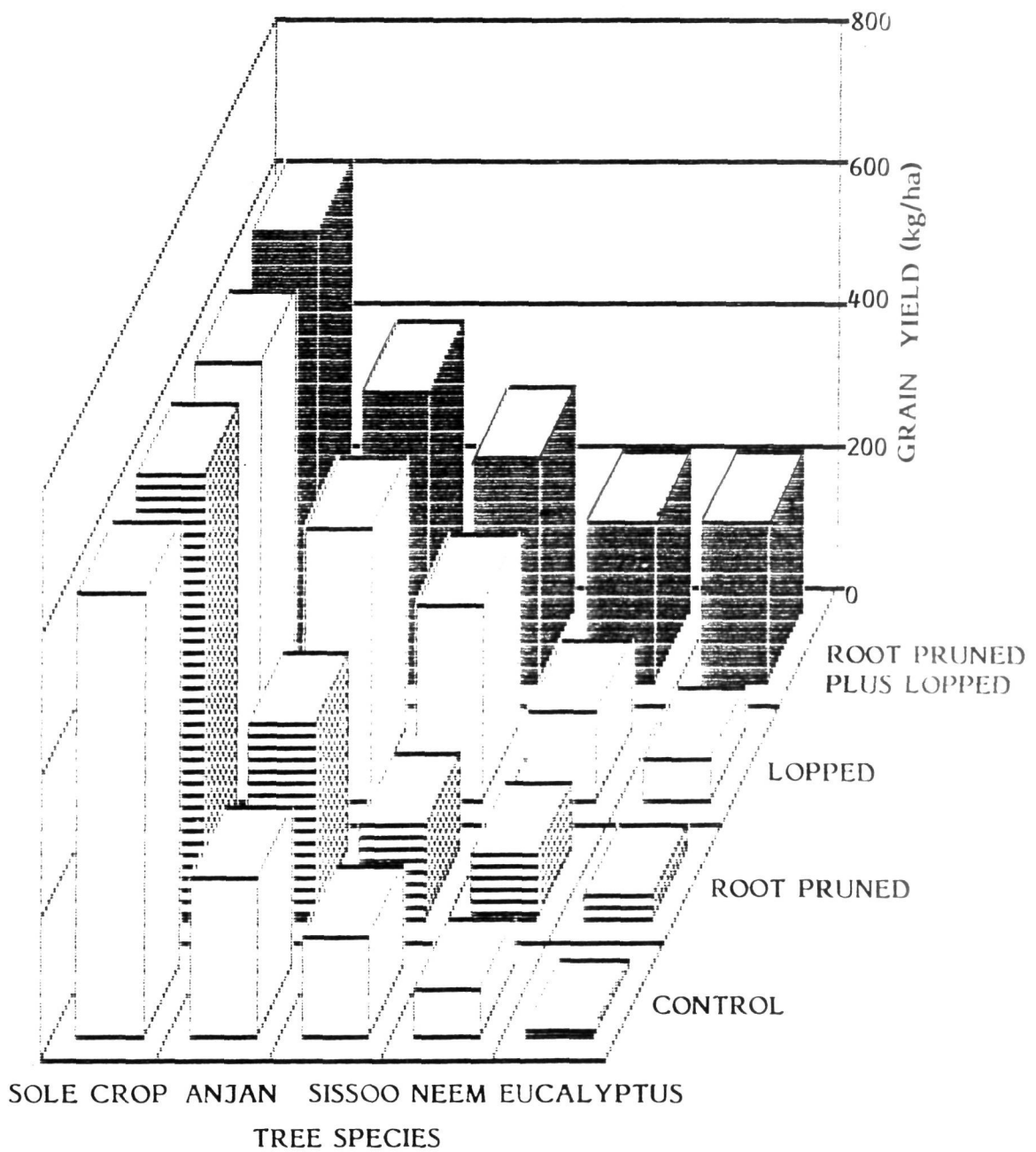


Fig.19. GRAIN YIELD OF SORGHUM AS INFLUENCED BY TREE SPECIES AND THEIR MANAGEMENT

anjan and lowest in eucalyptus. Mean data of the two years showed that in *anjan* per row grain yield was higher than that in eucalyptus by 1030, 258 and 126 per cent in rows one, two and three respectively.

In both the years significantly higher per row grain yield of *rabi* sorghum was recorded when grown in association with root pruned plus lopped trees in all the three rows. Highest per row grain yield was obtained in row three of root pruned plus lopped trees and lowest in row one of control trees. With increase in distance from tree line the per row grain yield increased, the rate of increase was highest in control trees and lowest in root pruned plus lopped trees. Mean data of the two years showed that per row grain yield with root pruned plus lopped trees was higher than that with control trees by 207, 202 and 101 per cent in rows one, two and three respectively.

The interaction between tree species and their management was significant in row two during 1990-91 (Table 58 a). The rate of increase in grain yield of *rabi* sorghum with root pruning and lopping of trees over control trees was higher in eucalyptus than other species.

Yield per hectare

During both the years grain yield differed significantly due to tree species. Lowest grain yield was obtained in eucalyptus and highest in sole crop. All the treatments varied from each other significantly during 1990-91, but, in 1989-90 eucalyptus and neem as well as neem and sissoo were at par. Mean data of the two years indicated that lowest (81 kg/ha) sorghum grain yield was obtained in association with eucalyptus and the highest (626 kg) in sole crop. Compared with eucalyptus grain yield was higher by

57, 170, 299 and 673 per cent in neem, sissoo, *anjan* and sole crop respectively. As per cent of sole crop the grain yield with eucalyptus, neem, sissoo and *anjan* was 13, 21, 35 and 51 per cent respectively.

During both the years grain yield differed significantly due to tree management. Lowest grain yield was obtained with control trees and highest with root pruned plus lopped trees. However, control and root pruned treatments were at par during 1989-90. During 1990-91 control, root pruned, and lopped as well as lopped and root pruned plus lopped treatments were at par. Mean data of the two years showed that root pruning, lopping and root pruning plus lopping increased grain yield by 9, 38 and 71 per cent respectively over control trees which produced the lowest yield (212 kg/ha). The interaction between tree species and their management was not significant during both the years.

4.3.1.7 Stover yield (cf. Table 59, Fig. 20)

Yield per row

During both the years per row stover yield (g/ 10 m rowlength) differed significantly due to tree species in all the three rows. Lowest yield was obtained in row one of eucalyptus and the highest in row three of *anjan*. With increase in distance from the tree line per row stover yield increased, the rate of increase was highest in eucalyptus and lowest in *anjan*. In all the three rows lowest yield was obtained in eucalyptus and the highest in *anjan*. Mean data of the two years showed that in *anjan* per row stover yield was higher than that in eucalyptus by 246, 102 and 73 per cent in rows one, two and three respectively.

Table 59 : Sorghum stover yield per row and per hectare as influenced by tree species and management

Treatment	1989-90			1990-91			MEAN					
	Per 10 m row length (g)			Per Hectare	Per 10 m row length(g)			Per Hectare	Per 10 m row length (g)			Per Hectare
	ROW 1	ROW 2	ROW 3	(kg/ha)	ROW 1	ROW 2	ROW 3	(kg/ha)	ROW 1	ROW 2	ROW 3	(kg/ha)
Tree species (S)												
Eucalyptus	138	281	356	240	138	272	363	236	138	277	360	238
Neem	166	359	419	294	144	331	388	268	155	345	404	281
Sissoo	375	538	632	494	313	480	565	430	344	509	599	462
Anjan	497	591	668	569	456	528	576	509	477	560	622	539
Sole crop (No trees)				1019				901				960
SE±	5.6	9.7	27.6	9.8	21.0	9.2	17.2	18.9				
CD5%	25.0	43.7	124.2	38.7	94.5	41.6	77.4	74.1				
Management (M)												
Control Trees	205	344	428	451	198	300	388	402	202	322	408	427
Root pruned	234	343	428	466	200	324	400	411	218	334	414	439
Lopped	328	484	556	547	288	444	500	494	308	464	528	521
Root pruned plus lopped	406	597	663	628	364	544	603	568	385	571	633	598
SE±	20.1	32.1	60.8	8.3	9.5	4.5	26.7	24.0				
CD5%	90.2	144.6	NS	37.3	42.6	20.2	120.1	108.0				
Interaction												
For comparing means of :												
S at same M	SE±	39.6	62.1	91.5	80.0	38.1	52.51	50.1	46.7			
	CD5%	NS	NS	NS	NS	NS	NS	NS	NS			
M at same S	SE±	44.1	69.3	106.3	82.4	33.1	51.26	54.1	50.2			
	CD5%	NS	NS	NS	NS	NS	NS	NS	NS			

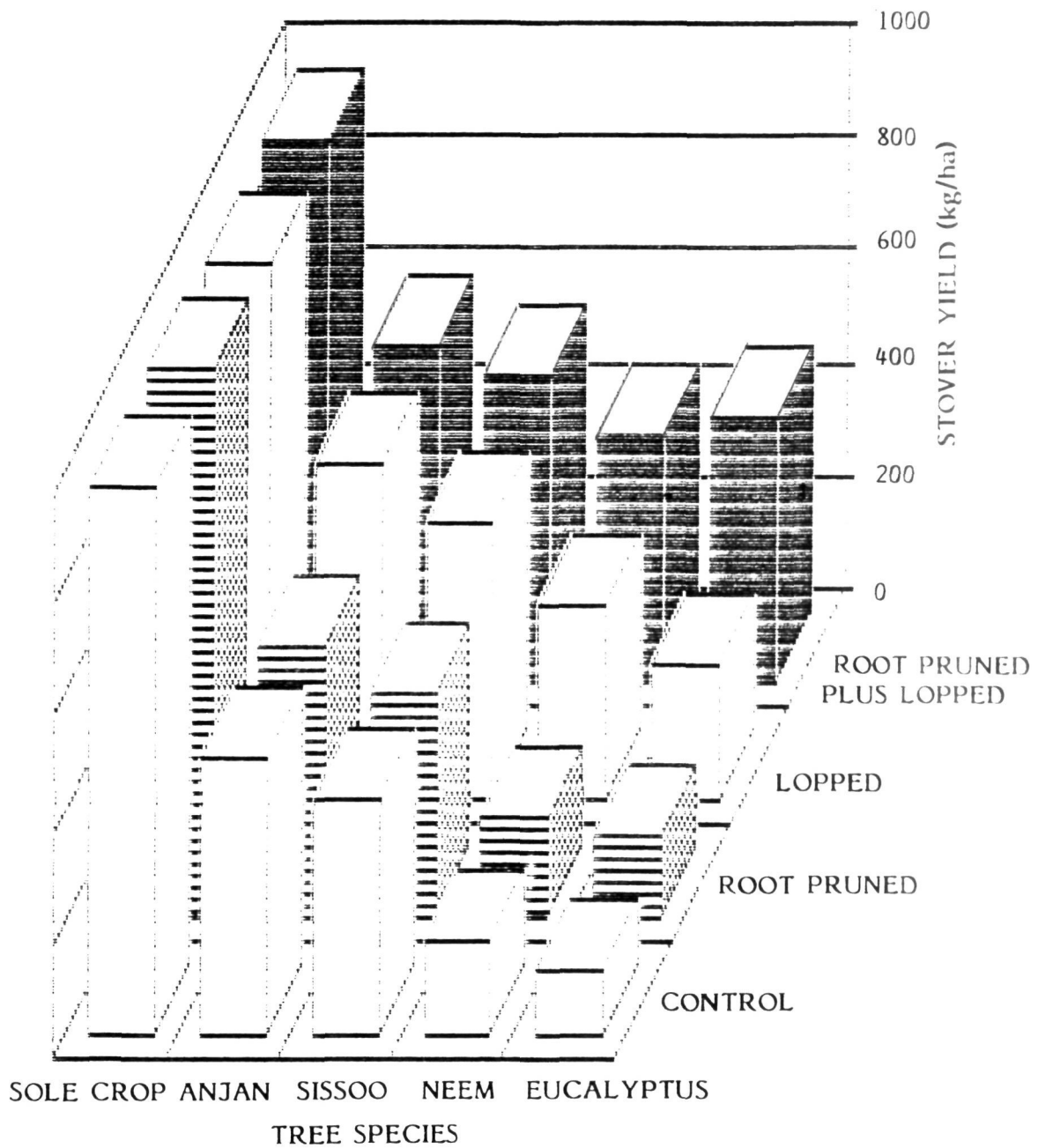


Fig.20. STOVER YIELD OF SORGHUM AS INFLUENCED BY TREE SPECIES AND THEIR MANAGEMENT

Per row stover yield of *rabi* sorghum differed significantly due to tree management treatments in rows one and two during 1989-90, and in all the three rows during 1990-91. Highest stover yield was obtained in row three of root pruned plus lopped trees and the lowest in row one of control trees. With increase in row distance from tree line the per row stover yield increased, the rate of increase was highest in control trees and lowest in root pruned plus lopped trees. In all the three rows highest stover yield was obtained with root pruned plus lopped trees and the lowest with control trees. Mean data of the two years showed that per row stover yield was higher with root pruned plus lopped trees than with control trees by 91, 77 and 55 per cent in rows 1, 2 and 3 respectively. The interaction between tree species and their management was not significant during both the years.

Yield per hectare

During both the years stover yield differed significantly due to tree species. Lowest yield was obtained with eucalyptus and the highest in sole crop. All the treatments differed from each other significantly in 1989-90, but in 1990-91 eucalyptus and neem were at par. Mean data of the two years showed that stover yield with neem, sissoo, *anjan* and in sole crop was higher than that with eucalyptus (238 kg/ha) by 18, 94, 126 and 303 per cent respectively. As per cent of sole crop the stover yield was 25, 29, 48 and 56 per cent with eucalyptus, neem, sissoo and *anjan* respectively.

In both the years stover yield of *rabi* sorghum differed significantly due to tree management treatments. Highest yield was obtained with root pruned plus lopped trees and the lowest with control trees. However, during 1989-90 control and root pruned trees were at par. During 1990-91 control, root

pruned and lopped as well as lopped and root pruned plus lopped treatments were at par. Mean data of the two years showed that the stover yield was higher in root pruned, lopped and root pruned plus lopped trees than in control trees (427 kg/ha) by 3, 22 and 24 per cent respectively. The interaction between tree species and their management was not significant during both the years.

4.3.2 Trees

4.3.2.1 Tree height (cf. Table 60, Fig. 21)

June 1989

At the initiation stage of the experiment (June 89) tree height (m) differed significantly due to species. Eucalyptus recorded maximum (7.45 m) height and *anjan* the lowest (2.89m). The height of *sissoo*, *neem* and *eucalyptus* was higher than that of *anjan* by 24, 40 and 157 per cent respectively. However, *neem* and *sissoo* were on par. Tree management did not influence tree height significantly.

June 1990

Tree species differed significantly in their height. Maximum height was observed in *eucalyptus* (8.6m) and the minimum in *anjan* (3.73m). The tree height was higher than that in *anjan* by 19, 33 and 130 per cent in *sissoo*, *neem* and *eucalyptus* respectively. Management did not influence tree height significantly, however control trees recorded more height than root pruned and lopped trees. Between June 1989 and June 1990 height increased by 15, 22, 24 and 29 per cent in *eucalyptus*, *neem*, *sissoo* and *anjan* respectively.

Table 60 : Height (m) and Diameter at Breast Height (cm) of different tree species as influenced by management

Treatment	Height (m)			Diameter at Breast Height (cm)			
	June 89	June 90	June 91	June 89	June 90	June 91	
Tree species (S)							
Eucalyptus	7.45	8.60	9.69	8.50	10.50	12.40	
Neem	4.05	4.95	5.79	7.30	8.80	10.40	
Sissoo	3.59	4.45	5.21	3.90	5.80	7.60	
Anjan	2.89	3.73	4.46	4.20	6.00	7.70	
SEm±	0.116	0.10	0.105	0.34	0.32	0.36	
CD5%	0.521	0.45	0.472	1.55	1.43	1.62	
Management (M)							
Control Trees	4.46	5.53	6.45	6.00	8.00	10.00	
Root pruned	4.45	5.43	6.05	6.00	7.80	9.50	
Lopped	4.49	5.50	6.38	6.10	7.80	9.40	
Root pruned plus lopped	4.58	5.28	6.05	6.00	7.60	9.20	
SEm±	0.053	0.127	0.126	0.11	0.20	1.61	
CD5%	NS	NS	NS	NS	NS	NS	
Interaction							
For comparing means of :							
S at same M	SEm±	0.263	0.278	0.282	0.49	0.57	0.60
	CD5%	NS	NS	NS	NS	NS	NS
M at same S	SEm±	0.242	0.289	0.291	0.36	0.51	0.51
	CD5%	NS	NS	NS	NS	NS	NS

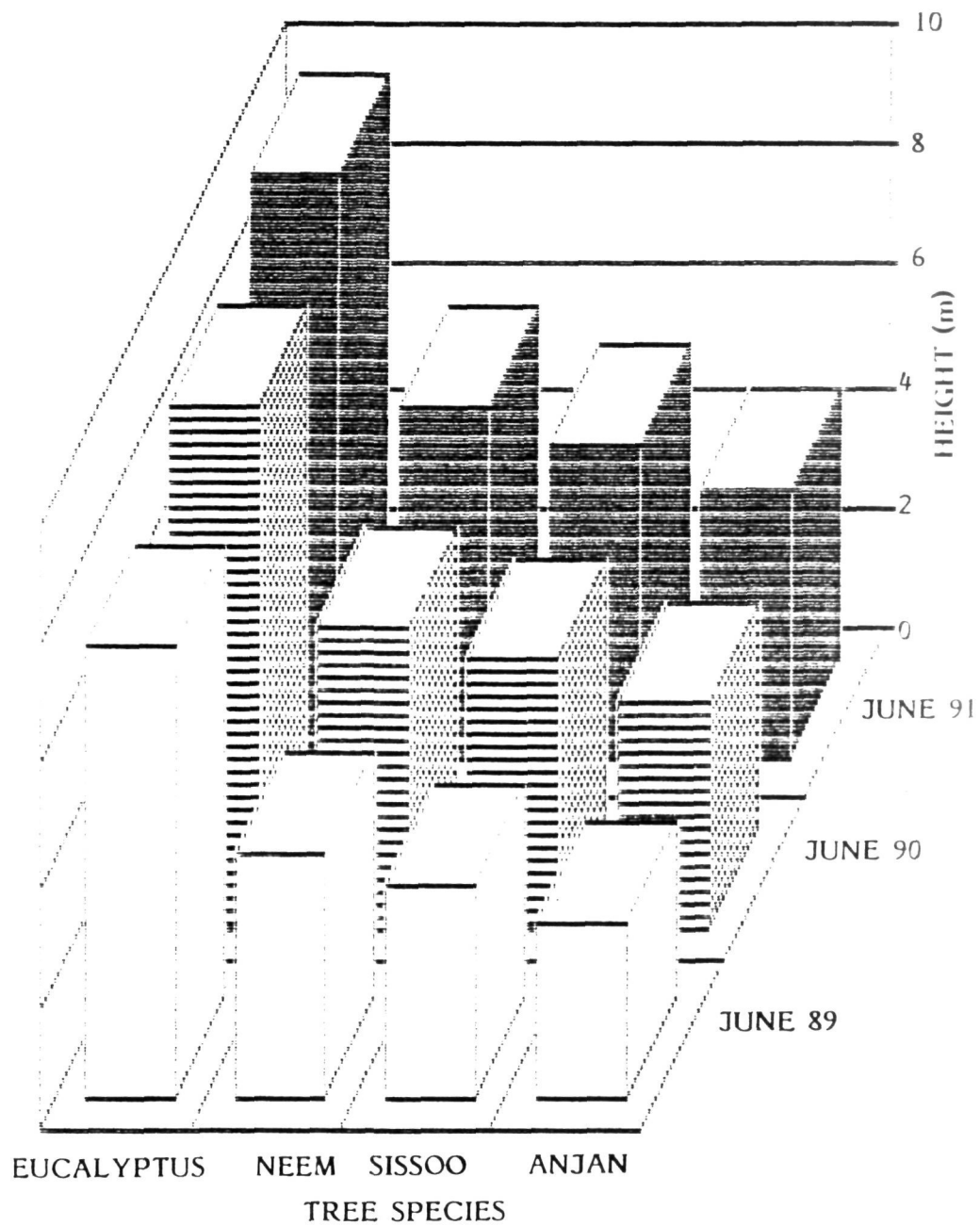


Fig.21. HEIGHT OF TREE SPECIES ON DIFFERENT DATES OF OBSERVATION

June 1991

Tree species differed significantly in their height. Maximum height was recorded in eucalyptus (9.69m) and minimum in *anjan* (4.46m). Tree height was higher than that in *anjan* by 17, 30 and 117 per cent in *sissoo*, *neem* and eucalyptus respectively. Tree management did not cause significant variation in their height, however, control trees recorded more (6.45 m) height than root pruned plus lopped (6.05m) trees.

Between June 1990 and June 1991 tree height increased by 13, 17, 17 and 20 per cent in eucalyptus, *neem*, *sissoo* and *anjan* respectively. Between June 1989 and June 1991 the increase was 30, 43, 45 and 53 per cent respectively.

4.3.2.2 Tree diameter at breast height (cf. Table 60, Fig. 22)**June 1989**

Trees differed significantly in their diameter at breast height (DBH). Eucalyptus recorded maximum (8.5 cm) and *sissoo* the minimum (3.9cm). DBH was higher than that of *sissoo* by 8, 87 and 118 per cent in *anjan*, *neem* and eucalyptus respectively, *anjan* and *sissoo* were at par. The DBH did not vary significantly due to tree management.

June 1990

Tree species differed significantly in their DBH. Maximum DBH (10.5 cm) was observed in eucalyptus and minimum in *sissoo* (5.8 cm). DBH was higher than that of *sissoo* by 3, 51 and 81 per cent in *anjan*, *neem* and eucalyptus respectively, *anjan* and *neem* were at par. DBH did not vary significantly due to management, however, control trees had higher DBH (8.0cm) than root

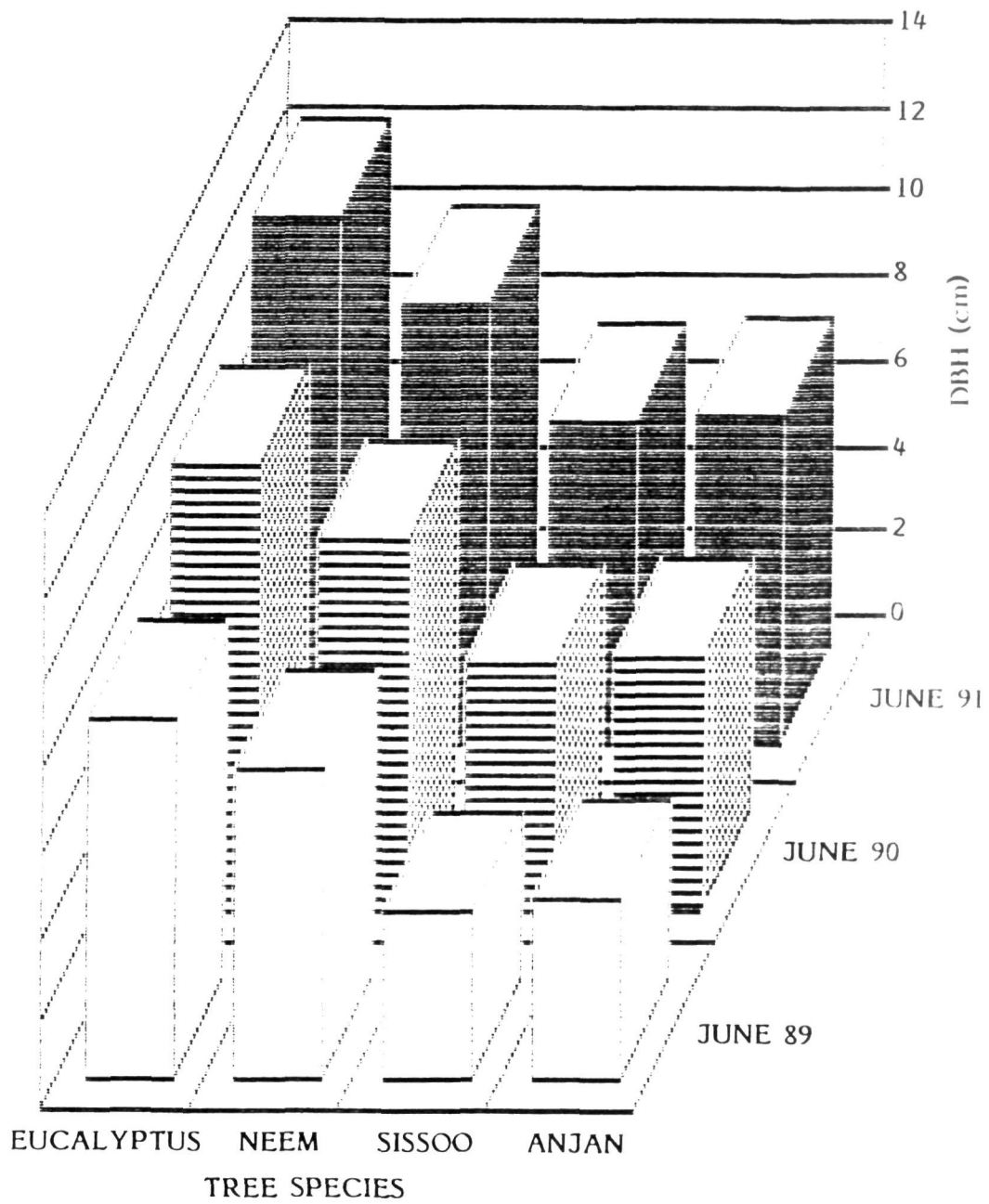


Fig.22. DIAMETER AT BREAST HEIGHT (DBH) OF TREE SPECIES ON DIFFERENT DATES OF OBSERVATION

pruned and lopped trees (7.6cm). Over June 1989 DBH increased by 49, 43, 24 and 21 per cent in *sissoo*, *anjan*, eucalyptus and neem respectively.

June 1991

Trees differed in their DBH significantly. Highest DBH (12.4 cm) was observed in eucalyptus and lowest in *sissoo* (7.6 cm). The DBH was higher than that of *sissoo* by 1, 37 and 63 per cent in *anjan*, neem and eucalyptus respectively. However, *sissoo* and *anjan* were at par. DBH did not vary significantly due to tree management, however, control trees recorded higher DBH (10.0 cm) than root pruned and lopped (9.2 cm). Over June 1990, DBH increased by 31, 28, 18 and 18 per cent in *sissoo*, *anjan*, eucalyptus and neem respectively. Over June 1989 the respective increase was 95, 81, 46 and 42 per cent.

4.3.2.3 Tree dry matter in June 1989 (cf. Table 61)

Leaf

Tree species differed significantly in their leaf dry matter (DM) in June 1989. Eucalyptus had the highest (3.816 kg/tree) leaf DM and *anjan* the lowest (0.332 kg). Leaf dry matter was higher than that of *anjan* by 359, 436 and 1049 per cent in *sissoo*, neem and eucalyptus trees respectively. However, neem and *sissoo* were at par. Leaf DM did not vary significantly due to tree management.

Branch

Species differed significantly in their branch DM. Maximum branch DM was recorded in eucalyptus (2.260 kg/tree) and minimum in *anjan* (0.224kg). Branch DM was higher by 290, 536 and 909 per cent in *sissoo*, neem and eucalyptus respectively, over that in *anjan*. Branch DM did not vary significantly due to tree management treatments.

Table 61 : Leaf, branch, stem and total dry matter in tree species in June 89, June 91, and their increment between June 89 and June 91 (Age 6 to 8 yrs) as influenced by their management

Treatment	Dry matter (kg/tree)								Increment between June 89 and June 91 (Age 6 to 8 yrs) (kg/tree/yr)				
	June 1989				June 1991				Leaf	Branch	Stem	Total	
	Leaf	Branch	Stem	Total	Leaf	Branch	Stem	Total					
Tree species (S)													
Eucalyptus	3.816	2.260	9.243	15.32	7.920	4.220	24.80	36.94	2.053	0.978	7.780	10.80	
Neem	1.781	1.421	4.021	7.22	3.070	2.320	9.85	15.24	0.644	0.449	2.920	4.01	
Sissoo	1.524	0.873	1.968	4.36	3.410	2.320	5.59	11.33	0.946	0.724	1.820	3.49	
Anjan	0.332	0.224	1.506	2.06	1.670	0.847	7.37	9.89	0.671	0.312	2.930	3.91	
SE±	0.072	0.030	0.091	0.167	0.280	0.068	0.221	0.556	0.113	0.026	0.074	0.203	
CD5%	0.323	0.134	0.410	0.752	1.262	0.304	0.996	2.504	0.507	0.119	0.332	0.916	
Management (M)													
Control Trees	1.824	1.215	4.239	7.275	5.490	2.580	12.49	20.55	1.831	0.683	4.130	6.64	
Root pruned	1.825	1.180	4.10	7.100	4.760	2.460	11.68	18.91	1.470	0.642	3.790	5.90	
Lopped	1.935	1.186	4.169	7.290	3.120	2.350	11.83	17.29	0.596	0.579	3.830	5.00	
Root pruned plus lopped	1.870	1.196	4.230	7.296	2.700	2.320	11.62	16.64	0.417	0.559	3.690	4.67	
SE±	0.097	0.087	0.428	0.603	0.364	0.237	1.483	2.066	0.145	0.078	0.538	0.743	
CD5%	NS	NS	NS	NS	1.636	NS	NS	NS	0.655	NS	NS	NS	
Interaction													
For comparing means of :													
S at same M	SE±	0.301	0.186	0.754	1.215	0.698	0.380	2.013	3.032	0.216	0.110	0.657	0.943
	CD5%	NS	NS	NS	NS	2.380	NS	NS	NS	0.767	NS	NS	NS
M at same S	SE±	0.309	0.204	0.862	1.346	1.735	0.443	2.490	3.626	0.234	0.132	0.846	1.183
	CD5%	NS	NS	NS	NS	2.508	NS	NS	NS	0.833	NS	NS	NS

Table 61 a : Leaf dry matter in June 91 and leaf dry matter increment as influenced by tree species x management

Tree species	Leaf Dry matter (Kg/tree) June 91				Leaf Dry matter Increment (Kg/tree/yr)			
	Control trees	Root pruned	Lopped	Root pruned plus lopped	Control trees	Root pruned	Lopped	Root pruned plus lopped
Eucalyptus	11.74	9.52	5.65	4.97	3.98	2.90	0.81	0.52
Neem	4.03	4.25	2.13	1.88	1.18	1.24	0.08	0.08
Sissoo	4.52	3.79	3.08	2.27	1.51	1.14	0.76	0.38
Anjan	1.66	1.50	1.84	1.70	0.65	0.60	0.75	0.69
For comparing means of :								
Species at same Management			SE±	CD5%		SE±	CD5%	
Management at same species			0.698	2.380		0.216	0.767	
			1.735	2.508		0.234	0.833	

Stem

Dry matter in stem differed significantly in the tree species. Highest stem DM (9.243 kg/tree) was recorded in eucalyptus and the lowest (1.506kg) in *anjan*. Stem DM was higher than that of *anjan*, by 31, 167 and 514 per cent in *sissoo*, *neem* and eucalyptus respectively. The DM in stem did not vary significantly due to management.

Total

Like leaf, branch and stem, the total dry matter of tree species differed significantly. Highest total DM (15.319 kg/tree) was observed in eucalyptus and lowest (2.063kg) in *anjan*. Total dry matter was higher than that of *anjan* by 111, 250 and 643 per cent in *sissoo*, *neem* and eucalyptus respectively. Tree management did not influence total DM significantly.

4.3.2.4 Tree dry matter in June 1991 (cf. Table 61)

Leaf DM

Leaf dry matter differed significantly in the species. Highest leaf DM (7.923 kg/tree) was in eucalyptus and lowest (1.674kg) in *anjan*. Leaf DM was higher than that of *anjan* by 83, 104 and 373 per cent in *neem*, *sissoo* and eucalyptus respectively. However, *neem* and *sissoo* were at par. Over June 1989 the per cent increase was 404 in *anjan*, 107 in eucalyptus, 52 in *sissoo* and 30 in *neem*.

Leaf DM differed significantly due to tree management. Maximum was recorded in control trees (5.485 kg/tree) and minimum (2.702 kg) in root pruned plus lopped trees. Compared with control trees leaf DM decreased by 13, 43 and 51 per cent due to root pruning, lopping and root pruning plus

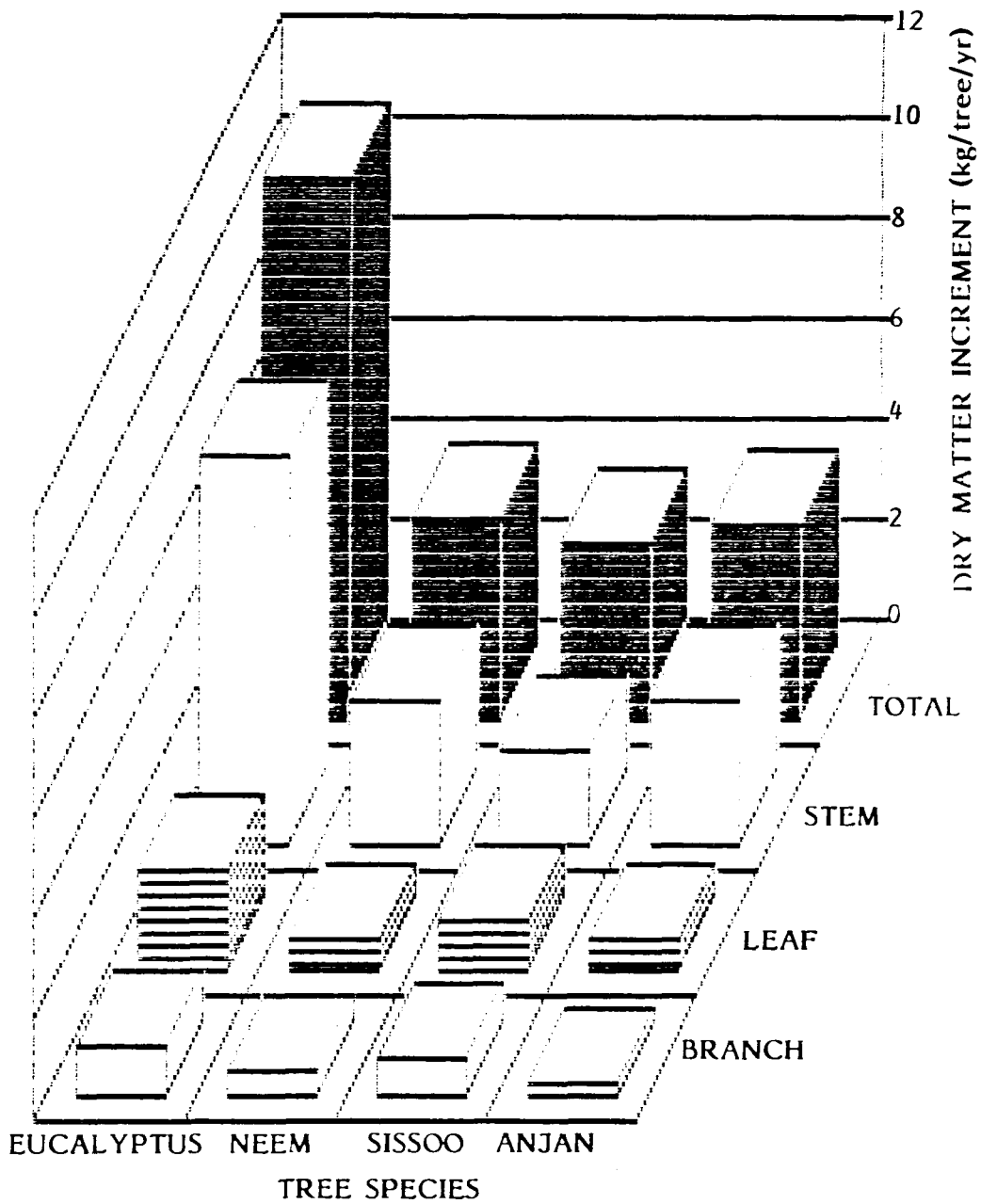


Fig.23. DRY MATTER INCREMENT IN DIFFERENT PARTS OF TREE SPECIES

lopping respectively. However, control and root pruned, and, lopped and root pruned plus lopped trees were on par.

The interaction between species and management was significant (Table 61 a). In *anjan* *sissoo* and *neem* different tree management treatments did not vary leaf DM significantly, but in *eucalyptus* lopping and root pruning plus lopping reduced leaf DM significantly as compared with control and root pruned trees.

Branch DM

Branch DM in June 1991 differed significantly in the tree species. Highest (4.216 kg/tree) was observed in *eucalyptus* and lowest (0.847 kg) in *anjan*. Branch DM was higher than that in *anjan* by 174, 174 and 398 per cent in *sissoo*, *neem* and *eucalyptus* respectively. *Sissoo* and *neem* were at par. Branch DM did not vary significantly due to tree management. Over June 1989, branch DM increased by 63, 87, 166 and 278 per cent in *neem*, *eucalyptus* *sissoo* and *anjan* respectively.

Stem DM

Stem DM differed significantly in tree species. Maximum stem DM was recorded in *eucalyptus* (24.799 kg/tree) and the minimum (5.593 kg) in *sissoo*. *Anjan*, *neem* and *eucalyptus* had higher stem DM than that of *sissoo* by 31, 76 and 343 per cent respectively. Management treatments did not vary stem DM significantly. Over June 1989 per cent increase in stem DM was 145, 168, 184 and 389 in *neem*, *eucalyptus*, *sissoo* and *anjan* respectively.

Total DM

Total DM in the tree species differed significantly. Highest total DM was recorded in eucalyptus (36.938 kg/tree) and lowest (9.889 kg/tree) in *anjan*. Total DM was higher than that of *anjan* by 15, 54 and 273 in *sissoo*, *neem* and eucalyptus respectively. However, *anjan* and *sissoo* were at par. Total DM did not vary significantly due to management. Over June 1989 total DM increased by 111, 141, 160 and 379 per cent in *neem*, eucalyptus, *sissoo* and *anjan* respectively.

4.3.2.5 Increment in Dry matter between June 1989 and June 1991 (Age 6 to 8 yrs) (cf. Table 61, Fig. 23)

Leaf

Leaf DM increment (kg/tree/yr) differed significantly in the tree species. Highest increment (7.923 kg) was recorded in eucalyptus and lowest in *neem* (0.644 kg). The increment in *anjan*, *sissoo* and eucalyptus was higher than that in *neem* by 4, 47 and 219 per cent respectively. However, *neem* and *anjan* were at par.

Leaf DM increment differed significantly due to tree management. Highest increment (1.831 kg) was recorded in control and lowest (0.417 kg) in root pruned plus lopped trees. As compared with control trees leaf DM increment decreased by 20, 68 and 73 per cent due to root pruning, lopping and root pruning plus lopping respectively.

The interaction between species and management was significant (Table 61a). In *anjan* all management treatments were at par. In *sissoo* root pruning plus lopping reduced leaf DM increment significantly. In *neem* lopping, and root pruning plus lopping reduced leaf DM increment significantly. In eucalyptus, root pruning, lopping and root pruning plus lopping reduced leaf DM increment significantly.

Branch

Branch DM increment differed significantly in the tree species. Highest increment (0.978 kg/tree/yr) was observed in eucalyptus and lowest in *anjan* (0.312 kg). The increment was higher than that in *anjan* by 44, 132 and 213 per cent in neem, *sissoo* and eucalyptus respectively. Though branch DM increment did not vary significantly due to management, control trees recorded 22 per cent more increment than root pruned plus lopped trees.

Stem

Stem DM increment in tree species differed significantly. Highest increment was observed in eucalyptus (7.778 kg/tree/yr) and lowest (1.816 kg) in *sissoo*. The increment was higher than that in *sissoo* by 61, 61 and 328 per cent in *anjan*, neem and eucalyptus respectively. Neem and *anjan* were at par. Tree management did not vary stem DM increment significantly, however, control trees recorded 12 per cent more increment than root pruned plus lopped.

Total

Total DM increment in the tree species differed significantly. Highest was observed in eucalyptus (10.81 kg/tree/yr) and lowest in *sissoo* (3.489 kg). The increment was higher than that in *sissoo* by 12, 15 and 210 per cent in *anjan*, neem and eucalyptus respectively. However, *sissoo*, *anjan* and neem were at par. Total DM increment did not vary significantly due to tree management. However, control trees recorded maximum increment (6.643 kg). The increment reduced by 11, 25 and 30 per cent respectively due to root pruning, lopping and root pruning plus lopping.

4.3.2.6 Yield of loppings (cf. Table 62)

Leaf biomass yield

During both the years leaf biomass yield through lopping differed significantly due to tree species. During 1989-90 eucalyptus produced the

Table 62 : Leaf, wood and total biomass yield of loopings (kg/tree/yr) as influenced by tree species and their management

Species	1990-91																										
	1989-90				1990-91				MEAN																		
	Leaf	Wood	Total	Leaf	Wood	Total	Leaf	Wood	Total	Leaf	Wood	Total															
	Looping only	Root pruning plus looping	Mean Looping only plus looping	Root pruning plus looping	Mean Looping only plus looping	Root pruning plus looping	Mean Looping only plus looping	Root pruning plus looping	Mean Looping only plus looping	Root pruning plus looping	Mean Looping only plus looping	Root pruning plus looping	Mean Looping only plus looping														
Eucalyptus	4.70	4.42	4.56	2.46	1.93	2.19	7.16	6.35	6.75	0.90	0.79	0.85	0.37	0.26	0.32	1.27	1.05	1.16	2.80	2.60	2.70	1.12	1.10	1.26	4.21	3.70	3.96
Neem	1.35	1.22	1.29	1.95	1.84	1.90	3.31	3.06	3.18	0.47	0.19	0.33	0.23	0.04	0.13	0.70	0.22	0.46	0.91	0.70	0.81	1.09	0.94	1.01	2.00	1.64	1.82
Sissoo	1.39	1.16	1.27	0.88	0.73	0.81	2.30	1.89	2.10	1.08	0.98	1.03	0.72	0.45	0.59	1.80	1.43	1.61	1.23	1.07	1.15	0.80	0.59	0.70	2.05	1.66	1.86
Anjan	1.01	0.75	0.88	0.18	0.21	0.19	1.19	0.96	1.07	0.90	1.02	0.96	0.11	0.04	0.08	1.02	1.05	1.03	0.96	0.89	0.92	0.15	0.12	0.14	1.10	1.00	1.05
Mean	2.11	1.89	1.37	1.18	1.27	3.49	3.06	0.84	0.84	0.74	0.79	0.36	0.20	1.20	0.94	1.07	1.47	1.31	0.86	0.69	0.78	2.34	2.00				

For comparing means of : SE± CD% SE± CD% SE± CD% SE± CD%

Species (S)	0.103	0.33	0.051	0.163	0.074	0.236	0.032	0.104	0.008	0.026	0.34	0.109
Management (M)	0.028	0.127	0.011	0.049	0.023	0.103	0.028	NS	0.016	0.071	0.037	0.166
S at same M	0.112	NS	0.059	0.188	0.091	0.292	0.046	0.146	0.018	0.058	0.051	0.163
M at same S	0.061	NS	0.037	0.119	0.070	0.235	0.048	0.153	0.025	0.081	0.059	0.190

highest followed by neem, sissoo, and *anjan*, however neem and sissoo were on par. During 1990-91 sissoo produced the highest followed by *anjan*, eucalyptus and neem, however difference between sissoo and *anjan* was not significant. Mean data of the two years showed that leaf biomass yield through lopping was higher in *anjan*, sissoo and eucalyptus than that in neem (0.81 kg/tree/yr) by 14, 42 and 233 per cent respectively.

During first year leaf yield through loppings was significantly higher in lopping only treatment than that in root pruning plus lopping treatment (1.8 g kg/tree/yr) by 12 per cent. During second year they were on par. The interaction between tree species and their management was significant in 1990-91. In neem lopping only was superior to root pruning plus lopping, but in other species both these management treatments were at par.

Wood biomass yield

Wood biomass yield through lopping differed significantly due to tree species in both the years. During 1989-90 highest wood biomass yield was obtained from eucalyptus followed by neem, sissoo and *anjan*, they differed from each other significantly. During 1990-91 highest wood biomass yield through lopping was obtained from sissoo followed by eucalyptus, neem and *anjan*, they differed from each other significantly. Mean data of the two years showed that wood biomass yield through loppings was higher in sissoo, neem and eucalyptus than that in *anjan* (0.14 kg/tree/yr) by 400, 621 and 800 per cent respectively.

Wood biomass yield through lopping differed significantly due to tree management during both the years. Lopping only resulted in significantly higher wood biomass yield than root pruning plus lopping. Mean data of the two years showed higher wood biomass yield by 25 per cent in lopped than root pruned plus lopped trees (0.69 kg/tree/yr).

The interaction between tree species and their management was significant during both the years. In 1989-90 the reduction in wood biomass yield of loppings due to root pruning in addition lopping was more (22%) in eucalyptus than other species. In 1990-91 the reduction in wood biomass yield through lopping due to root pruning in addition to lopping was higher in neem (83%) than that in other species.

Total biomass yield

Total biomass yield of lopping differed significantly due to tree species during both the years. During 1989-90 highest total biomass yield of lopping was obtained from eucalyptus followed by neem, sissoo and *anjan*, they differed from each other significantly. During 1990-91, highest total biomass yield of loppings was obtained from sissoo followed by eucalyptus, *anjan* and neem respectively, they differed from each other significantly. Mean data of the two years showed that total biomass yield of loppings was higher in eucalyptus, sissoo and neem than that in *anjan* (1.05 kg/tree/yr) by 277, 77, 73 per cent respectively.

During both the years total biomass yield of loppings was significantly higher in lopped trees than root pruned plus lopped, showing a mean increase of 17 per cent over root pruned plus lopped (2 kg/tree/yr). During both the years interaction between tree species and their management was significant. In *anjan* lopped and root pruned plus lopped trees were on par with respect to total biomass yield of loppings but in the other tree species the former was significantly superior to the latter.

4.3.3 Soil moisture (cf. Table 63)

At sowing

During both years soil moisture content (cm water in 0-30 cm soil layer) was highest in sole crop (no trees) followed by *anjan*, sissoo, neem and eucalyptus. The mean data of the two years showed that soil moisture

Table 63 : Soil moisture content (cm water in 0-30 cm soil profile) at different stages of sorghum growth as influenced by tree species and their management

Species	1989-90					1990-91					MEAN				
	Control Trees	Root pruned	Lopped	Root pruned plus lopped	Mean	Control Trees	Root pruned	Lopped	Root pruned plus lopped	Mean	Control Trees	Root pruned	Lopped	Root pruned plus lopped	Mean
SOWING															
<i>Eucalyptus</i>	6.5	7.9	7.8	7.9	7.5	6.0	7.4	7.4	7.5	7.1	6.3	7.7	7.6	7.7	7.3
<i>Neem</i>	8.7	9.3	9.2	9.3	9.1	8.1	8.7	8.6	8.8	8.6	8.4	9.0	8.9	9.1	8.9
<i>Sissoo</i>	9.2	9.5	9.4	9.5	9.4	8.5	8.8	8.7	9.0	8.8	8.8	9.2	9.0	9.2	9.1
<i>Anjan</i>	9.5	9.6	9.5	9.7	9.6	8.9	9.0	9.1	9.0	9.0	9.2	9.3	9.3	9.4	9.3
Sole crop (No trees)	9.7	9.6	9.7	9.6	9.7	9.1	9.0	9.2	9.1	9.1	9.4	9.3	9.5	9.3	9.4
Mean	8.7	9.2	9.1	9.2		8.1	8.6	8.6	8.7		8.4	8.9	8.9	9.0	8.8
FLOWERING															
<i>Eucalyptus</i>	5.8	6.2	6.4	6.5	6.2	5.5	5.8	6.0	6.1	5.9	5.7	6.0	6.2	6.3	6.1
<i>Neem</i>	6.8	7.0	7.3	7.5	7.2	6.4	6.7	6.9	7.1	6.8	6.6	6.9	7.1	7.3	7.0
<i>Sissoo</i>	7.0	7.2	7.5	7.8	7.4	6.5	6.7	7.0	7.5	6.9	6.8	7.0	7.3	7.7	7.2
<i>Anjan</i>	7.9	8.0	8.1	8.2	8.1	7.4	7.6	7.7	7.8	7.6	7.7	7.8	7.9	8.0	7.9
Sole crop (No trees)	8.1	8.2	8.1	8.0	8.1	7.7	7.8	7.8	7.6	7.7	7.9	8.0	8.0	7.8	7.9
Mean	7.1	7.3	7.5	7.6		6.7	6.9	7.1	7.2		6.9	7.1	7.3	7.4	
HARVEST															
<i>Eucalyptus</i>	4.5	4.9	5.2	5.4	5.0	4.3	4.7	5.0	5.1	4.8	4.4	4.8	5.1	5.3	4.9
<i>Neem</i>	4.9	5.2	5.5	5.6	5.3	4.5	4.9	5.3	5.7	5.1	4.7	5.1	5.4	5.7	5.2
<i>Sissoo</i>	5.0	5.1	5.5	5.6	5.3	4.7	5.0	5.4	5.5	5.2	4.9	5.1	5.5	5.1	5.3
<i>Anjan</i>	5.8	5.8	6.0	6.0	5.9	5.1	5.5	5.6	5.7	5.5	5.5	5.7	5.8	5.9	5.7
Sole crop (No trees)	6.2	6.1	6.0	6.0	6.1	5.9	6.0	5.8	5.9	5.9	6.0	6.1	5.9	6.0	6.0
Mean	5.3	5.4	5.6	5.8		4.9	5.2	5.4	5.6		5.1	5.3	5.5	5.7	

content in sole crop, *anjan*, *sissoo* and *neem* was higher than that in *eucalyptus* (7.3 cm) by 29, 27, 25 and 22 per cent respectively.

Among the management treatments highest soil moisture content at sowing was observed in root pruned plus lopped and lowest in control trees during both the years. Mean data of the two years showed that soil moisture content at sowing was higher in root pruned plus lopped, lopped, and root pruned trees than that in control (8.4 cm) by 7, 6 and 6 per cent respectively.

At flowering

During both the seasons soil moisture content at flowering was higher in sole crop and *anjan* followed by *sissoo*, *neem* and *eucalyptus*. Mean data of the two years showed that soil moisture in sole crop, *anjan*, *sissoo* and *neem* was higher than that in *eucalyptus* (6.1cm) by 30, 30, 18 and 15 per cent respectively.

Highest soil moisture was observed in root pruned plus lopped, followed by lopped, root pruned and control trees during both the years. Mean data of the two years showed higher soil moisture in root pruned plus lopped, lopped and root pruned trees than control trees (6.9cm) by 7,6 and 3 per cent respectively.

At harvest

During both the years soil moisture content at harvest was highest in sole crop followed by *anjan*, *sissoo*, *neem* and *eucalyptus*. Mean data of the two years showed that soil moisture in no tree control, *anjan*, *sissoo* and *neem* was higher than that in *eucalyptus* by 22, 16, 8 and 6 per cent respectively.

During both the years higher soil moisture content at harvest was observed in root pruned plus lopped trees followed by lopped, root pruned and control trees. Mean data of the two years showed that soil moisture content was higher in root pruned plus lopped, lopped and root pruned than control trees (5.1cm) by 12, 8 and 4 per cent respectively.

4.3.4 Net returns (cf. Table 64)

During both the years net returns (Rs/ha/yr) differed significantly due to tree species. During 1989-90 highest net returns were obtained from eucalyptus followed by *anjan*, neem, sissoo and sole crop. However, differences between *anjan* and neem as well as neem and sissoo were not significant. During 1990-91 highest net returns were obtained from eucalyptus followed by *anjan*, sissoo, neem and sole crop respectively. However, difference between sissoo and neem was not significant. Mean data of the two years showed that net returns were higher from eucalyptus, *anjan*, neem and sissoo than that from sole crop (Rs 1135/ha/yr) by 270, 160, 93 and 80 per cent respectively.

Net returns did not differ significantly due to tree management treatments during both the years. Mean data of the two years showed that net returns were higher from lopped, root pruned plus lopped and control trees than that from root pruned trees (Rs 2133/ha/yr) by 28, 27 and 13 per cent respectively.

The interaction between tree species and their management was significant during 1990-91. In *anjan* net returns were significantly higher in lopped and root pruned plus lopped trees than control and root pruned trees. In sissoo, eucalyptus and neem, either lopping or lopping coupled with root pruning did not improve net returns significantly over control trees.

Table 64 : Net returns (Rs/ha/yr) as influenced by tree species and their management

Species	1990-91										MEAN				
	1989-90					1990-91									
	Control Trees	Root pruned	Lopped	Root pruned plus lopped	Mean	Control Trees	Root pruned	Lopped	Root pruned plus lopped	Mean		Control Trees	Root pruned	Lopped	Root pruned plus lopped
Eucalyptus	4289	3384	5018	5485	4534	4260	3345	3583	4259	3861	4275	3365	4301	4852	4198
Neem	2110	2267	2936	3097	2603	2047	2180	1471	1406	1776	2079	2224	2204	2252	2190
Sissoo	2262	1506	2955	2069	2198	2148	1390	2406	1567	1878	2205	1448	2681	1818	2038
Anjan	2435	2586	3366	3501	2972	2236	2415	3412	3451	2878	2336	2501	3389	3476	2925
Sole crop (No trees)	1399	1383	1308	1404	1374	862	876	914	931	896	1131	1130	1111	1168	1135
Mean	2499	2225	3117	3103	2310	2041	2357	2323	2405	2133	2737	2713			
For comparing means of :															
Species (S)	SEM±					SEM±					CD5%				
Management (M)	127					80					313				
S at same M	165					180					NS				
M at same S	287					231					736				
	314					288					916				

4.4 Screening of *rabi* crops for intercropping with tree species

4.4.1 Crops

4.4.1.1 Plant Height (cf. Table 65)

Safflower

At 30 DAS, during both the years plant height of safflower varied significantly due to tree species. Maximum height was recorded in sole crop (no trees) followed by *anjan*, *sissoo*, *neem* and *eucalyptus*. However, differences between sole crop and *anjan*; *anjan*, *sissoo* and *neem*; and *sissoo*, *neem* and *eucalyptus* were not significant during both the years. Mean data of the two years showed that maximum plant height (12.6 cm) was recorded in sole crop and the lowest with *eucalyptus* (7.6 cm).

At 60 DAS during both the years plant height of safflower varied significantly due to tree species. Maximum plant height was recorded in sole crop followed by *anjan*, *neem*, *sissoo* and *eucalyptus*. However, sole crop and *anjan*; *anjan*, *neem* and *sissoo*; and *neem*, *sissoo* and *eucalyptus* were at par during both the years. Mean data of the two years showed maximum height in sole crop (31.4 cm) and minimum with *eucalyptus* (19.2 cm).

At 90 DAS, during both the years plant height of safflower varied significantly due to tree species. Maximum height was recorded in sole crop followed by *anjan*, *neem*, *sissoo* and *eucalyptus*. However, sole crop and *anjan*; *anjan* and *neem*; and *neem*, *sissoo* and *eucalyptus* were at par during both the years. Mean data of the two years showed that maximum height was observed in sole crop (39.2 cm) and the minimum with *eucalyptus* (25 cm).

Table 65 : Plant height (cm) and dry matter (g/plant) of crops at different growth stages as influenced by tree species

Species	SAFFLOWER				SORGHUM				SUNFLOWER			
	Plant Height (cm)		Drymatter (g/plant)		Plant Height (cm)		Drymatter (g/plant)		Plant Height (cm)		Drymatter (g/plant)	
	30 DAS	60 DAS	90 DAS	at 60 DAS	30 DAS	60 DAS	90 DAS	at 60 DAS	30 DAS	60 DAS	90 DAS	at 60 DAS
	1989-90											
Eucalyptus	7.6	19.0	25.3	2.00	5.8	11.3	19.7	2.53	16.4	39.4	39.9	6.33
Neem	9.1	23.2	31.0	5.53	6.3	12.6	42.7	6.00	17.6	37.9	43.0	8.00
Sissoo	9.3	22.9	29.7	75.3	8.1	20.3	51.0	12.00	19.3	42.5	47.3	14.20
Anjan	11.1	28.3	37.7	8.37	8.2	20.5	71.0	15.13	20.7	47.5	51.8	20.47
Sole crop (No trees)	12.6	31.3	41.3	9.17	8.8	22.1	83.7	16.33	24.7	55.4	55.4	26.57
Mean	9.9	25.0	33.0	6.52	7.5	17.4	53.6	10.40	19.8	44.6	47.5	15.11
SE _m	0.84	1.96	2.64	0.588	0.25	0.58	2.68	0.597	1.34	3.20	2.66	1.779
CD 5%	2.75	6.38	8.61	1.92	0.80	1.88	8.74	1.946	4.35	10.44	8.67	5.800
	1990-91											
Eucalyptus	8.0	19.3	24.7	1.57	5.9	11.5	19.0	2.40	16.9	37.5	39.5	5.73
Neem	9.3	23.4	28.3	4.67	6.4	13.1	41.0	5.70	17.8	38.4	42.0	7.27
Sissoo	9.4	23.3	27.7	6.43	8.6	20.5	47.0	11.40	19.9	43.1	44.0	12.80
Anjan	11.2	27.7	35.0	7.13	8.4	21.2	67.7	14.40	21.3	47.2	50.7	18.40
Sole crop (No trees)	13.0	31.4	37.0	7.80	9.0	22.2	81.3	15.57	25.5	55.4	55.7	23.90
Mean	10.2	25.0	30.5	5.52	7.7	17.7	51.2	9.89	20.3	44.3	46.4	13.60
SE _m	0.90	1.86	2.15	0.44	0.41	0.54	1.97	0.553	1.46	2.19	2.38	1.32
CD 5%	2.92	6.06	7.01	1.42	1.35	1.77	6.42	1.800	4.76	7.15	7.76	4.29
	MEAN											
Eucalyptus	7.6	19.2	25.0	1.79	5.9	11.4	19.4	2.47	16.7	38.5	39.7	6.03
Neem	9.2	23.3	29.7	5.10	6.4	12.9	41.9	5.85	17.7	38.2	42.5	7.64
Sissoo	9.4	23.1	28.7	6.98	8.4	20.4	49.0	11.70	19.6	42.8	45.7	13.50
Anjan	11.2	28.0	36.4	7.75	8.3	20.9	69.4	14.77	21.0	47.4	51.3	19.44
Sole crop (No trees)	12.6	31.4	39.2	8.49	8.5	22.2	82.5	15.95	25.1	55.4	55.6	25.24
Mean	10.0	25.0	31.8	6.02	7.5	17.6	52.4	10.15	20.0	44.5	47.0	14.11

Sorghum

At 30 DAS, during both the years plant height of sorghum differed significantly due to tree species. Maximum height was recorded in sole crop (no trees) followed by *anjan*, *sissoo*, *neem* and *eucalyptus*. However, differences between sole crop, *anjan* and *sissoo*; and *neem*, and *eucalyptus* were not significant during both the years. Mean data of the two years showed maximum height in sole crop (8.5 cm) and, the minimum in *eucalyptus* (5.9 cm).

At 60 DAS, during both the years plant height of sorghum differed significantly due to tree species. Maximum height was recorded in sole crop, followed by *anjan*, *sissoo*, *neem* and *eucalyptus*. However, differences between sole crop, *anjan* and *sissoo*; and *neem* and *eucalyptus* were not significant during both the years. Mean data of the two years showed that plant height was maximum (22.2 cm) in sole crop and minimum in *eucalyptus* (11.4 cm).

At 90 DAS, during both the years plant height of sorghum differed significantly due to tree species. Maximum height was recorded in sole crop followed by *anjan*, *sissoo*, *neem* and *eucalyptus*. However *sissoo* and *neem* were at par during both the years. Mean data of the two years showed that maximum plant height of sorghum was recorded in sole crop (82.5 cm) and the minimum (19.4 cm) in *eucalyptus*.

Sunflower

At 30 DAS, during both the years plant height of sunflower differed significantly due to tree species. Maximum plant height was observed in sole crop and the minimum in *eucalyptus*. However, differences between sole crop and *anjan*; *anjan*, *sissoo*, *neem* and *eucalyptus* were not significant during both the years. Mean data of the two years showed that plant height was maximum in sole crop (25.1 cm) and minimum with *eucalyptus* (16.7 cm).

At 60 DAS, during both the years plant height of sunflower differed significantly due to tree species. Maximum height was recorded in sole crop and the minimum in neem during 1989-90. However, sole crop and *anjan*; and, *anjan*, *sissoo*, *eucalyptus* and neem were at par. During 1990-91 maximum height was recorded in sole crop and the minimum in *eucalyptus*. However, *anjan* and *sissoo*; and, *sissoo*, neem and *eucalyptus* were at par. Mean data of the two years showed that plant height was maximum in sole crop (55.4 cm) and minimum with neem (38.2 cm).

At 90 DAS, during both the years, plant height of sunflower differed significantly due to tree species. Maximum height was recorded in sole crop and the minimum with *eucalyptus*. However, sole crop and *anjan*; *anjan* and *sissoo*; and *sissoo*, neem and *eucalyptus* were at par during both years. Mean data of the two years showed maximum plant height in sole crop (55.6 cm) and minimum with *eucalyptus* (39.7 cm).

4.4.1.2 Dry matter at 60 DAS (cf. Table 65)

Safflower

During both the years dry matter in safflower plant differed significantly due to tree species. Maximum dry matter was recorded from sole crop and the minimum from *eucalyptus*. However, sole crop, *anjan* and *sissoo* were at par during both the years. Mean data of the two years showed that dry matter was maximum with sole crop (8.49 g/plant) and minimum with *eucalyptus* (1.79 g).

Sorghum

During both the years dry matter in sorghum plant differed significantly due to tree species. Maximum dry matter was observed in sole crop and the minimum in *eucalyptus*. However, differences between sole crop and *anjan*

were not significant during both the years. Mean data of the two years showed that dry matter was maximum (15.95 g/plant) in sole crop and minimum (2.47 g) in eucalyptus.

Sunflower

During both the years dry matter in sunflower differed significantly due to tree species. Maximum dry matter was observed in sole crop and the minimum in eucalyptus. However, neem and eucalyptus were at par during both the years. Mean data of the two years showed that dry matter was maximum in sole crop (25.24 g/plant) and the minimum (6.03g) with eucalyptus.

4.4.1.3 Light transmission ratio (cf. Table 66)

Light transmission ratio (LTR) recorded above the crop canopy did not vary much due to crops at any of the stages during both the years, but it differed due to tree species.

At 30 DAS during both the years maximum LTR was recorded in sole crop, followed by *anjan* eucalyptus, neem and sissoo. The mean data for the two years indicated maximum LTR (100%) in sole crop. The reduction in LTR was 8, 33, 47.7 and 51.5 per cent under *anjan*, eucalyptus neem and sissoo respectively.

At 60 DAS, during both the years maximum LTR was recorded in sole crop, followed by *anjan*, eucalyptus sissoo and neem. Mean data for the two years indicated maximum LTR (100%) in sole crop. The reduction in LTR was 0.8, 23.5, 43 and 48 per cent under *anjan*, eucalyptus, sissoo and neem respectively.

Table 66 : Light Transmission Ratio (%) at different stages of crop growth as influenced by tree species and crops

Species	1990-91										Mean	
	Safflower	Sorghum	Sunflower	Mean	Safflower	Sorghum	Sunflower	Mean	Safflower	Sorghum		Sunflower
	30 DAS											
Eucalyptus	64	65	66	65	68	70	69	69	66	67.5	67.5	67
Neem	51	52	50	51	54	53	54	53.7	52.5	52.5	52.0	52.3
Sissoo	48	48	50	48.7	50	47	48	48.3	49.0	47.5	49.0	48.5
Anjan	90	92	90	90.7	93	94	93	93.3	91.5	93.0	91.5	92.0
Sole crop (No trees)	100	100	100	100	100	100	100	100	100	100	100	100
Mean	70.6	71.4	71.2	71.1	73	72.8	72.8	72.9	71.8	72.1	72.0	72.0
	60 DAS											
Eucalyptus	80	78	79	79	73	75	74	74	76.5	76.5	76.5	76.5
Neem	52	53	54	53	52	50	51	51	52	51.5	52.5	52
Sissoo	58	56	55	56.3	59	58	57	58	58.5	56.5	56	57
Anjan	98	100	99	99	99	100	99	99.3	98.5	100	99	99.2
Sole crop (No trees)	100	100	100	100	100	100	100	100	100	100	100	100
Mean	77.6	77.4	75.4	76.8	76.6	76.6	76.2	76.5	77.1	76.9	76.8	76.9
	90 DAS											
Eucalyptus	72	70	71	71	72	73	72	72.3	72	71.5	71.5	71.7
Neem	72	70	71	71	70	68	71	69.7	71	69	71	70.3
Sissoo	66	68	64	66	68	67	69	68	67	67.5	66.5	67
Anjan	82	81	82	81.7	80	81	82	81	81	81	82	81.3
Sole crop (No trees)	100	100	100	100	100	100	100	100	100	100	100	100
Mean	78.4	77.8	77.6	77.9	78.0	77.8	78.8	78.2	78.2	77.8	78.2	78.1

At 90 DAS, during both the years maximum LTR was recorded in sole crop, followed by *anjan*, eucalyptus, neem and sissoo. Mean data for the two years indicated highest LTR (100%) in sole crop. The reduction in LTR was 18.7, 28.3, 29.7 and 33 per cent under *anjan*, eucalyptus, neem and sissoo respectively.

4.4.1.4 Effective (Productive population) (cf. Table 67)

Effective population differed significantly in all the crops due to tree species during both seasons. In all the three crops tested, viz., safflower, sorghum and sunflower the adverse effect of different tree species was almost similar. Eucalyptus had maximum adverse effect and *anjan* had the minimum adverse effect.

Safflower

During both the years highest effective population was observed in sole crop followed by *anjan*, sissoo, neem and eucalyptus. However, *anjan*, sissoo and neem were at par during 1989-90. Similarly during 1990-91 *anjan* and sissoo; and sissoo and neem were at par. Mean data of the two seasons showed maximum effective population in sole crop (22,267/ha). As per cent of sole crop the effective population was 61, 50, 42 and 18 per cent under *anjan*, sissoo, neem and eucalyptus respectively.

Sorghum

During both the years highest effective population was observed in sole crop followed by *anjan*, sissoo, neem and eucalyptus. However, neem and eucalyptus were on par during 1989-90. Mean data of the two years showed maximum effective population (40,667/ha) in sole crop. The effective population under *anjan*, sissoo, neem and eucalyptus was 45, 26, 13 and 4 per cent of sole crop respectively.

Table 67 : Yield components and yield of crops as influenced by tree species

Species	SAFFLOWER					SORGHUM					SUNFLOWER							
	Effective Plants/ha	Grain wt/plant (g)	1000 Grain wt. (g)	Grain Yield (kg/ha)	Effective Plants/ha	Grain wt/plant (g)	1000 Grain wt. (g)	Grain yield (kg/ha)	Stover Yield (kg/ha)	Effective Plants/ha	Grain wt/plant (g)	1000 Grain wt. (g)	Grain yield (kg/ha)	Stover Yield (kg/ha)	Effective Plants/ha	Grain wt/plant (g)	1000 Grain wt. (g)	Grain yield (kg/ha)
	1989-90																	
Eucalyptus	4667	2.03	47.40	11	1657	3.17	23.9	17	80	14000	8.27	20.90	77					
Neem	11000	3.43	48.47	30	6000	11.23	24.2	43	170	14000	5.47	23.07	50					
Sissoo	12000	4.03	50.33	40	12000	15.10	29.03	143	467	15000	8.00	24.53	80					
Anjan	14667	5.50	46.07	67	19667	16.17	31.00	257	497	18333	18.67	34.93	227					
Sole crop (No trees)	24000	19.67	51.03	385	43667	19.40	30.97	727	997	27333	24.30	35.17	437					
Mean	13267	6.93	48.66	107	16600	13.01	27.82	237	442	17733	12.94	27.72	174					
SE _{mt}	1698	0.531	1.429	9.74	1732	0.481	1.041	20.3	14.7	856	1.725	2.218	28					
CD 5%	5539	1.731	NS	31.78	5650	1.569	3.395	66.3	47.8	2793	5.626	7.336	92					
	1990-91																	
Eucalyptus	3333	2.00	46.67	7	1333	3.10	23.63	13	130	13333	6.97	20.33	60					
Neem	8000	3.20	47.70	20	5667	10.43	24.17	37	170	12000	5.27	22.67	40					
Sissoo	10667	4.30	50.0	30	9333	14.00	28.60	117	403	14333	6.33	24.00	63					
Anjan	13000	5.07	46.70	50	16667	15.50	30.43	207	467	17333	14.70	34.33	170					
Sole crop (No trees)	21333	16.73	50.27	270	37667	19.17	30.40	587	933	25333	20.40	34.73	330					
Mean	11267	6.26	48.27	75	14133	12.44	27.45	192	421	16467	10.73	27.213	133					
SE _{mt}	1138	0.803	1.221	9	1011	0.718	1.06	15.2	48.8	1043	1.27	2.297	16					
CD 5%	3711	2.620	NS	30	3298	2.343	3.46	49.7	159.0	3404	4.14	7.494	52					
	MEAN																	
Eucalyptus	4000	2.02	47.54	9	1500	3.14	23.77	15	105	13667	7.62	20.62	69					
Neem	9500	3.32	48.09	25	5834	10.83	24.19	40	170	13000	5.37	22.87	45					
Sissoo	11334	4.17	50.17	35	10667	14.55	28.82	130	435	14667	7.17	24.27	72					
Anjan	13834	5.29	45.89	59	18167	15.84	30.72	232	482	17833	16.69	34.64	190					
Sole crop (No trees)	22667	18.20	50.65	328	40667	19.29	30.69	657	965	26333	22.35	35.0	384					
Mean	12267	6.60	48.47	91	15234	12.42	27.64	215	432	17100	11.84	27.48	154					

Sunflower

During both the years highest effective population was observed in sole crop followed by *anjan*, *sissoo*, *eucalyptus* and *neem*. However, during 1989-90 *sissoo*, *eucalyptus* and *neem* were at par. During 1990-91 *sissoo*, *eucalyptus* and *neem*; and *anjan* and *sissoo* were at par. Mean data of the two years indicated that highest effective population of sunflower was observed in sole crop (25,333/ha). Effective population of 68, 56, 52 and 49 per cent of sole crop was observed with *anjan*, *sissoo*, *eucalyptus* and *neem* respectively.

4.4.1.5 Grain weight per plant (cf. Table 67)

Grain weight per plant (g) differed significantly due tree species in all the three crops during both the years.

Safflower

During both the years highest grain weight per plant was recorded in sole crop (no trees), followed by *anjan*, *sissoo*, *neem* and *eucalyptus*. However, during 1989-90, *anjan* and *sissoo*; *sissoo* and *neem*; and *neem* and *eucalyptus* were at par. During 1990-91 *anjan*, *sissoo* and *neem*; and, *sissoo*, *neem* and *eucalyptus* were at par. Mean data of the two years indicated highest grain weight per plant (18.2 g) in sole crop and the lowest in *eucalyptus*. (2.02g).

Sorghum

During both the years highest grain weight per plant was recorded in sole crop (no trees), followed by *anjan*, *sissoo*, *neem* and *eucalyptus*. However, *anjan* and *sissoo* were at par during both the years. Mean data of the two years indicated highest per plant grain weight (19.29g) in sole crop (no trees) and the lowest in *eucalyptus* (3.14g).

Sunflower

During both the years highest grain weight per plant was recorded in sole crop followed by *anjan*, eucalyptus, sissoo and neem, however the latter three were at par. Mean data of the two years indicated that grain weight per plant was highest in sole crop (22.35g) and lowest in neem (5.27g).

4.4.1.6 Thousand grain weight (cf. Table 67)**Safflower**

During both the years thousand grain weight (g) of safflower was not significantly influenced by tree species. However, highest thousand grain weight was recorded in sole crop.

Sorghum

During both the years highest thousand grain weight was recorded in *anjan* followed by sole crop (no trees), sissoo, neem and eucalyptus. However, during both the years *anjan*, sole crop and sissoo; and neem and eucalyptus were on par. Mean data of the two years showed highest thousand grain weight in sole crop (30.72 g) and the lowest in eucalyptus (23.77 g).

Sunflower

During both the years highest thousand grain weight was recorded in sole crop (no trees) followed by *anjan*, sissoo, neem and eucalyptus. However, sole crop and *anjan*; and, sissoo, neem and eucalyptus were on par during both the years. Mean data of the two years indicated that thousand grain weight was highest in sole crop (35.00 g) and the lowest in eucalyptus (20.62 g).

4.4.1.7 Grain yield (cf. Table 67, Fig. 24)

Grain yield in all the three crops differed significantly due to tree species in both the years. Yield of the three crops was drastically reduced in association with trees. In all the crops the effect of trees was more or less similar. Eucalyptus had maximum adverse effect and *anjan* had the least adverse effect. Among the crops safflower was most affected and sunflower was least affected, sorghum was in between safflower and sunflower.

Safflower

During both the years grain yield of safflower was highest in sole crop (no trees) followed by *anjan*, *sissoo*, *neem* and *eucalyptus*. However, during 1989-90 *sissoo*, *neem* and *eucalyptus* were at par. During 1990-91 *anjan*, *sissoo* and *neem*; and, *sissoo*, *neem* and *eucalyptus* were at par. Mean data of the two years showed that grain yield of safflower was 18, 11, 8 and 3 per cent of sole crop (328 kg/ha) with *anjan*, *sissoo*, *neem* and *eucalyptus* respectively.

Sorghum

During both the years highest grain yield of sorghum was obtained from sole crop, followed by *anjan*, *sissoo*, *neem* and *eucalyptus*. However, *neem* and *eucalyptus* were at par during both the years. Mean data of the two years showed that, grain yield was 35, 20, 6 and 2 per cent of sole crop (657 kg/ha) under *anjan*, *sissoo*, *neem* and *eucalyptus* respectively.

Sunflower

During both the years highest grain yield was obtained from sole crop, followed by *anjan*, *sissoo*, *eucalyptus* and *neem*, however, the latter three were at par during both the years. Mean data of the two years showed that

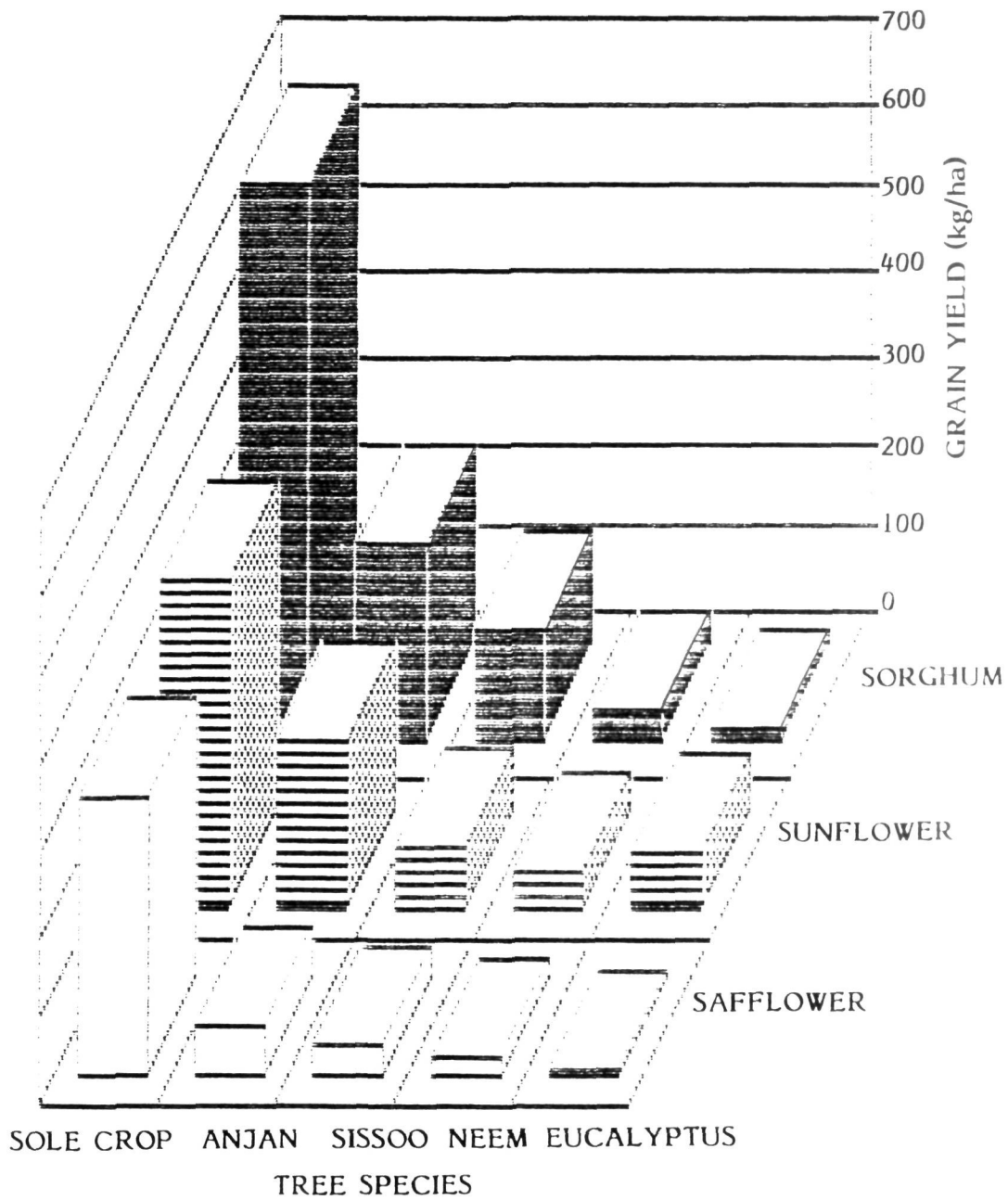


Fig.24. GRAIN YIELD OF CROPS AS INFLUENCED BY TREE SPECIES



A



B



C

Plate 12. Adverse effect of trees on growth of crops:
A. Safflower B. Sorghum C. Sunflower
(Expt. 4)

grain yield of sunflower was 52, 19, 18 and 12 per cent of sole crop (384 kg/ha) under *anjan*, *sissoo*, *eucalyptus* and *neem* respectively.

4.4.1.8 Sorghum stover yield (cf. Table 67)

During both the years highest sorghum stover yield was obtained from sole crop followed by *anjan*, *sissoo*, *neem* and *eucalyptus*. However, *anjan* and *sissoo* were on par during 1989-90, similarly in 1990-91 *anjan* and *sissoo*; and, *neem* and *eucalyptus* were at par. Mean data of the two years showed that stover yield was 50, 45, 18 and 11 per cent of sole crop with *anjan*, *sissoo*, *neem* and *eucalyptus* respectively.

4.4.1.9 Crop equivalent yield (cf. Table 68, Fig. 25)

Crop equivalent yield (kg/ha) converted to that of *rabi* sorghum differed significantly due to tree species during both the years. Highest yield was recorded in sole crop, followed by *anjan*, *sissoo*, *neem* and *eucalyptus*. However, during 1989-90 *sissoo*, *neem* and *eucalyptus* were at par, and, similarly during 1990-91, *neem* and *eucalyptus* were at par. Mean data of the two years showed that crop equivalent yield was 37, 17, 9 and 9 per cent of sole crop (781 kg/ha) under *anjan*, *sissoo*, *neem* and *eucalyptus* respectively.

During both the years highest crop equivalent yield was obtained from sunflower followed by *sorghum* and *safflower*, however *sorghum* and *safflower* were at par during both the years. Mean data of the two years showed that crop equivalent yield was 55 and 50 per cent of sunflower (393 kg/ha) in *sorghum* and *safflower* respectively.

The interaction between tree species and crops was significant during both the years. During 1989-90 all crops were at par under *eucalyptus*, *neem* and *sissoo*, but, under *anjan* sunflower was significantly superior to *sorghum* and *safflower*. In 1990-91 under *eucalyptus* sunflower was

Table 68 : Crop Equivalent yield (kg/ha) in different crops as influenced by tree species

Species	1989-90					1990-91					MEAN		
	Safflower	Sorghum	Sunflower	Mean Safflower	Mean Sorghum	Safflower	Sorghum	Sunflower	Mean Safflower	Mean Sorghum	Sunflower	Sunflower	Sorghum
Eucalyptus	21	13	133	56	15	17	200	77	18	15	182	67	182
Neem	60	37	100	66	47	43	133	74	54	40	117	70	117
Sissoo	80	117	160	119	70	143	211	141	75	130	186	130	186
Anjan	134	204	453	265	117	257	567	313	126	232	510	289	510
Sole crop (No trees)	770	727	873	790	630	587	1100	772	700	657	987	781	987
Mean	213	220	344	259	176	209	442	276	195	215	393	267	393
For comparing means of:													
Species (S)		SEM±	CD 5%				SEM±	CD 5%					
		22.29	72.72				14.87	48.49					
Crops (C)		21.91	86.03				18.83	73.94					
S at same C		35.70	110.68				34.69	105.65					
C at same S		37.59	116.54				39.16	119.26					

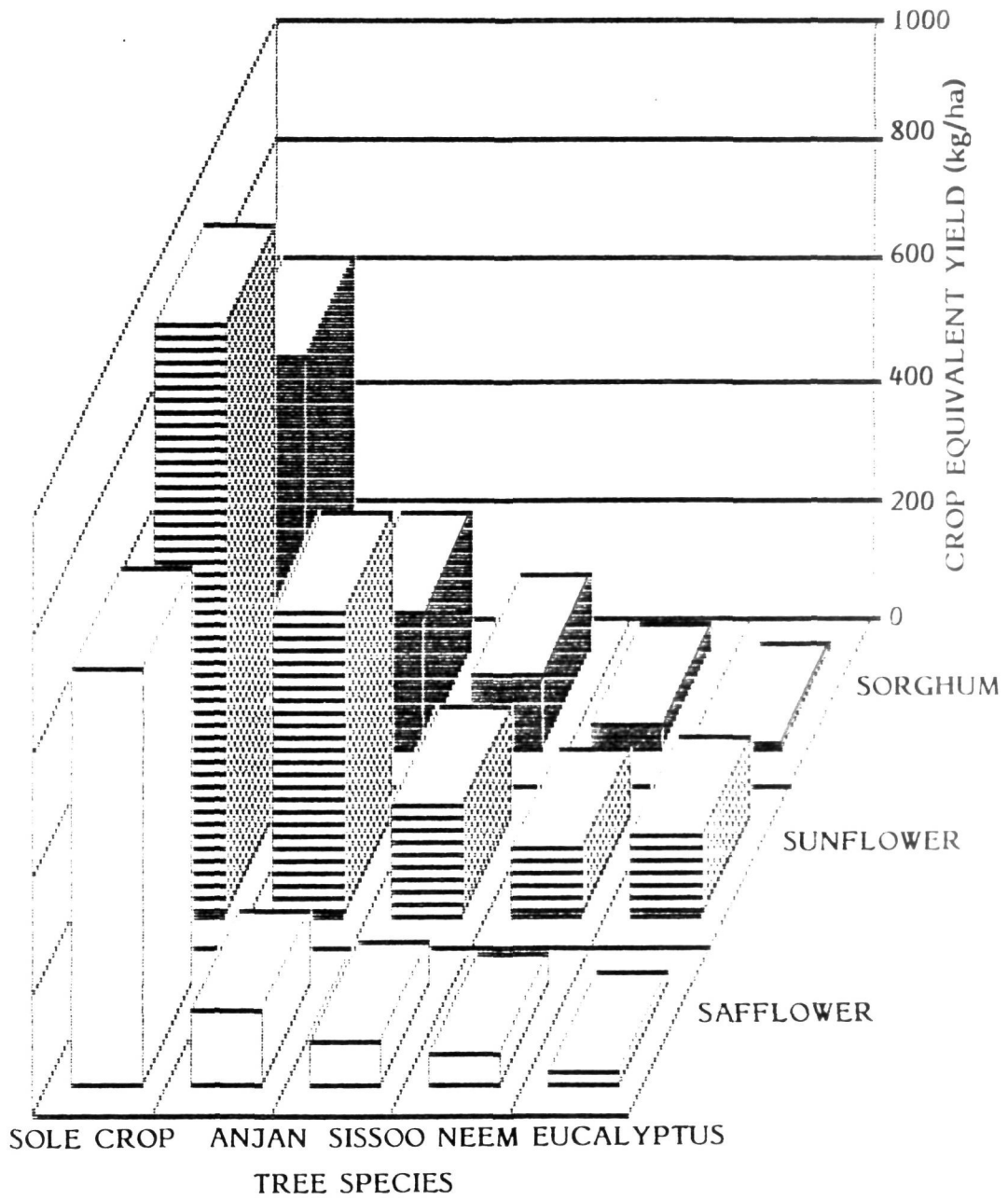


Fig.25. CROP EQUIVALENT YIELD AS INFLUENCED BY TREE SPECIES

Table 69 : Height and Diameter at Breast Height (DBH)
of tree species as influenced by crops

Treatments	Height (m)			Diameter at Breast Height (cm)		
	1989-90	1990-91	Mean	1989-90	1990-91	Mean
Tree species (S)						
Eucalyptus	7.59	9.09	8.34	8.83	11.21	10.03
Neem	4.12	4.86	4.49	7.40	9.21	8.31
Sissoo	3.59	4.59	4.09	3.89	6.42	5.16
Anjan	2.91	3.89	3.04	4.30	5.92	5.11
SEm±	0.086	0.116		0.063	0.207	
CD 5%	0.297	0.400		0.218	0.716	
Crops (C)						
Safflower	4.56	5.60	5.08	6.10	8.23	7.17
Sorghum	4.56	5.61	5.09	6.11	8.18	7.15
Sunflower	4.54	5.60	5.07	6.11	8.18	7.15
SEm±	0.051	0.040		0.039	0.167	
CD 5%	NS	NS		NS	NS	
Interaction						
For comparing means of :						
S at same C	SEm±	0.139	0.158	0.107	0.275	
	CD5%	NS	NS	NS	NS	
C at same S	SEm±	0.126	0.121	0.099	0.255	
	CD5%	NS	NS	NS	NS	

significantly superior to sorghum and safflower which were on par. In neem and sissoo all crops were at par. In *anjan* sunflower was significantly superior to sorghum which was significantly superior to safflower.

4.4.2 Trees

4.4.2.1 Tree height (cf. Table 69)

Tree species differed significantly in respect of their height recorded at sowing stage of crops during both the years. Eucalyptus recorded maximum height followed by neem, sissoo and *anjan*. However, neem and sissoo were on par during 1990-91. Mean data of the two years showed that tree height was 54, 49 and 36 per cent of eucalyptus (8.34 m) in neem, sissoo and *anjan* respectively. Crops or the interaction between tree species and crops did not cause any significant variation in tree height during both the years.

4.4.2.2 Tree diameter at breast height (cf. Table 69)

Tree species differed significantly in respect of their diameter at breast height (DBH) during both the years. During 1989-90 maximum DBH was recorded in eucalyptus followed by neem, *anjan* and sissoo. During 1990-91 maximum DBH was recorded in eucalyptus, followed by neem, sissoo and *anjan*, however the latter two were on par. Mean data of the two years showed that DBH was 83, 51 and 51 per cent of eucalyptus (10.03 cm) in neem, sissoo and *anjan* respectively. Crops or the interaction between tree species and crops did not cause any significant variation in DBH during both the years.

4.4.3 Soil moisture (cf. Table 70)

At sowing

During both the years soil moisture content (cm water in 0-30 cm soil layer) was highest in sole crop, followed by *anjan*, sissoo, neem and eucalyptus. Mean data of the two years indicated that soil moisture was

Table 70 : Soil moisture content (cm water in 0-30 cm soil profile) at different stages of crop growth as influenced by tree species in different crops

Species	1989-90				1990-91				MEAN			
	Safflower	Sorghum	Sunflower	Mean	Safflower	Sorghum	Sunflower	Mean	Safflower	Sorghum	Sunflower	Mean
SOWING												
<i>Eucalyptus</i>	6.3	6.4	6.3	6.3	6.0	6.0	6.2	6.1	6.2	6.2	6.2	6.2
<i>Neem</i>	8.9	8.8	8.9	8.9	7.8	8.0	8.1	8.0	8.5	8.4	8.5	8.5
<i>Sissoo</i>	9.0	9.1	9.0	9.0	8.4	8.5	8.6	8.5	8.7	8.8	8.8	8.8
<i>Anjan</i>	9.4	9.4	9.5	9.4	9.0	8.9	9.1	9.0	9.2	9.1	9.3	9.2
Sole crop (No trees)	9.5	9.6	9.5	9.5	9.1	9.0	9.2	9.1	9.3	9.4	9.3	9.3
Mean	8.6	8.7	8.6		8.1	8.1	8.2	8.1	8.4	8.4	8.4	
FLOWERING												
<i>Eucalyptus</i>	5.8	5.9	6.5	6.1	5.4	5.5	6.2	5.7	5.6	5.7	6.3	5.9
<i>Neem</i>	6.8	6.7	7.2	6.9	6.4	6.3	6.8	6.5	6.6	6.5	7.0	6.7
<i>Sissoo</i>	7.0	7.1	7.6	7.2	7.4	7.3	7.1	7.3	7.2	7.2	7.4	7.3
<i>Anjan</i>	8.1	8.0	8.6	8.2	7.5	7.6	8.1	7.7	7.8	7.8	8.7	7.9
Sole crop (No trees)	8.0	8.1	8.7	8.3	7.6	7.5	8.3	7.8	7.8	7.8	8.5	8.0
Mean	7.1	7.2	7.7		6.9	6.8	7.3		7.0	7.0	7.5	
HARVEST												
<i>Eucalyptus</i>	4.5	4.6	4.9	4.7	4.3	4.2	4.4	4.3	4.4	4.4	4.7	4.5
<i>Neem</i>	4.8	4.7	5.0	4.8	4.5	4.6	4.7	4.6	4.7	4.6	4.9	4.7
<i>Sissoo</i>	5.0	4.9	5.2	5.0	4.8	4.7	5.4	5.0	4.9	4.8	5.3	5.0
<i>Anjan</i>	5.8	5.7	6.0	5.8	5.0	5.1	5.5	5.2	5.4	5.4	5.7	5.5
Sole crop (No trees)	6.2	6.1	6.4	6.2	5.8	6.0	6.2	6.0	6.0	6.1	6.3	6.1
Mean	5.3	5.2	5.5		4.9	4.9	5.2		5.1	5.1	5.4	

67, 91, 95 and 99 per cent of sole crop (9.3 cm) in eucalyptus, neem, sissoo and *anjan* respectively. Soil moisture at sowing did not vary much in different crops during both the years.

At flowering

During both the years highest soil moisture was recorded in sole crop followed by *anjan*, sissoo, neem and eucalyptus. Mean data of the two years showed that, soil moisture was 74, 84, 91 and 99 per cent of sole crop (8 cm) in eucalyptus, neem, sissoo and *anjan* respectively.

Soil moisture at flowering stage was higher in sunflower than that in sorghum and safflower during both the years. Mean data of the two years showed that soil moisture was 93 and 93 per cent of sunflower (7.5 cm) in safflower and sorghum respectively.

At harvest

At harvest stage during both the years highest soil moisture was observed in sole crop followed by *anjan*, sissoo, neem and eucalyptus. Mean data of the two years showed that, soil moisture was 76, 77, 81 and 94 per cent of sole crop (6.2 cm) in eucalyptus, neem, sissoo and *anjan* respectively.

Soil moisture at harvest was higher in sunflower than that in sorghum and safflower during both the years. Mean data of the two years showed that, soil moisture was 94 and 94 per cent of sunflower (5.4 cm) in sorghum and safflower respectively.

4.4.4 Net returns (cf. Table 71)

During both the years net returns differed significantly due to tree species. Highest net returns were realised from eucalyptus followed by *anjan*, neem, sissoo and sole crop. However, neem and sissoo were at par

Table 71 : Net returns (Rs/ha/yr) as influenced by tree species and crops

Species	1989-90					1990-91					MEAN	
	Safflower	Sorghum	Sunflower	Mean	Safflower	Sorghum	Sunflower	Mean	Safflower	Sorghum		Sunflower
Eucalyptus	4187	4313	4616	4372	4170	4333	4756	4420	4179	4323	4686	4396
Neem	1908	2026	2061	1998	1868	2006	2161	2012	1888	2016	2111	2005
Sissoo	1742	2219	2015	1992	1712	2113	2168	1998	1727	2166	2092	1995
Anjan	1769	2436	2760	2322	1717	2274	3100	2364	1743	2355	2930	2343
Sole crop (No trees)	1023	1454	1389	1289	603	1007	2069	1226	813	1231	1729	1258
Mean	2126	2489	2568	2394	2014	2347	2851	2404	2070	2418	2399	

For comparing means of:

	SEm±	CD 5%	SEm±	CD 5%
Tree species (S)	65.98	215.22	47.03	153.41
Crops (C)	59.18	232.39	59.07	231.94
S at same C	108.27	335.11	104.78	319.60
C at same S	111.11	343.89	118.36	361.02

during both the years. Mean data of the two years showed that net returns were 53, 46, 45 and 29 per cent of eucalyptus (Rs.4,396/ha/yr) from anjan, neem, sissoo and sole crop respectively.

During both the years net returns differed significantly due to crops. Highest net returns were obtained from sunflower, followed by sorghum and safflower, however sunflower and sorghum were at par during 1989-90. Mean data of the two years showed that net returns were 89 and 76 per cent of sunflower (Rs 2,710/ha/yr) from sorghum and safflower respectively.

The interaction between tree species and crops was significant during both the years. During 1989-90, all crops were at par under neem; and sorghum and safflower were at par under eucalyptus. During 1990-91, sorghum and safflower were at par under eucalyptus; all crops were at par under neem; and, sorghum and sunflower were at par under sissoo. Mean data of the two years indicated that highest net returns (Rs 4,686/ha/yr) were obtained from eucalyptus+sunflower system and the lowest (Rs 813/ha/yr.) from sole safflower.

DISCUSSION

V DISCUSSION

Results of the four experiments, viz., 1. Influence of root pruning and cutting interval of *Leucaena* hedgerows on alley cropped *rabi* sorghum; 2. Evaluation of effects of nitrogen and *Leucaena* prunings application to alley cropped *rabi* sorghum; 3. Effect of tree species and their management on intercropped *rabi* sorghum and 4. Screening of *rabi* crops for intercropping with different tree species, conducted at Regional Research Station, Bijapur on black soils during 1989-90 and 1990-91 are discussed in this chapter.

Bijapur is situated in the Northern dry zone (zone 3) of Karnataka which is characterised by low, erratic and ill-distributed rainfall and is known for its recurring droughts since time immemorial. Rainfall during 1989-90 and 1990-91 exceeded 50 years average (643.6 mm) by 22.5 and 9.2 per cent respectively. However, the number of rainy days during 1989-90 (43 days) and 1990-91 (29 days) were less than the long term average number of rainy days (55.4 days). The rainfall distribution during 1989-90 was more favourable than that of 1990-91 for arable crops. A total rainfall of 393.4 mm was received in September during 1989-90 sharply contrasting with only 16.6 mm rainfall during 1990-91. This was a marked departure compared to the 50 years average (157.5 mm). However, both the seasons were not as congenial as an average season for arable crops, because of lesser amount of rainfall in October and November months. On the contrary, 1990-91 was more favourable for growth of perennial component especially *Leucaena* hedgerows. In the months of May and June 313.1 mm and 225 mm rainfall was received during 1990-91 as compared to 58.6 and 125.6 mm during 1989-90; the 50 years average being 42.9 mm and 96.2 mm respectively. Better rainfall during May and June during 1990-91 favoured growth and production of *Leucaena* hedgerows.

During 1989-90, the minimum temperature varied from 13.4°C in December to 23.5°C in May, the values for 1990-91 were 15.2°C in December and 23.3°C in April. The maximum temperature varied from 28.4°C in December to 39°C in May during 1989-90 and 29°C in December to 39.4°C in April during 1990-91. Open pan evaporation varied from 112.1 mm in October to 362.1 mm in May during 1989-90, and from 146.4 mm in November to 375.9 mm in April during 1990-91.

5.1 Influence of root pruning and cutting interval of *Leucaena* hedgerows on alley cropped *rabi* sorghum

5.1.1 Performance of *rabi* sorghum

Arable crops when grown mixed with tree species (in agroforestry systems) either in the unmanaged (full grown) form or well managed hedgerows form do interact. The interaction might be positive, negative or complex; and it would be mostly for light, moisture and nutrients. The hedgerows and trees because of their perennial nature and well established deep and horizontal spreading root system have an upper hand over arable crops, especially under rainfed conditions and more so under receding moisture situations in *rabi* season. Under these conditions, the interaction will be often negative resulting in severe competition from perennial component with arable (field crops) component for light and moisture. This competition from perennial component on field crops for light and moisture can be minimised (if not totally eliminated) by appropriate canopy and root management practices respectively.

In the present investigation, root pruning of *Leucaena* hedgerows increased sorghum grain yield by 33 per cent (Table 11) over root unpruned (646kg/ha). This increase can be attributed to reduced competition of

Leucaena hedgerows with sorghum crop for soil moisture, as indicated by higher soil moisture in root pruned plots than root unpruned plots at sowing, flowering and harvest stages of sorghum crop (Table 19). The soil moisture was higher both near the hedgerows and also in the centre of the alley in root pruned plots than that in root unpruned. Row-wise analysis of grain yield (Table 10) showed that yield increased in all the five rows (from hedgerow to centre of the plot) due to root pruning over root unpruned plots. However, this increase was more (61%) near the hedgerows than the centre of the alley (25%). Further, both in root unpruned and root pruned hedgerows, sorghum yield increased with increasing distance from the hedge till centre of the alley, and the rate of increase was higher in root unpruned hedgerows. This indicates that though root pruning reduced the root competition between the hedgerows and the alley (field) crop, it did not completely eliminate the same. This is also supported by the higher soil moisture observed in the centre of the alley than near the hedgerows even in root pruned plots at all the growth stages of sorghum (Table 19).

The findings of this study are in conformity with those of Gaddanakeri (1991), who reported 18 to 28 per cent increase in yield of *rabi* sorghum by minimising root effect of *Leucaena* live-bunds through trenching and polythene root barriers respectively. The grain yields in general, in the present study were lower than that of the study cited above as the alleys were narrower (6.6m) than the above study (13m). Singh *et al.* (1989b) working near Hyderabad, were able to completely eliminate reduction in yield of *kharif* sorghum and cowpea crops by placing a polythene root barrier (50 cm deep) near the *Leucaena* hedge-cum-pole rows. However, they were not successful in eliminating the yield reduction in castor crop, which grows both in *kharif* and *rabi* season i.e. some reduction was seen even with root barrier in this crop, which they attributed to the crop's

growth continuing in receding moisture conditions in the *rabi* season. The findings of the present investigation are similar to the above study. The row-wise yield analysis of castor in the above study and *rabi* sorghum in the present study are in agreement.

Stover yields of sorghum (Table 12) also increased by 17 per cent due to root pruning over root unpruned hedgerows (1251 kg/ha). This was again due to the same reasons as explained above for grain yields. The row-wise effect on stover yield was similar to that of grain yield. This finding is in conformity with that of Rao *et al.* (1991) and Gaddanakeri (1991). The extent of reduction in stover yield due to root competition was less than that in grain, probably moisture was more limiting for *rabi* sorghum crop at later stages of crop growth as practically no rains were received after sowing and the crop was grown on stored soil moisture, which recedes with time. So, the partitioning of dry matter to grain was affected.

The relationship between grain yield of alley cropped *rabi* sorghum and cutting interval of *Leucaena* hedgerows was observed to be a sigmoid type of curve (Fig. 10). The shape of the curve was like the mirror image of 'S'. With increase in cutting interval grain yield in general decreased. The rate of decrease was less initially i.e., with increase in cutting interval from one to two months. Steep reduction in sorghum grain yield was observed with further increase in cutting interval from two to three months. The reduction again slowed down with increase in cutting interval from three to six months. Hence if *Leucaena* is allowed to grow without cutting beyond 60 days, there will be a greater reduction in yield of alley cropped sorghum.

Shorter cutting intervals (1 and 2 months) of *Leucaena* hedgerows were better (954 and 912 kg/ha) than longer (3 and 6 months) intervals (629 and 524 kg/ha) for sorghum grain production (Table 11). In the longer cut-

ting intervals (3 and 6 months) hedgerows competed more with arable crop both for moisture (Table 19) and light (Table 5). The effect of light in reducing the growth and yield of *rabi* sorghum was more with longer intervals of cutting, as seen in the light interception studies (Table 5). The response in stover yield to cutting interval was similar to that of grain. Cutting intervals of hedgerows at one two and three months produced higher stover yield by 75, 66, and 18 per cent respectively over 6 months interval (Table 13).

The findings of this study are similar to those obtained by Duguma *et al.* (1988), who observed reduction in yield of maize and cowpea alley cropped with *Leucaena*, *Gliricidia* and *Sesbania* hedgerows when the cutting interval was increased from one to six months.

Field and OeMaton (1990) working in Indonesia also reported similar findings, where they obtained higher maize yields with lower cutting intervals of *Leucaena* hedgerows. VanDenBeldt (1990) also suggested frequent pruning of hedgerows especially under SAT conditions to reduce the competition between the arable crops and hedgerows.

The increase in yield of *rabi* sorghum with root pruning was due to increase in effective population (41600 to 47100 /ha), grain weight per ear (17.9 to 21.7 g) and grain number per ear (521 to 630). The extent of reduction in ear bearing plants, grain weight per ear and grain number per ear in roots unpruned plots compared with root pruned plots was 12, 17 and 17 per cent respectively. This thereby indicates that the adverse effect of competition for moisture was more on grain number and grain weight per ear than ear bearing plants. These parameters had highly significant correlation with grain yield during both the years (Table 21). The increase in harvest index (.371 to .408) with root pruning also contributed to the increased grain yield of sorghum.

Similarly, the increase in yield of *rabi* sorghum with decrease in cutting interval from six to one month was through increase in effective population (36900 to 50500/ha), grain weight per ear (from 16.2 to 23.0 g) and grain number per ear (from 460 to 681). The reduction in grain yield with increase in cutting interval from one to six months was through decrease in ear bearing plants, grain weight per ear and grain number per ear to the tune of 27, 30 and 32 per cent respectively. This indicates more adverse effect of competition for moisture on the grain number and grain weight per ear than ear bearing plants.

The difference in yield and yield components was in turn caused by the difference in growth (height and dry matter accumulation) of sorghum plants (Table 3). Root pruning increased sorghum plant height at different growth stages and finally at harvest (from 123.4 cm to 138 cm) and dry matter per plant (Table 4) at different stages and finally at harvest (from 33.9 to 42.2 g).

Similarly, decreasing cutting interval from six to one month increased sorghum plant height at different growth stages and finally at harvest (from 102.2 to 151.4 cm); and similarly dry matter per plant (from 25.4 to 48.8 g/plant). The increase in sorghum yield through increase in growth and yield components is reported by many workers (Palled, 1985; Mallappa, 1990; Gaddanakeri, 1991), and these components correlated positively with grain yield.

Growth conditions like soil moisture in root pruned alley crop; and, soil moisture and light in shorter cutting intervals were favourable for sorghum plant growth and yield. Similar results were obtained by Singh *et al.* (1989c), where they observed increased dry matter production in sorghum and cowpea by placing root barrier near *Leucaena* hedge-cum-pole rows.

Between the two factors, moisture was more critical than light as seen through lower soil moisture content in roots unpruned plots and with increasing cutting intervals from one to six months. Light Transmission Ratio (LTR) was low only near the hedgerows and that too in 6 months cutting interval only (Table 5). Therefore, light is not a big constraint in alley cropping system in semiarid tropics especially when the hedgerows are cut close (10-15 cm) to the ground. Similar conclusions were drawn by Singh *et al.* (1989c).

5.1.2. Performance of *Leucaena*

Sole *Leucaena* produced 126 per cent more leaf than the hedgerows (Table 15), because hedgerows occupied only 16.7 per cent area of sole *Leucaena*. Higher *Leucaena* yields in sole cropping compared with hedgerows have been reported (ICRISAT, 1988; ICRISAT, 1989; Siaw *et al.*, 1991).

Leucaena leaf biomass production was similar (2671 and 2677 kg/ha) in roots unpruned and roots pruned hedgerows. This suggests that root pruning of the *Leucaena* hedgerows did not adversely affect the performance of *Leucaena*. The results further indicate that by pruning the horizontal root spread of *Leucaena* the uptake of water and nutrients by the plant was not restricted to a significant extent and the plant seems to have made up the uptake through the roots located at the deeper layers. Similar results were reported by Gaddanakeri (1991) who obtained 15.4 q per ha dry matter of *Leucaena* in root unpruned *Leucaena* live bund, 15.8 in trenched plots and 13.7 in polythene barrier. Higher *Leucaena* yields in trenched plots was explained to be due to harvested rain water conserved by the trench.

Cutting intervals varied *Leucaena* leaf biomass production. *Leucaena* leaf biomass was higher in two, three and six months cutting intervals than that in one month by 15, 15 and 12 per cent respectively.

The trend in production of *Leucaena* wood and total biomass was similar to that of leaf production with respect to root pruning. However, with respect to cutting interval, there was a slight change. In leaf the increase with two, three and six months cutting interval was 15, 15 and 12 per cent respectively over one month (3434 kg/ha), whereas in wood biomass the increase was 10, 40 and 65 per cent over one month (2000kg/ha) cutting interval respectively. This indicates increased proportion of woody biomass with increase in cutting interval. Similar results were reported by Duguma *et al.* (1988) and Siaw *et al.* (1991).

Total biomass production of *Leucaena* was similar in root unpruned (4533 kg/ha) and root pruned (4555 kg/ha). Increasing cutting intervals increased *Leucaena* total biomass production by 13, 24 and 31 per cent in two, three and six months compared to one month (Table 17) mainly due to increase in wood biomass. Further, the reduction in leaf biomass in one month cutting interval was significant compared to other three cutting intervals (Table 15). This reduction might be due to two reasons; 1. Shorter period available for sprouting and consequent new leaf production in one month cutting interval, 2. The incidence of psyllid bug was observed, which has a preferential feeding habit for newly formed younger shoots resulting in more loss of leaf in shorter cutting interval.

The low yield of *Leucaena* at shorter cutting intervals was attributed by Duguma *et al.* (1988) to the following reason: with tree growth the main capital and periodic dry matter gains take place simultaneously. Newly formed wood automatically becomes part of the capital gain which will contribute to subsequent growth. Intensive cutting cause frequent disruptions in dry matter and wood production and nutrient accumulation which negatively affect subsequent regrowth. Kang *et al.* (1984), Field and OeMaton(1990) and Ezenwa *et al.* (1990) also obtained similar results.

The response pattern of *Leucaena* to cutting interval depicted in Fig. 13 and reported in results section 4.1.6 indicates that, in 1989-90 the rate of response of *Leucaena* to cutting interval (in terms of total biomass production) has approached near zero at 159 days cutting interval in roots unpruned hedgerows, at 137 days roots pruned hedgerows and at 136 days sole *Leucaena*. Whereas, in 1990-91 the response of *Leucaena* is observed even after 180 days cutting interval in roots unpruned and roots pruned hedgerows. In sole *Leucaena* the response is approaching to zero at 152 days cutting interval. This difference in the nature of response during the two years is due to the difference in distribution of rainfall.

5.1.3 Performance of the system (*Leucaena* - *rabi* sorghum hedgerow intercropping system)

Land equivalent ratio (LER) increased from 0.79 in root unpruned to 0.95 in root pruned hedgerows (Table 20). The LER decreased with increasing cutting interval from 1.01 in one month interval to 0.71 in 6 months interval. Further, the LER observed with root pruned hedgerows subjected to one month cutting interval was 1.07 and with two months cutting interval it was 1.03. This indicates that little improvement in LER could be derived by the modification in the management practices of hedgerows, viz., root pruning before sowing and cutting the hedgerows at close intervals of one or two months (Table 20). The increase in LER with root pruning and decrease in cutting interval was due to decreased competition between the crop and hedgerows.

5.1.4 Economics

Root pruning of *Leucaena* hedgerows increased net returns from the system by Rs 647 per ha over root unpruned hedgerows (Table 22). However, the net returns were highest in sole *Leucaena* compared to alley cropping.

These findings are in agreement with AICRPDA (1986), where sole *Leucaena* was found to be superior to *Leucaena*-pearl millet and *Leucaena*-pigeonpea alley cropping systems. Studies at ICRISAT also revealed the superiority of sole *Leucaena* over sole sorghum or hedgerow system especially at higher price range of *Leucaena* (ICRISAT, 1989). Among the cutting intervals, 2 months resulted in highest net returns (Rs 3970), which was higher by 12, 18 and 27 per cent compared to one, three and six months intervals respectively. In hedgerow intercropping system 2 months cutting interval followed by one month was better, this suggests the superiority of shorter cutting intervals in hedgerow system. The net returns realised from sole *Leucaena*, sole sorghum (expt. 2 @ 25kg N/ha), roots pruned hedgerows (with 2 months cutting interval) and roots unpruned hedgerows (with 2 months cutting interval) were Rs 4821, 3684, 3599 and 3287 respectively, which indicates the superiority of sole *Leucaena* in low rainfall dryland areas.

Leucaena, which is very hardy can use precipitation whenever it occurs, and it is not much adversely affected by dry spells and continues to grow and produce biomass, unlike arable crops which are adversely affected by moisture stress and cannot use off-season precipitation.

However, the growing of sole *Leucaena* by the farmers on their holding is not likely to be an acceptable practice. Any alley cropping system to be recommended should provide normal or near normal yield of the base crop (field crop) in addition to the advantages derived from the perennial (tree) component. Under such circumstances, as the net returns derived from sole sorghum and alley cropping system with root pruning of hedgerows of *Leucaena* are almost equal. Therefore, hedgerow planting of *Leucaena* is advantageous in view of its ability to conserve soil and water and yield multiple products.

5.2 Evaluation of effects of N and *Leucaena* prunings application to alley cropped *rabi* sorghum

5.2.1 Performance of *rabi* sorghum

Prunings of a leguminous tree species like *Leucaena*, which is rich in N (3.8 to 4 % N on dry weight basis) when applied to alleys can benefit by supplying N to the alley crop. High N fixing ability (650 kg/ha/yr) of *Leucaena* has been reported (Kang *et al.*, 1990).

In the present investigation, alley cropped sorghum grain yield increased by 22 per cent with prunings application over that in prunings unapplied alley crop (712kg/ha). Stover yield also increased by 18 per cent due to prunings application over prunings unapplied (1184 kg/ha). The grain and stover yields in prunings applied alley cropped sorghum was only 77.5 and 70 per cent of sole sorghum (1117 kg/ha and 2019 kg/ha) respectively; slightly less than the area planted to sorghum (83.3%) in alley cropping. The response to prunings application in grain and stover yields was higher (38 and 32 %) during the second year than the first (10 and 6%). This is attributed to higher amount of prunings produced and received (Tables 42 and 43) by the alley crop in the second year (2646 kg/ha) than the first year (1184kg/ha). This was also reflected in higher soil available N content of the soil at sowing (Table 44) during the second (239.1 kg/ha) than the first (227.4 kg/ha) year.

The increase in alley cropped sorghum yields with prunings application compared to prunings unapplied was through increase in yield contributing characters (Table 27), namely, grain weight per plant (17.3 to 20.8 g) and grain number per ear (506 to 610). This was in turn due to N supplied to the crop through the prunings applied as indicated by increase in soil available N content (Table 44) at sowing with prunings application (from

202.7 to 233.3 kg/ha). The findings of this study are similar to those obtained by Narkhede and Ghugare (1987b) who observed 25.9 to 73.9 per cent increase in *rabi* sorghum grain yield with prunings application. Korwar (1992) also obtained 3 to 18 per cent increase in sorghum and pearl millet grain yields with prunings application. However studies at ICRISAT (ICRISAT, 1989) and also by Singh *et al.* (1989c) did not show significant increase in grain yields of alley crops due to prunings application under SAT conditions.

The lower yield in prunings applied alley crop than sole sorghum crop in the present study is attributed firstly to reduction in area planted to sorghum (by 16.7%) in alley cropping and secondly to competition between hedgerows and sorghum crop for moisture (Table 45). The soil moisture content (cm water in 0-90 cm soil profile) was markedly higher in sole sorghum than prunings unapplied and applied alley sorghum at sowing (34.1 cm than 26.7 cm and 27.2 cm) and flowering (26.3 cm than 22.7 cm and 22.9 cm) stages. This finding is in conformity with that of Lal (1990b), who also obtained 10 per cent yield reductions in maize and 30 to 50 per cent in cowpea when alley cropped with *Leucaena* even in higher rainfall region (1100 - 1300 mm annual rainfall) of Nigeria. This he attributed to competition for moisture and phosphorus.

The higher grain yield of sole sorghum than prunings applied alley sorghum was due to higher effective population (64400 than 49800/ha), higher grain number per ear (676 than 506) and higher thousand grain weight (31.9 than 29.4 g). The higher effective population in sole sorghum appears to be due to two reasons: 1) higher area planted to sorghum (100% as compared to 83.3% in alley crop) and 2) no competition for soil moisture in sole sorghum unlike by hedgerows in alley cropped sorghum. The higher

thousand grain weight and higher grain number per ear in sole sorghum were due to better soil moisture conditions prevailing during reproductive phase of crop growth.

The improvement in yield and yield components in prunings applied alley sorghum over prunings unapplied alley sorghum and sole sorghum over prunings applied alley sorghum were in turn due to the increased growth components, viz., plant height at all growth stages and finally at harvest (from 130.5 to 139.8 to 163 cm) and increased dry matter accumulation at different stages and finally at harvest (from 37.6 to 43.3 to 56.6 g/plant). Dry matter was positively correlated ($r = +0.99$ and 0.97 at 60 DAS; 0.98 and 0.97 at 90 DAS; and, 0.82 and 0.98 at harvest during 1989-90 and 1990-91 respectively) with grain yield (Table 47). Positive correlation between dry matter and sorghum yield was reported by Palled (1985).

Prunings application through the increase in available soil N at sowing (Table 44) increased the concentration of N in leaf, stem and grain; grain protein and N uptake in leaf, stem, grain and total (Tables 32 to 39). Similar observations were also made by Narkhede and Ghugare (1987b). The N concentration in leaf, stem and grain in sole sorghum was lower than that in the alley sorghum, which was probably due to dilution effect i.e., higher quantity of dry matter produced and also due to lower N availability in sole sorghum plots. The findings are in conformity with the observations made by Narkhede and Ghugare (1987b). Leaf, stem and total N uptake was higher in prunings applied than unapplied alley sorghum, and in sole sorghum than prunings applied alley sorghum. This appears to be due to the higher dry matter production in sole sorghum though N concentration was higher in the alley sorghum.

The increase in soil organic carbon in prunings unapplied and applied alley crop by 17 and 25 per cent over sole sorghum at sowing stage (Table 44), and by 8 and 10 per cent at harvest stage respectively was due to organic matter addition through the prunings in prunings applied plot and due to leaf litter fall in prunings unapplied plot. Similar results were reported by Narkhede and Ghugare (1987b) and Sheelavantar (1990).

Application of 12.5, 25 and 50 kg N per ha increased the grain yield by 28, 45 and 59 per cent and stover yield by 23, 37 and 47 per cent respectively compared to 0 kg N per ha. Owing to low N content in the soil N application made more N available for plant growth and improved the yield components, and these in turn increased the grain and stover yields. Similar results have been reported by many workers (Kang *et al.*, 1984; Yamoah *et al.*, 1986b; Narkhede and Ghugare 1987b).

The rate of increase in sorghum yield was different in prunings unapplied, applied and sole sorghum plots (Table 29) at different N levels. At 0 kg N level, prunings applied alley sorghum produced higher grain yield (785 kg/ha) than sole (750 kg/ha) and prunings unapplied alley sorghum (490). But at other N levels, sole sorghum was superior to prunings applied, which was superior to prunings unapplied alley sorghum, and the difference between prunings applied and unapplied narrowed at higher N levels.

Regression analysis (4.2.8, Fig.16) showed that in prunings unapplied alley sorghum the sorghum grain yield response to applied N was quadratic during both the years. The optimum N and maximum yield were 37.41 and 955.2 kg per ha in 1989-90; and, 45.33 and 780 in 1990-91 respectively. In prunings applied alley sorghum during 1989-90, there was a small linear rate of increase in grain yield with increase in applied N. This was

because though applied prunings supplied N, the quantity was low during this year. In 1990-91 the response to applied N was constant as sufficient N was already supplied through the application of large quantity of prunings in this treatment, and hence there was no much response to applied N during the year 1990-91. In sole sorghum the response to applied N was linear in 1989-90. It was quadratic in 1990-91, the optimum N and maximum yield were 40.34 and 1339 kg per ha respectively. The linear response to N in sole sorghum is explained to be due to better soil moisture availability than that in alley sorghum. The better response to applied N in prunings unapplied than prunings applied alley sorghum is due to N supplied through prunings in the latter case. Similar results were reported by Narkhede and Ghugare (1987b) where response to prunings application was higher at lower N levels. Kang *et al.* (1981) also observed benefits of prunings applied at lower levels of production.

The increase in sorghum yield due to N application was mainly through increase in yield components, viz., grain weight per plant (from 15.1 to 23.8) and grain number per ear (457 to 726). This increase in yield and yield components was in turn due to increase in growth and dry matter accumulation. Plant height at all growth stages and finally at harvest increased (126.9 cm to 148.2 cm), concurrently the dry matter increased at all stages and finally at harvest (34.8 to 55 g/plant). This improvement in plant growth and dry matter production was brought about probably by the improved nitrogen availability to crop due to N application, as could be seen through the increase in N content of plant due to application of N (Tables 32, 33 and 34).

The N concentration in leaf, stem and grain, grain protein; and uptake of N through leaf, stem and grain, and the total uptake increased due to N application which was due to better N supply to plants. At 0 kg N per ha

the N concentration and uptake in leaf, stem and grain of sorghum was higher in prunings unapplied plot (Tables 32 to 39) than sole sorghum, which was probably due to leaf litter fall (though prunings were not applied) and N fixed by *Leucaena* roots. Similar observations were made by Yamoah *et al.* (1986b).

Light transmission ratio (Table 15) did not vary due to N levels or prunings application. However, the LTR was marginally lower (90-94%) in alley plots than sole sorghum (100%). Therefore, light was not a limiting factor. Similar report has been made by Singh *et al.* (1989b).

Soil moisture at sowing, flowering and harvest (Table 45) stages of sorghum was higher in sole sorghum than prunings unapplied and applied alley sorghum. This was mainly due to competition for moisture between hedgerows and sorghum. Similarly Narkhede and Ghugare (1987b) reported that *Leucaena*-sorghum alley cropping system resulted in more moisture depletion compared with sole sorghum crop.

5.2.2 Performance of *Leucaena*

Leucaena leaf, wood and total biomass production did not vary due to prunings application and N to the alley crop (tables 40, 41 and 42). This is obvious because *Leucaena* being a leguminous species would not respond to nitrogen once its root system is well established. Further, in in this study N was applied to the alley crop and not directly to the hedgerows and N was applied to the crop only in moderate levels (upto 50 kg/ha). This suggests that once the hedgerows of *Leucaena* are established, the plant does not respond to N application. Similar results were reported by Kang *et al.* (1990).

Leucaena net biomass harvest (Table 43) in prunings unapplied plot was higher by 50 and 75 per cent than that in prunings applied during 1989 and 1990 respectively. This is expected because part of *Leucaena* produced (i.e., *Leucaena* total biomass production - *Leucaena* net biomass harvest) was applied to the alleys as part of the treatment. The higher total biomass production and net biomass harvest during the second year was due to the favourable rainfall (May and June) for the growth of hedgerows.

The *Leucaena* total biomass production obtained from the hedgerows in this study (4145 to 4453 kg/ha) is comparable with that of studies at ICRISAT (ICRISAT, 1989). However, the total biomass production in this study was almost double of that (1975 kg/ha) obtained by Narkhede and Ghugare (1987 a) even at a narrow alley width of 3 m. This is probably due to the fact that in the above study the *Leucaena* cutting regime followed during the rainy season was higher (three times) than the present investigation (once). This also explains the reason for reduction in alley crop yield even with prunings application compared to sole sorghum in the present investigation, which was not the case in the above study. However, this reduction in alley crop sorghum grain yield was more than compensated through the higher *Leucaena* yields obtained in this investigation (to be discussed later in economic analysis).

5.2.3 Performance of the system

5.2.3.1 Land Equivalent Ratio (LER)

Average LER was similar (1.07) in both prunings applied and unapplied alley cropping systems (Table 46). The LER decreased systematically from 1.20 at 0 kg N to 0.99 in 50 kg N per ha. At 0 kg N prunings applied alley cropping system had higher LER (1.32) than prunings unapplied alley system (1.07). As the N levels increased LER in prunings unapplied alley system

was higher than that in prunings applied alley system. This may be explained by the fact that prunings application gave response only at 0 kg N. With N application at as low as 12.5 kg N per ha the yield in prunings unapplied alley crop increased significantly, while in prunings applied plots though with increasing N sorghum yield increased but, it did not sufficiently compensate the loss in net biomass harvest (which was applied to the plots) from *Leucaena* hedgerows (in prunings application treatment).

The LER values obtained in this study are comparable with those reported by ICRISAT (ICRISAT, 1989), where LER of 1.14 to 1.18 were reported. Singh *et al.* (1989c) while reviewing data of different dryland research centres reported LER values ranging from 0.83 to 1.22 for alley cropping system involving *Leucaena* hedgerows and different intercrops. Earlier workers (ICRISAT, 1989) opined that LER value of 1.18 is insufficient to compensate for the loss in economic returns from grain yield at 3 m alley width and supported the hypothesis that alley cropping based on *Leucaena* is not more productive than sole *Leucaena* even when *Leucaena* is not managed optimally.

The findings of the present investigation show that prunings applied alley system is more productive (by 32%) than prunings unapplied alley system when the farmer has no capacity to apply fertiliser nitrogen. If the farmer has capacity to apply even a small dose of fertiliser (12.5 kg N/ha), alley cropping without prunings application is more productive (by 14%) than sole sorghum. The *Leucaena* leaf which is a rare and valuable commodity in dryland areas can be profitably used as a green fodder for milch cattle to improve their milk yield as reported by Hegde (1986).

The benefits of alley cropping in terms of productivity (LER) are small (20% at 0 kg N and no advantage at 50 kg N/ha). Of course, when we

consider the intangible benefits like advantages of alley cropping in soil and water conservation in low rainfall areas as observed in the earlier studies (ICRISAT, 1989) alley cropping would be advantageous in the long run. This is more appropriate in the face of high soil erosion in black soils (Mallappa, 1990). Heavy cracking in these soils during summer leads to breaching of bunds with the receipt of *kharif* rains, and hence the mechanical conservation structures are not stable on such soils

5.2.3.2 Economics

Prunings unapplied alley system resulted in 32 percent higher net returns than sole sorghum (Rs 3176/ha). Prunings applied alley system resulted in 6 per cent higher net returns than sole sorghum. This is because of higher total productivity and biomass production (sorghum + *Leucaena*) in alley cropping system than sole sorghum system. Interestingly, the net returns derived from prunings unapplied system was higher than that in prunings applied plot. This was probably because of the fact that the sorghum yield response with prunings application was not commensurate with the economic loss due to prunings returned to the soil. These results suggest that in the absence of sufficient response to prunings application, farmer may get higher returns by selling *Leucaena* as fodder and buying fertiliser N for his crop. Further, *Leucaena* leaf is a valuable fodder for the milch cattle. Similar was the opinion of Singh *et al.* (1989c). Guevara (1976) also reported low efficiency of N contribution from *Leucaena* prunings in maize crop, where it was observed that only 36 per cent of the N supplied through the prunings was utilized by the alley crop.

Nitrogen application @ 12.5, 25 and 50 kg N per ha increased the net returns by 22, 33 and 42 per cent respectively over 0 kg N (Rs.2,889/ha). The rate of increase in net returns with increase in N was higher in sole

sorghum than the alley crops, this was due to the better response of sole sorghum to N application. However, the economic response was significant upto 50 kg N per ha in 1989-90 which was a near normal rainfall year and upto 25 kg N per ha only in 1990-91 which was a low rainfall year.

Though increased yield and LER give efficiency of a system, economics will give the exact advantage of a system in monetary terms and decide the adoption or non-adoption by the farmers. The economic analysis of this investigation have shown superiority of alley cropping over sole sorghum system. Considering the yield advantages, LER advantages, economics and the intangible benefits from alley cropping, it is opined that *Leucaena*-sorghum alley cropping is advantageous to sole sorghum cropping. Further, alley cropping without prunings application to soil is more remunerative than with prunings application.

5.3 Effect of tree species and their management on intercropped *rabi* sorghum

5.3.1 Performance of *rabi* sorghum

Sorghum grain yield was highest (626 kg/ha) in sole crop (no trees) and the lowest (81 kg/ha) in eucalyptus (Table 58). Among the tree species, *anjan* was the best performer, it resulted in highest yield of *rabi* sorghum (326 kg/ha), which was 51 per cent of sole crop (no trees) yield. The trend in stover yield production was similar to that of grain yield where sole sorghum crop (no trees) produced highest yield (960 kg/ha), followed by *anjan* (539 kg/ha) and the lowest was in eucalyptus (238 kg/ha). Considering the area occupied by sorghum i.e., only 3 m out of the 5 m between two rows of the tree, which makes 60 per cent, this yield in *anjan* appears reasonable. The probable reasons for better performance of sorghum with *anjan* are: i. this species is erect growing with light canopy and it did not heavily shade the companion crop (Table 53 to 55), and ii. it did

not compete much for soil moisture (Table 63). The better compatibility of *anjan* with under-storey grasses has been reported by Deb Roy (1989).

The lowest grain yield of sorghum recorded with eucalyptus was due to its strong competition for light and moisture (Tables 53, 54 and 55; 63) with the intercropped *rabi* sorghum. This competition suppressed sorghum crop growth and thus reduced its yield. The performance of sissoo and neem was intermediate between *anjan* and eucalyptus, where the yield reduction compared with *anjan* was due to competition for light and moisture.

Similar results have been reported by many workers. Chandrasekharaiah (1986) working at Dharwad observed higher reduction in maize and safflower yields in association with eucalyptus than *Leucaena* (native) and sissoo. Itnal (1987) working at Bijapur found *Acacia nilotica* and eucalyptus more competitive than *Albizia lebbek*, casuarina, *Leucaena* and sissoo with *rabi* sorghum. Bhat (1988) working at Dharwad also found eucalyptus more competitive with associated sunflower and pigeonpea crops than sissoo and teak. Nadagoud (1990) found eucalyptus most competitive, resulting in maximum yield reduction in groundnut even under irrigated conditions at Raichur.

The significantly better performance of *rabi* sorghum when intercropped with *anjan* compared to eucalyptus may be attributed to the following reasons; namely, increase in the effective plant population, improvement in grain weight per plant and, increased moisture and light availability. Although germination was not affected under different tree species, but, with advance in stage of crop growth, plants either withered away or did not produce earhead, as could be seen by the significant reduction in the effective population under eucalyptus (8010/ha) compared to *anjan* (22820/ha). Similar observations have been made by Itnal (1987) and

Nadagoud (1990). The per plant grain weight was significantly lower under eucalyptus compared with *anjan* (Table 57).

The reduction in effective population and grain weight per plant under eucalyptus has been caused probably by the reduced moisture availability. This could be supported by the better soil moisture content under *anjan* than eucalyptus (Table 63). Further, the more shading caused by eucalyptus on intercropped sorghum as seen through the significantly lower LTR values under eucalyptus compared with *anjan* at 30 and 60 DAS stages (Tables 53 and 54) reduced the plant height and dry matter production and consequently depressed the yield components as well as grain and stover yields.

The row-wise analysis of grain and stover yield indicated that with increase in distance from the tree line, the yields increased. The rate of increase was highest in eucalyptus and the lowest in *anjan*. It clearly indicates differential competition of tree species for moisture extraction which is reflected in the performance of intercropped sorghum at different distances from the tree line. Similar findings were reported by Chandrasekharaiah (1986), Itnal (1987), Bhat (1988) and Nadagoud (1990).

Tree management had significant influence on sorghum grain yield (Table 58). Grain yield increased in the roots pruned, branches lopped, and roots pruned plus branches lopped treatments by 9, 38 and 71 per cent respectively over control trees (212kg/ha). Similarly, the stover yield increase was by 3, 22 and 24 per cent over control trees (427 kg/ha). Thus, it clearly indicates that root pruning and lopping of tree branches before sowing of intercrop (sorghum) helps in increasing in grain and stover yields significantly.

It may be observed that root pruning was not as effective as lopping or root pruning plus lopping in reducing the competitive effects of trees on

crops. It was probably due to the reason that root pruning did not also improve the yield significantly (Table 58). On the other hand lopping increased the light availability to the crop to a great extent (Tables 53, 54 and 55). Similar conclusion was drawn by Verinumbe and Okali (1985) who opined that light was more limiting factor than root competition in teak - maize intercropping system, because teak was planted close (1.8 m x 1.8 m), as in the present study. Dhadwal *et al.* (1986) found response to trenching near boundary planted eucalyptus on yield of *rabi* wheat. They trenched to a depth of 1 m, whereas in the present study the root pruning was done upto 30 cm depth only, as the tree rows were spaced close. Similarly Singh and Dayal (1974) observed increase in yields by 10 per cent in cotton and by 54 per cent in tobacco by eliminating root effects of boundary planted *sissoo* and *A. nilotica* respectively. Here again the trench was dug to a deeper depth.

Yield increases of 3, 10 and 50 per cent in rainy season *kharif* sorghum have been reported due to light lopping, heavy lopping and pollarding of 4 year old *Leucaena* trees (Singh *et al.*, 1989 c). Mann and Saxena (1980) obtained six-fold increase in yield of mungbean by canopy pruning of 12 year old *Acacia tortilis* spaced 4 m x 4 m. Similar observations were made by Muthana and Arora (1977) in *guar* with 8 year old *Holoptelia integrifolia* trees.

The increases in sorghum yield due to tree management were through increase in the yield components (Tables 56 and 57) viz., effective population (15,457 to 24,200/ha) and grain weight per plant (12.32 to 17.81 g). The increases in the yield components were through increase in plant growth (plant height) at all stages and finally at harvest (71.2 to 90 cm). The significantly better growth of sorghum in root pruned plus lopped trees was due to higher soil moisture availability (Table 63) at sowing,

flowering and harvest stages (9.0cm than 8.4 cm; 7.4cm than 6.9cm 5.7cm than 5.1cm); and, better light availability (Tables 53 to 55) to crop growth at 30, 60 and 90 DAS. The LTR increased significantly due to lopping treatment over control (unmanaged trees) in *sissoo*, *neem* and *eucalyptus*. In *anjan* lopping did not cause any significant improvement in LTR over control, because of its light canopy.

5.3.2 Performance of Tree Species

The trend in tree performance followed opposite of intercropped *rabi* sorghum. *Eucalyptus* was the best performer and *anjan* the poor. Tree height on all the three dates of observation (June 89, June 90 and June 91) was maximum in *eucalyptus* (7.45, 8.6 and 9.69 m); which was higher than that of *anjan* by 24, 19 and 17 per cent respectively (Table 60). Almost similar trend was seen in tree diameter at breast height (DBH) also in the three stages, where *eucalyptus* topped followed by *neem*. *Sissoo* and *anjan* were on par, and were poor performers.

Tree dry matter (Table 61) was highest in *eucalyptus* both in June 1989 and June 91, and it was lowest in *anjan*. The dry matter in individual components, viz., leaf, branch and stem was similar to that of total. However, *anjan* had the lowest proportion of branch (8.6% of total dry matter) and *sissoo* the highest (20.5%). Low proportion of branch in *anjan* has been reported also by Deb Roy (1989).

The increment in dry matter (kg/tree/year) between June 89 and June 91 was highest in *eucalyptus* (36.938kg) and lowest in *sissoo* (3.489kg) which was on par with *anjan* (3.91kg) and *neem* (4.01 kg). The higher dry matter increment in *eucalyptus* was due to its faster rate of growth as indicated through its more height and DBH. The fast growth rate in this species is due to its genetic potential. Higher growth rate in *eucalyptus* has been

reported by many workers (Chandrasekharaiah, 1986; Itnal, 1987; Bhat, 1988; Nadagoud, 1990).

Relwani and Gandhe (1989) working near Poona found neem and *Leucaena* growing faster than *anjan* at 31.5 months age. The growth rate of *anjan* was especially slow at initial stages. With age tree growth would be better. Muthana and Harsh (1985) found that in arid conditions of Jodhpur, *anjan* grew faster (73.5 cm mean annual height increment) than *Acacia albida* (56cm) and *Leucaena* (32cm) at seven years age. Total yield of loppings (Table 62) was again highest in eucalyptus (3.96 kg/tree/yr) and the lowest in *anjan* (1.05 kg). Higher yield of loppings in eucalyptus was due to its better genetic potential.

Tree management treatments did not affect tree growth parameters significantly. This may be because root pruning was done in mid-*kharif* season and the lopping was done before sowing of *rabi* crops, by which time the trees might have completed their major growth (during the rainy season). The management treatments were not severe enough to affect tree growth parameters significantly. This allows for improving the performance and yield of interplanted arable crops without adversely affecting the tree performance.

Management treatments did not cause any significant difference in dry matter of the trees either in June 1989 or June 1991, this was due to the same reason as explained above for tree growth parameters. However, though the total dry matter increment did not vary significantly due to management, the increment in leaf dry matter was higher in control trees (1.821 kg/tree/yr) and root pruned (1.47 kg) than lopped (0.596 kg) and root pruned plus lopped (0.417 kg) trees. This was because part of the leaf was removed with lopping in the above treatments and hence the lower leaf dry matter increment.

The interaction between species and management was significant for leaf DM increment. In *anjan*, all management treatments were at par indicating lopping or root pruning did not adversely affect leaf DM production. In other species, viz., in *sissoo* root pruning plus lopping; in *neem* lopping, and root pruning plus lopping; and in *eucalyptus* root pruning, lopping, and root pruning plus lopping adversely affected leaf dry matter increment. This indicates that *anjan* can tolerate annual lopping without any adverse effect in the dry matter increment.

The yield of loppings (leaf, wood and total) was higher in lopping only treatment than in root pruning plus lopping treatment indicating some adverse effect of root pruning on annual loppings production. But, in *anjan* these two treatments were at par indicating its resistance to root pruning and lopping.

5.3.3 Economics

Net returns were highest from *eucalyptus+rabi sorghum* (Rs 4198/ha/yr) and the lowest from sole sorghum (Rs 1135/ha). *Eucalyptus* was followed by *anjan* (Rs 2925), *neem* (Rs 2190) and *sissoo* (Rs 2038). The higher net returns from *eucalyptus* intercropping system were due to the higher production potential of the tree component although the performance of intercrop was most adversely affected. The higher net returns from *anjan* intercropping system than other tree species were due to the reason that *anjan* did not adversely affect sorghum crop much and at the same time yielded the tree products.

Among the tree management treatments, maximum returns were from lopped (Rs 2737/ha) and minimum (Rs 2133) from root pruned trees. This was because of additional returns from loppings, and increased crop yield in the former case; and some reduction in tree dry matter increment (though not significant) and no much improvement in crop yield due to this treatment in

the latter case. Though tree dry matter increment in lopped or root pruned plus lopped was slightly reduced compared control trees (Table 61), this decrease was offset by the returns from loppings and also through the increased crop yields in these treatments.

Thus, this study clearly indicates that eucalyptus+ rabi crop system gives more income, though the yield of sorghum was reduced drastically (even with tree management practices). After eucalyptus, *anjan* is next best in economic terms and also does not reduce yields too much. So, if money is the criteria, eucalyptus + rabi sorghum is the best and if sorghum grain, fodder and money is desired *anjan* + rabi sorghum is better than sole sorghum.

5.4 Screening Rabi crops for intercropping with tree species

5.4.1 Performance of crops

The yield level of seasonal rabi crops grown on these shallow black soil was very low, ranging from 328 kg per ha in safflower to 657 kg per ha in sorghum. Further, the performance of these crops was adversely affected when intercropped with tree species because of quick exhaustion of stored soil moisture. Grain yield of the three crops tested, viz., safflower, sorghum and sunflower decreased drastically when grown with different tree species. The reduction was highest with eucalyptus and lowest with *anjan* (Table 67).

Safflower yield was 3 and 18 per cent of sole crop (no trees) with eucalyptus and *anjan* respectively. Neem and sissoo were in between eucalyptus and *anjan*. Sorghum yields were 2 and 35 percent of sole crop (no trees) with eucalyptus and *anjan* respectively. In sunflower the yields were 18 and 52 per cent of sole crop (no trees) with eucalyptus and *anjan* respectively. Sunflower yield with neem was marginally lower (12% of sole crop) than with eucalyptus, though they were statistically not significant.

Among the three crops, sunflower followed by sorghum performed better than safflower as their yields were 52 and 35 per cent of sole crop (no trees) respectively with *anjan*, the best performing tree species. The ranking of crops with other species was almost similar.

In safflower the higher grain yield in sole crop (no trees) and when grown with *anjan* than with eucalyptus was due to higher (22,667 and 13,814 than 4,000/ha) effective population (Table 67) and higher (18.2 and 5.29 than 2.02g) grain weight per plant (Table 67). The increase in yield and yield components was due to better (Table 65) growth (height and dry matter). At 90 DAS crop height was more (39.2 and 36.4 cm) in sole crop (no trees) and *anjan* than eucalyptus (25.0 cm). Similarly the dry matter at 60 DAS was more (8.49 and 7.75 g/plant) in sole crop (no trees) and *anjan* than eucalyptus (1.79 g). This better crop growth was promoted by the better light (Table 66) and soil moisture availability (Table 70).

Similarly in other crops viz., sorghum and sunflower the higher yield observed in sole crop (no trees) and with *anjan* over eucalyptus was through improvement in yield components which were due to increased growth promoted by the better soil moisture and light availability. Among the three crops, better performance of sunflower than sorghum when grown with tree species can be explained by its shorter duration. Before the tree species exhaust the soil profile of the stored soil moisture below critical level the crop completes its flowering and life cycle. This is supported by higher soil moisture at flowering stage of this crop as compared with other species (Table 70). The better performance of sorghum over safflower can be explained by the fact that the feeding zone of sorghum is shallower than that of safflower and is not affected as much as safflower by competition from tree species for soil moisture.

The findings of this study are similar to the earlier workers. Chandrasekharaiah (1986) observed eucalyptus more competitive than teak, sissoo, casuarina and *Leucaena* (native) with maize and safflower companion crops. Bhat (1988) also observed eucalyptus and sissoo more competitive than bamboo, teak, casuarina and *Leucaena* (native) on associated sunflower and pigeonpea crops.

The yield reduction due to tree species in this investigation are higher than those reported by Chandrasekharaiah (1986) and Bhat (1988). This is partly due to the reason that tree population in this study was higher (1000 trees/ha) than earlier studies (286 trees/ha). Increasing competition of trees with crops with increase in tree population has been reported by VanDenBeldt (1990). The other reason is the age of trees. In Chandrasekharaiah's studies it was four years, while in the present study it was six years. The adverse effect of trees on associated crops increases with age of trees. Bhat (1988) observed higher reduction (55.1 to 77.8%) in different tree species at 6 years age than Chandrasekharaiah (1986) at 4 years age (12 to 51%), in *kharif* crops.

The increase in adverse effect of trees on crops with increasing age has been reported by many workers. Khattak *et al.* (1981) from Pakistan reported this effect on wheat growing in association with eucalyptus, sissoo and poplar. Further, they also reported eucalyptus to be more competitive than sissoo and poplar. Ahmed (1989) reported increased adverse effect of boundary planted eucalyptus on wheat, rice and mustard with increasing age, Jama *et al.* (1989) from Kenya observed this in casuarina + maize intercropping system. *Rabi* crops were more affected than *kharif* crops (Chandrasekharaiah, 1986; Dhadwal *et al.*, 1986).

Crop equivalent yield (Table 68) converted to that of *rabi* sorghum shows highest in sole crop (781kg/ha), followed by *anjan* (289) and lowest (67) in eucalyptus. The trend is almost similar to the yield of individual crops. Comparison of crops showed that maximum crop equivalent yield was obtained in sunflower (393kg/ha) and the minimum in safflower (195). Though sorghum yield (Table 67) was higher (215) than that of sunflower (154), in equivalent yield sunflower was superior to sorghum because of its higher price (Rs 600/q vs 300 in the first year; Rs 1,000/q vs 300 in the second year). However, if the current (December, 1991) prices are considered (Rs 900/q for sunflower and Rs 600/q for sorghum) the crop equivalent yield of the two crops may not vary appreciably. So, crop equivalent yield comparison may be no better way of comparing crops than comparing their partial land equivalent ratio i.e., ratio of their yield when intercropped with trees to that of their yield when grown as sole crops. Of course the economics will dictate the adoption or non-adoption of a technology by the farmers.

5.4.2 Performance of tree species

As observed in experiment 3, the performance of trees was opposite to that of arable crops. Maximum height (8.34 m) was observed in eucalyptus and the minimum (3.04) in *anjan* (Table 69). The diameter at breast height (DBH) of trees was also having similar trend, where eucalyptus (10.03 cm) topped and *anjan* (5.11 cm) had the lowest DBH. The better performance of eucalyptus in terms of growth components, viz., height and DBH was due to its genetic potential as reported by many workers (Chandrasekharaiah, 1986; Bhat, 1988; Nadagoud, 1990).

Tree height and DBH did not vary due to crops. This is expected because trees of 7 to 8 years old having their full grown tall canopy had an upper hand and were in a better position than crops to utilise the resources.

Further, the crop growth was in post-rainy season by when most of tree species had completed their active growth for that year.

5.4.3 Economics

Economic evaluation shows that eucalyptus system fetched highest net returns (Rs 4,396/ha/yr) and the lowest (Rs 1,258) was in sole crop (no trees). The higher economic returns in eucalyptus system was due to its higher productivity. The low returns from sole crop were due to poor crop yields in these shallow black soils. *Anjan* (Rs 2343) was better than neem (Rs 2005) and sissoo (Rs 1995) as this tree had least effect on the intercropped arable crops. Nadagoud (1990) also reported economic superiority of eucalyptus-based intercropping system.

Among the three crops tested, sunflower resulted in highest net returns (Rs 2,710), followed by sorghum (Rs 2418) and safflower (Rs 2,070). Though the crop yield was higher in sorghum, net returns were higher in sunflower because of higher price of sunflower. The low net returns from safflower were due to its poor performance on these shallow black soils.

The low yields of the annual crop component with eucalyptus, neem and sissoo (Table 67) suggests that it is not worth growing annual crops with these species at that age of tree (6 to 7 years). Intercropping is possible with *anjan* even at this age. Even in *anjan*, growing safflower is not a profitable proposition. Of course, with canopy and root management crops can be grown profitably (as seen in experiment 3). But, without canopy management at this age (6 to 7 years onwards) in the trees like eucalyptus, neem and sissoo planted at a high density (1000 stems/ha) the interspace may be planted with grasses or cover crops to check weeds and soil erosion. Similar conclusions were drawn by Jama *et al.* (1989).

SUMMARY

VI SUMMARY

Agroforestry provides stability to dryland agriculture. The tree and crop components in an agroforestry system do interact. To study the interaction between tree and crop components of two agroforestry systems, viz., alley cropping and agrosilviculture, under dryland conditions on black soils, the following four experiments were carried out for two years at Regional Research station, Bijapur.

i. Influence of root pruning and cutting interval of *Leucaena* hedgerows on alley cropped *rabi* sorghum

In this trial root unpruned and root pruned hedgerows and sole *Leucaena* were subjected to four cutting intervals (1,2,3 and 6 months).

ii. Evaluation of effects of nitrogen and *Leucaena* prunings application to alley cropped *rabi* sorghum

Four N levels, (0, 12.5, 25 and 50 kg N/ha) were tested on sole sorghum, *Leucaena* - *rabi* sorghum alley cropping system with and without *Leucaena* prunings application to sorghum.

iii. Effect of different tree species and their management on intercropped *rabi* sorghum in shallow black soil

In this trial the effect of four (six-year old) tree species, viz., (*Eucalyptus tereticornis*, *Azadirachta indica*, *Dalbergia sissoo* and *Hardwickia binata*) and sole crop (no-trees) in combination with four levels of tree management, viz., control (unmanaged trees), root pruned, branches lopped and root pruned plus branches lopped were tested on intercropped *rabi* sorghum.

iv. Screening of *rabi* crops for intercropping with different tree species

In this trial, three *rabi* crops (safflower, sorghum and sunflower) were tested with four (six-year old) tree species (*Eucalyptus tereticornis*, *Azadirachta indica*, *Dalbergia sissoo* and *Hardwickia binata*) and as sole crops (no trees).

The findings from the above studies are summarised here.

1. Root pruning of *Leucaena* hedgerows increased grain and stover yields of intercropped *rabi* sorghum by 30 and 17 per cent over root unpruned.
2. Shorter cutting intervals of *Leucaena* hedgerows of one and two months increased grain and stover yields significantly over longer cutting intervals of three and six months.
3. Root pruned plots maintained higher soil moisture than root unpruned plots at sowing, flowering and harvest of sorghum.
4. Light transmission ratio (LTR) was lower near the hedgerows in six months cutting interval, whereas in other treatments it was unaffected.
5. Total biomass production of *Leucaena* was highest in sole plot (10,026 kg/ha/yr), while in root unpruned (4,533 kg/ha/yr) and root pruned (4,555 kg/ha/yr) it was on par. The production was high in longer cutting intervals viz., 3 months (6,764 kg/ha/yr) and 6 months (7,149 kg/ha/yr) and low in shorter cutting intervals of one (5,434 kg/ha/yr) and two (6,139 kg/ha/yr) months.
6. Land equivalent ratio (LER) was lower (0.79) in root unpruned than root pruned (0.95). LER decreased from 1.01 at one month cutting interval, to 0.98 at two, to 0.78 at three and 0.71 at six months interval.

7. Net returns were highest (Rs.4,821/ha/yr) from sole *Leucaena*, followed by root pruned (Rs 3,167) and root unpruned (Rs 2,520). Two months interval resulted in maximum returns (Rs 3,970) and six months in minimum (3,128). For root pruned and unpruned hedgerows, two months cutting interval gave highest returns, whereas for sole *Leucaena* three and six months cutting interval gave higher returns.
8. In alley cropped sorghum, grain yield was significantly higher (866 kg/ha) in prunings applied plots which was 22 per cent higher than prunings unapplied (712 kg/ha). However, sole sorghum produced the highest (1,117 kg/ha) grain yield. At 0 kg N prunings applied plots yielded more (785 kg/ha) than sole sorghum (750) and prunings unapplied (490 kg/ha). At other three levels of N, sole sorghum yielded highest followed by prunings applied and unapplied plots.
9. In alley cropping prunings application increased sorghum stover yield by 18 per cent over prunings unapplied plot. However, sole sorghum produced the highest (2,019 kg/ha) stover yield. Stover yield increased from 1,208 kg per ha at 0 kg N to 1,779 at 50 kg N per hectare.
10. Total N uptake in sorghum was more (15.46 kg/ha) in prunings applied plots than prunings unapplied (12.02kg/ha). Total N uptake increased with increasing N levels (from 9.58 at 0 to 19.1 at 50 kg N/ha).
11. Soil organic carbon and available N at sowing as well as at harvest of sorghum was higher in prunings applied followed by prunings unapplied than that in sole sorghum.

12. Soil moisture at sowing, flowering and harvest stages of sorghum was higher in sole sorghum than prunings applied or unapplied alley sorghum.
13. LER did not change in prunings unapplied and prunings applied alley systems. LER decreased from 1.20 at 0, to 0.99 at 50 kg N per hectare. At 0 kg N prunings applied alley systems had higher (1.32) LER than prunings unapplied (1.07).
14. Net returns were highest (Rs 4204/ha) in prunings unapplied followed by prunings applied (Rs 3382/ha) and sole sorghum (Rs 3176/ha). Net returns increased from Rs 2889 to Rs 4095 with increasing N level from 0 kg N to 50 kg N per ha.
15. Among the tree species tested, highest grain yield of intercropped *rabi* sorghum (323 kg/ha) was obtained with *anjan* and the lowest with eucalyptus (83kg/ha); while sole crop (no trees) produced 626 kg per ha. Sorghum grain yield was significantly higher with root pruned and branches lopped trees (363 kg/ha) than control (unmanaged) trees (212 kg/ha). Sorghum stover yield also showed similar trend.
16. Tree height was highest in eucalyptus and lowest in *anjan*. Tree DBH was highest in eucalyptus and lowest in *sissoo*.
17. Total dry matter increment was highest (10.81 kg/tree/yr) in eucalyptus. Other tree species viz., neem, *anjan* and *sissoo* had almost similar values (4.01, 3.91 and 3.49 kg/tree/yr).
18. Yield of loppings was highest (3.96 kg/tree/yr) in eucalyptus and lowest (1.05 kg/tree/yr) in *anjan*.

19. Among tree species, *anjan* recorded highest LTR and neem the lowest. LTR was higher in branches lopped trees than control trees.
20. Among the tree species soil moisture content at sowing, flowering and harvest stages of sorghum was highest in *anjan* and the lowest in eucalyptus. Soil moisture in sole crop (no trees) was better than that in *anjan*. Soil moisture was highest in root pruned plus branches lopped plots and the lowest in control plot.
21. Net returns in agrosilviculture system were highest (Rs 4198/ha/yr) from eucalyptus followed by *anjan* (Rs 2925/ha/yr) and the lowest were from sole crop (Rs 1135/ha/yr). Similarly net returns were higher in branches lopped (Rs 2737/ha/yr) and root pruned plus branches lopped plots (Rs 2713/ha/yr) than control (unmanaged) plots (Rs 2405/ha/yr).
22. Yield of all the *rabi* crops tested decreased when intercropped with tree species. Maximum reduction was with eucalyptus and minimum with *anjan*.
23. When grown with eucalyptus, neem, sissoo and *anjan* safflower yield was 3, 8, 11 and 18 per cent of sole crop; sorghum grain yield was 2, 6, 20 and 35 per cent of sole crop; and sunflower yield was 12, 18, 19 and 52 per cent of sole crop respectively.
24. Crop equivalent yield was highest (781 kg/ha) in sole crop (no tree) followed by *anjan* (289 kg/ha) and lowest in eucalyptus (67kg/ha). Sunflower recorded maximum crop equivalent yield (393 kg/ha) followed by sorghum (215 kg/ha) and safflower (195kg/ha).

25. LTR recorded at the canopy level of field crops was highest under *anjan* and lowest under neem in all the three crops.
26. Soil moisture content at all the growth stages of field crops was highest in sole crop (no trees) followed by *anjan* and lowest in eucalyptus.
27. Net returns were highest (Rs 4396/ha/yr) from eucalyptus and lowest (Rs 1258/ha/yr) from sole crop (no trees). *Anjan* (Rs 2343/ha/yr) was next best to eucalyptus. Among crops sunflower gave highest (Rs 2710/ha) net returns followed by sorghum (Rs 2418/ha) and safflower (Rs 2070/ha).

Results of Practical Utility

1. Root pruning of *Leucaena* hedgerows and adopting 2 months cutting interval for *Leucaena* is beneficial management practice in *Leucaena* - *rabi* sorghum hedgerow intercropping system by which 33 per cent increase over root unpruned and 74 per cent increase over six months interval in grain yield of sorghum can be derived. However, if food production (sorghum grain) is not primary objective of the farmer, adopting sole *Leucaena* system with 3 to 6 months cutting interval is even more beneficial than hedgerow intercropping system with root pruning of hedgerows.
2. Growing *rabi* sorghum in alley cropping system with *Leucaena* hedgerows, without prunings application, but with application of 50 kg N per ha to sorghum is more remunerative than sole sorghum. The prunings could be profitably utilized as green fodder for feeding milch cattle.
3. The advantages of alley cropping over sole sorghum cropping are more at low levels of N application, indicating suitability of alley cropping for adoption by resource poor farmers.
4. Growing eucalyptus is more remunerative than growing sole *rabi* sorghum on eroded shallow black soils. Eucalyptus caused maximum yield reduction and *anjan* caused minimum. However, considering the economics only eucalyptus + sorghum system is better.
5. Root pruning and tree lopping increase benefits from tree + crop intercropping system.
6. It is beneficial to intercrop sunflower than *rabi* sorghum or safflower with the tree species tested. Maximum reduction in yield of all crops was with eucalyptus and the least with *anjan*. However, eucalyptus + crops is most remunerative followed by *anjan* + crops, and the poorest is sole cropping.

Future Lines of Work

1. Identifying perennial legumes other than *Leucaena* for the hedgerows as it is being devastated by psyllid bug in recent years due to which the green biomass production is hampered substantially. Or identifying suitable psyllid resistant varieties of *Leucaena*.
2. Quantifying the benefits of alley cropping on soil and water conservation, on increase in milk yield when prunings from the hedgerows is fed to the milch cattle as green fodder.
3. Identifying easily practicable and less costly methods for deeper root pruning (50 to 60 cm or more) by using suitable tractor drawn implement to further reduce the competition between hedgerows and alley crop.
4. Testing tree species like *Prosopis cineraria*, *Acacia albida* etc., which have been reported to have positive effect on arable intercrops.
5. The reduction in yield of intercrops was more because of closer spaced trees. It is worthwhile to initiate studies to decide the optimum tree spacing without much yield reduction. By this the agroforestry system will become more popular among the farmers.
6. Agronomic experiments conducted on small plots do not give adequate information on economic feasibility of highly labour-intensive systems like alley cropping and agrosilviculture. Therefore, these systems should be tested on large plots to confirm their economic superiority.

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* Original not seen.

APPENDICES

APPENDIX I

Meteorological data for the period April 1988 to March 1991 and mean of last 50 years (1939 to 1988) at Regional Research Station, Bijapur

Months	Rainfall (mm)		Temperature °C		Relative humidity (%)		Open Pan Evaporation (mm)		Number of rainy days									
	Mean	90-91	Mean	90-91	Mean	90-91	Mean	90-91	Mean	90-91								
April	20.7	0	38.0	39.4	23.8	22.8	23.3	50.3	57.0	55.8	395.0	330.3	375.9	1.4	1	0		
May	42.9	58.6	313.1	38.5	39.0	35.3	23.9	23.5	23.1	58.1	68.5	81.6	399.9	362.1	230.0	4.0	5	8
June	96.2	125.6	225.0	33.3	32.3	30.5	22.4	22.8	23.0	74.8	85.6	87.9	254.6	234.3	147.0	8.5	8	7
July	81.4	133.5	15.2	30.1	30.0	31.2	21.7	22.0	22.0	80.1	84.1	89.3	209.0	142.3	175.5	10.4	8	3
August	90.2	13.3	110.0	30.1	30.6	30.5	21.3	21.8	16.0	80.1	85.8	86.6	183.0	178.3	215.8	8.1	2	5
September	157.5	393.4	16.6	30.6	30.0	29.5	21.1	21.5	21.0	80.1	91.4	82.4	174.5	84.7	162.0	10.7	15	2
October	106.9	7.5	12.4	31.0	32.5	32.1	20.6	18.5	20.2	69.9	77.3	87.1	167.1	112.1	165.2	6.5	1	3
November	29.2	15.0	8.6	29.7	29.1	30.0	17.3	15.0	19.1	60.1	82.6	73.2	146.5	134.9	146.4	2.9	1	1
December	6.4	32.2	0	29.0	28.4	29.0	15.3	13.4	15.2	58.2	78.0	58.0	151.8	122.4	152.0	1.1	1	0
January	2.4	5.4	0	30.2	30.3	30.2	16.1	14.4	16.2	56.2	68.1	56.0	175.5	176.7	176.0	0.6	1	0
February	2.6	0	0	32.9	32.4	33.8	18.0	15.7	18.2	46.9	65.1	66.6	228.6	200.1	234.4	0.2	0	0
March	7.2	0	0	36.0	35.1	37.8	21.3	16.7	23.4	45.2	65.5	68.0	327.3	266.5	353.4	1.0	0	0
Total	643.6	788.3	703.1													55.4	43.0	29

* Mean of 50 years (1939-1988)

APPENDIX II

Price of Inputs and Outputs used in calculating net returns

A. Inputs

Item	Unit	Price (Rs)
Seeds : Sorghum	Kg	5
Safflower	Kg	20
Sunflower	Kg	15
Fertilizers : Urea	Kg	2.3
Single super phosphate	Kg	0.97
Muriate of potash	Kg	1.30
Endosulfan	l	95
Labour : Male	Day	12.60
Female	Day	12.60
Bullock pair	Day	30
Tractor	Hour	40

B. Outputs

Item	Price (Rs/kg)	
	1989-90	1990-91
Sorghum : Grain	3.0	3.0
Fodder	0.4	0.4
Safflower : Grain	6.0	7.0
Sunflower : Grain	6.0	10.0
Green leaf biomass of <i>Leucaena</i> (DW basis)	0.8	0.8
Wood biomass of <i>Leucaena</i> (DW basis)	0.3	0.3
Green leaf of Neem, Sissoo and <i>Anjan</i> (DW basis)	0.8	0.8
Green leaf of eucalyptus (DW basis)	0.2	0.2
Branch/loppings Wood of Neem, Sissoo eucalyptus and <i>anjan</i> (DW basis)	0.5	0.5
Stem of Neem, sissoo and <i>Anjan</i> (DW basis)	0.8	0.8
Stem of Eucalyptus (DW basis)	0.7	0.7

APPENDIX III

Cost of cultivation in different experiments

Experiment 1		Experiment 2		Experiment 3			Experiment 4	
Treatment	Cost of cultivation (Rs/ha/yr)	Treatment	Cost of cultivation (Rs/ha/yr)	Treatment	Cost of cultivation (Rs/ha/yr)		Treatment	Cost of cultivation (Rs/ha/yr)
					1989-90	1990-91		
					Crop	Tree	Crop	Tree
					Total	Total	Total	Total
Roots Unpruned								
Eucalyptus								
1 month CI	1042	0 N	873	Control	920	1876	920	1876
2 months CI	1004	12.5 kg N/ha	926	Root pruned	920	1916	920	1916
3 months CI	1004	25 kg N/ha	979	Lopped	920	2626	920	2126
6 months CI	1004	50 kg N/ha	1085	Root pruned+ lopped	920	2666	920	2166
Roots pruned								
Prunings applied								
1 month CI	1072	0 N	898	Neem			1020	938
2 months CI	1034	12.5 kg N/ha	951	Control	920	938	1858	938
3 months CI	1034	25 kg N/ha	1004	Root pruned	920	978	1898	978
6 months CI	1034	50 kg N/ha	1110	Lopped	920	1313	920	1063
Sole Leucaena								
Sole sorghum								
1 month CI	1384	0 N	870	Root pruned+ lopped	920	1353	920	1103
2 months CI	1157	12.5 kg N/ha	934	Sissoo			987	938
3 months CI	1157	25 kg N/ha	998	Control	920	938	1858	938
6 months CI	1157	50 kg N/ha	1126	Root pruned	920	978	1898	978
Eucalyptus								
				Lopped	920	1188	920	1188
				Root pruned+ lopped	920	1228	920	1228
Anjan								
				Control	920	626	1546	626
				Root pruned	920	666	1586	666
				Lopped	920	791	1711	791
				Root pruned+ lopped	920	831	1751	831
				Sole crop (No trees)	1126	0	1126	0
				Control	920	626	1546	626
				Root pruned	920	666	1586	666
				Lopped	920	791	1711	791
				Root pruned+ lopped	920	831	1751	831
				Sole crop (No trees)	1287	0	1287	0
				Control	920	626	1546	626
				Root pruned	920	666	1586	666
				Lopped	920	791	1711	791
				Root pruned+ lopped	920	831	1751	831
				Sole crop (No trees)	1126	0	1126	0

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- 5 JAN 1996
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