STUDIES ON SILVICULTURAL AND ECOLOGICAL ASPECTS OF PROSOPIS JULIFLORA (SWARTZ) DC.

Thesis submitted in part fulfilment of the requirements
for the award of the degree of Doctor of Philosophy
(Agriculture) in Agronomy to the
Tamil Nadu Agricultural University,
Coimbatore.

By

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CERTIFICATE

This is to certify that the thesis entitled **"STUDIES ON SILVICULTURAL AND ECOLOGICAL ASPECTS OF PROSOPIS JULIFLORA (SWARTZ) DC."** submitted in part fulfilment of the requirement for the award of the degree of **DOCTOR OF PHILOSOPHY** (Agriculture) in Agronomy to the Tamil Nadu Agricultural University, Coimbatore, is a record of **bona fide** research work carried out by **Mr.V.CHELLAMUTHU** under my supervision and guidance and that no part of this thesis has been submitted for the award of any other degree/diploma/fellowship/other similar titles/prizes and that the work has not been published in part/full in any Scientific/Popular Journal/Magazine.

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PROSOPIS JULIFLORA

A POTENTIAL RENEWABLE SOURCE OF ENERGY AND BREAD WINNER FOR THE HUNGRY MILLIONS

ABSTRACT

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STUDIES ON SILVICULTURAL AND ECOLOGICAL ASPECTS OF PROSOPIS JULIFLORA (SWARTZ) DC.

By

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Degree : DOCTOR OF PHILOSOPHY (Agriculture) in Agronomy

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Investigation on the silvicultural and ecological aspects of **Prosopis juliflora** (Swartz) DC. were carried out both through field and pot culture experiments. Totally 13 experiments were conducted throughout the course of investigation.

Big sized seeds with 100 seed weight of 3.07 g sown at a depth of 2 to 4 cm resulted in early germination, shorter germination period, higher cumulative germination percentage and higher DMP of seedlings. Sowing hot water

treated seeds of **P.juliflora** upto 15 days after hot water treatment did give better germination indicating that such seeds could be kept for a fortnight without any loss of viability. DMP of above ground portion (Shoot) of six months old seedlings shall be taken as a scientific parameter for selecting better planting stocks of **P.juliflora**, instead of considering seedlings height alone.

Higher plant density of 4444 plants ha^{-1} (1.5 x 1.5 m) recorded higher total biomass compared to that of medium plant density of 2500 plant ha^{-1} (2.0 x 2.0 m) and lower plant density of 1600 plants ha^{-1} (2.5 x 2.5 m) in a short rotation energy plantation of 2.7 years. The total biomass production increased with the age of the first cut and coppicing duration at all the plant densities. The total biomass production was higher at the age of 15 MAP (months after planting) compared to 9 and 12 MAP. Similarly the total DMP was higher at longer coppicing duration of 12 MAFC (months after first cut) compared to 6 and 9 MAFC. Coppicing **P.juliflora** upto 15 MAP was not beneficial. For coppicing, the age of the crop must be definitely more than 15 MAP.

P.juliflora gave higher total biomass when grown in alluvial sandy soil and black soil than in red soil. Charcoal recovery increased with the increase in the diameter of **P.juliflora** fuelwood billets and the recovery was higher in root stocks than in the fuelwood billets of same diameter class (>10.5 cm).

Comparative performance of **P.juliflora** with other six MPTs (Multipurpose tree species) at 4th year revealed that in terms of total biomass ha^{-1}, the MPTs were in the order of **Eucalyptus tereticornis** > **Prosopis juliflora** > **Eucalyptus camaldulensis** > **Acacia nilotica** > **Azadirachta indica** > **Casuarina equisetifolia** > **Acacia leucophloea. Prosopis juliflora** was on par with both the species of **Eucalyptus**. However, considering the utilizable biomass yield (fuelwood), the MPTs were ranked in the order of **Eucalyptus camaldulensis** > **Eucalyptus tereticornis** > **Acacia nilotica** >**Prosopis juliflora** > **Casuarina equisetifolia** > **Azadirachta indica** > **Acacia leucophloea** wherein **Eucalyptus camaldulensis** and **Eucalyptus tereticornis** were comparable and they were significantly superior to other tree species. **A.nilotica** and **P.juliflora** were also comparable. The utilizable biomass (UB) of **P.juliflora** was 49.5, 48.7 and 11.7 per cent, respectively, lower than that of **E.camaldulensis, E.tereticornis** and **A.nilotica**. In **P.juliflora** basal diameter (BD) contributed more directly to UB and total biomass (TB) while branch number (BN) contributed more to the non-utilizable biomass (NUB). Both BD and BN were found to be important parameters for prediction of UB, NUB and TB of **P.juliflora**.

The nutrient uptake increased with the increase in UB in all the MPTs studied. Highest total uptake of macro as well as micronutrients were seen in both the species of **Eucalyptus**, followed by **P.juliflora**. The microbial population (bacteria, fungi and actinomycetes) was highest in the soil under **A.leucophloea** followed by **A.nilotica** and **P.juliflora**. Lowest microbial load was registered under **Eucalyptus camaldulensis** and **Eucalyptus tereticornis**. Similarly the understorey weed biomass was also lowest under them. The weed biomass was highest under **C.equisetifolia** followed by **Azadirachta indica**. The soil fertility in terms of soil organic carbon content, available NPK and micronutrients (Fe, Mn, Zn and Cu) had increased under the canopy of all the MPTs evaluated compared to the open field (control).

Except **C.equisetifolia**, all other MPTs put forth coppice shoots when cut at 4th year. In respect of coppice numbers per stool, the trees were ranked in the order of **P.juliflora >Azadirachta indica > Acacia nilotica > E.tereticornis > E.camaldulensis > A.leucophloea** but they were all comparable statistically except the last one. In terms of coppice height **E.camaldulensis** recorded significantly higher height growth compared to all other MPTs followed by **E.tereticornis**. **Acacia leucophloea** was the poor coppicer among the MPTs.

P.juliflora leaf litter inhibited the germination of blackgram, sorghum and **P.juliflora** due to its allelopathic effect of phenolic compounds. Allelopathic effect was persistent upto two weeks. Sowing blackgram and **P.juliflora** after one week and sorghum after two weeks of **P.juliflora** leaf litter incorporation found to mitigate the allelopathic effect. **Prosopis juliflora** leaf litter though found to be allelopathic in the initial stages, it added more of nutrients to the soil at later stages, a possible cause for increase in soil fertility under field conditions. **Prosopis juliflora** leaves were mineralized within 30 days of leaf incorporation. Bacteria and fungi were responsible for the degradation of **P.juliflora** leaf litter. **Prosopis juliflora** leaf litter mulch at one per cent level (W/W basis), root extract and leaf extract at five per cent concentration reduced the germination per cent as well as DMP of **Parthenium hysterophorus**. Fresh and dry leaf incorporation of **P.juliflora** into the soil reduced the population of root-knot nematode (**Meloidogyne incognita**) as well as their egg masses in the roots of tomato inoculated with root-knot nematode and resulted in an increase in fruit numbers and fruit yield per plant.

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CHAPTER I

INTRODUCTION

The genus prosopis consists of **44** species (Burkart, 1976) and accounts for one-third forest **area** in the world (Chojnacky, 1991). Globally it is used for **fuel**, charcoal and fodder. It is found to occur almost in all continents except the icy continent of Antartica.

In India, the current availability of fuelwood is about 58 million tonnes against the demand of about 157 million tonnes. Hence, there is a wide gap for fuelwood (Dayar and Singh Gurbachan, 1994). This gap is further widened with the increase in population. Considering this trend of fuel shortage, the FAO panel (FAO, 1977) and the National Academy of Sciences, Washington (NAS, 1980) had recommended fast growing **Prosopis** species for energy plantations in the arid and semi-arid regions of the world including India. Felker and Bandurski (1979) and Felker (1979), suggested that the **Prosopis** is the ideal tree legume for minimal energy input agriculture in semi arid regions.

About 175 million hectares of wastelands in India are of different categories (Puri and Viswanatham, 1988) with 4 million hectares of wastelands in Tamil Nadu. **Prosopis** species can be better exploited for fuel, charcoal and fodder in such of those areas, as it is an aggressive, fast spreading and highly adaptable species for all types of soil including saline and alkali soils, except cold desert and water stagnant areas (Troup, 1983; Singh Gurbachan, 1994). **Prosopis juliflora** is a versatile tree species that could come up almost in all categories of wastelands besides withstanding the biotic influence of people, goats, cattle, etc. Hence its establishment becomes easy in highly neglected as well as uncared wastelands of any category.

Eventhough the estimate of wasteland in Tamil Nadu is around 4 million hectares, the area under **Prosopis juliflora** has been roughly estimated to be 3 to 4.5 lakh hectares, that too mainly confined in five southern districts viz., Ramanathapuram, Pasumpon Muthuramalinga Thevar, Kamarajar, Chidambaranar and Nellai Kattabomman districts (Kondas, 1992). As fuelwood and charcoal, **Prosopis juliflora** offers employment to the tune of 6.34 million man days and 7.03 million woman days per annum in the above five districts (Kondas, 1992). These facts and figures imply the socioeconomic importance of this tree crop for Tamil Nadu.

In the survey conducted by the Department of Statistics, Tamil Nadu, it has been spelt out that about 53 per cent of total fuelwood in rural Tamil Nadu comes from forest tree species. Of which, **Prosopis juliflora** alone, as a single dominant species, accounts for 36.94 per cent, followed by **Acacia nilotica** (23.22 per cent), **A.planifrons** (6.4 per cent), **A.leucophloea** (4.85 per cent), **Casuarina equisetifolia** (3.79 per cent) and other species (24.79 per cent) (Dept. of Statistics, 1984). This again reiterates the importance of **P.juliflora** for rural Tamil Nadu.

Besides being fuelwood for household purposes, **P.juliflora** fuelwood is also being used extensively for brick kilns, tile works, lime kilns, blacksmithy and carpentry works (Kondas, 1992). It is not an exaggeration if we say that but for **Prosopis juliflora** the forest areas in the Western ghats of Tamil Nadu might have shrunken, inspite of the protective measures taken by the forest department. This is because **P.juliflora** acts as a buffer and protective forest along the boundaries of or adjacent to the reserved forests (Reynolds and Wood, 1977). **P.juliflora** also helps to maintain ecosystem of wastelands by giving a green cover over barren soils besides giving shelter for varieties of wildlives.

Against the importance of this tree, the policy makers provide little attention to maintain the genetic purity as well as to reduce the genetic erosion of **P.juliflora**. Wunder (1966) remarked that the discrimination of **Prosopis** species by many as 'not a forestry tree' and consequently the disregard of its many advantages, has resulted in the lack of research on this species. This is quite true under Indian conditions also. Lot of research work have been done on this tree from 1904 to 1980 in South and North American countries as evident from the bibliographic compilation by Pedersen and Grainer (1981). Still work is in progress with greater intensification on **Prosopis** species. In India, research work on **Prosopis** species is very much limited and that too restricted in Rajasthan and Gujarat states. Of late, CAZRI, Jodhpur; Central Soil Salinity Research Centre, Karnal and IGFRI, Jhansi are concentrating more on **Prosopis** species. In other parts of India, the work on **Prosopis** is yet to gain momentum. In fact seed to seed silvicultural/agronomical packages for **Prosopis** cultivation is not available.

Information on silvicultural aspects of **Prosopis juliflora** viz., scientific parameter for selection of better planting stocks; effect of seed sizes and depths of sowing on germination; germinability of hot water treated **Prosopis** seeds with lapse of time; biomass production potential of **Prosopis** in different soil types; effect of plant density, age of first cutting and coppicing duration on the biomass production of **Prosopis**; comparative performance of **Prosopis** with other multipurpose tree species; coppicing potential of **Prosopis**; Charcoal recovery from **Prosopis** fuelwood etc., are very much lacking. Similarly informations on the ecological aspects of **Prosopis juliflora** viz., allelopathic effect; dynamics of understorey vegetation; soil fertility and nutrient cycling; microbial load in soil and leaf litter; exploiting allelopathy for biocontrol of pests including weeds are very less.

Hence, considering the importance of **P.juliflora**, especially for Tamil Nadu, studies on the silvicultural and ecological aspects of **Prosopis juliflora** were undertaken at the Tamil Nadu Agricultural University, Coimbatore. The studies comprised of 13 experiments with the following major objectives.

* To find out the relationship between root and shoot length and also between root and shoot weight of **P.juliflora** seedlings.

* To compare the growth, biomass production and wood density of **P.juliflora** with other multipurpose tree species (MPTs).

* To develop linear regression models for prediction of biomass in **P.juliflora** and other MPTs.

* To find out the effect of different plant densities, ages of first cutting and coppicing durations on the biomass production of **P.juliflora** under short rotation of 2.3 years.

- To find out the influence of different soil types on the biomass production of **P.juliflora**.

- To find out the charcoal recovery from different diameter classes of **P.juliflora** fuelwood.

- To develop silvicultural practices like seed germinability under different conditions.

- To study the allelopathic effect of **P.juliflora** leaf litter and plant extracts on the germination and DMP of test crops.

- To study the effect of leaf litter and plant extracts of **P.juliflora** on the germination and DMP of weeds and control of root-knot nematodes in tomato.

- To find out the time needed for mineralization of **P.juliflora** leaf litter in the soil.

- To find out the soil fertility changes due to **P.juliflora** leaf litter addition.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

More than 70 per cent of the total cultivable area in India is under rainfed agriculture, where crop production is dictated by vagaries of monsoon rainfall. In majority of these areas frequent crop failures are not uncommon. Tree cropping may form an alternative for these areas as a component of agroforestry systems. In the wastelands, especially degraded, saline and alkali lands, **Prosopis juliflora** is found to colonise aggressively in nature. Though **Prosopis** is the main source of fuelwood in many parts of India, its pods also are used as animal feed, especially for sheep and goats. Its value as a potential source of charcoal adds further to this tree crop. Its viability in agroforestry and energy plantations has not been fully exploited and understood. Research work conducted on this tree crop is reviewed and presented in this chapter.

2.1. The genus Prosopis

2.1.1. Description and origin

The genus **Prosopis** belongs to the family leguminosae (sub-family : Mimosoideae). The genus represents 44 species in nature and occur both in arid and semi-arid regions of the world (Burkart, 1976). The members of the genus **Prosopis** are called 'mesquite' or 'screw beans' in

North America and 'algarrobo' in South America (Robelo, 1948. p. 548 as quoted by Simpson and Solbrig, 1977). **Prosopis** is basically a new world species, its native home has not been clearly identified. Kaul (1956) and Duthie (1960) reported that **Prosopis** was indigenous to Central America. But Burkart (1976) proposed that the genetic centre of **Prosopis** was in South America.

2.1.2. Distribution of Prosopis in the world

Prosopis species are seen in lower California, Southern Colorado, Utah, Arizona, Texas and Northern Mexico extending upto Argentina, Southern Brazil, Republic of Chile and drier parts of the islands of Jamaica. It was successfully grown in arid tracts of Asia, Australia, South Africa and Sudan where the rainfall varied from 4 to 8 inches per year (Raizada and Chatterji, 1954, Burkart, 1976). Of the 44 species reported, 35 are found in South America, three species (**Prosopis cineraria, P.farcta** and **P.koelziana**) occur in Asia and Africa and one species viz., **P.africana** in Africa (Burkart, 1976).

The geographical area under **Prosopis** is not exactly known in view of its dynamic fast spreading nature on the one hand and its indiscriminate continued exploitation for fuel, charcoal etc., on the other hand. **Prosopis** is reported to occur in an area of over 30 million hectares in semi-arid areas of Oklahoma, Texas, New Mexico, Arizona, Nevada and California (Parker and Martin, 1952. p.70). Though **Prosopis** grows extensively in semi-arid regions of Argentina, Chile, Venezuela, North East Africa, the Middle East and India (Griffith, 1961), area under **Prosopis** cultivation has not been quantified so far.

2.1.3. Botanical and taxonomical exploration of Prosopis

The earliest botanical account of **Prosopis juliflora** (Swartz) DC. was published in 1788 by the Swedish traveller Swartz, who found natural vegetation of the **Prosopis** in jamaica (Raizada and Chatterji, 1954). Later there was a lot of confusion in distinguishing different species of **Prosopis** until 1975. This confusion was cleared with the detailed taxonomical publication of Burkart (1976). His monograph on the genus **Prosopis** is the only taxonomical reference available as on date.

2.2. Introduction and distribution of Prosopis juliflora (Swartz) DC. in India

Introduction of **Prosopis** to India was reported as early as 1857 from Mexico (Gupta and Balara, 1972) and 1878 from Kew (Raizada and Chatterji, 1954). Confirming this, Konda Reddy (1978) stated that **Prosopis** was introduced during 1876 at Camalapur of Cuddapah district in the old Madras Presidency by Lt. Col.R.H. Beddome, conservator of forests, and from there it had spread to other parts of India. On the contrary, Kaul (1956) was of the opinion that it was first introduced in Sindh during 1877. Later, Rawat **et al**. (1992) reported that **Prosopis** was first introduced in Punjab during 1875 and from there it had spread to other parts of India. Though reports on the first introduction of **Prosopis juliflora** varied, it can be generalised that it was introduced during 1870's in India. The indigenous **P.cineraria** was existing in India long before the introduction of **P.juliflora**, which was introduced mainly because of its fast growth and wider adaptability than that of indigenous **P.cineraria**.

Though **Prosopis juliflora** was exotic (Verma, 1987), it was declared as the 'royal plant' in 1940 by the former Jodhpur state and it was placed under government protection (Kaul, 1956). Different morphological variations were reported in India among the natural stand of **P.juliflora** and the attributed reason was the existence of five different forms viz., Argentine form, Arid form, Mexican form, Peruvian form and Australian form (Raizada and Chatterji, 1954). At present very prolific and predominant growth of **Prosopis** is found in Rajasthan, Gujarat, Punjab, Haryana, Uttar Pradesh, Karnataka, Andhra Pradesh, Orissa, Tamil Nadu and West Bengal (NAS, 1980).

2.3. Socioeconomic importance of the genus Prosopis

Prosopis species is one among the members of the leguminosae family and this family accounts for nearly one-third of the world's forest (Chojnacky, 1991). This is mainly due to its multipurpose use and wider adaptability.

2.3.1. Fuelwood and Charcoal

2.3.1.1. Fuelwood

Prosopis was a very suitable fuelwood in view of its high calorific value of 8050 BTU per pound (Singh Gurbachan and Singh, 1993). The fast growing **Prosopis** species were recommended all over the world to meet fuelwood demand (NAS, 1980. p. 237). More than 1.5 billion people in the developing countries depend on wood and charcoal for cooking and heating (Arnold and Jongma, 1978).

2.3.1.2. Charcoal

Charcoal is the residue of wood as a result of heating it to high temperature in a closed space without free access of air and allowing to cool on its own without entry of air. During the process, wood becomes bone dry at 110°C and further rise to 300°C initiates pyrolysis, which breaks down the wood into water vapour, gases, wood acids and tars with the evolution of heat resulting in charcoal. Good commercial charcoal contains 72 per cent fixed carbon, 17 per cent volatiles, 8 per cent moisture and 3 per cent ash. Charcoal is commonly used for drying, raising steam and smelting metals in steel and polyfibre industries. It is used in carbide and ferro-silicon industries. The broken pieces of charcoal and its powders are used for agarbathi manufacturing. Charcoal is a much sought after fuel in houses (Kondas, 1992).

2.3.2. Timber

The potential of **Prosopis** as a construction timber has not gained momentum because of poor tree form with crooked branches as well as lack of long straight trunks or stems (Leakey and Last, 1980). But considering its quality in terms of striking grains and polish (Sekhar, 1955), its timber value was equated to that of walnut, rosewood or mahogany in certain parts of the world (Dobio, 1943 as quoted by Verma, 1987). In South Western parts of the US, **Prosopis** was one of the chief sources of wood for making furniture, floorings, sports goods and craft articles (Singh Gurbachan and Singh, 1993).

In India, **Prosopis** timber was mainly accepted for making fence post and small pilings (Verma, 1987). If teak is considered as the royal timber, then **Prosopis** is to be considered as loyal timber for the poor in India (Konda Reddy, 1978).

2.3.3. Feed and forage for animals

Due to high phenolic content in the leaves of **Prosopis juliflora** it is not liked by the cattle (Lyon **et al.**, 1988). But the leaves of **P.cineraria** (indigenous to

India) are relished by sheep, goats, cows and camels (Bohra, 1980; Srivastava and Hetherington, 1991). The pods of all the **Prosopis** species including **Prosopis juliflora** are relished by the animals (Felker, 1981; Talpada and Shukla, 1992) as they contain 12 to 14 per cent crude protein, 20 to 30 per cent sucrose (Figueirdo, 1975), 44 to 55 per cent carbohydrate (Contreras, 1978; Felger, 1979) and amino acids to the magnitude of 0.11 to 1.54 per cent (Talpada and Shukla, 1988) besides considerable quantity of micronutrients (Talpada, 1988). The feeding of **Prosopis juliflora** pods at 15 to 30 per cent of body weight was found to be safer and reduced the cost kg^{-1} of milk production by about 5 to 10 per cent, respectively (Talpada, 1988).

2.3.4. Human use

2.3.4.1. Food

The pods and seeds of many **Prosopis** species including **Prosopis juliflora** were consumed by the West Indians and white pioneers either as raw or after processing. The flour of **Prosopis** pods and seeds was used for bread making and it formed a staple desert food (Forbes, 1895; Felger, 1979). **Prosopis** pods and seeds form food of the human since seeds contain 34 to 39 per cent protein and 7 to 8 per cent oil (NAS, 1979). It also contains 15 types of amino acids (Beri **et al.**, 1982). The protein quality of **Prosopis** was reported to be comparable with those of maize, rice and certain beans (Felker, 1981).

2.3.4.2. Honey

The honey extracted from **Prosopis** species was reported to be of superior quality with attractive flavour (Verma, 1987). In India, about one lakh kilogram of honey came annually from the **Prosopis** infested Kutch district of Gujarat (Verma, 1987), where **Prosopis juliflora** is the predominant tree.

2.3.5. Biochemicals, industrial products and medicinal value of Prosopis

2.3.5.1. Biochemicals

Many types of biochemicals viz., tannin (Doat, 1978), ellagic acid glycocides (Malhotra and Misra, 1981), amino acids (Beri **et al.**, 1982), steroids (Pant and Bishnoi, 1982), alkaloids (Ahmad **et al.**, 1989), phenols (Pancholy **et al.**, 1989; Ikramov **et al.**, 1990), growth regulators like triacontanol (Khan **et al.**, 1992) etc., were reported to be present in different **Prosopis** species.

2.3.5.2. Industrial product

The potential of obtaining several industrial products such as alcohol, gums, cocoa powder substitute and sweetening agents from pods of **Prosopis** species was reported (CENDES, 1981 as reported by Marangoni and Alli, 1988; Anderson and Wang, 1989).

2.3.5.3. Medicinal value

In India **Prosopis cineraria** was used as indigenous medicine for rheumatism and also against miscarriage (Chopra **et al.**, 1956). Some of the alkaloids of **Prosopis** species were reported to be antifungal (Ahmad **et al.**, 1989) and antibacterial (Zainal **et al.**, 1988).

2.3.6. Paper making

In India, laboratory and pilot studies had shown that writing and printing papers could be produced from **Prosopis juliflora** logs (30 to 50 cm in girth with 50 per cent cellulose and 30.9 per cent lignin). As the wood was very crooked, difficulties were observed in chipping (Guha **et al.**, 1970).

2.3.7. Shelterbelts

Prosopis juliflora alone as well as in combination with other tree species is found to be a very good candidate for shelter belt (Rao, 1964) for conserving soil and moisture besides increasing crop yields to some extent (Prajapati and Nambiar, 1977; Gupta and Ramakrishna, 1988). It also increased the WUE of different crops (Mertia **et al.**, 1988).

2.3.8. Agroforestry

A dual cropping system of **Prosopis juliflora** and **Hordeum vulgare** (barely) was reported in Arizona, where barley was raised as intercrop in both summer and winter rainy seasons (Fowler and Ffolliot, 1986).

Prosopis cineraria was a promising agroforestry tree in many parts of Rajasthan (Shankarnarayan **et al.**, 1987; Puri and Bangarwa, 1992) and it was also a suitable component for silvipasture systems (Chouhan **et al.**, 1992) because of less allelopathic effect. **Prosopis juliflora** intercropped with Karnal grass (**Diplachne fusca**) in a highly sodic soil (ESP 94) at Karnal was found to be the best biological means to reclaim the sodic soil economically (Singh Gurbachan and Singh, 1993). Under this system both fuelwood and green grass were obtained besides great improvement in soil fertility. **Prosopis juliflora** as a major component in agroforestry was recommended for reclamation and profitable return from alkali soils (Ahmad, 1991), salty lands and semi-arid lands (Singh Gurbachan, 1994).

2.3.9. Bioconservation in arid regions

In new Mexico, **Prosopis juliflora** seeds were the principal food of the quail (**Callipepla sqamata**) (Davis **et al.**, 1975). **Prosopis** leaves, flowers, pods and seeds were important source of food for varieties of insects (Cates and Rhoades, 1977; Simpson **et al.**, 1977) and animals, including small to big mammals (Kingsolver **et al.**, 1977; Mares **et al.**, 1977). **Prosopis** leaves and pods in wilderness was a food for deers (Beason **et al.**, 1982). Many species of insects, snakes, lizards and wild animals like jackals, wolves, hares etc., got shelter under **Prosopis** due to its dense growth and shade (Sharma, 1981). In widespread thickets of **Prosopis** species, 20 to 40 per cent more rain was reported than the open area and 4 to 7°C reduction in temperature under **Prosopis** over the open area was observed (Sharma, 1981).

2.4. Ecological aspects of Prosopis

2.4.1. Soil

Though **Prosopis** came up in a wide range of soils from salt deserts to fertile alluvium (Troup, 1983. p. 126-137; Vimal and Tyagi, 1984. p. 117-142), it was very invasive and prolific only when the soil was relatively deep with ground water very nearer to the surface (Harding and Bate, 1991). It was found to adapt to non-humus nitrogen-less soil; being a legume it derived its own nitrogen requirement through fixation (Coventry, 1922).

2.4.2. Climate

In Western Rajasthan **Prosopis juliflora** seedlings frequently suffered from frost injury, whereas **Prosopis cineraria** was frost resistant (Muthana, 1977). Some of the accessions of **Prosopis** species were found to tolerate varying degree of cold and frost (Felker **et al.**, 1982a). **Prosopis** was not only confined to the low rainfall arid regions, but also in areas of significantly higher rainfall in South Africa (Harding and Bate, 1991).

It has been found to tolerate a temperature level upto 46°C. Greatest growth of **Prosopis** seedlings was observed in full sunlight compared to shade (Bush and Auken, 1990) as it was a great demander of light (Coventry, 1922).

2.4.3. Adaptation

Mesquite roots, under dry situations, were found commonly upto 7m depth and occasionally observed upto 18m depth (Meinzer, 1927), a typical pheratophytic adaptation (Robinson, 1958). Under certain situation the roots of **Prosopis** were found upto 50m depth (Philips, 1963). The lateral roots were recorded upto 48m in a shelter belt plantation of **Prosopis juliflora** (Prajapati **et al.**, 1971).

The smaller leaves of **Prosopis** were found to reduce the heat load (Martin, 1943; Mooney **et al.**, 1977) in day time when the insolation was higher and during night time the smaller leaves with unusual epicuticular configurations (Hull and Bleckmann, 1977) were able to trap atmospheric moisture (Sudzuki, 1985) and dew (Anderson, 1988). The presence of polyanions in the stomata (Serrato Valenti **et al.**, 1989) in the walls of special cells were found to be helpful for trapping the moisture and dew.

Prosopis was found to behave like a 'xerophyte', though it was not strictly so, due to its smaller leaves, spines etc., a typical adaptation under arid condition. It was considered a 'halophyte' as it could tolerate salinity equivalent to sea water (Felker **et al.**, 1981b). **Prosopis** was found to behave like a 'pheratophyte' as it was able to draw water from deeper soil layers through its deep root system when the water table is very low. It was also found to be a 'facultative pheratophyte' in sites with shallow water table, as it mostly depends on its lateral roots to absorb water under such condition (Ansley **et al.**, 1990).

2.4.4. Phytosociology of Prosopis

2.4.4.1. Understorey vegetation

Only few plants of **Tephrosia purpurea, Dactyloctenium sindicum** and **Peristrophe bicalyculata** were found to be present, with reduced ground cover of only 0.18 to 0.25 per cent, under **Prosopis juliflora** (Lahiri and Guar, 1969).

At CAZRI, Jodhpur, maximum number of annuals and perennials came up well under **Prosopis cineraria** as compared to **Prosopis juliflora** under similar soil and climatic conditions (Aggarwal **et al.**, 1976).

In Savanna woodlands of Southern Texas, the establishment of other woody species under mesquite was found to occur within 10 to 15 years. The understorey species richness increased rapidly for 35 to 45 years and became asymptotic afterwards (Archer, 1989).

2.4.4.2. Associative Vegetation

The associative vegetation with **Prosopis** species in natural environment was found to differ with climatic and edaphic factors. At San Diego, Chile, mesquite had grown in association with live oak (**Quercus agrifolia**). In USA, **Prosopis** species were found growing in association with other trees like **Acacia redolens, Acacia salicina, Eucalyptus microtheca, Nerium oleander** etc., in free way landscape (Niemiera and Goy, 1990). In Ennore backwaters of Madras coast, **Prosopis cineraria** had come up well in association with some mangrove species (Selvam **et al.**, 1991). **Prosopis cineraria** was also found to grow with **Opuntia monocantha** in the adjoining mangrove forest of Cauvery basin in Muthupet (Gunasekaran **et al.**, 1992). The association of **Prosopis cineraria** with **Azadirachta indica** has been reported in CAZRI campus (Arya **et al.**, 1992). Such reports are not available for **Prosopis juliflora.**

2.4.5. Prosopis-nematode complex

The number of nematodes found in mesquite infested soil was within the range of values as reported for other woody species in desert ecosystem (Freckman and Virginia, 1989; Virginia **et al.**, 1992). The density of plant-feeding nematodes was significantly correlated with total N, NH_4^+ and extractable P of soil under **Prosopis** (Virginia **et al.**, 1992). The nematodes had been found to increase the mineralization of N and P of the soil under **Prosopis**, even though the bacterial populations were less. This has been attributed to the grazing of rhizosphere microflora by the nematodes and microarthropods (Setala and Huhta, 1991).

In **Prosopis chilensis** seedlings, gall formation on the roots, upto 15 to 50 per cent, was reported due to two species of root-knot nematode viz., **Meloidogyne javanica** and **Meloidogyne** species in the nursery in U.P. (Mehrotra and Sharma, 1990; 1992). However, no extensive damage was observed in **Prosopis** elsewhere.

2.5. Silvicultural aspects of Prosopis

2.5.1. Phenology

Prosopis juliflora was reported to be an evergreen or semi-ever green tree (Troup, 1983. p. 126-137). In general, flowering occurred twice a year. First flowering was found from September to October while the second flowering had been noticed from February to March. Occasionally third flowering occurred between June and August in some forms of **Prosopis**. Similarly pod ripening was observed from November to January, April to June and September to November, respectively, for the first, second and third flowering phases (Troup, 1983. p. 126-137, Talpada and Shukla, 1992).

Maximum fruiting was seen from first flowering (49.20 per cent), followed by second flowering (45.30 per cent) and least in third flowering (5.50 per cent) under North Indian situations (Talpada and Shukla, 1992).

In Tamil Nadu, it was found that the pods attained physiological maturity 91 days after anthesis in **P.juliflora** (Masilamani, 1992). High variability in respect of branching, flowering, number of seeds per pod, pod length and seed weight was observed in **Prosopis** species (Peinetti **et al.**, 1991). Morphological variations in pod and seed characteristics had also been reported due to geographical locations (Masilamani, 1992; Manjit Singh **et al.**, 1993).

2.5.2. Seeds

2.5.2.1. Viability and vigour

Mesquite seeds were found to remain viable in the soil for 10 years and even upto 50 years when put under dry storage (Reynolds and Glendening, 1949). Seeds of **Prosopis juliflora** collected from the middle position of the pod was found to be more vigorous compared to that from proximal and distal position (Masilamani, 1992).

2.5.2.2. Seed germination Vs Scarification techniques

2.5.2.2.1. Dry method

Shaking the seeds of **P.juliflora** for 10 to 15 minutes in a metal or glass containers resulted in 95 per cent germination (Nambiar, 1944). Scarification of seed by pounding them with sand was also found to give more germination (Khudari, 1956). Nelson **et al.** (1978) observed increased germination by exposing the **Prosopis** seeds to various periods of radio frequency. But while subjecting the **P.juliflora** seeds to different doses of gamma rays (5 to 60 Krad) the germination did not improve; at higher doses (50 to 60 Krad) the survival percentage of seedlings was slightly affected (Goel, 1987a).

2.5.2.2.2. Wet method

Simply immersion of **Prosopis** seeds in cold water for 24 hours slightly improved the germination (Griffith, 1945) and soaking for 72 to 96 hours resulted in 75 per cent germination (Marmillon, 1986). Seed soaking in hot water or boiling water for 24 hours gave higher germination percentage (Ffolliot and Thames, 1983a). Cowdung curing of seeds for 49 days was found to give 95 per cent germination (Rawat **et al.**, 1992).

Acid scarification gave better results than mechanical scarification and hot water treatment (Flynt and Morton, 1969). Treating with 0.1N HCl for 24 hours gave better results (Vasavada and Lakhani, 1973). By treating with acid the seed coat permeability was increased (Mahmoud and El-Sheikh, 1978).

Similarly treating the **Prosopis** seeds with concentrated sulphuric acid for 10 minutes (Nimbal **et al.**, 1990; Pharande **et al.**, 1990) and for 24 minutes (Lopez and Aviles, 1988) had resulted in higher germination percentage.

2.5.2.2.3. Germination period

Studies at CAZRI, Jodhpur revealed that upto 4th day of sowing there was no germination of **Prosopis** seeds. The germination was very slow during the earlier stages but between 6th and 9th day of sowing maximum germination was recorded. The total germination percentage recorded after 17 days of sowing was 67 per cent (Gupta and Balara, 1972).

2.5.2.3. Seed germination Vs agronomic practices

Direct sowing of **Prosopis** seeds in pits, trenches, contour ridges, contour ploughed furrows etc., was the very practical way when large area is to be sown for afforestation programmes (Kaul, 1956). Direct sowing gave only 50 per cent survival after three months (Marmillon, 1986).

Soil type is also found to influence the germination of seeds. Kuleshov (1946) reported that light loam soils gave better germination than medium and heavy loam soils. Studies in Iraq with sand, clay and loamy soils had shown that sandy soil was the best medium for germination; loamy soil was better for seedling growth for the test crop of **Prosopis juliflora** (Al-Kawaz and Allawi, 1989).

Depth of planting and temperature was found to play major role in radical emergence in **Prosopis** (El-Sharkawi **et al.**, 1989). The optimum temperature for germination was about 28^{o}C for **Prosopis** species (Scifres and Brock, 1970). The same authors stated that some pre-treatment of soil by ridging was advantageous for seedling survival, especially for hard soils.

Fertilizer application was another aspect influencing germination and growth of seedlings. N application did not influence the hypocotyl emergence in **P.juliflora** (El-Sharkawi **et al.**, 1989). Soil moisture was also one of the important criteria for germination of **Prosopis** seeds. An irrigation interval of one day was recommended for better germination of seeds, survival and growth of **P. tamarugo** seedlings (Al-Kawaz and Allawi, 1989) although the seedlings exhibited drought resistance characteristics at different degrees when irrigated at 2, 3 and 4 days interval.

Regeneration of **Prosopis** using seeds in animal droppings is a common practice in Sudan (Ahmed, 1986) and Argentina (Marmillon, 1986).

2.5.3. Seedling establishment

2.5.3.1. Methods of planting

Site preparation to produce saucer-pits, ridges and furrows was successful for establishing **P.chilensis** in Sudan (Ahmed, 1986). In Arizona, water harvesting technique using microcatchments had increased the survival of **Prosopis** (35.8 per cent) than without microcatchment (Fowler and Ffolliot, 1986).

Mesquite growth was better when planted by auger hole (15 x 90 cm) and pit (30 cm^3) method over trench method (30 x 30 x 24 cm) of planting in a highly sodic soil (ESP 94), when filling was done with a mixture of original soil, 3 kg gypsum and 8 kg FYM per plant (Singh Gurbachan and Singh, 1993).

2.5.3.2. Planting depth and irrigation

Planting depth and irrigation were found to affect seedling survival of **Prosopis**. Studies in Iraq revealed that planting seedlings at 70 cm depth gave higher survival percentage compared to 30 and 50 cm planting depths. Irrigation at 15 days interval was the best compared to 30 and 45 days interval (Al-Kawaz and Allawi, 1990). Frequent irrigation in early stages tended to make the **Prosopis** bushy (Troup, 1983. p. 126-137).

2.5.3.3. Planting material

Transplanting of one year old seedlings after root pruning (Keeping about 1 1/2 feet root and pruning all side roots) was also found to establish well when it was planted on the same day (Kaul, 1956). Successful establishment of **Prosopis** plantation using seedlings raised in earthern pots (Rao, 1964) and polypots (Marmillon, 1986) was reported.

Planting pre-rooted stumps of one year old was also found to have good sprouting and survival in adverse condition (Jha and Choudhary, 1990).

2.5.3.4. Age of seedlings

Under rainfed conditions transplanting of 9 to 12 months old **Prosopis** seedlings rather than direct sowing of seeds was better (Muthana **et al.**, 1976). Three to six months old seedlings had established successfully in sodic soils with the addition of amendments (Singh Gurbachan **et al.**, 1988).

2.5.3.5. Vegetative propagation

2.5.3.5.1. Cuttings

Propagation of **Prosopis juliflora** through branch cutting was found possible. But it took long time to sprout, needed very frequent watering and were susceptible to white ant attack besides very low sprouting and survival percentage (Kaul, 1956). Better sprouting and survival of root and shoot cuttings had also been reported (Felker and Clark, 1981; Dick **et al.**, 1991; Sandys-Winsch and Harris, 1991).

2.5.3.5.2. Grafting and air layering

Success in grafting of **Prosopis** species had also been observed. In a grafting study, eight years after grafting, scions from thornless branches remained thornless; whereas scions from thorny branches remained thorny (Wright,

1976. p. 130- 133). Air layering of **P.juliflora** without using growth regulator has been reported by Kurian **et al.** (1983).

2.5.3.5.3. Tissue culture

Vegetative propagation through tissue culture had been attempted in **P.juliflora, P.cineraria** and **P.tamarugo** (Goyal and Arya, 1984; Jordan, 1988). But it was success in laboratory condition. Still there are many barriers for success under field conditions (Nandwani and Ramawat, 1992).

2.5.4. Biomass productivity of Prosopis

Prosopis juliflora is considered as an excellent candidate for short rotation energy plantations considering its fast growing nature and higher biomass production with good coppicing potential.

2.5.4.1. Comparative performance of Prosopis

Comparative evaluation of **Prosopis** species with **Leucaena leucocephala** and **Parkinsonia aculeata** in a green house experiment in California revealed that some of the **Prosopis** selections had greater productivity than the above two genus (Felker **et al.**, 1983a).

In Gujarat, three years old plantations of **P.juliflora** was found to produce a total biomass of 114 dry tonnes (dt) ha^{-1} which was on par with **Dalbergia sissoo** under same environment (Kimothi **et al.**, 1983. p. 135-153).

In an another energy plantation at Gandhinagar, Gujarat, **P.juliflora** ranked first amongst the high biomass producing native trees of arid and semi-arid regions of India.

At the age of 18 months **P.juliflora** produced the highest biomass of 19 dt ha^{-1} as against 13.6 dt ha^{-1} of **Eucalyptus** under similar edaphic and climatic conditions. In the same plantations at the end of fifth year, **Prosopis** produced a total biomass of 167.2 dt ha^{-1} as against **Albizia lebbeck** (66.3 dt), **Dalbergia sissoo** (82.0 dt), **Eucalyptus hybrid** (83.4 dt), **Cassia siamea** (85.4 dt), **Acacia nilotica** (113.5 dt) and **A.tortilis** (116.9 dt) under rainfed condition (Gurumurti **et al.**, 1984).

The highest yield of **Prosopis** was attributed to its ability for higher solar energy conversion efficiency, which was 0.59 per cent at 18th months to 1.68 per cent at 48th months with a peak value of 1.87 per cent at 36 months (Gurumurti **et al.**, 1984).

The higher biomass production potential of **Prosopis** was comparable with that of C4 pathway plants that fixed Co_2 effectively during photosynthesis. This pathway which was found to operate in sugarcane, sorghum, maize etc., had, however, been not reported in any of the trees (Mathur **et al.**, 1984).

2.5.4.2. Intra and inter-specific variations in biomass productivity of Prosopis

For a range of **Prosopis** varieties, yield variations from 13 to 8000 kg ha^{-1} was also on record (Ahmed, 1961). Ecologists have reported that net primary productivity of **Prosopis** dominated ecosystem in India receiving 360 mm annual rainfall to be 14500 Kg ha^{-1} (Murphy, 1975). Annual yield of **P.juliflora** was found to vary from 3 to 5 m^3 ha^{-1} (Webb **et al.**, 1980).

Nearly 20 to 30 fold difference in biomass productivity was observed among different accessions of **Prosopis** species in Texas (Felker **et al.**, 1981a; 1983b). In a two years old **Prosopis** plantation, planted at a uniform spacing of 1.5 m, there was wide variation in the biomass productivity of **Prosopis** species (7 to 14.5 dt ha^{-1} $year^{-1}$) in California (Felker **et al.**, 1983a).

In Northern Chilean salt desert, **P.tamarugo** was found to produce 14000 kg ha^{-1} $year^{-1}$ including leaves and pods (Salinas and Sanchez, 1971). A stand of **P.glandulosa** near the Salton sea, California, had produced 13000 kg ha^{-1} above ground biomass with a productivity of 3700 kg ha^{-1} $year^{-1}$ (Rundel **et al.**, 1982).

Wide variations in productivity of **Prosopis** species had been greatly attributed to variations in management practices (Esbenshade, 1980), genetic materials

(Felker **et al.**, 1981a), soil fertility and rainfall or soil moisture (Wightman and Felker, 1990).

2.5.4.3. Effect of silvicultural practices on biomass production of Prosopis

2.5.4.3.1. Plant density Vs biomass

The tree biomass yield of fully stocked stands was independent of the number of stems ha^{-1} over a wide range of spacing in accordance with the 'law of constant final yield' of Hozumi **et al.** (1956). In some tree species, increasing plant densities was found to increase the current drymatter increment passing to the stem (Mitchell, 1975) and the total wood biomass yield was asymptotically related to planting density (Ek and Dawson, 1976). In **P.juliflora**, the DMP tree^{-1} was higher under closer spacing of 1 x 1 m (10000 plants ha^{-1}) than under wider spacing of 2 x 1 m (5000 plants ha^{-1}) (Singh Gurbachan and Singh, 1993).

2.5.4.3.2. Irrigation Vs biomass

At California, 40.3 dt ha^{-1} in 2.5 years with three season total irrigation plus rainfall of 1390 mm had been reported (Felker **et al.**, 1983b). Depending on the species, 5 to 10 times increase in the biomass of **Prosopis** had been reported under irrigated condition (Johansson **et al.**, 1990).

Prosopis juliflora planted at 1 x 1 m (10000 plants ha^{-1}) produced 39 kg DM $tree^{-1}$, while at 2 x 1 m (5000 plants ha^{-1}) the DM accumulation was 32.2 kg $tree^{-1}$, after 7 years, under irrigated conditions (Singh Gurbachan and Singh, 1993).

2.5.4.3.3. Intercropping Vs biomass

Yield reduction due to intercropping has been reported in **Prosopis**. When karnal grass was intercropped with **Prosopis juliflora**, planted at 2 x 2 m, 3 x 3 m and 4 x 4 m spacing, three-fold reduction in biomass of **Prosopis** was recorded due to grass in two years old crop (Singh Gurbachan **et al.**, 1988). In the same studies, the lateral branches of **Prosopis** were lopped to facilitate better grass growth. The lopped biomass of **Prosopis** was higher under 2 x 2 m spacing compared to 3 x 3 m and 4 x 4 m spacings both at 16th and 40th months after planting.

2.5.4.4. Partitioning of biomass

In **P.glandulosa**, 51.5 per cent of the total biomass was allocated to trunk and branches and 33.6 per cent to leaves in Sonaran desert of California (Sharifi **et al.**, 1982). At the age of 3 years, **P.juliflora** which produced 114 dt ha^{-1} was found to accumulate 88.87 dt ha^{-1} in stems and branches as utilizable biomass (Kimothi **et al.**, 1983).

2.5.4.5. Production strategy for higher biomass in Prosopis

After considering the wide variations in the biomass production of **Prosopis**, Felker **et al.** (1983a) suggested a production strategy of employing clonal materials of **Prosopis** at 3 x 3 m spacing, for three years harvest cycle (rotation), to derive 45 kg DM tree^{-1} and a resultant production of 50 dt ha^{-1} at the end of third year and subsequent 3 years rotation for coppice growth.

2.5.4.6. Coppicing

Coppice method of regeneration of plant was most promising for short rotation intensive culture (SRIC) because it allowed at least for a limited number of years and for repeated harvesting at short intervals and exploitation of exceptionally high-early growth rates (Blake, 1980).

In forestry literature, the term coppice used as noun is referred to the shoots or sprouts that develop on a stump following cutting. Used as a verb, the term refers to the act of cutting trees under a coppice silvicultural system to promote regeneration from the stem sprouts (Blake, 1983).

In **P.cineraria**, annual lopping resulted in maximum forage yield without detriment to its growth. The forage yield from trees below 45 cm girth was significantly low, suggesting a lower girth limit for the trees to be lopped (Srivastava, 1978). **P.juliflora** was found to withstand annual coppicing from the second year of planting (Tiwari, 1983).

Seasonal influence on the lopped forage yield in **P.cineraria** was observed. Lopping in spring and summer was found detrimental. Winter was found to be the ideal season for lopping as it had given not only good quality fodder but also boosted up the plant height and bole diameter of trees. One year rest period was found essential for sustained forage yield (Sharma and Gupta, 1981).

Pruning or topping of shoot tip in young plants of **Prosopis chilensis** increased the number of branches and biomass of stem and leaves, but reduced the length of branches resulting in bushy appearance. By pruning, the biomass production was increased by 147 per cent over control (Kathiresan and Kumaravel, 1990).

An increase in tree diameter was observed 31 months after pruning, with chain saw, to single stem and one per cent NAA application in **P.glandulosa**. Pruning improved tree form and **P.glandulosa** was found to have potential as lumber producing trees suited to xerophytic regions of South West USA (Meyer and Felker, 1990).

For **P.juliflora**, scientific information on coppicing age, coppicing interval (rotation), optimum stump height for coppice, season of coppicing, yield of coppicing etc., are lacking.

2.5.5. Water relations of Prosopis

2.5.5.1. ET Vs water table

The ET of mesquite was found to vary between 3.8 and 10.4 mm day^{-1} during May and June, respectively, in Arizona valley (Anderson, 1970). Diurnal water table fluctuations under mesquite vegetation of 80 per cent canopy cover was found to be 30 mm in USA. The water table beneath mesquite decreased as ET increased (Tromble, 1977).

2.5.5.2. ET Vs water potential

The leaf water potential of pheratophytic trees was found to be due to the combined result of ground water availability and transpiration from the leaves (Nilsen **et al.**, 1991). Water limitations had induced an increase in fruit production in **P.glandulosa** (Nilsen **et al.**, 1991). Positive relationship between water availability and transpiration (Cuomo **et al.**, 1992), pre-dawn leaf water potential and daily stomatal conductance were established in **Prosopis** species (Ansley **et al.**, 1992).

2.5.5.3. Seasonal variations in water use

Seasonal variations in water use has been reported and maximum loss was found during November under North

Indian condition in **P.cineraria** and **P.juliflora** (Mathur and Sen, 1972).

2.5.5.4. Water use Vs plant density

It was reported that as much as 222 mm of water was lost to the atmosphere annually from **P.cineraria** when the plant density was 50 trees ha^{-1} and the annual rainfall was 366 mm (Lahiri and Kumar, 1967). Daily water loss was found to vary with soil type, plant density, age of the trees and the availability of soil moisture or ground water. When ground water was not limiting, the daily water loss was as high as 30 to 75 litres $tree^{-1}$ in **P.glandulosa** in Texas (Ansley **et al.**, 1991).

2.5.5.5. Water use efficiency

P.chilensis produced 13.4 dt ha^{-1} $year^{-1}$ with 460 mm water in California and the WUE was found to be 345 kg water Kg DM^{-1}, which was considered greater than for some of the domestic legumes, which ranged from 500 to 900 kg water kg DM^{-1} (Briggs and Shantz, 1914; Ludlow and Wilson, 1972). This could be compared favourably with maize and sorghum whose WUE is 240 to 315 and 223 to 360 kg water Kg DM^{-1}, respectively (Briggs and Shantz, 1914). Strong relationship between biomass and water consumption in tree crops, including **Prosopis**, has been established. One year old **P.juliflora** tree was found to consume 3588 litres of water for producing 4.01 kg biomass (Chaturvedi **et al.**, 1988).

2.5.6. Regeneration

2.5.6.1. Natural regeneration

The seeds of **Prosopis** were found to regenerate naturally without human effort with the help of some of the biological and non-biological dispersal agents. For example, the seeds got dispersed through rodents, ants, birds, hares, cattle etc., which were all biological agents (Reynolds and Glendening, 1949). Rain water and wind are the non-biological agents associated with the dispersal of **Prosopis** seeds.

Goats and sheep were found to be effective for long distance dispersal (Ahmed, 1986). The **Prosopis** seeds collected from goat droppings recorded maximum germination (Masilamani, 1992) as against the sheep droppings which had less germinability as the whole pods eaten by them were found to be destroyed (Harding, 1991).

Prosopis juliflora was found to produce thousands of seeds per plant. One kilogram of freshly collected ripe pods contained about 333 pods with 5661 seeds. One kilogram of seeds contained 37037 seeds (Rawat **et al.**, 1992). Atleast few hundreds of seeds will definitely regenerate accounting for after all the natural calamities.

2.5.6.2. Artificial regeneration

In artificial regeneration, seed dormancy due to hard seeds was a common problem in nearly all cultivated species belonging to leguminosae and **P.juliflora** is not an exception (Harrington, 1916). The impermeability of hard seed coat was attributed to fatty or waxy substances in the cuticle (Rees, 1910). Nelson (1926) was of the opinion that hardness was the result of the evaporation and deposition on the seed surface of the watery fluid surrounding the seed in the immature pods.

Ffolliot and Thames (1983b) stated that two processes must take place for germination to occur in **Prosopis** : water imbibition and gas exchange. Hard seed coat causes impermeability to water, oxygen and physiological barrier to the radical and all resulted in dormancy. They suggested that one possible exception to this state of physical dormancy of the genus **Prosopis** is the freshly collected, undried seeds which can germinate rapidly without any treatment.

Histochemical investigation on the **P.juliflora** seed coat indicated that the occurrence of a 'hydrophobic strip' as the primary water barrier. Its position and structure and histochemistry of the palisade cells of the seed coat differed according to their location on the seed. These differences might be responsible for variations in the water permeability of various parts of the seed coat (Serrato Valenti **et al.**, 1990).

2.6. Nutritional studies in Prosopis

2.6.1. Nutrient cycling

Nutrient addition under natural condition, was found to happen through litter fall, rain water and nitrogen fixation in leguminous trees. In rainless regions of Atacama desert mesquite leaf litter accumulation to a depth of 45 cm had been observed. This was the result of lesser or no decomposition for want of soil moisture in addition to higher litter fall (Ehleringer **et al.**, 1992).

Under Indian conditions, leaf litter fall under **P.juliflora** was found to vary between 500 to 1000 g m^{-2} at different sites in Rajasthan depending on the age and plant density (Lahiri and Gaur, 1969). In a 4 to 6 years old **P.juliflora**, litter fall of 5 to 8 t ha^{-1} $year^{-1}$ has been reported at Karnal, which was found to add to the soil about 88 to 132 kg N, 8 to 16 kg P and 60 to 70 kg K ha^{-1} $year^{-1}$ (Singh Gurbachan and Singh, 1993).

In Tamil Nadu, in a two years old **P.juliflora** plantation, litter fall of 3715 kg ha^{-1} $year^{-1}$ was observed which contributed to the soil about 16.2 kg N, 6.2 kg P, 34.6 kg K, 72.8 kg Ca and 29.6 kg Mg ha^{-1} $year^{-1}$. Among 13 tree species tested, **P.juliflora** was found to add maximum P and K through litter fall (M.Shanmugam, Personal Communication, 1994).

2.6.2. Nitrogen fixation

Nodulation in **P.juliflora** has been found both under uninoculated natural condition (Pokhriyal **et al.**, 1990) and with inoculation of indigenous soil rhizobia (Basak and Goyal, 1975) and by the combined inoculation of rhizobia and azotobacter (Basu and Kabi, 1987) in India under green house pot culture experiments.

Nodulation under highly saline condition has also been reported (Bala **et al.**, 1990). Absence of nodulation under field conditions upto 1 m soil depth (Tea **et al.**, 1988; Miettinen **et al.**, 1988) has caused some speculation that mesquite may not fix N in field settings (Allerd, 1949; Bailey, 1976). But Felker and Clark (1980; 1982) demonstrated in a pherotophytically simulated green house experiment that nodulation and acetylene reduction had occurred at 3.2 m depth, suggesting that nodulation at field conditions could occur at soil depths below 3 m.

Studies at California desert revealed that **Prosopis** species produced 30 kg N ha^{-1} when their crown coverage was 34 per cent of the land area and it was suggested that upto 100 kg N ha^{-1} $year^{-1}$ might be fixed by **Prosopis** species with greater ground cover and better management (Rundel **et al.**, 1982).

2.6.3. Nutrient uptake

Nutrient contents were the highest in leaves of **Prosopis juliflora**, decreasing in the order of leaves, branches and stems. The nutrient contents were comparatively more in roots than in stems (Singh Gurbachan **et al.**, 1990). The N content of leaves was higher than that of P and K (Sharma, 1984; Garg, 1993). The N content was found to vary from 0.35 to 3.60 per cent; while Ca and K contents ranged from 2.14 to 2.64 per cent. The P and Mg contents were less than 1.0 per cent (Sharma, 1984).

The P and K contents of the soil were fairly related to their foliar concentrations. Such relations were not significant in respect of other nutrients (Sharma, 1984). The leaf nutrient contents were found to vary with season and advancement of time (age) (Garg, 1993) as observed in 15 years old **P.juliflora** trees.

In soils under **Prosopis**, the inorganic P fractions were not affected; but the total P, organic P and available P were affected (Sereno and Hang, 1989). Compared to other tree species, **P.juliflora** was found to have more efficient uptake of P in P deficient sites (Nyami, 1991).

In two year old **P.juliflora** trees, the concentrations of P, K, Ca, Mg, S, Mn, Zn and Cu were increased with an increase in the levels of gypsum application in a highly sodic soil (Singh Gurbachan **et al.**, 1989). The foliar concentrations of all the above nutrients except Ca, Mg and S were highly correlated with soil nutrients, especially when the silt content of the soil was more. Similar trend was observed in respect of Na and Fe also (Wightman and Felker, 1990).

As far as Na content of leaves of **P.juliflora** is concerned, it was low compared to the high concentration of salt in the soil as well as the water used for irrigation. However Na concentrations were found to be high in the soil under mesquite. This suggested that **Prosopis** appeared to exclude Na very effectively (Virginia and Jarrell, 1983).

Under Sandy soils of Thar desert (pH 7.0 to 7.9), **Prosopis** leaves were fairly rich in Na to the tune of 3.94 to 4.51 per cent, as reported by Sharma (1984). This indicates further that Na uptake was more in sodic soils with slightly lower pH compared to sodic soils with high salt concentration and **Prosopis** appeared to exclude Na under high salinity.

Another possible reason for higher Na in the soils under **Prosopis** and lesser Na in the leaves is due to addition of litter fall on the one hand and leaching of leaf Na to the soil by rain water as in spruce (**Picea abies**) and pines (**Pinus sylvestris**), in which 2 to 3 kg each of K, Na and Ca were found to be leached out to the ground by rain water (Tamm, 1951; Sviridova, 1960) on the other hand.

2.6.4. Effect of Prosopis on soil fertility

An improvement in physical and chemical properties of soil underneath **P.cineraria** compared to open fields was observed (Aygarwal **et al.**, 1976). Soils under **P.juliflora** were found to be two to three times richer in organic matter and N than the soils more distant from the trees (Falpler and Maines, 1977 as quoted by Verma, 1987). The sand dunes of Nevada under the coppice **Prosopis** were found to have high organic matter, lower bulk density and less silt than the interdune soils (Wood **et al.**, 1978).

Soil fertility was improved considerably under tree cover (Sharma and Gupta, 1989) compared to fallow land (Rao **et al.**, 1989). The build up of organic carbon and N was found to be maximum under **P.cineraria** and lowest under **P.juliflora** compared to **Albizia lebbeck, Tecomella undulata** and **Acacia senegal** in a loamy sand over a period of 14 years (Aggarwal and Lahiri, 1977).

Prosopis juliflora was found to reduce soil pH, salinity and alkalinity (Shah, 1957) and increased the status of organic matter and N in the upper 15 cm soil layer, though soluble salts increased to some extent below 15 cm depth (Yadav and Singh, 1970).

The available micronutrients (Zn, Mn, Cu & Fe) content of soil were greatly influenced by both **P.cineraria** and **P.juliflora** in a 14 years old plantation (Aggarwal **et al.**, 1976) as well as under other tree species (Muthana **et al.**, 1976).

The increase in the DMP of pearl millet by 2 to 3 times on soils collected under **P.cineraria** (Aggarwal **et al.**, 1993) indicated an enhanced soil fertility build up underneath **P.cineraria** (Aggarwal and Kumar, 1990).

2.6.5. Microbial load under Prosopis

The population of bacteria, fungi, actinomycetes, free living N fixing bacteria and nitrifying bacteria in soil beneath different tree species, including **Prosopis** was found to be higher, compared to those found in the bare site (Rao **et al.**, 1989). Among different organisms, actinomycetes were abundant as indicated from the studies at Kenya (Meiklejohn, 1957) and at CAZRI, Jodhpur (Rao **et al.**, 1989). The attributed reason was the greater resistance of this group of organisms to higher soil temperature and desiccation (Pochan **et al.**, 1957; Sasson, 1972).

Rao **et al.** (1989) suggested that the leguminous trees were better than **Eucalyptus** in building up of the soil fertility and this was closely linked with the activities of soil microorganisms (Shankarnarayan, 1988). The microbial numbers, microbial biomass and N transformations were influenced by soil types and vegetation types (Theodorou and Bowen, 1983; Theodorou, 1984). The microbial density on leaf litter was dependent on type of leaves (species), their physical and chemical properties (Witkamp, 1966).

In mesquite dominated Sonaran desert, higher carbon content and lower C/N ratio for mesquite soil was found to result from the decomposition of leaf litter. This suggested that carbon rich mesquite soil provided readily utilizable energy source which allowed bacterial reactions such as denitrification to proceed at much higher rate (Virginia **et al.**, 1982).

Prosopis juliflora leaf litter was found to be resistant to biodegradation in soil suspension and inhibited the growth of bacteria and fungi, including a clinical isolate of **Candida albicans**. This effect proved to be antibacterial (or bactericidal) (Zainal **et al.**, 1988). Leaf extracts of **P.juliflora** also reduced the total number of cellulolytic and symbiotically nitrogen fixing bacteria. These results suggested that soil receiving **Prosopis** leaf litter were particularly low in fertility (Zainal **et al.**, 1988).

2.7. Allelopathic effect of Prosopis

Allelopathy is the direct or indirect deleterious effect of one plant upon another (Muller, 1969). Whittaker, 1970 (as quoted by Tukey, 1970) had suggested the term "allelochemics" to describe chemicals from one plant which influenced another, without specifying the nature of reaction.

Lack of herbaceous growth under multipurpose tree species was very often attributed to allelopathy (Suresh and Rai, 1987; 1988). Lack of understorey vegetation as allelopathic effect in **Eucalyptus** (del Moral and Muller, 1969; 1970; Florence, 1986), **Casuarina** species (Story, 1967), **Leucaena leucocephala** (Kuo et al., 1982; Chou and Kuo, 1986), **Acacia auriculiformis** (Setiadi and Samingan, 1978), **Populus** species (Shoup and Witcomb, 1981) and **Prosopis juliflora** (Sankhla et al., 1965; Srivastava and Hetherington, 1991) were reported. **Leucaena leucocephala** was not autotoxic since the dominant understorey species was **L.leucocephala** itself (Suresh and Rai, 1988).

Different types of plant extracts from different plant parts of tree species were found to have allelopathic effect on other tree species. For example, aqueous leaf extracts (1 or 2.5 per cent) of **Cupressus lusitanica, Eucalyptus globulus, E.camaldulensis** and **E.saligna** had significantly reduced both germination and radical growth of field crops like chick pea, maize and pea (Lisanework and Michelsen, 1993).

Mulching of dry leaves or aqueous leaf extracts of **Leucaena leucocephala, Casuarina equisetifolia** and **E.tereticornis** were found to affect germination, root length and DMP of sorghum, cowpea and sunflower. The maximum deleterious effects were observed in **Eucalyptus** and minimum in **Casuarina** (Suresh and Rai, 1988).

Allelopathy has been found to be a potential cause for the failure of regeneration in many forest species (Horsley, 1977; Fisher **et al.**, 1978). Regeneration failures due to allelopathy has been reported in **Birch** species (Bode, 1958), black locust, red clover, black alder (Larson and Schwarz, 1980) and slash pines (Hollis **et al.**, 1982).

Allelochemics were found produced in all parts of the plant, but the highest concentrations was seen in the foliage and fruits. Allelochemics were released by volatilization or by leaching and exudation from the foliage, fruits and the roots (Fisher, 1980). Many allelochemics were responsible for allelopathic effects. But among them the most often implicated ones was phenols and terpenoids (Fisher, 1980).

Monoterpenes such as alpha-pinene, camphene, camphor, cineole and dipentene were somewhat volatile inhibitors isolated from **Eucalyptus** and several desert shrubs (del Moral and Muller, 1970). Gant and Clebsch (1975) found that sassafras produced alpha-pinene, alpha-phellandrene, citral and eugenol, all terpenoid phytotoxins.

A range of phenolic compounds, from the simple hydroquinone of manzanita (**Arctostaphylos**) (Chou and Muller, 1972) to the complex quercetin of **Eucalyptus** (del Moral and Muller, 1970) had been found to be allelopathic.

Sometimes, the reduction or failure of germination under leaf mulching was mistaken for allelopathic effect. The decreased germination of winter wheat due to mulching of straw (Kimber, 1973) and the retardation of the growth of maize due to mulching of **Eucalyptus** leaves (Adams and Attiwil, 1986; Trenbath, 1991) were attributed to temporary immobilization of nutrients as a result of high C/N ratio (Sanginga and Swift, 1992).

The allelopathic potential of some of the tree species could be better exploited for controlling problematic weeds. For example, **Leucaena leucocephala** suppressed hagonoy (**Chromolaena odorata**), a noxious weed in the Philippines (Benge and Ciesielski, 1977).

The soil beneath the tree species was sometimes found to have allelopathic chemicals that affect germination. Rhizosphere soils collected from 3 years old **Leucaena**, **E.tereticornis** and **Casuarina** plantations were found to affect the germination and growth of cowpea, sorghum and sunflower (Suresh and Rai, 1987) in pot culture studies, in Tamil Nadu. The results from Nigeria was quite contradictory to the above findings. Maize, sorghum and groundnut recorded the highest yields when grown on the soils collected under **Eucalyptus** species and **Prosopis juliflora** (Verinumbe, 1987). This might be due to short term persistence of phytotoxins in the soils as reported by Rice (1979) under certain situation when there was no constant input through litter fall.

2.8. Wasteland development

2.8.1. Prosopis for reclamation of wastelands

In India about 175 million hectares of wastelands have been identified under different categories (Puri and Viswanatham, 1988). Among them the salt affected (salinity and alkalinity) soils alone accounts for about 8.11 million hectares (Singh Gurbachan, 1994).

Prosopis juliflora is a suitable candidate for arid zone afforestation and sand dune stabilization (Sharma and Gupta, 1989; Alonso, 1990). They come up in all types of land such as abandoned lands, degraded forest lands, denuded hills, rocky terrains with shallow soil depths, mined wastelands, etc., (Sastry and Kavathekar, 1990. p. 569-610; Singh Gurbachan, 1994).

Prosopis juliflora seedlings established satisfactorily even with saline water of EC as high as 7 to 9 dSm^{-1} (Tomar and Yadav, 1985). **Prosopis** species was the first legume known to grow in salinities equivalent to sea water (Felker **et al.**, 1981b). Approximately EC 28 dSm^{-1} was considered the potential threshold for mesquite salt tolerance (Jarrell and Virginia, 1990).

The **P.juliflora** was superior in terms of germination, survival and growth rate compared to other tree species viz., **Acacia nilotica, A.auriculiformis, Dalbergia sissoo, Eucalyptus** species and **Terminalia arjuna** in a non-saline sodic soil (pH 9 to 10; EC 430-955 dSm^{-1}, exchangeable Na 5.6 to 12.28 me 100 g^{-1} soil), in U.P (Goel, 1987b).

2.8.2. Prosopis as biological means for reclamation of wastelands

Under certain specific situations where the amendments are either costlier or scarce the only solution would be the use of tree crops as a biological means for reclamation of highly saline and alkaline lands (Singh Gurbachan **et al.**, 1991). **Prosopis** species along with **eucalyptus, casuarina, tamarix, populus, leucaena, acacia** and **salt bush** have been recommended to act as 'biological pump' to mitigate salinity problems along the canal command areas, as they could transpire large quantity of water (Singh Gurbachan, 1994).

At Lucknow, U.P., four tree species viz., **P.juliflora, Dalbergia sissoo, Eucalyptus hybrid** and **Acacia nilotica** were evaluated for their relative efficiency as biological means for improvement of sodic soils. Maximum reduction in EC and pH was brought about by **P.juliflora** after two years of growth. The organic carbon content was increased under tree cover. The efficiency of trees in enriching soil with N was in the order of **Prosopis juliflora** > **Dalbergia sissoo** > **Acacia nilotica** > **Eucalyptus hybrid** (Shukla and Misra, 1993). A reduction of pH from 10.3 to 8.03 and an increase in organic carbon from 0.12 to 0.58 per cent has been reported for a 20 year old **Prosopis** plantation (Singh Gurbachan and Singh, 1993).

Maximum reduction in Na content of surface soil layer (upto 45 cm); increase in Ca content and hydraulic conductivity of soil (Khanduja **et al.**, 1986. p. 54-61; Shukla and Misra, 1993); reduction in bulk density and increase in WHC (Pathak **et al.**, 1964) were brought by **P.juliflora** compared to other tree species (Shukla and Misra, 1993).

2.9. Correlation and regression studies

Non-destructive estimation of tree biomass through regression equations is known as 'dimension analysis of wood plot' (Whittaker, 1961) and 'allometry' (Kira and Shidei, 1967). About 50 observations, made independently and randomly, were found to justify the assumption of regression analysis (Mishra, 1976). Tree weight was found to be closely related to the size and increasing proportionally to diameter raised to the power between 2 and 3 (Satoo and Madgwick, 1982. p. 152).

In **P.juliflora** the diameter at breast height (DBH) and tree height were positively correlated with fuel yield. For predicting fuelwood, DBH alone was quite sufficient (Kaul **et al.**, 1964; Bhimaya **et al.**, 1967). Biomass of **Prosopis** species was estimated using linear regression equations (Whisenant and Burzlaff, 1978) as well as log-log regression equations (Felker **et al.**, 1982b).

From the above review, the following research lacunae have been identified for Prosopis juliflora

- Silvicultural studies on phenology, seed size, depth of sowing, growth and biomass production under different plant densities and under different soil types have been done only to limited level and further studies on coppicing and biomass are lacking.
- In **Prosopis juliflora** only few information on the biomass production is available, that too for a plantation of 4 to 6 years. But there is no information

on the biomass production in a short rotation energy plantation of less than three years, which may meet the present day increasing demand for fuelwood.

- Regarding build up of soil fertility under **Prosopis**, only limited information is available. Further intensive research is needed.
- The allelopathic effect of **Prosopis** on field crops under field conditions has not been clearly demonstrated.
- The charcoal productivity and its potential use in industry need more evaluation.
- Work on hybridization in **Prosopis** is another area to increase the biomass in short rotation energy plantations.
- Propagation of elite **Prosopis** clone through tissue culture is still in its infant stage. We have to go a long way to implement the laboratory results in the fields.
- The mechanism of salt tolerance of **Prosopis** is not fully understood.
- Work on the potential use of **Prosopis** under different agroforestry systems is very much lacking.

- The water relations of **P.juliflora** under different situations, ground water fluctuations and soil moisture depletion needs more attention, especially, under arid conditions, where moisture is limiting.
- The monoculture of **Prosopis** may create problems like pest and disease build up and elimination of other useful MPTs. Hence the concept of mixed wood lot by including other MPTs with **Prosopis** have to be evaluated.
- **Prosopis** though considered as a menace in fertile and cultivable lands, its presence in arid and desert lands greatly helps to improve the environment and ecosystem. More studies are needed on these aspects.
- Research on screening of different **Prosopis** species with straight stem will be very useful for using it in paper making and for use as timber.
- The potential of **Prosopis** species has not yet been fully exploited as cattle feed, poultry feed, human food and timber and for producing biochemicals, industrial products and paper making.

Eventhough the agenda for further research is longer as cited above, in the present study the following aspects of **Prosopis juliflora** were taken for research.

Allometric relationship in **Prosopis** seedlings; germinability of hot water treated seeds under different times of sowing; effect of seed size and depths of sowing on the germination of **Prosopis**; comparative performance of **Prosopis** with other MPTs in terms of growth, DMP, nutrient uptake, soil fertility, coppicing potential, understorey weed dynamics etc., effect of plant density, age of first cutting and coppicing duration on the DMP of **Prosopis** raised under short rotation plantations of less than three years and its impact on soil fertility; comparative performance of **Prosopis** in different soil types; charcoal recovery from **Prosopis** fuelwood; allelopathic effect of **Prosopis** on field crops; possibility of exploiting **Prosopis** for weed control and biocontrol of nematode; nutrient addition through litter fall and microbial load in **Prosopis** leaf litter.

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

An investigation on the silvicultural and ecological aspects of **Prosopis juliflora** (Swartz) DC. was carried out both through field and pot culture experiments. The entire study was divided into three parts viz., Part I, part II and part III and totally 13 experiments were conducted throughout the investigation as listed in Table 1. The materials and methods adopted in the 13 experiments are described in this chapter.

3.1. Location

The investigations were carried out in the following three locations. The climate and soil types of the locations and the details of experiments conducted therein are described below.

3.1.1. Mettupalayam

Experiments 1, 2 and 3 were conducted at the Forest College and Research Institute, Mettupalayam which is situated at $11^{o}20^{'}$N latitude and $76^{o}57^{'}$E longitude. The altitude is 300 m above MSL. Mettupalayam is at the foot hills of Kothagiri of the western agroclimatic zone of Tamil Nadu. The mean annual rainfall is 830 mm (average of 10 years) distributed in 45 rainy days. The total rainfall

Table 1. Details of the experiments conducted

Sl. No.	Title of the experiment	Nature of experiment	Location	Period of study	Objectives
			PART I STUDY		
1.	Study on the allometric relationship of the **Prosopis juliflora** (Swartz) DC. seedlings	Polypot culture	Forest College and Research Institute, Mettupalayam	May 1991 to October 1991	(i) To find out the relationship between the root length and shoot length. (ii) To find out the relationship between the root weight and shoot weight.
2.	Comparative performance of **Prosopis juliflora** (Swartz) DC. with other multipurpose tree species (MPTs)	Field experiment (Already established plantation was utilized for this study)	Forest College and Research Institute, Mettupalayam	October 1988 to October 1992	(i) To compare the growth, biomass production and wood density of MPTs. (ii) To study the microbial population under different MPTs. (iii)To study the weed flora under the canopy of MPTs. (iv) To study the nutrient uptake of MPTs and their impact on soil fertility. (v) To study the coppicing potential OF MPTs. (vi) To develop linear regression models for prediction of biomass in MPTs.
			PART II STUDY		
3.	Effect of plant densities, ages of first cutting and coppicing durations on the biomass production of **Prosopis juliflora** (Swartz) DC.	Field experiment (New plantation was establisned for this study)	Forest College and Research Institute, Mettupalayam	October 1991 to December 1993	(i) To find out the effect of different plant densities on the biomass production. (ii) To find out the effect of different ages of first cut on the biomass production and coppice growth. (iii) To find out the interaction effect of plant density and age of first cuttin on the biomass producti of coppice crop.

					(iv) To find out the advantageous of cutting and coppicing **Prosopis** at early stages (v) To study the adaptatic of **Prosopis** interms of relative water content of leaves under different. plant densities. (vi) To estimate the nutrient uptake by **Prosopis** and soil fertility changes under different plant densities of **Prosopis** plantations.
4.	Comparative performance of **Prosopis juliflora** (Swartz) DC. under different soil types (off station study)	Field experiment in the natural stand of **Prosopis**	Tiruchuli taluk (Kamarajar district)	June 1993 to September 1993	To find out the influence of soil types on the biomass production of **Prosopis**
5.	Study on the charcoal recovery from **Prosopis juliflora** (Swartz) DC. fuelwood (off station study)	Field experiment in farmers' fields	Tiruchuli taluk (Kamarajar district)	September 1993	To find out the charcoal recovery from the different diameter classes of **Prosopis** fuelwood/root stock.

PART III STUDY (FEEDER EXPERIEMENTS)

6.	Germinability of hot water treated **Prosopis juliflora** (Swartz) DC. seeds under different times of sowing	Pot culture experiment	Tamil Nadu Agricultural University, Coimbatore.	November 1993 to December 1993	To find out the germinability of hot water treated **Prosopis** seeds under different times of sowing
7.	Effect of seed sizes and depths of sowing on the germination of **Prosopis juliflora** (Swartz) DC.	Pot culture experiment	Tamil Nadu Agricultural University, Coimbatore.	November 1993 to December 1993	(i) To find out the effect of seed sizes and depths of sowing on germination and DMP of **Prosopis** seedlings. (ii) To find out the peak period of germination and the length of germination period.

8.	Allelopathic effect of **Prosopis juliflora** (Swartz) DC. on field crops	Pot culture experiment	Tamil Nadu Agricultural University, Coimbatore.	November 1993 to December 1993	To study the allelopathic effect of **Prosopis** leaf litter and plant extracts on the germination and dry matter production of field crops.
9.	Effect of different times of sowing of test crops to mitigate the allelopathic effect of **Prosopis juliflora** (Swartz) DC. leaf litter on the germination and DMP of test crops	Pot culture experiment	Tamil Nadu Agricultural University, Coimbatore.	January 1994 to February 1994	(i) To find out the length of inhibitory period of germination of test crops due to **Prosopis** leaf litter. (ii) To find out the optimum time of sowing of field crops to mitigate the allelopathic effect of **Prosopis** leaf litter.
10.	Effect of leaf litter and plant extracts of **Prosopis juliflora** (Swartz) DC. on weed control	Pot culture experiment	Tamil Nadu Agricultural University, Coimbatore.	January 1994 to March 1994	To study the effect of leaf litter and plant extracts of **Prosopis** on the germination and DMP of weeds.
11.	Effect of leaf incorporation and plant extracts of **Prosopis juliflora** (Swartz) DC. on the control of root-knot nematode (**Meloidogyne incognita** (Kofoid and White, 1919) Chitwood, 1949) in tomato (**Lycopersicon esculentum** Mill.)	Pot culture experiment	Tamil Nadu Agricultural University, Coimbatore.	January 1994 to April 1994	(i) To find out the effect of **Prosopis** leaf litter and plant extracts on the nematode population and egg masses of tomato inoculated with root-knot nematode. (ii) To study the effect of leaf incorporation and plant extracts of **Prosopis** on fruit number and fruit yield of tomato inoculated with root-knot nematode.
12.	Estimation of nutrient addition through **Prosopis juliflora** (Swartz) DC. leaves	Lab experiment	Tamil Nadu Agricultural University, Coimbatore.	December 1993 to March 1994	(i) To find out the time needed for decomposition of leaf litter in the soil. (ii) To find out the nutrient addition through leaf litter.
13.	Enumeration of microbial load in **Prosopis juliflora** (Swartz) DC. leaf litter collected from the field	Lab experiment	Tamil Nadu Agricultural University, Coimbatore.	February 1994	To find out the microbial population in the **Prosopis** leaf litter that are responsible for the degradation.

received during the cropping period, from nursery to final harvest, was 2092.8 mm in 132 rainy days. The maximum and the minimum temperature, respectively, ranged from 19.6 to 28.9°C and 17.1 to 37.8°C during the cropping period (Table 2).

3.1.2. Tiruchuli taluk

Experiments 4 and 5 were conducted at Tiruchuli taluk of Kamarajar district which is situated $9^{\circ}40'$N latitude and $78^{\circ}25'$E longitude. Tiruchuli taluk is in the southern agroclimatic zone of Tamil Nadu. The altitude is 50 m above MSL. The mean annual rainfall is 736.2 mm distributed in 41 rainy days (mean of 10 years). The rainfall and temperature particulars during the experimental period are furnished in Table 3. The prevailing environment of this taluk is favourable for the natural growth of **Prosopis**. About 45 per cent of the people living in this taluk are dependent on felling of **Prosopis** and processing it for charcoal making.

3.1.3. Coimbatore

Experiments 6 through 13 were conducted at the Agricultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore which is located at 11°N latitude and 77°E longitude. The altitude is 426.72 m above MSL. Coimbatore is also in the western agroclimatic zone of

Table 2. Rainfall and temperature during the cropping period (May 91 to Dec. 93) at Mettupalayam

Year	Month	Rainfall (mm)	Rainy days	Mean Temperature° C	
				Maximum	Minimum
1991					
	May	56.6	5	36.9	25.0
	June	81.2	3	33.2	24.9
	July	33.6	3	34.2	24.3
	Aug.	21.8	2	35.1	24.6
	Sep.	38.9	4	32.6	24.2
	Oct.	125.6	9	32.5	23.0
	Nov.	166.5	9	31.1	20.4
	Dec.	8.1	1	29.3	20.8
	Total	532.3	36	-	-
1992					
	Jan.	-	-	28.3	20.2
	Feb.	-	-	36.2	25.6
	Mar.	-	-	37.8	22.7
	Apr.	29.8	3	36.3	25.1
	May	63.8	5	36.9	25.0
	June	40.2	7	41.9	21.9
	July	18.8	3	38.8	22.9
	Aug.	64.8	2	38.1	22.1
	Sep.	208.9	12	38.7	18.5
	Oct.	72.5	5	38.8	17.1
	Nov.	231.0	9	38.4	18.8
	Dec.	13.0	2	38.9	18.5
	Total	742.8	48	-	-
1993					
	Jan.	-	-	29.6	19.6
	Feb.	43.4	2	30.2	20.2
	Mar.	37.2	3	34.8	20.5
	Apr.	29.0	3	35.8	24.0
	May	58.0	2	36.7	25.9
	June	11.6	1	30.7	22.2
	July	33.4	4	31.1	23.6
	Aug.	31.6	4	32.8	22.5
	Sep.	41.4	4	33.0	22.0
	Oct.	177.5	11	30.7	21.2
	Nov.	320.8	12	29.8	21.2
	Dec.	33.8	2	29.9	18.3
	Total	817.7	48	-	-
Grand total		2092.8	132	-	-

Table 3. Rainfall and temperature during the cropping period at Tiruchuli taluk for 1993

Month	Rainfall (mm)	Rainy days	Mean Temperature °C	
			Maximum	Minimum
January	-	-	29.5	19.7
February	-	-	32.0	20.6
March	3.1	-	35.7	22.8
April	1.5	-	37.2	24.3
May	52.5	5	38.8	28.4
June	101.2	6	35.2	25.6
July	94.0	5	36.6	25.0
August	17.5	2	35.8	24.3
September	111.4	5	34.4	23.7
October	165.3	8	31.3	23.9
November	276.5	15	28.8	22.1
December	113.9	5	28.3	21.9
Total	936.9	51	-	-

Tamil Nadu. The mean annual rainfall is 640 mm (average of 83 years) received in 47 rainy days. The rainfall and the temperature particulars for the experimental period are furnished in Table 4.

3.2. Materials and Methods

PART I STUDY

3.2.1. Experiment 1

Study on the allometric relationships of the Prosopis juliflora (Swartz) DC. seedlings

Prosopis seeds were treated in hot water (500 ml of water was boiled in a vessel. About 200 g seeds were immersed in boiling water immediately after the vessel was removed from the stove). The seeds were kept overnight soaking for imbibition. Next day morning water was drained and the seeds were shade dried. About 2 to 3 seeds were sown in each of 5000 polypots (35 x 20 cm size of 400 gauge) containing nursery medium (native soil : sand : FYM at 3:1:1 ratio). Before sowing, the nursery medium in the polypots was saturated with water for uniform wetting. After sowing the shade dried seeds, watering was done immediately. Thereafter watering was continued through rose can twice a day. On 30th day when seedlings were about 15 cm height, thinning was done leaving one healthy seedling per polypot. Thereafter watering was done regularly once a day to keep the seedlings without any moisture stress. At sixth month,

Table 4. Rainfall and temperature during the cropping period at Coimbatore (TNAU Campus) for 1993 and 1994

Year	Month	Rainfall (mm)	Rainy days	Mean Temperature$^{\circ}$ C Maximum	Mean Temperature$^{\circ}$ C Minimum
1993					
	Jan.	-	-	30.4	15.7
	Feb.	17.5	1	32.4	18.5
	March	39.7	2	34.3	22.0
	April	10.0	1	36.3	23.1
	May	55.6	4	35.8	23.8
	June	21.9	4	32.8	23.8
	July	30.5	2	31.1	23.2
	Aug.	28.9	4	31.9	22.8
	Sep.	24.3	3	32.5	21.0
	Oct.	154.5	12	30.5	22.3
	Nov.	248.7	11	28.5	21.1
	Dec.	29.1	5	27.7	19.5
1994					
	Jan.	72.7	2	29.2	18.6
	Feb.	29.0	3	31.8	20.5
	March	6.0	1	35.1	20.4
	April	138.3	7	33.9	23.4
	May	31.3	5	35.0	23.6
	June	28.0	3	31.1	22.3

500 seedlings were selected randomly from the lot of 5000 seedlings. The selected seedlings were removed from the polypots carefully to secure roots intact by immersing the ball of soil around the roots in a bucket of water.

Then the root and shoot length were measured (Saravanan, 1991). The dry matter production (DMP) of seedlings was estimated by drying the seedlings first in open air and then in hot air oven at 75°C till a constant weight was obtained. The dry weight of both root and shoot were also recorded separately for each seedling. A simple correlation and regression was done between shoot length (Y) and root length (X) as well as between shoot weight (Y) and root weight (X) following the procedures outlined by Snedecor and Cochran (1968).

3.2.2. Experiment 2

Comparative performance of Prosopis juliflora (Swartz) DC. with other multipurpose tree species (MPTs)

Four years old existing plantations of following seven MPTs available at the Forest College and Research Institute, Mettupalayam, were utilized for this study.

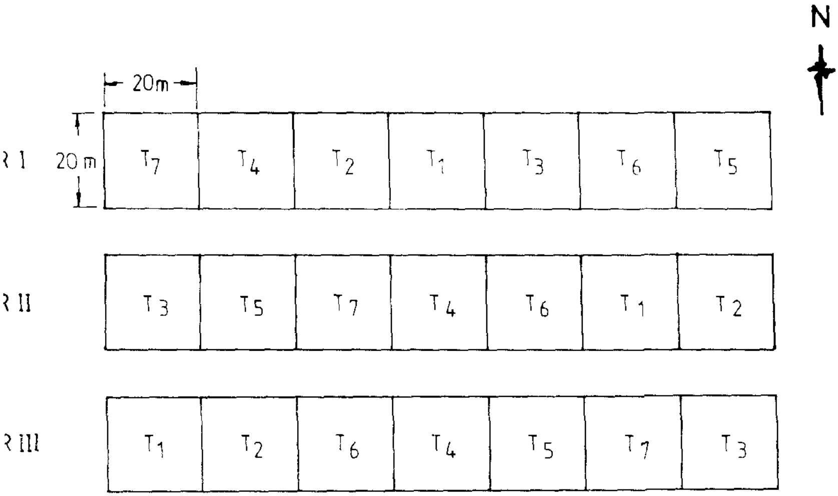
1. **Prosopis juliflora** (Swartz) DC.
2. **Casuarina equisetifolia** Forst.
3. **Eucalyptus camaldulensis** Dehnh.
4. **Eucalyptus tereticornis** Sm.

5. **Azadirachta indica** A.Juss.
6. **Acacia nilotica** (L.) Willd.
7. **Acacia leucophloea** (Roxb.) Willd.

The trees were planted already on 15.10.1988 at a uniform spacing of 2 x 2 m in a compact block of 0.063 ha. For the study purpose a plot size of 20 x 20 m was taken for each MPTs to block them under RBD with three replications on 14.10.1991. The layout of the experiment is furnished in Fig.1. Immediately after blockings, the cultural operations hitherto followed from the time of planting were continued. A circular basin around each tree was formed with a radius of 0.5 m from the base of the tree and with a depth of 10 cm at the centre of the basin to harvest and conserve the rain water around the root zone. The basins were kept weed free besides maintaining their shape by cleaning them once in a month. The above cultural operations were carried out from the day of blocking to felling. Biometric observations viz., tree height and diameter at base (basal diameter) were taken at monthly interval from the day of blocking to felling.

The trees were felled in the fourth year (15.10.1992 to 18.10.1992) to estimate the biomass of different MPTs. After felling, the tree height, basal diameter, the diameter at breast height and biomass were recorded as follows :

FIG.1 FIELD LAYOUT PLAN (Experiment.2)



R I	T_7	T_4	T_2	T_1	T_3	T_6	T_5
R II	T_3	T_5	T_7	T_4	T_6	T_1	T_2
R III	T_1	T_2	T_6	T_4	T_5	T_7	T_3

T_1 - *Casuarina equisetifolia* Forst.

T_2 - *Azadirachta indica* A. Juss.

T_3 - *Eucalyptus tereticornis* Sm.

T_4 - *Eucalyptus camaldulensis* Dehnh.

T_5 - *Acacia leucophloea* (Roxb.) Willd.

T_6 - *Acacia nilotica* (L.) Willd.

T_7 - *Prosopis juliflora* (Swartz) Dc.

3.2.2.1. Tree height

From the base of the tree trunk to the tip of the terminal shoot of the felled trees, the height was measured for all the MPTs and expressed in meter (Srinivasan, 1989).

In the case of **Prosopis** since there were about 2 to 3 branches, the height of the tallest branch in a stool from the base to the tip was recorded and the same was treated as tree height. The data on tree height were analysed statistically.

3.2.2.2. Basal diameter (BD)

The diameter of the tree trunk at the base was measured after felling in all MPTs by using both vernier and tree calipers and expressed in cm (Srinivasan, 1989). The data were analysed statistically.

3.2.2.3. Diameter at breast height (DBH)

For all the MPTs except **Prosopis** the diameter of the felled trees at breast height level (1.37 m from the base of the tree) was measured using vernier and tree calipers (Srinivasan, 1989). In the case of **Prosopis** the DBH of individual branches was measured at 1.37 m from the base and then the average DBH per tree was worked out and expressed in cm. The data on DBH were analysed statistically.

3.2.2.4. Biomass

3.2.2.4.1. Utilizable biomass (UB)

This is the weight of the trunk (stem) and branches of more than 2.5 cm in diameter. This is because the branches with less than 2.5 cm diameter are not used for fuel wood considering their burning quality and economics and hence they were not considered for UB. The UB was recorded **in situ** on fresh weight basis at the time of felling. The UB on dry weight basis was estimated after air drying the samples of UB first and then in hot air oven at 75°C till a constant weight was obtained and expressed in kg tree^{-1} and kg ha^{-1}. The data were analysed statistically.

3.2.2.4.2. Branch Biomass (BB)

This is the weight of branches of less than 2.5 cm diameter without leaves. The BB was recorded on dry weight basis and expressed in kg tree^{-1} and kg ha^{-1}. The data were analysed statistically.

3.2.2.4.3. Leaf biomass (LB)

This is the weight of leaves alone (removed from the UB and BB) recorded on dry weight basis and expressed in kg tree^{-1} and kg ha^{-1}. The data were analysed statistically.

3.2.2.4.4. Non-utilizable biomass (NUB)

Since the BB and LB are generally considered as unsuitable for fuelwood, the combined biomass of branches and leaves were grouped under NUB and expressed on dry weight basis as kg $tree^{-1}$ and kg ha^{-1}. The data were analysed statistically.

3.2.2.4.5. Total biomass

This is the combined weight of both UB and NUB expressed on dry weight basis as kg $tree^{-1}$ and kg ha^{-1}. The data were analysed statistically.

3.2.2.5. Moisture content

Twenty five samples each of UB, BB and LB were taken at random for each MPTs while felling **in situ.** The fresh weight was recorded immediately. After air drying the samples were dried in hot air oven at 75°C till a constant weight was obtained. The difference between fresh and dry weight was considered as moisture and the average moisture percentage of different plant samples were worked out and it was used to estimate the dry weight from the fresh weight.

3.2.2.6. Wood density

Twenty numbers of small billets of the tree species (about 15 cm length) of different diameter representing the main trunk and branches of more than 2.5 cm diameter were randomly selected. Their initial weight was recorded. Then the volume of water displaced by each billet was recorded using a measuring cylinder. The density of each billet was worked out as per the following equation (Worsnop and Flint, 1971. p.23).

$$\text{Density } (\text{g cm}^{-3}) = \text{Mass } (\text{g})/\text{volume } (\text{cm}^{3})$$

The wood density was estimated both on fresh and dry weight basis of the billets and expressed in g cm^{-3}. The data were analysed statistically.

3.2.2.7. Microbial load

Rhizosphere soil samples were collected from upper 30 cm soil layers, using soil auger, for all seven MPTs at the time of felling. The population of bacteria, fungi and actinomycetes were estimated by serial dilution plate technique (Praner and Schmidt, 1964. p. 107) using soil extract agar for bacteria (Allen, 1953. p. 69-70). Martin's rose bengal agar for fungi (Martin, 1950) and Kenknight's agar medium for actinomycetes (Allen, 1953. p. 69-70). The soil samples collected from the adjacent open field was treated as control for this study. The data were analysed statistically.

3.2.2.8. Weed flora

Ten quadrates were randomly placed for each tree species. Similar quadrates in the open area served as control. Weed species in each quadrate were identified and their numbers were counted. Then the relative density (RD) and relative frequency (RF) of each weed species were computed and the importance value (IV) was worked out (Bhandari, 1981) using the following formulae.

$$\text{Relative density (RD)} = \frac{\text{Absolute density for a given species}}{\text{Total absolute density for all species}} \times 100$$

$$\text{Relative frequency (RF)} = \frac{\text{Absolute frequency value for a given species}}{\text{Total of absolute frequency values for all species}} \times 100$$

$$\text{Importance value (IV)} = \text{RD} + \text{RF}$$

The dry matter production (DMP) of weeds under each tree species was also estimated. The data on DMP were analysed statistically.

3.2.2.9. Nutrient studies in MPTs

The content of nitrogen, phosphorus, potassium, sodium and the micronutrients viz., Fe, Cu, Zn and Mn were estimated for different parts of the trees viz., leaves and stems (wood) as per the standard procedures (Table 5). The nutrient uptake of the MPTs was estimated by multiplying the nutrient content with the concerned dry matter. The data were statistically analysed.

3.2.2.10. Soil fertility changes under MPTs

Soil samples were collected at random from each plot under all MPTs from 0 to 45 cm depth using soil auger. The soil samples collected from the adjacent open field

Table 5. Methods of soil and plant analysis

Parameters	Method	Reference
SOIL ANALYSIS		
1. Soil reaction (pH)	Potentiometry (1:2.5 soil, water ratio)	Jackson (1973)
2. Electrical conductivity (EC)	Conductometry (1:2.5 soil, water ratio)	Jackson (1973)
3. Organic carbon	Chromic acid wet digestion	Walkley and Black (1934)
4. Available nitrogen	Alkaline permangnate method	Subbiah and Asija (1956)
5. Available phosphorus	0.5 M sodium bicarbonate extract	Olsen **et al.** (1954)
6. Available sodium and potassium	Neutral N NH_4 OAc extract read through flame photometer	Hanway and Heidal (1952) Stanford and English (1949)
7. Available Fe, Cu, Zn and Mn	DTPA extract - read through Atomic Absorption Spectrophotometer (AAS) using appropriate cathode lamps	Lindsay and Norvell (1978)
PLANT ANALYSIS		
8. Nitrogen	Micro Kjeldhal (Diacid extract)	Humphries (1956
9. Phosphorus	Vanadomolybdate yellow colour (Tri acid extract)	Piper (1966)
10. Potassium and sodium	Flame photometry (Tri acid extract)	Piper (1966) Standford and English (1949)
11. Fe, Cu, Zn and Mn	Triacid extract - read through AAS	Jackson (1973)

served as control. After shade drying, the soil samples were processed by quartering method and sieved through 0.5 mm wire mesh for analyzing organic carbon content and through 2 mm wire mesh for analysing nutrients.

The soil samples were analysed for EC, pH, organic carbon content, available N, P, K, Na and micronutrients viz., Cu, Fe, Zn and Mn following the standard procedures (Table 5). The data were analysed statistically.

3.2.2.11. Coppice growth/regeneration

After felling the trees, coppice growth (regeneration) from the stumps (or stools) of the trees were observed. The number of coppice shoots per stump, the height and the basal diameter of the coppice shoots were recorded on 10th and 15th month after felling. The data were statistically analysed.

3.2.2.12. Path coefficient and regression analysis

The relationship between different component traits viz., tree height, BD, DBH etc., and the biomass viz., utilizable biomass, non-utilizable biomass and total biomass and the direct and indirect effect of different component traits on the biomass yield were analysed using path coefficient analysis (Dewey and Lu, 1959). Simple and multiple regression analysis were done as per the procedure outlined by Snedecor and Cochran (1968).

3.2.2.13. Historical data

From the history of this plantation, the data on tree height and BD recorded from January 1989 to December 1992 were gathered from the experimental records of Forest College and Research Institute, Mettupalayam and were utilized along with the data collected now at the time of felling for working out mean annual increment (MAI) and current annual increment (CAI) of tree height and basal diameter.

3.2.2.14. Statistical analysis

The parameters listed from section 3.2.2.1. to 3.2.2.11 were statistically analysed adopting the procedure of Sukhatme and Amble (1985).

PART II STUDY

3.2.3. Experiment 3

Effect of plant densities, ages of first cutting and coppicing durations on the biomass production of Prosopis juliflora (Swartz) DC.

This experiment was conducted at the Forest College and Research Institute, Mettupalayam. The soil type in the study area is gravelly red loam with a depth of 45 cm. The physico-chemical properties of the soil are furnished in Table 6. Six months old polypot seedlings (already raised for the first experiment) were planted as per the following treatment schedule.

Table 6. Physico-chemical properties of the experimental site at Forest College & Res. Instt., Mettupalayam

Soil type : Non-calcareous red sandy loam (Irugur series)

PHYSICAL PROPERTIES :		
Apparent density	:	1.52 g cm^{-3}
Absolute specific gravity	:	2.5
Maximum water holding capacity	:	25-30 per cent
Porespace	:	42.5 per cent
Volume expansion	:	1.5 per cent
CHEMICAL PROPERTIES :		
Soil reaction (pH)	:	7.2
Electrical conductivity (EC)	:	0.15 dSm^{-2}
Available nitrogen	:	180 kg ha^{-1}
Available phosphorus	:	4.5 kg ha^{-1}
Available potassium	:	195 kg ha^{-1}
Organic carbon	:	0.48 per cent

3.2.3.1. Treatments

A. Main plot treatments

I. Plant density

d_1 : 4444 plants ha^{-1} (1.5 x 1.5 m spacing)
d_2 : 2500 plants ha^{-1} (2.0 x 2.0 m spacing)
d_3 : 1600 plants ha^{-1} (2.5 x 2.5 m spacing)

II. Age of first cutting

a_1 : Cutting at 9 MAP*
a_2 : Cutting at 12 MAP
a_3 : Cutting at 15 MAP
* (MAP : Months after planting)

B. Sub-plot treatments

III. Coppicing duration

c_1 : Allowing the coppice growth for 6 MAFC*
c_2 : Allowing the coppice growth for 9 MAFC
c_3 : Allowing the coppice growth for 12 MAFC
* MAFC : Months after first cut

Design : Split-plot; Replications : Three

3.2.3.2. Planting

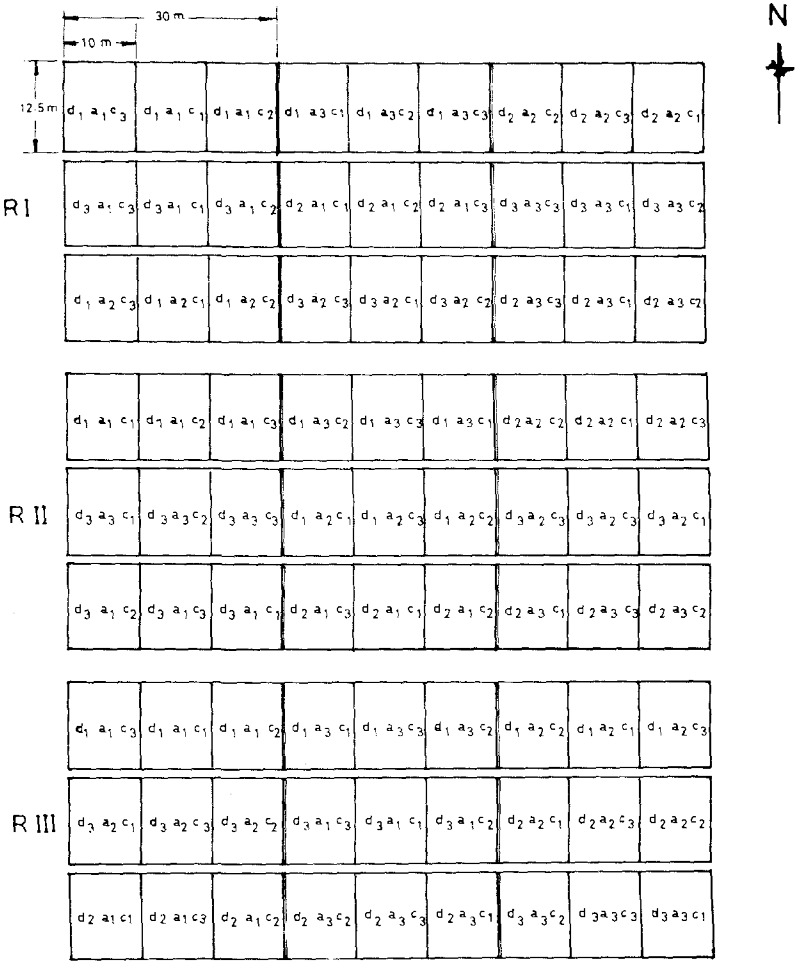
The soil of the experimental area formerly supported a degraded scrub jungle. After clearing the scrub growth, the area was ploughed once with disc plough followed by cultivator once. Then pits of 30 cm^3 were dug out in the ploughed field as per layout. The seedlings were planted on

10.10.1991 with the onset of NE monsoon rain. Only one seedling was planted per pit. No fertilizer was added. Similarly no plant protection was given. The rainfall during the crop including nursery period was 2092.8 mm in 132 rainy days (Table 2). After planting, a circular saucer basin around the **Prosopis** seedlings was formed with a radius of 50 cm from the base of the tree seedlings with a depth of about 10 cm at the centre of the basin. This microcatchment was formed with the aim to harvest and conserve the rainwater around the root zone. The basins were kept weed free besides maintaining their shape through periodical cleaning once in a month. This was the only cultural operation carried out throughout the study period.

The size of the main plot and sub-plot were 30.0 x 12.5 m and 12.5 x 10.0 m, respectively. The layout plan of the experiment is shown in Fig.2. The details of the net area and the number of plants or stools felled for biomass estimation both for first cutting and coppice cutting under each plant density (Fig. 3) are furnished below.

Plant density	First cut		Coppice cut	
	Net area (m^2)	No. of plants	Net area (m^2)	No. of plants
d_1	81.0	36.0	27.0	12.0
d_2	144.0	36.0	48.0	12.0
d_3	112.5	18.0	37.5	6.0

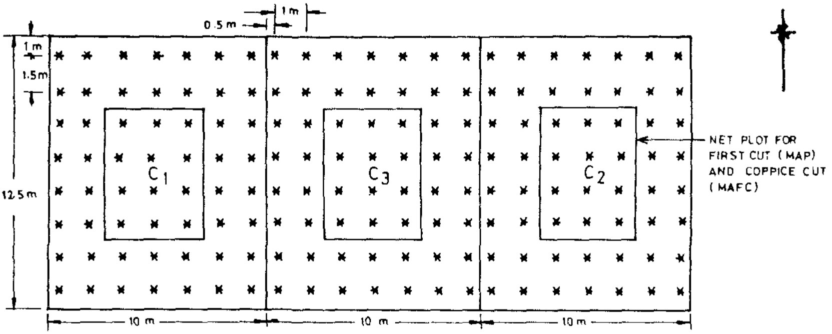
FIG. 2 FIELD LAYOUT PLAN (Experiment. 3)



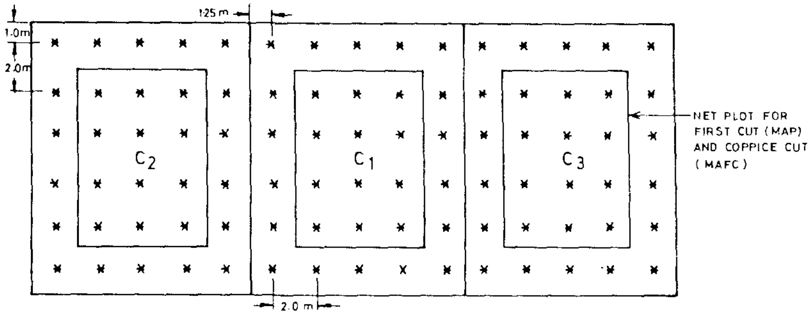
	$d_1 a_1 c_3$	$d_1 a_1 c_1$	$d_1 a_1 c_2$	$d_1 a_3 c_1$	$d_1 a_3 c_2$	$d_1 a_3 c_3$	$d_2 a_2 c_2$	$d_2 a_2 c_3$	$d_2 a_2 c_1$
R I	$d_3 a_1 c_3$	$d_3 a_1 c_1$	$d_3 a_1 c_2$	$d_2 a_1 c_1$	$d_2 a_1 c_2$	$d_2 a_1 c_3$	$d_3 a_3 c_3$	$d_3 a_3 c_1$	$d_3 a_3 c_2$
	$d_1 a_2 c_3$	$d_1 a_2 c_1$	$d_1 a_2 c_2$	$d_3 a_2 c_3$	$d_3 a_2 c_1$	$d_3 a_2 c_2$	$d_2 a_3 c_3$	$d_2 a_3 c_1$	$d_2 a_3 c_2$
	$d_1 a_1 c_1$	$d_1 a_1 c_2$	$d_1 a_1 c_3$	$d_1 a_3 c_2$	$d_1 a_3 c_3$	$d_1 a_3 c_1$	$d_2 a_2 c_2$	$d_2 a_2 c_1$	$d_2 a_2 c_3$
R II	$d_3 a_3 c_1$	$d_3 a_3 c_2$	$d_3 a_3 c_3$	$d_1 a_2 c_1$	$d_1 a_2 c_3$	$d_1 a_2 c_2$	$d_3 a_2 c_3$	$d_3 a_2 c_3$	$d_3 a_2 c_1$
	$d_3 a_1 c_2$	$d_3 a_1 c_3$	$d_3 a_1 c_1$	$d_2 a_1 c_3$	$d_2 a_1 c_1$	$d_2 a_1 c_2$	$d_2 a_3 c_1$	$d_2 a_3 c_3$	$d_2 a_3 c_2$
	$d_1 a_1 c_3$	$d_1 a_1 c_1$	$d_1 a_1 c_2$	$d_1 a_3 c_1$	$d_1 a_3 c_3$	$d_1 a_3 c_2$	$d_1 a_2 c_2$	$d_1 a_2 c_1$	$d_1 a_2 c_3$
R III	$d_3 a_2 c_1$	$d_3 a_2 c_3$	$d_3 a_2 c_2$	$d_3 a_1 c_3$	$d_3 a_1 c_1$	$d_3 a_1 c_2$	$d_2 a_2 c_1$	$d_2 a_2 c_3$	$d_2 a_2 c_2$
	$d_2 a_1 c_1$	$d_2 a_1 c_3$	$d_2 a_1 c_2$	$d_2 a_3 c_2$	$d_2 a_3 c_3$	$d_2 a_3 c_1$	$d_3 a_3 c_2$	$d_3 a_3 c_3$	$d_3 a_3 c_1$

FIG.3 NET PLOT AREA FOR FIRST CUT AND COPPICE CUT

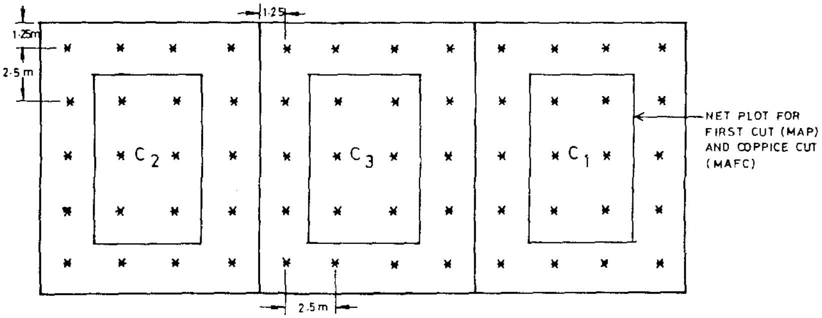
(d1 : High density (1.5 x 1.5 m) + a1 : 9 MAP)



(d2 : Medium density (2.0 x 2.0 m) + a1 : 9 MAP



(d3 : Low density (2.5m x 2.5m) + a1 : 9 MAP



NB : This plan holds good for other age (a_2 and $_3$) combination

3.2.3.3. Establishment of seedlings in the mainfield

Initial stand count was made in each plot two months after planting (MAP) and the mean percentage establishment was worked out and reported.

3.2.3.4. Biometric observation (first crop)

3.2.3.4.1. Tree height

Five trees were selected randomly for each plot and tagged. The tree height was measured from the collar region to the tip of the main stem (Srinivasan, 1989) at monthly intervals upto 9 MAP and expressed in cm. The data were statistically analysed.

3.2.3.4.2. Basal diameter (BD)

Using vernier calipers the BD of trees were measured at collar region of the tagged plants (Srinivasan, 1989) at monthly intervals upto 9 MAP and expressed in cm. The data were analysed statistically.

3.2.3.4.3. Number of primary branches

The number of primary branches per tree was counted in the tagged plants at 6 and 9 MAP. The data were analysed statistically.

3.2.3.4.4. Relative water content (RWC)

The RWC of leaves of tagged plants were estimated by following the procedures outlined by Barr's and Wealherly

(1962) at monthly intervals from 2 to 9 MAP. The following formula was used.

$$\text{Relative water content (RWC) \%} = \frac{\text{Fresh weight - Dry weight}}{\text{Turgid weight - Dry weight}} \times 100$$

To relate the RWC of leaves with actual soil moisture, soil samples were taken at two soil depths (0 to 30 cm and 30 to 60 cm) for each plot within a radius of 60 cm from the base of the trees. Since the roots had gone beyond 60 cm depth with the advancement of age beyond 9 MAP, estimation of actual soil moisture was done only upto 9 MAP. The collected data were not analysed statistically because data were collected from only one replication.

3.2.3.4.5. Biomass estimation

All the trees in the net plot were cut leaving about 10 to 15 cm stump from the ground level for coppice growth. The biomass of leaves and stems were recorded separately **in situ** on fresh weight basis. Sufficient samples for each treatment were air dried first and then, they were dried in hot air oven at 75°C till a constant weight was obtained. Dry matter production (DMP) for each treatment was estimated based on the dry weight of the representative samples. Leaf/stem ratio (LSR) was also worked out on dry weight basis to elucidate the partitioning of biomass. The data were statistically analysed.

3.2.3.5. Biometric observations (Coppice crop)

3.2.3.5.1. Number of coppice shoots

For each coppice duration five trees in the net plot were tagged. The number of coppice shoots per tree was recorded at monthly intervals upto 6 MAFC and the average number of coppice shoots per tree was worked out. The data were statistically analysed.

3.2.3.5.2. Height of coppice shoots

Five coppice shoots per tree (already tagged for counting the number of coppice shoots) were tagged. The height was measured from the base to tip of the coppice shoot at monthly intervals upto 6 MAFC and expressed in cm. The data were statistically analysed.

3.2.3.5.3. Basal diameter (BD)

Using vernier calipers the diameter of each tagged coppice shoots was measured at the base at monthly intervals upto 6 MAFC and expressed in cm. The data were statistically analysed.

3.2.3.5.4. Biomass estimation

All the trees in the net area were cut and the leaf and stem biomass were recorded separately on fresh weight basis. The DMP was estimated as done in the first crop and expressed in kg ha^{-1}. Leaf/stem ratio (LSR) was also worked out on dry weight basis to elucidate the partitioning of biomass. The data were analysed statistically.

3.2.3.6. Nutrient uptake

The dried samples of leaves and stems of **Prosopis** were ground into powder separately. The nutrient content of nitrogen, phosphorus, potassium, sodium and micronutrients (Cu, Fe, Zn and Mn) were estimated following the standard procedures listed in Table 5. The nutrient uptake of **Prosopis** was estimated by multiplying the nutrient content with the concerned dry matter. The data were analysed statistically.

3.2.3.7. Soil fertility changes under Prosopis plantation

At the end of the experiment (2.3 years old), soil samples were collected at random from each plot at 0 to 45 cm depth. The soil samples were processed and analysed for EC, pH, organic carbon, available N, P, K, Na, Cu, Fe, Zn and Mn as done in experiment 2 following the standard procedures (Table 5). The data were analysed statistically.

3.2.3.8. Statistical analysis

For the analysis of the above listed parameters, the procedures outlined by Sukhatme and Amble (1985) were followed. The parameters viz., tree height, BD and the number of primary branches of the first crop were analysed in RBD (Randomized Blocks Design) while the biomass was analysed in FRBD (Factorial Randomized Blocks Design). In the coppice crop, the parameters viz., number of coppice shoots per stool, height and BD of coppice shoots were analysed in FRBD. The biomass, nutrient uptake of the plants and available nutrients in the soil were analysed in split-plot design.

3.2.4. Experiment 4

Comparative performance of Prosopis juliflora (Swartz) DC. under different soil types (off station study)

Natural stand of four years old **Prosopis** were selected at random in seven locations for each soil type (black soil, red soil and alluvial sandy soil) at Tiruchuli taluk of Kamarajar district of Tamil Nadu. In each location, a sample plot of 10 x 10 m^2 was marked in such a way that 25 stools were accommodated to simulate the population of about 2500 plants ha^{-1} (2 m x 2 m spacing). This was done to compare the biomass production at uniform plant density.

Biometric observations viz., tree height, BD, DBH and number of branches per stool were recorded in five tagged trees for each sample plot. Biomass on fresh weight basis was recorded separately for UB, NUB and total biomass at the time of felling **in situ** and later on DMP was estimated after air drying the samples and then drying them in hot air oven at 75°C till a constant weight was obtained. All observations were recorded as per the procedure indicated in experiment 2. The data were analysed statistically in RBD (Sukhatme and Amble, 1985).

3.2.5. Experiment 5

Study on the charcoal recovery from Prosopis juliflora (Swartz) DC. fuelwood (off station study)

The fuelwood billets of about 75 cm length were sorted into six different diameter classes viz., (i) less than 2.5 cm, (ii) 2.6 to 4.5 cm, (iii) 4.6 to 6.5 cm, (iv) 6.6 to 8.5 cm, (v) 8.6 to 10.5 cm and (vi) greater than 10.5 cm. **Prosopis** root stocks (approximately more than 10.5 cm diameter) were also included in addition to the above categories. In each category 200 kg dry matter was taken. They were subjected to burning under anaerobic condition following the charcoal making procedures adopted by the local people (Karimoottam). The charcoal recovery percentage in terms of utilizable charcoal (UC) and non-utilizable charcoal (NUC) was estimated. This experiment was conducted in a farmer's field at Manikattienthal village of Tiruchuli taluk of Kamarajar district, Tamil Nadu. The data were not put under statistical scrutiny since this study was made from a single location.

PART III STUDY (Feeder experiments)

3.2.6. Experiment 6

Germinability of hot water treated Prosopis juliflora (Swartz) DC. seeds under different times of sowing

In large scale afforestation of **Prosopis** it is difficult to adopt recommended seed rate due to many practical difficulties viz., loss of vigour of seeds, presence of hard seeds, ill filled and chaffy seeds etc. Hence, naturally higher seed rate has to be used giving allowance for these problems. Under such situation surplus quantity of hot water treated seeds may be available after sowing. Presently there is no information on the longevity of the surplus hot water treated **Prosopis** seeds. With the above objective this experiment was designed.

Hot water treated **Prosopis** seeds were sown in pots filled with nursery media (native soil : sand : FYM at 3:1:1 ratio) during November 1993. The treatments consisted of the following.

T_1 - Sowing the seeds on the day of HWT
T_2 - Sowing the seeds 1 DAHWT
T_3 - Sowing the seeds 2 DAHWT
T_4 - Sowing the seeds 3 DAHWT
T_5 - Sowing the seeds 4 DAHWT
T_6 - Sowing the seeds 5 DAHWT
T_7 - Sowing the seeds 6 DAHWT
T_8 - Sowing the seeds 7 DAHWT
T_9 - Sowing the seeds 8 DAHWT
T_{10} - Sowing the seeds 9 DAHWT
T_{11} - Sowing the seeds 10 DAHWT
T_{12} - Sowing the seeds 11 DAHWT
T_{13} - Sowing the seeds 12 DAHWT
T_{14} - Sowing the seeds 13 DAHWT
T_{15} - Sowing the seeds 14 DAHWT

T_{16} - Sowing the seeds 15 DAHWT

HWT : Hot water treatment;

DAHWT : Day(s) after hot water treatment

Design : CRD; Replications : Three

Prosopis juliflora seeds were treated in hot water as described elsewhere (Experiment 1). One hundred seeds were sown in each pot commencing from 2.11.1993. Germination count was taken on 10th day of sowing for each treatment. The germination percentage was worked out and the data were analysed statistically in CRD after necessary arc sine transformation (Sukhatme and Amble, 1985).

3.2.6.2. Experiment 7

Effect of seed sizes and depths of sowing on the germination of Prosopis juliflora (Swartz) DC.

In large scale afforestation of **Prosopis** through broadcasting of seeds, there was a problem in getting uniform population due to gaps in the field even in the same type of soil. This may be possibly due to variation in seed size and depth of sowing. To find out the influence of seed sizes and the depths of sowing on the germination of **Prosopis** this experiment was designed.

Based on the seed size (visual grading) and 100 seed weight, two groups of seeds were sorted out viz., small seeds (2.438 g/100 seeds) and big seeds (3.070 g/100 seeds) from a seed lot of **Prosopis**. The treatment details are given below.

T_1 - Small seeds sown at 2 cm depth
T_2 - Small seeds sown at 4 cm depth
T_3 - Small seeds sown at 6 cm depth
T_4 - Small seeds sown at 8 cm depth
T_5 - Big seeds sown at 2 cm depth
T_6 - Big seeds sown at 4 cm depth
T_7 - Big seeds sown at 6 cm depth
T_8 - Big seeds sown at 8 cm depth
Design : CRD; Replications : Three

The hot water treated seeds were sown as per the treatment schedule in the pots containing nursery media (native soil : sand : FYM at 3:1:1 ratio) at the rate of 100 seeds per pot. Sowing was done on 3.11.93. Germination count was recorded everyday starting from the first day to 16th day after sowing to find out the peak period of germination and the length of germination period. Finally the germination percentage was worked out. The data were analysed statistically in CRD after arc sine transformation (Sukhatme and Amble, 1985). On 30th day the DMP per plant and per pot was estimated and statistically analysed.

3.2.6.3. Experiment 8

Allelopathic effect of Prosopis juliflora (Swartz) DC. on field crops

It was observed that the germination and the growth of field crops were much affected in the vicinity of both the live fence and the dead fence of **Prosopis** in the farmers' fields. Similarly no crop or even weeds comes up under **Prosopis** when the crown closure is almost full. This could be due to many reasons viz., root effect, shade effect, allelopathy etc. The experiments 8, 9 and 10 were designed to study only the allelopathic effect of **Prosopis** on field crops and weeds.

Top soil (0 to 30 cm) and sub soil (30 to 60 cm) were collected around the root stocks of about 10 years old natural stand of **Prosopis** from Fd.No.37 of eastern block of TNAU, Coimbatore. Similarly, top soil (0 to 30 cm) was collected from the adjacent open fallow field where there was neither **Prosopis** nor any field crops. This served as control for the study. The soil type in both locations was clay loam. Two kg in each category of soil were filled up in the pots and the treatments were imposed as detailed below.

T_1 - Top soil (UP)
T_2 - Sub soil (UP)
T_3 - Top soil (FL) + PLL 1 per cent
T_4 - Top soil (FL) + PLL 2 per cent
T_5 - Top soil (FL) + PLE 1 per cent

T_6 - Top soil (FL) + PLE 2 per cent
T_7 - Top soil (FL) + PLPE 1 per cent
T_8 - Top soil (FL) + PLPE 2 per cent
T_9 - Top soil (FL) + PRE 1 per cent
T_{10} - Top soil (FL) + PRE 2 per cent
T_{11} - Top soil (FL) + tap water (control)
UP : under **Prosopis**; FL : Fallow land;
PLL : **Prosopis** leaf litter; PLE : **Prosopis** leaf extract
PLPE : **Prosopis** leaf powder extract;
PRE : **Prosopis** root extract; Design : CRD; Replications : 3

Prosopis leaf litter was incorporated into two kg soils before sowing test crops, at the rate of 1 per cent and 2 per cent (w/w basis) for the treatments T_3 and T_4. The different extracts of **Prosopis** (leaf, leaf powder and root) were added after sowing the test crops in the concerned treatments. The test crops were Sorghum (Co.26), sunflower (Co.2), blackgram (Co.5) and **Prosopis** (local). One day before sowing the test crops, all the pots were saturated with tap water to allow the soil to settle intact. Fifty seeds in each of the test crops were sown in the pots as per the treatment schedule on 5.11.93. **Prosopis** seeds were treated with hot water before sowing. The plant extracts were added at the rate of 250 ml per pot only once immediately after sowing. Subsequently daily watering was done with tap water in such a way that there is no percolation/drainage from the pots so that the different extracts of **Prosopis** added already did not get leached out.

3.2.6.3.1. Preparation of extract

The different plant extracts were prepared (w/v basis) by soaking the fresh leaves, dry leaf powder and fresh roots of **Prosopis** in tap water for 24 hours. The final extracts were obtained by filtering through two layers of muslin cloth (which was approximately equal to or less than 0.5 mm wire mesh) as per the procedure given by Usha Goel **et al.** (1989). The extracts so prepared were used immediately for imposing the treatments.

3.2.6.3.2. Germination count

Germination count of test crops was taken on 10th day of sowing. The test crops were pulled out on 15th day. The DMP per plant was estimated by drying the plant samples first under natural condition and then in hot air oven at 75°C till a constant weight was obtained.

The data on germination were analysed statistically in CRD after arc sine transformation and the data on DMP were analysed as such in CRD (Sukhatme and Amble, 1985). After 15 days of estimation of DMP of first test crop, the same test crops viz., blackgram, sunflower, sorghum and **Prosopis** were sown as residue crop in order to assess the persistence of allelopathic effect of **Prosopis** plant materials.

3.2.6.3.3. Estimation of phenols and C:N ratio in plant materials of Prosopis

The phenolic content of dry bark, fresh roots, dry leaves, dry leaf powder, fresh leaves and dry stem (without bark) of **Prosopis** were estimated following the procedure outlined by Bray and Thorpe (1954) and expressed in mg g^{-1} of plant material. The C:N ratio of **Prosopis** leaves was also estimated as per the procedure outlined by Piper (1966).

3.2.6.4. Experiment 9

Effect of different times of sowing of test crops to mitigate the allelopathic effect of Prosopis juliflora (Swartz) DC. leaf litter on the germination and DMP of test crops

From the previous experiment it was found out that the dry leaves of **Prosopis** had more inhibitory effect on test crops (except sunflower) than the other extracts. The inhibitory effect of dry leaves of **Prosopis** on the germination of test crops was found due to the phenols present in the **Prosopis.** Hence the present experiment was designed.

For this study, only the top soil from the fallow land (Fd.No.37) was taken. Similarly, only the dry leaves (leaf litter) were used at two levels (1 per cent and 2 per cent on W/W basis). Sunflower was not included as test crop as it was able to withstand the inhibitory effect of

Prosopis leaf litter. The different times of sowing of test crop were as follows.

T_1 - Sowing at the time of LI

T_2 - Sowing 1 WALI

T_3 - Sowing 2 WALI

T_4 - Sowing 3 WALI

T_5 - Sowing 4 WALI

T_6 - Sowing 5 WALI

T_7 - Sowing 6 WALI

(LI : Leaf litter incorporation; WALI : Week after leaf litter incorporation)

Design : CRD; Replications : 3

Two kg top soil was taken in 21 small pots and the **Prosopis** dry leaves were incorporated on 2.1.1994 at the rate of 1 per cent and 2 per cent (w/w basis) to have different quantity of dry leaves in a known quantity of soil. The test crops viz., sorghum (Co.26), blackgram (Co.5) and **Prosopis** (local), were sown as per schedule. Right from the first sowing, water was sprinkled to all the pots containing soil incorporated with leaf litter in which subsequent sowings are to be taken at different weeks as per the treatment schedule. The water was sprinkled almost everyday to all the pots so as to accelerate the process of leaf degradation or decomposition. Fifty seeds each of test crops were sown in the pots. The **Prosopis** seeds were sown after hot water treatment. Before sowing all the pots (soil with dry leaves) were saturated with tap water as done in the previous experiment.

Germination count was taken on 10th day of sowing of respective treatments. On 30th day, the seedlings were pulled out and the DMP per plant was estimated after drying the plant samples in shade first and then at 75°C till a constant weight was obtained. The germination data were analyzed statistically in CRD after arc sine transformation and other data were analysed as such in CRD (Sukhatme and Amble, 1985).

3.2.6.5. Experiment 10

Effect of leaf litter and plant extracts of Prosopis juliflora (Swartz) DC. on weed control

About 12 kg soil (clay loam) was taken in each of 36 pots. Three test weed species viz., **Cyanodon dactylon** (Haryali), **Cyprus rotundus** (Nut grass) and **Parthenium hysterophorus** (Parthenium) were selected for this study. Two per cent extracts of **Prosopis** fresh leaves and fresh roots were prepared (w/v basis) as per the procedure given by Usha Goel **et al.** (1989). **Prosopis** leaf litter was incorporated into the soil at the rate of 2 per cent (w/w basis) before sowing/planting of test weeds. The extracts of leaves and roots were added after sowing of weed seeds/ stolons/ rhizomes. The following is the structure of the treatments.

T_1 - HS + PRE

T_2 - HS + PLE

T_3 - HS + PLL

T_4 - HS + tap water (control)

T_5 - NG + PRE

T_6 - NG + PLE

T_7 - NG + PLL

T_8 - NG + tap water (control)

T_9 - Parthenium + PRE

T_{10} - Parthenium + PLE

T_{11} - Parthenium + PLL

T_{12} - Parthenium + tap water (control)

HS - Haryali stolon; NG - Nut grass rhizome;

PRE - **Prosopis** root extract; PLE - **Prosopis** leaf extract;

PLL - **Prosopis** leaf litter; Design : CRD; Replications : 3

As per the treatments, 10 stolons of haryali, 10 rhizomes of nut grass and 50 seeds of Parthenium per pot were sown separately, on 10.1.94. 250 ml of extract was added to the pots as per treatment immediately after sowing/planting of weeds. Germination count was taken on 10th day of sowing and DMP per pot was estimated on 20 DAS. Since there was only little inhibition on the germination of test weeds, this experiment was repeated with some modifications viz., the concentration of leaf and root extracts was increased from 2 per cent to 5 per cent. The quantity of leaf litter was reduced from 2 per cent to 1 per cent. Instead of incorporating the leaf litter, it was applied on the soil surface of the pots as a layer simulating the natural fall of leaf litter like a mulch. In addition to weeds, sorghum was also included as a test crop. The germination count was taken on 10th day of sowing and the DMP per pot was estimated on 45th day of sowing after pulling out the weeds from the respective pots. The germination data were subjected to arc sine transformation. Then all the data were analysed statistically in CRD design (Sukhatme and Amble, 1985).

3.2.6.6. Experiment 11

Effect of leaf incorporation and plant extracts of Prosopis juliflora (Swartz) DC. on the control of root - knot nematode (Meloidogyne incognita (Kofoid and White, 1919) Chitwood, 1949) in tomato (Lycopersicon esculentum Mill.)

It has been observed in the farmers' fields that application of **Prosopis** leaf litter to the tomato crop in their kitchen garden as manure has incidentally controlled the nematode infection. To ascertain the nematicidal effect of **Prosopis** this experiment was designed to get some more additional informations.

The pot mixture (red soil and sand at 2:1 ratio) was sterilized with formalin at the rate of 20 ml per kg pot mixture. Tomato (Co.3) (test crop) nursery was raised using pot mixture on 1.1.94. The treatment details were as follows.

T_1 - Control (no plant extract)

T_2 - Dry stem extract of **Prosopis**

T_3 - Fresh bark extract of **Prosopis**

T_4 - Dry bark extract of **Prosopis**

T_5 - Charcoal powder extract of **Prosopis**

T_6 - Dry leaf powder extract of **Prosopis**

T_7 - Fresh root extract of **Prosopis**

T_8 - Fresh leaf extract of **Prosopis**

T_9 - Incorporation of dry leaves of **Prosopis**

T_{10} - Incorporation of fresh leaves of **Prosopis**

Design : CRD; Replications : 3

Two kg pot mixture was taken for each pot. Fresh leaves of **Prosopis** were incorporated (T_{10}) into pot mixture 10 days earlier to planting of tomato. Dry leaves were incorporated one day before transplanting tomato seedlings in the pot. Twenty five days old tomato seedlings were planted in the pots at the rate of 2 seedlings per pot on 29.1.94. After 10 days of transplanting, the root-knot nematode (**Meloidogyne incognita**) larvae were inoculated to the pots having tomato seedlings at the rate of 2000 larvae per pot (2 kg pot mixture). Before inoculation thinning was done and only one plant per pot was maintained. After inoculation, the treatments were imposed immediately. The dry and fresh leaves were incorporated at the rate of 1 per cent (w/w basis). The different extracts of **Prosopis** were prepared at 1 per cent concentration (w/v basis) as per the procedure given by Usha Goel **et al.** (1989). About 200 ml of extracts were added per pot as per treatment. Subsequent watering was done every day with enough care against leaching of extracts added already.

The fruits were harvested on 4th month after planting, in a staggered way as and when they ripe. The fruit numbers and fruit yield per plant were recorded. The nematode number per 200 g of rhizosphere soil and the number of egg masses per gram of root were estimated in the laboratory following the standard procedure (Heald **et al.**, 1989). The data were analysed statistically in CRD (Sukhatme and Amble, 1985).

3.2.6.7. Experiment 12

Estimation of nutrient addition through Prosopis juliflora (Swartz) DC. leaves

It has been observed that **Prosopis** leaf litter contributes very much to the soil fertility. The time taken for mineralization of the **Prosopis** leaves and the quantum of nutrients it adds to the soil and hence the ultimate change in soil pH, EC and organic carbon are unknown. To elucidate these information this experiment was designed.

About two kg of red loamy soil **was taken** in plastic trays of 45 x 30 x 10 cm size. Two grams of dried leaves of **Prosopis** was incorporated to a depth of 2.5 of soil layers in the trays. Then the trays were watered to make the soil wet and kept for incubation. Subsequently water was sprinkled whenever hair line cracks were observed at the surface of the soil. The soil samples were drawn from the trays at specified interval of time viz., 30, 45, 60, 75 and 90 days after leaf incorporation. A control treatment was also maintained without leaf incorporation. The soil samples were analysed for EC, pH, organic carbon, available N, P and K following the standard procedures (Table 5). The data were analysed statistically in CRD (Sukhatme and Amble, 1985).

3.2.6.8. Experiment 13

Enumeration of microbial load in Prosopis juliflora (Swartz) DC. leaf litter collected from the field

Mineralization of **Prosopis** leaf litter depends on many factors viz., leaf moisture, soil moisture, soil temperature, microorganisms etc. With an objective of finding out the specific group of microorganisms involved in the mineralization process, this experiment was designed.

Prosopis leaf litter was collected from two locations viz., Fd.No.62 (About 10 years old natural stand) and Fd.No.37 (About six years old natural stand) of the TNAU main campus during Feb. 1994 . The soil type of these fields was clay loam. The leaf litter was grouped into two classes viz., (i) the top layer of undecomposed leaves of **Prosopis** of about 0.5 to 1.0 cm thickness; (ii) the bottom layer - partly/fully decomposed leaves of about 0.5 cm thickness which had close contact with soil surface. About 1 cm thickness of such soil layer was also scrapped out for analysis.

It was assumed that any microorganism degrading **Prosopis** leaf litter must be capable of degrading tannins (Polyphenolic compounds) as there is some quantity of tannins present in **Prosopis** leaves as reported in section 3.2.6.3.3. Hence two levels of tannin viz., 0.1 per cent and 0.25 per cent were incorporated into the respective media for screening the microorganisms present in the **Prosopis** leaf litter. The population of bacteria, fungi and actinomycetes were estimated in the two layers of leaf litter and top soil layer following the standard procedures outlined elsewhere (Section 3.2.2.7).

3.3. References

References have been presented based on the latest guidelines of the American Society of Agronomy, USA, published in Agronomy Journal, 85(6): 1280-1281, 1993.

RESULTS

CHAPTER IV

RESULTS

The results of the 13 experiments (Table 1) conducted on the silvicultural and ecological aspects of **Prosopis juliflora** have been presented in this chapter.

PART I STUDY

4.1. EXPERIMENT 1 : Study on the allometric relationship of the Prosopis juliflora (Swartz) DC. Seedlings

In order to find out the fundamental relationship between root and shoot of six months old **Prosopis juliflora** seedlings, this experiment was conducted.

Simple linear regression study was done to find out the influence of shoot length on root length of **Prosopis juliflora** seedlings. Similarly the relationship between shoot and root weight was also probed.

The regression result was not significant when shoot length was related to root length of **Prosopis juliflora** seedlings. The simple regression equation obtained for this study is written as follows.

$$Y_{SL} = 2.060 + 4.916_{RL} \ (R^2 = 0.326NS)$$

Where, SL = Shoot length; RL = Root length.

At the same time, it is evidently proved from this study that the shoot weight had profound influence on root weight. This is seen through the simple linear regression equation developed.

$$Y_{SW} = 0.982 + 0.889_{RW} \ (R^2 = 0.909^{**})$$

Where, SW = Shoot weight; RW = Root weight.

Hence, the result of the present study could be interpreted that the DMP of shoot (Shoot weight) could be considered a scientific parameter for evaluating six months old **Prosopis juliflora** seedlings for the selection of better planting stocks as compared to the other parameters like height of the seedlings.

4.2. EXPERIMENT 2 : Comparative performance of Prosopis juliflora (Swartz) DC. with other multipurpose tree species (MPTs)

Prosopis juliflora has been found to grow very fast even in degraded and uncared waste lands. But its growth, biomass production and its impact on soil fertility in comparison with other exotic and indigenous MPTs are very much lacking. Hence, this study was undertaken to assess the relative performance of **Prosopis juliflora** with other MPTs.

4.2.1. Biometrics

4.2.1.1. Tree height, BD and DBH

The data on growth of **Prosopis juliflora** in terms of tree height, BD and DBH was compared with other MPTs and presented in Table 7.

Table 7. Mean tree height, BD and DBH of the MPTs (4th year)

Tree species	Tree height (m)	Basal diameter (cm)	DBH (cm)
1. **Azadirachta indica**	4.50	5.91	4.51
2. **Acacia nilotica**	4.58	5.41	4.18
3. **Acacia leucophloea**	3.47	4.51	3.68
4. **Prosopis juliflora**	4.40	5.33	3.95
5. **Casuarina equisetifolia**	5.91	4.75	3.54
6. **Eucalyptus camaldulensis**	6.77	6.91	5.43
7. **E.tereticornis**	6.68	7.56	5.63
SE_d	0.49	0.48	0.54
CD ($P = 0.05$)	1.06	1.05	1.17

The tree height of **Eucalyptus camaldulensis** was significantly higher and it was comparable with that of **E.tereticornis** and **Casuarina equisetifolia**. **Acacia leucophloea** recorded lesser tree height. On comparison, tree height of **Prosopis juliflora** was 35.0, 34.1 and 25.6 per cent lesser than that of **E.camaldulensis, E.tereticornis** and **C.equisetifolia**, respectively.

Significantly higher BD and DBH were observed in **E.tereticornis, E.camaldulensis** and **Azadirachta indica** which were comparable. The lowest BD and DBH were recorded in **Acacia leucophloea**. The BD of **Prosopis juliflora** was 29.5, 22.9 and 9.8 per cent, respectively, which were lower than that of **E.tereticornis, E.camaldulensis** and **A.indica**. Similarly, the DBH of **Prosopis juliflora** was lesser than that of **E.tereticornis, E.camaldulensis** and **A.indica** by 29.8, 27.3 and 12.4 per cent, respectively.

4.2.1.2. Current annual increment (CAI) and mean annual increment (MAI) of tree height and BD (Table 8 and 9)

During first and second year, the CAI of height was higher with **Eucalyptus camaldulensis, E.tereticornis** and **Casuarina equisetifolia**, while in the 3rd year it was higher in **Azadirachta indica, Acacia nilotica** and **Prosopis juliflora**. But in 4th year there was no such significant difference among **Eucalyptus camaldulensis, E.tereticornis,**

Table 8. Current annual increment (CAI) and mean annual increment (MAI) of height growth of MPTs

Tree species	CAI (cm)				MAI (cm)
	Ist year	2nd year	3rd year	4th year	
1. **Azadirachta indica**	77.1	31.7	156.9	38.2	84.9
2. **Acacia nilotica**	62.4	49.9	104.2	39.8	73.6
3. **Acacia leucophloea**	39.8	81.4	64.2	47.0	61.7
4. **Prosopis juliflora**	59.6	83.7	89.8	52.9	80.8
5. **Casuarina equisetifolia**	113.7	107.0	78.2	77.7	99.6
6. **Eucalyptus camaldulensis**	216.9	167.7	35.7	62.6	125.7
7. **E.tereticornis**	187.9	146.6	53.6	81.5	123.8
SE_d	43.1	29.3	22.3	12.5	6.5
CD (P = 0.05)	105.5	71.6	54.7	30.6	15.9

Table 9. Current annual increment (CAI) and mean annual increment (MAI) of basal diameter of MPTs

Tree species	CAI (cm)				MAI (cm)
	Ist year	2nd year	3rd year	4th year	
1. **Azadirachta indica**	1.19	0.86	2.93	1.25	1.64
2. **Acacia nilotica**	1.10	1.05	1.95	1.42	1.44
3. **Acacia leucophloea**	0.69	1.28	1.11	1.43	1.19
4. **Prosopis juliflora**	0.90	1.07	1.40	1.33	1.26
5. **Casuarina equisetifolia**	1.21	1.97	0.41	1.33	1.27
6. **Eucalyptus camaldulensis**	2.89	2.56	0.60	1.37	1.90
7. **E.tereticornis**	1.13	2.21	1.22	1.12	1.89
SE_d	0.18	0.17	0.21	0.07	0.20
CD (P = 0.05)	0.45	0.42	0.51	NS	0.50

Casuarina equisetifolia and **Prosopis juliflora** (Fig. 4). In general the same trend was observed for CAI of basal diameter also (Fig. 5).

Among all the seven MPTs evaluated, **A.leucophloea** was found to be very slow in growth as evident from lesser MAI of tree height and BD (Fig. 6).

4.2.1.3. Biomass (DMP)

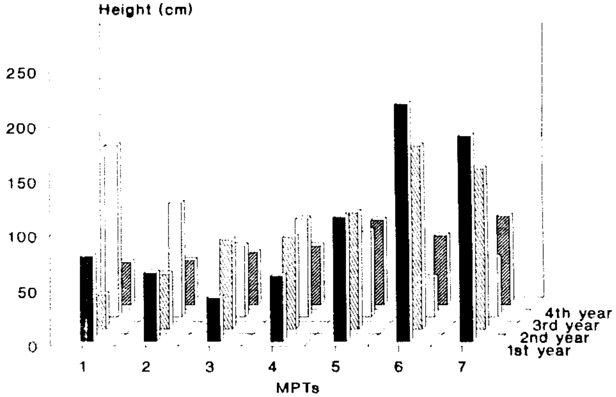
The DMP of leaves, branches, NUB, UB and total biomass on per tree and per hectare basis for **Prosopis juliflora** and other MPTs are presented in Table 10; Fig. 7 and 8.

The leaf biomass on per tree basis was the highest in **E.tereticornis** and was comparable with that of **E.camaldulensis**, **Prosopis juliflora**, **Acacia nilotica** and **Casuarina equisetifolia**. The leaf biomass was the lowest in **A.leucophloea**.

The branch biomass per tree was significantly higher in **Prosopis juliflora** compared to other MPTs. It was the lowest in **A.leucophloea**. Similar to branch biomass trend, the NUB (leaf + branch) was also higher in **Prosopis juliflora** and was comparable with that of **E.tereticornis**. Lowest NUB per tree was recorded with **A.leucophloea**.

The UB (fuelwood) per tree was higher in **E.camaldulensis** and was on par with **E.tereticornis** and

Fig. 4 Current annual increment of height of MPTs



1 - Azadirachta indica

2 - Acacia nilotica

3 - Acacia leucophloea

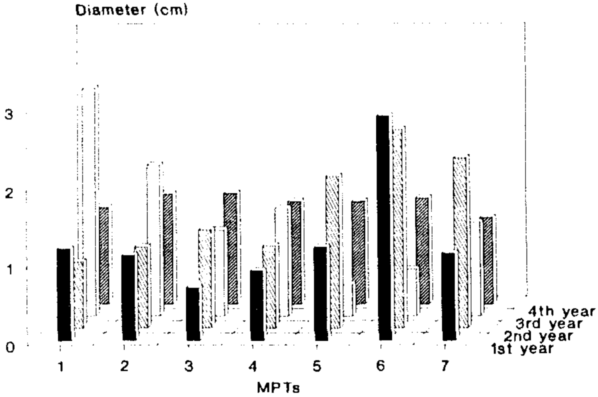
4 - Prosopis juliflora

5 - Casuarina equisetifolia

6 - Eucalyptus camaldulensis

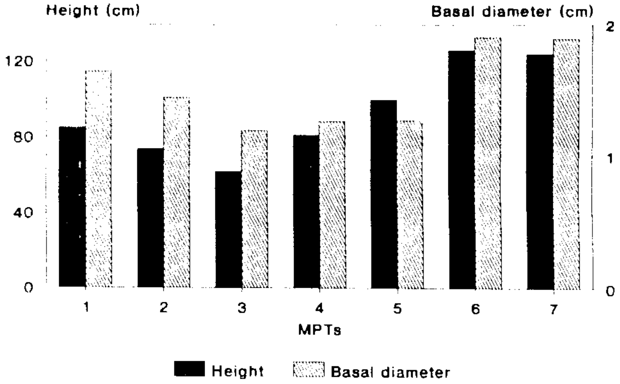
7 - E.tereticornis

Fig. 5 Current annual increment of basal diameter of MPTs



1 - Azadirachta indica	5 - Casuarina equisetifolia
2 - Acacia nilotica	6 - Eucalyptus camaldulensis
3 - Acacia leucophloea	7 - E.tereticornis
4 - Prosopis juliflora	

Fig. 6 Mean annual increment of height and basal diameter of MPTs



1 - **Azadirachta indica**

2 - **Acacia nilotica**

3 - **Acacia leucophloea**

4 - **Prosopis juliflora**

5 - **Casuarina equisetifolia**

6 - **Eucalyptus camaldulensis**

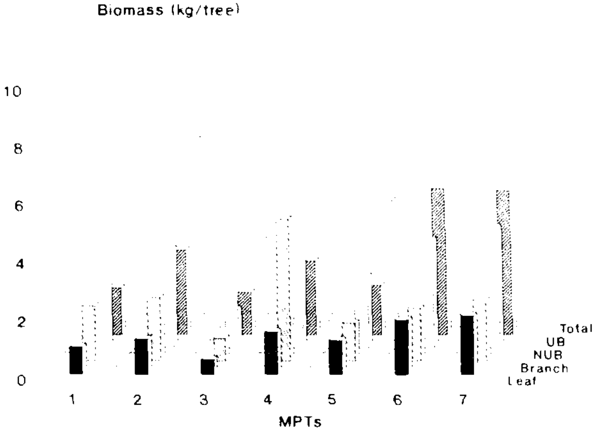
7 - **E.tereticornis**

Table 10. Mean biomass production potential of MPTs (Dry weight basis) in the 4th year

Tree species	Biomass (kg $tree^{-1}$)					Biomass (t ha^{-1})				
	Leaf	Branch	NUB	UB	Total	Leaf	Branch	NUB	UB	Total
1. **Azadirachta indica**	0.94	1.89	2.83	1.63	4.46	2.36	4.72	7.08	4.08	11.15
2. **Acacia nilotica**	1.22	2.18	3.40	2.90	6.30	3.06	5.46	8.52	7.24	15.75
3. **Acacia leucophloea**	0.52	0.80	1.32	1.46	2.78	1.30	2.01	3.30	3.65	6.95
4. **Prosopis juliflora**	1.47	4.89	6.36	2.56	8.92	3.67	12.22	15.89	6.41	22.30
5. **Casuarina equisetifolia**	1.16	1.32	2.48	1.72	4.20	2.89	3.29	6.18	4.31	10.50
6. **Eucalyptus camaldulensis**	1.87	1.82	3.69	5.07	8.76	4.68	4.54	9.23	12.67	21.90
7. **E.tereticornis**	2.03	2.12	4.15	4.99	9.14	5.08	5.31	10.38	12.47	22.85
SE_d	0.41	0.73	1.04	1.09	1.54	0.74	0.77	1.87	1.90	2.44
CD (P = 0.05)	0.88	1.58	2.27	2.38	3.36	1.56	1.65	3.97	4.02	5.18

NUB : Non-utilizable biomass
UB : Utilizable biomass

Fig. 7 Biomass production in MPTs



1 - Azadirachta indica

2 - Acacia nilotica

3 - Acacia leucophloea

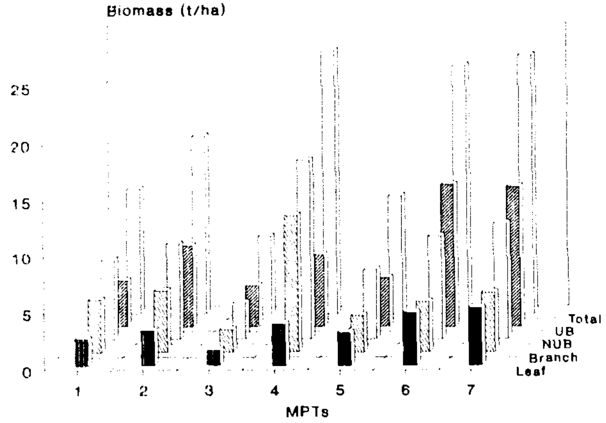
4 - Prosopis juliflora

5 - Casuarina equisetifolia

6 - Eucalyptus camaldulensis

7 - E.tereticornis

Fig. 8 Biomass production of MPTs



1 - Azadirachta indica

2 - Acacia nilotica

3 - Acacia leucophloea

4 - Prosopis juliflora

5 - Casuarina equisetifolia

6 - Eucalyptus camaldulensis

7 - E.tereticornis

Acacia nilotica. The UB of **Prosopis juliflora** was 49.5, 48.7 and 11.7 per cent, respectively, lower than the UB of **E.camaldulensis, E.tereticornis** and **A.nilotica**. The lowest UB was obtained in **A.leucophloea.**

As far as the total biomass (leaf + branch + stem) per tree was concerned, **E.tereticornis, E.camaldulensis** and **Prosopis juliflora** were statistically on par. The lowest total biomass per tree was recorded in **A.leucophloea.**

Regarding partitioning of biomass on per tree basis the leaf, branch, NUB and UB in **Prosopis juliflora** accounted for 16.48, 54.82, 71.30 and 28.70 per cent of its total biomass, respectively. The NUB was higher than UB in **Prosopis juliflora.** In **Eucalyptus tereticornis** and **E.camaldulensis** the trend was quite different wherein the UB was higher than NUB (Table 10).

In **E.tereticornis**, the UB, NUB, leaf and branch biomass accounted for 54.60, 45.21, 22.21 and 23.20 per cent, respectively, to the total biomass on per tree basis. Similarly, in **E.camaldulensis,** the UB, NUB, leaf and branch biomass contributed 57.88, 42.12, 21.35 and 20.78 per cent, respectively, to the total biomass on per tree basis (Table 10).

With reference to biomass production per hectare, these parameters behaved similar to biomass production observed on per tree (Table 10).

The above results indicated the superiority of **Eucalyptus tereticornis** and **E.camaldulensis** in producing 94 to 97 per cent higher UB over **Prosopis juliflora** (Fig. 9), though **Prosopis juliflora** was on par with **Eucalyptus tereticornis** and **E.camaldulensis** in terms of total biomass production at 4th year.

4.2.1.4. Wood density

The wood density on fresh weight basis was more than 1.0 g cm^{-3} for all the MPTs studied except **Casuarina equisetifolia**. **Acacia leucophloea** recorded significantly higher wood density and was comparable to that of **E.camaldulensis, Prosopis juliflora** and **E.tereticornis** (Table 11).

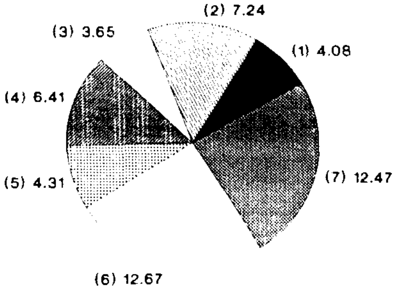
On dry weight basis higher wood density was seen with all MPTs studied except for **Acacia nilotica** and **Prosopis juliflora**. The wood density was the lowest in **Prosopis juliflora** and it was comparable with that of **A.nilotica, A.leucophloea** and **Azadirachta indica**.

4.2.2. Microbial load (Table 12)

4.2.2.1. Bacteria

Among the three microbes studied, bacteria was the most predominant group followed by actinomycetes and fungi in the soils under different MPTs evaluated. The bacterial population in the soil under different MPTs studied ranged from 24.40×10^5 to 104.60×10^5 numbers g^{-1} dry soil.

Fig. 9 Utilizable biomass (fuel wood) production by different MPTs at 4th year



Biomass (t/ha)

1 - **Azadirachta indica**
2 - **Acacia nilotica**
3 - **Acacia leucophloea**
4 - **Prosopis juliflora**
5 - **Casuarina equisetifolia**
6 - **Eucalyptus camaldulensis**
7 - **E.tereticornis**

Table 11. Mean wood density of MPTs (4 years old)

Tree species	Wood density (g cm^{-3})	
	Fresh weight basis	Dry weight basis
1. **Azadirachta indica**	1.019	1.118
2. **Acacia nilotica**	1.051	1.001
3. **Acacia leucophloea**	1.132	1.064
4. **Prosopis juliflora**	1.070	0.928
5. **Casuarina equisetifolia**	0.969	1.226
6. **Eucalyptus camaldulensis**	1.074	1.139
7. **E.tereticornis**	1.057	1.306
SE_d	0.035	0.113
CD (P = 0.05)	0.076	0.246

Table 12. Mean microbial population under four years old different MPTs

Tree species	Bacteria $x\ 10^5$ g^{-1} dry soil	Fungi $x\ 10^3$ g^{-1} dry soil	Actinomycetes $x\ 10^5$ g^{-1} dry soil
1. **Azadirachta indica**	32.67	8.35	17.67
2. **Acacia nilotica**	81.67	20.00	64.33
3. **Acacia leucophloea**	104.60	23.20	100.00
4. **Prosopis juliflora**	42.67	6.00	59.00
5. **Casuarina equisetifolia**	34.20	6.00	23.30
6. **Eucalyptus camaldulensis**	26.00	3.67	27.10
7. **E.tereticornis**	24.40	2.67	19.00
SE_d	2.87	2.25	2.55
CD (P = 0.05)	6.26	4.91	5.56

Maximum number of bacteria was recorded under **A.leucophloea** followed by **A.nilotica.** The observed bacterial population under **Prosopis juliflora** was third in the order, next to **A.nilotica.** The lowest bacterial population was observed under **E.tereticornis** and **E.camaldulensis.**

4.2.2.2. Fungi

The fungal population varied from 2.67 x 10^3 g^{-1} (**E.tereticornis**) to 23.20 x 10^3 g^{-1} dry soil (**A.leucophloea**). Under **Prosopis juliflora** the fungal population was moderate (6 x 10^3 number g^{-1} dry soil). As in the case of bacteria, lowest fungal population was observed under **Eucalyptus tereticornis** and **E.camaldulensis.**

4.2.2.3. Actinomycetes

The population ranged from 19 x 10^5 g^{-1} dry soil (**E.tereticornis**) to 100 x 10^5 g^{-1} (**A.leucophloea**). The actinomycetes population under **A.nilotica** and **Prosopis juliflora** were on par with each other and significantly higher than that of **Azadirachta indica, Casuarina equisetifolia, Eucalyptus tereticornis** and **E.camaldulensis.**

It is inferred that among the MPTs evaluated, **A.leucophloea** recorded the highest number of bacteria, fungi and actinomycetes population followed by **A.nilotica** and **Prosopis juliflora** ranked third next to them. Lesser microbial population were recorded under **Eucalyptus tereticornis** and **E.camaldulensis.**

4.2.3. Weed flora (Table 13)

In the experimental site under the canopy of the different MPTs studied, 15 weed species were identified. Maximum weed density (number m^{-2}) was observed under **Casuarina equisetifolia** (13), followed by **Azadirachta indica** (10), **Prosopis juliflora** (9), **E.camaldulensis** (8), while the minimum was recorded under **A.nilotica** (7) and **A.leucophloea** (7).

Based on relative density (RD), relative frequency (RF) and the importance value (IV), **Oscimum canum** and **Vernonia cinera** were the dominant weed species under **Prosopis juliflora** and **Casuarina equisetifolia.** Under all other MPTs as well as in the adjacent open field (control), grassy weeds such as **Andropogon pumilus, Cymbopogon martini** and **Eragrostis** species were predominantly observed.

In terms of DMP of weeds, it was significantly higher under the canopy of **Casuarina equisetifolia** followed by **Azadirachta indica,** while the DMP of weeds was lower under **E.camaldulensis** and **E.tereticornis** than in the open field (control) and under other MPTs. The DMP of weeds under the canopy of **Prosopis juliflora** was comparable with that of **A.leucophloea** and the open field (control). The DMP of weeds under **Prosopis juliflora** was 36.9 per cent of the DMP under **Casuarina equisetifolia** and 43.4 per cent of the DMP under **Azadirachta indica.**

Table 13. Dynamics of weed flora under the canopy of four years old MPTs

	P.juliflora			**A.indica**			**E.camaldalensis**			**E.tereticornis**			**A.nilotica**			**A.leucophloca**			**C.equisetifolia**			Open field (control)		
	RD	RF	IV	RD	RF	IV	RD	RF	IV	RD	RF	IV	RD	RF	IV	RD	RF	IV	RD	RF	IV	RD	RF	
1. **Oscimum canum**	37.9	17.1	55.0	15.1	14.3	29.4	-	-	-	-	-	-	-	-	-	-	-	-	23.8	17.4	41.2	18.4	12.2	3
2. **Vernonia cinera**	23.5	12.2	35.7	11.9	12.5	24.4	-	-	-	-	-	-	1.1	3.6	4.7	-	-	-	21.6	15.2	36.8	4.9	10.2	1
3. **Leucus aspera**	-	-	-	1.9	5.4	7.3	1.8	5.6	7.4	4.2	6.1	10.3	1.1	3.6	4.7	2.7	6.6	9.3	3.0	6.3	9.3	3.3	6.1	
4. **Corchorus** spp.	2.6	4.9	7.5	1.3	5.4	6.7	-	-	-	-	-	-	-	-	-	-	-	-	0.9	2.1	3.0	-	-	
5. **Cleome viscosa**	3.3	4.9	8.2	0.1	3.6	3.7	2.4	5.6	8.0	2.6	6.1	8.7	3.7	7.1	10.8	1.1	3.3	4.4	2.6	6.3	8.9	-	-	
6. **Abuttilon indicum**	-	-	-	0.1	1.8	1.9	-	-	-	1.0	3.0	4.0	0.5	3.6	4.1	1.1	3.3	4.4	-	-	-	-	-	
7. **Lantana camera**	-	-	-	-	-	-	0.1	2.8	2.9	0.5	3.0	3.5	-	-	-	-	-	-	0.4	2.1	2.5	-	-	
8. **Commelinea bengalensis**	1.3	4.9	6.2	0.1	3.6	3.7	-	-	-	1.0	3.0	3.1	-	-	-	-	-	-	1.3	2.1	3.4	-	-	-
9. **Tephrosia purpurea**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.9	2.1	3.0	5.7	8.2	1
10. **Boerheavia diffusa**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.8	2.0	2
11. **Andropoon pumilus**	13.1	12.2	25.3	19.9	17.9	37.8	35.9	27.8	63.7	33.7	30.3	64.0	45.5	35.7	81.2	43.5	30.3	73.8	10.8	10.9	21.7	24.5	20.4	44
12. **Cymbopogon martini**	9.8	2.4	12.2	26.5	17.9	44.4	41.9	27.8	69.7	41.5	30.3	71.8	40.1	35.7	75.8	32.6	30.3	62.9	13.0	13.0	26.0	28.6	20.4	49
13. **Eragrostis** spp.	6.5	17.1	23.6	21.2	17.9	39.1	13.8	19.4	33.2	10.4	9.1	19.5	-	-	-	16.3	21.2	37.5	17.3	15.2	32.5	20.5	20.4	40
14. **Cyperus rotundus**	2.0	2.4	4.4	-	-	-	0.1	2.8	2.9	3.6	6.1	9.7	8.0	10.7	18.7	2.7	6.6	9.3	1.3	2.1	3.3	-	-	-
15. **Cyanodon dactylon**	-	-	-	-	-	-	3.0	5.6	8.6	1.6	3.0	4.6	-	-	-	-	-	-	0.8	4.2	5.0	-	-	-
DMP of weeds (g m^{-2})		305.3			703.8			150.6			175.3			352.3			340.7			826.5			2[illegible]	
*SE$_d$		19.3																						
*CD (P=0.05%)		41.4																						

4.2.4. Nutrient uptake in MPTs

The uptake of eight nutrients such as N, P, K, Na, Fe, Mn, Zn and Cu was studied in the present investigation. Though Na is strictly not a major/micronutrient, in the present investigation, its uptake by different MPTs with reference to its availability in the soil was studied for the following reasons. **Prosopis juliflora** appeared to exclude Na very effectively under saline-alkaline soil as inferred through review of literature. At the same time, there were reports that **Prosopis juliflora** leaves were fairly rich in Na to the tune of 3.94 to 4.51 per cent in alkaline soils. The above reports suggested that Na uptake was more in sodic soils and **Prosopis juliflora** appeared to exclude Na under saline-alkaline soil. Information on the relative uptake of Na by different MPTs including **Prosopis juliflora** in normal soil is lacking. Hence, in the present investigation, study on Na was done along with other nutrients.

4.2.4.1. Macronutrients (Table 14 and 15)

Higher leaf NPK uptake was observed with **Prosopis juliflora** followed by **Eucalyptus tereticornis** and **E.camaldulensis**, while the leaf Na uptake was found highest with the leaves of **Eucalyptus tereticornis** and **E.camaldulensis** followed by **Casuarina equisetifolia** and **Prosopis juliflora**.

Table 14. Mean uptake of nutrients in the leaves of 4 years old MPTs (kg ha^{-1})

Tree species	N	P	K	Na	Fe	Mn	Zn	Cu
1. **Acacia nilotica**	65.63	4.28	20.48	1.74	0.326	0.316	0.107	0.116
2. **Prosopis juliflora**	103.38	7.45	73.77	2.06	0.330	0.367	0.135	0.122
3. **Eucalyptus tereticornis**	90.02	4.57	44.17	2.69	0.339	1.066	0.152	0.095
4. **Eucalyptus camaldulensis**	84.92	4.22	45.43	2.81	0.312	0.999	0.156	0.084
5. **Azadirachta indica**	44.29	3.70	36.21	1.18	0.212	0.189	0.063	0.044
6. **Acacia leucophloea**	21.79	1.78	8.82	0.65	0.197	0.095	0.030	0.023
7. **Casuarina equisetifolia**	43.21	1.94	12.65	2.32	0.540	0.270	0.101	0.056
SE_d	16.78	0.97	12.16	0.49	0.050	0.059	0.035	0.026
CD (P = 0.05)	35.60	2.05	25.80	1.03	0.105	0.125	0.075	0.056

Table 15. Mean uptake of nutrients in stems of 4 years old MPTs (kg ha^{-1})

Tree species	N	P	K	Na	Fe	Mn	Zn	Cu
1. **Acacia nilotica**	87.77	14.69	29.67	8.68	6.126	1.038	0.651	0.549
2. **Prosopis juliflora**	131.60	13.46	22.69	10.26	4.658	0.855	0.428	0.450
3. **Eucalyptus tereticornis**	162.93	23.69	76.04	20.32	9.391	2.575	1.288	0.944
4. **Eucalyptus camaldulensis**	189.22	23.57	67.17	18.12	8.111	2.727	1.346	0.957
5. **Azadirachta indica**	57.06	8.93	25.27	5.42	3.207	0.598	0.367	0.391
6. **Acacia leucophloea**	57.87	6.57	21.90	5.47	2.712	0.499	0.316	0.257
7. **Casuarina equisetifolia**	52.33	6.90	20.58	6.73	3.581	0.992	0.388	0.352
SE_d	23.68	3.91	5.12	3.70	1.030	0.402	0.371	0.295
CD (P = 0.05)	50.28	8.30	10.86	7.85	2.186	0.852	0.786	0.625

The uptake pattern of stem (UB) was quite reverse. Both the species of **Eucalyptus** recorded higher stem uptake of NPK and Na followed by **Prosopis juliflora** (Table 15).

Lowest leaf and stem uptake of all the above four nutrients was observed in **A.leucophloea** and **Casuarina equisetifolia.**

The leaf uptake of NPK was in the ratio of 14:1:10 in **Prosopis juliflora** while, the ratio between Na and K was 1:40. In **Eucalyptus camaldulensis** and **E.tereticornis** the uptake in the leaves was in the proportion of 21:1:10 for NPK and 1:16 for Na and K.

On the contrary, there was a change in the proportion of the uptake or accumulation of nutrients in the stems (UB). In **Prosopis juliflora** it was 11:1:2 ratio for NPK and 1:2 for Na and K. Whereas, in **Eucalyptus camaldulensis** and **E.tereticornis** the accumulation of NPK was in the order of 9:1:3 and for Na and K it was 1:4.

4.2.4.2. Micronutrients (Table 14 and 15)

In general the uptake of all the four micronutrients studied viz., Fe, Mn, Zn and Cu was higher in the stems (UB) than in leaves for all the MPTs. Among them, Fe and Mn were removed from the soil relatively in larger quantities than Zn and Cu.

Maximum accumulation of Fe was found in the leaves of **Casuarina equisetifolia** while it was minimum in the leaves of **A.leucophloea**. The uptake of Fe in the stem was the highest in **Eucalyptus camaldulensis** and **E.tereticornis**, followed by **A.nilotica** and **Prosopis juliflora** and the lowest in **A.leucophloea**.

Regarding the uptake of Mn, it was the highest in the leaves of **Eucalyptus camaldulensis** and **E.tereticornis** and lowest in **A.leucophloea**. Uptake by stem was the highest in **Eucalyptus camaldulensis** and **E.tereticornis**, followed by **Prosopis juliflora** and least in **A.leucophloea**.

The uptake of Zn and Cu was found to be higher in **Eucalyptus camaldulensis** and **E.tereticornis** both in the stem and leaves while, they were the lowest in the leaves and stems of **A.leucophloea**.

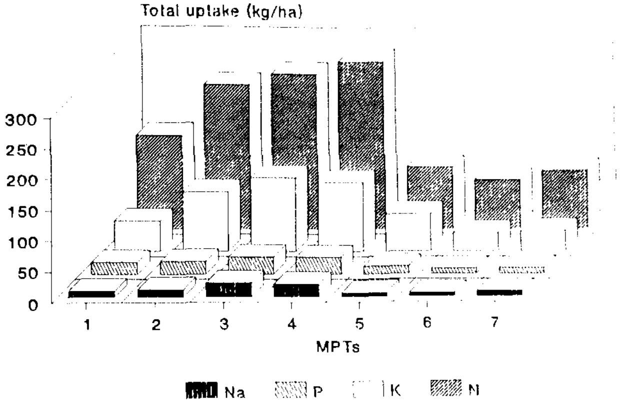
The total uptake of all the nutrients studied were highest in both the species of **Eucalyptus camaldulensis** and **E.tereticornis**. **Prosopis juliflora** was next to them. Lowest total uptake of nutrients was observed in **A.leucophloea** (Table 16 and Fig. 10 and 11).

The total nutrient drain from the soil through plant uptake was in the order of N > K > P > Na for the macronutrients and for the micronutrients it was in the order of Fe > Mn > Zn > Cu (Table 16). The quantum of total depletion of nutrients was the highest by **Eucalyptus**

Table 16. Total mean uptake of nutrients through leaves and stems in 4 years old MPTs ($kg\ ha^{-1}$)

Tree species	N	P	K	Na	Fe	Mn	Zn	Cu
1. **Acacia nilotica**	153.40	18.97	50.15	10.42	6.452	1.354	0.758	0.665
2. **Prosopis juliflora**	234.98	20.91	96.46	12.32	4.988	1.222	0.563	0.572
3. **Eucalyptus tereticornis**	252.95	28.26	120.21	23.01	9.730	3.641	1.440	1.039
4. **Eucalyptus camaldulensis**	274.14	27.79	112.60	20.93	8.423	3.726	1.502	1.041
5. **Azadirachta indica**	101.35	12.63	61.48	6.60	3.419	0.787	0.430	0.435
6. **Acacia leucophloea**	79.66	8.35	30.72	6.12	2.909	0.594	0.346	0.280
7. **Casuarina equisetifolia**	95.54	8.84	33.23	9.05	4.121	1.262	0.489	0.408
SE_d	16.59	2.52	10.95	2.72	1.451	0.607	0.393	0.340
CD (P = 0.05)	35.16	5.50	23.85	5.93	3.162	1.322	0.856	0.741

Fig. 10 Total uptake (leaves and stems) of N, P, K. and Na of MPTs



1 - Acacia nilotica

2 - Prosopis juliflora

3 - Eucalyptus tereticornis

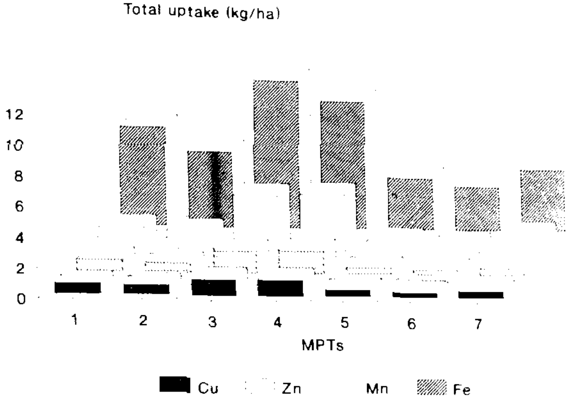
4 - Eucalyptus camaldulensis

5 - Azadirachta indica

6 - Acacia leucophloea

7 - Casuarina equisetifolia

Fig.11 Total uptake (leaves and stems) of Fe, Mn, Zn and Cu of MPTs



1 - **Acacia nilotica**

2 - **Prosopis juliflora**

3 - **Eucalyptus tereticornis**

4 - **Eucalyptus camaldulensis**

5 - **Azadirachta indica**

6 - **Acacia leucophloea**

7 - **Casuarina equisetifolia**

NB: For clarity of results, figures have been drawn in the order of Cu, Zn, Mn and Fe according to the level of their uptake

camaldulensis and **E.tereticornis**, followed by **Prosopis juliflora** and **Acacia nilotica**. The nutrient uptake or depletion got increased with the increase in total biomass, especially when the UB was in higher proportion (Table 10).

4.2.5. Soil fertility changes under MPTs (Table 17 and 18)

There was significant increase in the soil organic carbon content (Fig. 12), available N, P, K and decrease in Na under all the MPTs studied compared to open field (control) (Fig. 13). The EC and pH of the soil were not significantly altered by the MPTs evaluated in the present study.

Though there was significant increase in soil organic matter under different MPTs compared to control, such increase in organic carbon content of the soil among the different MPTs did not differ. A similar trend was observed for N and K and not for P. The available soil P was significantly higher under **Prosopis** and lower under **Acacia nilotica.** There was no significant difference in available Na in soil under different MPTs evaluated.

There was a trend of increase in the available micronutrient contents in the soil under different MPTs compared to control (open field) but the result was not significant except for Mn. There was significant increase in Mn availability under MPTs compared to control but among the

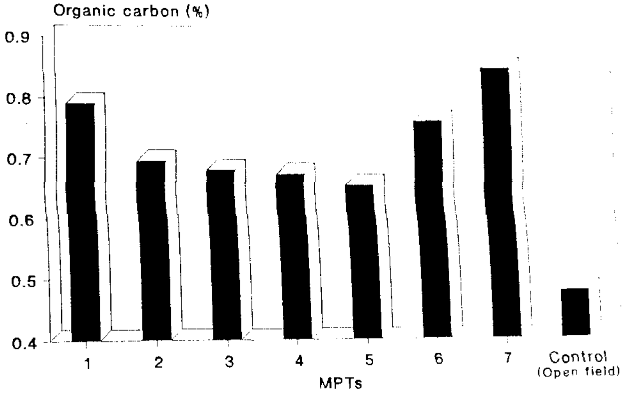
Table 17. Effect of different MPTs on the soil organic carbon content and available macronutrients (4th year)

Tree species	Mean organic carbon (%)	Mean available nutrients in the soil (kg ha^{-1})				EC (dSm^{-1})	pH
		N	P	K	Na		
1. **Acacia nilotica**	0.790	236	4.60	278	154	0.13	7.33
2. **Prosopis juliflora**	0.695	252	8.77	253	132	0.16	7.10
3. **Eucalyptus tereticornis**	0.681	253	6.97	287	158	0.20	7.40
4. **Eucalyptus camaldulensis**	0.675	231	7.16	280	154	0.17	7.29
5. **Azadirachta indica**	0.657	272	8.06	275	136	0.15	7.30
6. **Acacia leucophloea**	0.764	274	6.60	268	143	0.14	7.25
7. **Casuarina equisetifolia**	0.852	249	7.30	270	152	0.18	7.18
Open field (control)	0.478	190	4.50	205	185	0.15	7.50
SE_d	0.104	21	1.05	28	47	0.06	0.04
CD (P = 0.05)	0.215	45	2.26	60	NS	NS	NS

Table 18. Mean available soil micronutrients (ppm) under MPTs (4th year)

Tree species	Fe	Mn	Zn	Cu
1. **Acacia nilotica**	17.40	22.95	0.50	2.96
2. **Prosopis juliflora**	16.07	21.71	0.67	3.23
3. **Eucalyptus tereticornis**	13.20	22.16	0.66	2.60
4. **Eucalyptus camaldulensis**	17.87	21.96	0.43	2.83
5. **Azadirachta indica**	17.67	20.46	0.57	2.98
6. **Acacia leucophloea**	16.20	20.63	0.47	2.70
7. **Casuarina equisetifolia**	15.73	20.11	0.43	2.77
Open field (control)	14.20	16.13	0.50	2.64
SE_d	1.83	1.28	0.08	0.37
CD (P = 0.05%)	NS	2.74	NS	NS

Fig. 12 Effect of different MPTs on soil fertility in terms of organic carbon content



1 - **Acacia nilotica**

2 - **Prosopis juliflora**

3 - **Eucalyptus tereticornis**

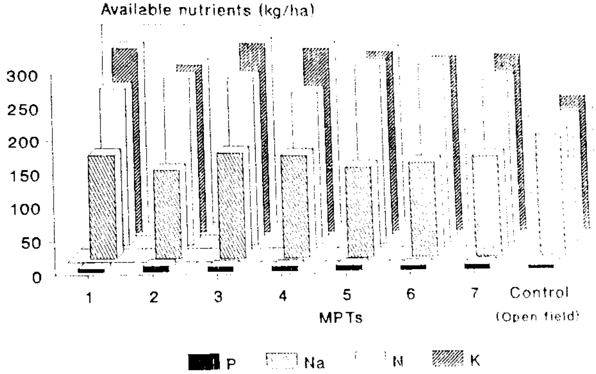
4 - **Eucalyptus camaldulensis**

5 - **Azadirachta indica**

6 - **Acacia leucophloea**

7 - **Casuarina equisetifolia**

Fig.13 Effect of different MPTs on soil fertility in terms of available N, P, K and Na



1 - **Acacia nilotica**

2 - **Prosopis juliflora**

3 - **Eucalyptus tereticornis**

4 - **Eucalyptus camaldulensis**

5 - **Azadirachta indica**

6 - **Acacia leucophloea**

7 - **Casuarina equisetifolia**

MPTs the differences were not significant (Table 18 and Fig. 14).

4.2.6. Coppicing potential of MPTs (Table 19)

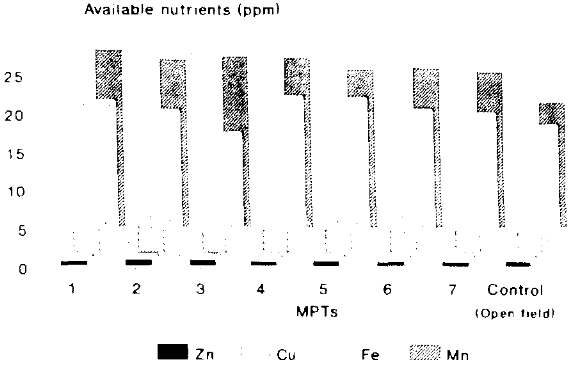
Except **Casuarina equisetifolia**, all other MPTs had given coppice shoots. **Acacia leucophloea** was found to be a poor coppicer as indicated by the lowest number of coppice shoots at 10 months after first cut among the MPTs evaluated. The coppice numbers per stool was in the order of **Prosopis juliflora** > **Azadirachta indica** > **Acacia nilotica** > **E.tereticornis** > **E.camaldulensis**, but they were all comparable statistically.

The poor coppicing nature of **Acacia leucophloea** was further confirmed by lesser height growth and BD of coppice shoots compared to that of other MPTs. **E.camaldulensis** recorded maximum coppice height of 191.2 cm which was significantly greater than that of other MPTs. The coppice height of **E.tereticornis** (161.6 cm) and **A.nilotica** (153.6 cm) were on par. Next in the order was **Prosopis juliflora** whose coppice height (91.7 cm) was on par with **Azadirachta indica** (89.1 cm).

However, there was no significant difference among these MPTs in respect of BD of coppice shoots.

At 15th month after first cut, there was slight reduction in coppice number per stool in all the MPTs indicating self-thinning of coppice shoots with the

Fig.14 Effect of different MPTs on soil fertility in terms of available Fe, Mn, Zn and Cu



1 - **Acacia nilotica**

2 - **Prosopis juliflora**

3 - **Eucalyptus tereticornis**

4 - **Eucalyptus camaldulensis**

5 - **Azadirachta indica**

6 - **Acacia leucophloea**

7 - **Casuarina equisetifolia**

NB: For clarity of results, figures have been drawn in the order of Zn, Cu, Fe and Mn according to their available levels

Table 19. Coppicing potential of different MPTs cut at 4th year

Tree species	10 months after first cut			15 months after first cut		
	Mean No.of coppice per stool	Mean height of coppice (cm)	Mean BD of coppice (cm)	Mean No.of coppice per stool	Mean height of coppice (cm)	Mean BD of coppice (cm)
1. **Azadirachta indica**	13.4	89.1	0.77	11.8	129.5	1.76
2. **Acacia nilotica**	13.2	153.6	1.25	11.8	193.6	2.17
3. **Acacia leucophloea**	3.5	50.3	0.50	2.8	89.4	0.55
4. **Prosopis juliflora**	14.1	91.7	0.83	13.0	130.5	1.87
5. **Casuarina equisetifolia**	-	-	-	-	-	-
6. **Eucalyptus camaldulensis**	10.3	191.2	1.23	9.6	343.7	2.80
7. **E.tereticornis**	10.8	161.6	1.19	9.9	352.5	2.90
SE_d	2.1	8.4	0.22	0.8	7.8	0.50
CD (P = 0.05)	5.2	20.6	0.55	2.1	19.0	1.23

advancement of age. The height and BD of coppice shoots increased considerably and the differences among the MPTs were almost in similar term as observed 10 months after first cut.

4.2.7. Path coefficient and regression analysis

The data on the results of the path and regression analysis of the seven MPTs evaluated are presented in this section (Table 20 to 33).

4.2.7.1. Prosopis juliflora

The plant component viz., branch number (BN), tree height (TH), basal diameter (BD) and diameter at breast height (DBH) had significant positive correlation with utilizable biomass (UB), non-utilizable biomass (NUB) and total biomass (TB) (Table 20). Among them, BN had the highest direct effect on NUB and total biomass, followed by BD. But the highest direct contribution to the UB (stem) was from BD followed by BN.

Based on the above results, stepwise linear regression models were developed to predict the UB, NUB and total biomass (Table 21). The results indicated that both BD and BN could be used as better predictor variables.

4.2.7.2. Eucalyptus

The variables viz., TH, BD and DBH had significant positive correlation with UB, NUB and TB for both the

Table 20. Path coefficient analysis in **Prosopis juliflora** (4 years old) between component traits

	BN	TH	BD	DBH	Correlation coefficient (r)
			(i) With total biomass		
BN	**0.514**	-0.006	-0.061	-0.002	**0.445****
TH	-0.032	**0.098**	0.372	0.033	**0.471****
BD	-0.055	0.064	**0.573**	0.042	**0.624****
DBH	-0.019	0.070	0.529	**0.046**	**0.626****
			(ii) With utilizable biomass		
BN	**0.461**	-0.009	-0.064	0.001	**0.389****
TH	-0.029	**0.149**	0.390	-0.008	**0.502****
BD	-0.049	0.097	**0.602**	-0.010	**0.640****
DBH	-0.017	0.106	0.556	**-0.011**	**0.634****
			(iii) With non-utilizable biomass		
BN	**0.568**	0.661	-0.053	-0.005	**0.511****
TH	-0.036	**-0.005**	0.320	0.103	**0.382****
BD	-0.061	-0.003	**0.493**	0.134	**0.563****
DBH	-0.021	-0.003	0.456	**0.145**	**0.577****

Diagonal values denote the direct effect
** Significant at one per cent level

BN : Branch number
TH : Tree height
BD : Basal diameter
DBH : Diameter at breast height

Table 21. Estimation of UB, NUB and total biomass of **Prosopis juliflora** (4 years old) using regression equations (N 100)

Yield to be Predicted/ estimated		Regression equations	R^2 value
NUB	i.	$Y = -23.518 - 0.043\ TH^{NS} + 7.163\ BN^{**} + 3.301\ BD^{*} + 1.467\ DBH^{NS}$	0.639^{**}
	ii.	$Y = -22.714 + 7.268\ BN^{**} + 4.164\ BD^{**}$	0.631^{**}
	iii.	$Y = 0.884 + 6.426\ BN^{**}$	0.263^{**}
	iv.	$Y = -5.717 + 3.753\ BD^{**}$	0.324^{**}
UB	i.	$Y = -43.168 + 2.927\ TH^{NS} + 8.378\ BN^{**} + 5.937\ BD^{**} - 0.164\ DBH^{NS}$	0.628^{**}
	ii.	$Y = -37.036 + 8.782\ BN^{**} + 6.936\ BD^{**}$	0.617^{**}
	iii.	$Y = 2.269 + 7.380\ BN^{**}$	0.156^{**}
	iv.	$Y = -21.535 + 9.933\ BD^{**}$	0.403^{**}
Total biomass	i.	$Y = -66.695 + 2.875\ TH^{NS} + 15.485\ BN^{**} + 9.179\ BD^{**} + 1.423\ DBH^{NS}$	0.659^{**}
	ii.	$Y = -59.707 + 16.003\ BN^{**} + 11.108\ BD^{**}$	0.652^{**}
	iii.	$Y = 3.241 + 13.757\ BN^{**}$	0.205^{**}
	iv.	$Y = -22.282 + 10.202\ BD^{**}$	0.392^{**}

Y - Biomass, TH - Tree height, BN - Branch number

BD - Basal diameter, DBH - Diameter at breast height

N - No.of trees taken for regression analysis

* Significant at five per cent level

** Significant at one per cent level

NS - Not Significant

species of **Eucalyptus** (**E.tereticornis** and **E.camaldulensis**) (Table 22 and 23).

In **E.tereticornis**, DBH did exhibit the highest direct contribution to the UB and NUB. Whereas for the TB, tree height was found to contribute more.

In **E.camaldulensis** the trend was quite different. The tree height followed by BD had more direct contribution to TB and UB. The basal diameter was found to contribute more directly to NUB. The DBH had negative effect on UB, NUB and TB.

Stepwise linear regression models based on these results revealed that for **E.tereticornis**, DBH alone was sufficient to predict the UB and TB and BD for predicting NUB. However, the prediction was better in respect of UB, NUB and TB with high R^2 values when tree height, BD and DBH were included in the model (Table 24). Similar results were obtained for **E.camaldulensis** (Table 25).

4.2.7.3. Acacia nilotica

All the three tree component traits viz., TH, BD and DBH had significant positive correlation with UB, NUB and TB (Table 26). The DBH for UB and TB; the BD for NUB were found to have more direct contribution. The TH had negative direct effect on UB, NUB and TB. This was confirmed in the stepwise linear regression models (Table 27).

Table 22. Path coefficient analysis in **Eucalyptus tereticornis** (4 years old) between component traits

	TH	BD	DBH	Correlation coefficient (r)
		(i) With total biomass		
TH	**0.297**	0.018	0.070	**0.944****
BD	0.101	**0.026**	0.138	**0.935****
DBH	0.129	0.025	**0.151**	**0.923****
		(ii) With utilizable biomass		
TH	**0.382**	-0.178	0.437	**0.651****
BD	0.258	**-0.263**	0.546	**0.705****
DBH	0.294	-0.253	**0.567**	**0.753****
		(iii) With non-utilizable biomass		
TH	**-0.083**	-0.363	0.468	**0.558****
BD	-0.056	**-0.536**	0.586	**0.879****
DBH	-0.064	-0.516	**0.608**	**0.879****

Diagonal values denote the direct effect
** Significant at one per cent level

TH : Tree height
BD : Basal diameter
DBH : Diameter at breast height

Table 23. Path coefficient analysis in **Eucalyptus camaldulensis** (4 years old) between component traits

	TH	BD	DBH	Correlation coefficient (r)
		(i) With total biomass		
TH	**0.342**	0.210	-0.313	**0.985****
BD	0.292	**0.246**	-0.336	**0.950****
DBH	0.306	0.236	**-0.350**	**0.990****
		(ii) With utilizable biomass		
TH	**0.525**	0.269	-0.418	**0.743****
BD	0.449	**0.315**	-0.449	**0.735****
DBH	0.469	0.302	**-0.468**	**0.734****
		(iii) With non-utilizable biomass		
TH	**0.078**	0.210	-0.349	**0.681****
BD	0.067	**0.246**	-0.374	**0.782****
DBH	0.069	0.236	**-0.390**	**0.778****

Diagonal values denote the direct effect
** Significant at one per cent level

TH : Tree height
BD : Basal diameter
DBH : Diameter at breast height

Table 24. Estimation of UB, NUB and total biomass of **E.tereticornis** (4 years old) using regression equations (N = 100)

Yield to be Predicted estimated	Regression equations	R^2 value
UB	i. Y = -14.62 + 0.0002 BD^{NS} + 2.712 DBH^{NS} + 1.358 TH^{NS}	0.927**
	ii. Y = -9.365 + 4.299 DBH** - 0.677 BD^{NS}	0.901**
	iii. Y = -17.832 + 1.719 BD** + 2.183 TH**	0.890**
	iv. Y = -14.619 + 2.712 DBH** + 1.357 TH^{NS}	0.921**
	v. Y = -18.916 + 4.281 TH**	0.701**
	vi. Y = -9.406 + 2.538 BD**	0.802**
	vii. Y = -9.740 + 3.459 DBH**	0.903**
NUB	i. Y = -3.295 + 1.452 BD^{NS} + 0.629 DBH^{NS} - 0.588 TH^{NS}	0.678**
	ii. Y = -5.572 - 0.059 DBH^{NS} + 1.745 BD^{NS}	0.641**
	iii. Y = -4.040 + 1.850 BD** - 0.397 TH^{NS}	0.650**
	iv. Y = -0.995 + 2.659 DBH** - 1.005 TH^{NS}	0.621**
	v. Y = -4.606 + 2.107 DBH**	0.621**
	vi. Y = -5.572 + 1.701 BD**	0.670**
	vii. Y = -5.207 + 1.861 TH^{NS}	0.25NS
Total biomass	i. Y = -17.915 + 1.452 BD^{NS} + 3.341 DBH^{NS} + 0.769 TH^{NS}	0.869**
	ii. Y = -21.872 + 3.569 BD** + 1.786 TH^{NS}	0.840**
	iii. Y = -14.978 + 4.239 BD**	0.830**
	iv. Y = -15.614 + 5.371 DBH** + 0.353 TH^{NS}	0.852**
	v. Y = -14.937 + 4.24 DBH^{NS} + 1.068 BD^{NS}	0.851**
	vi. Y = -14.346 + 5.565 DBH**	0.861**
	vii. Y = -24.124 + 6.142 TH**	0.543**

Y - Biomass; TH - Tree height
BD - Basal diameter; DBH - Diameter at breast height
N - No.of trees taken for regression analysis
* Significant at five per cent level
** Significant at one per cent level
NS - Not significant

Table 25. Estimation of UB, NUB and total biomass of **E.camaldulensis** (4 years old) using regression equations (N 100

Yield to be Predicted estimated	Regression equations	R^2 value
UB	i. Y = -12.112 + 0.278 BD^{NS} + 2.347 DBH** + 0.946 TH^{NS}	0.887**
	ii. Y = -15.627 + 1.841 BD** + 1.624 TH**	0.862**
	iii. Y = 11.789 + 2.697 DBH** + 0.941 TH^{NS}	0.884**
	iv. Y = -9.363 + 3.053 DBH** + 0.258 BD^{NS}	0.876**
	v. Y = -9.077 + 3.327 DBH**	0.873**
	vi. Y = -11.014 + 2.893 BD**	0.816**
NUB	i. Y = -6.263 + 0.513 BD^{NS} + 2.381 DBH** - 0.549 TH^{NS}	0.797**
	ii. Y = -9.757 + 2.066 BD** + 0.323 TH^{NS}	0.753**
	iii. Y = -5.665 + 2.935 DBH** - 0.559 TH^{NS}	0.795**
	iv. Y = -7.858 + 2.000 DBH** + 0.525 BD^{NS}	0.794**
	v. Y = -7.275 + 2.56 DBH**	0.792**
	vi. Y = -8.94 + 2.252 BD**	0.750**
Total biomass	i. Y = -18.375 + 0.792 BD^{NS} + 4.777 DBH** + 0.397 TH^{NS}	0.878**
	ii. Y = -25.386 + 3.907 BD** + 2.147 TH*	0.835**
	iii. Y = -19.954 + 5.145 BD**	0.827**
	iv. Y = -17.454 + 5.631 DBH** + 0.382 TH^{NS}	0.869**
	v. Y = -17.227 + 5.053 DBH** + 0.793 BD^{NS}	0.873**
	vi. Y = -16.353 + 5.887 DBH**	0.872**

Y - Biomass; TH - Tree height

BD - Basal diameter; DBH - Diameter at breast height

N - No.of trees taken for regression analysis

* Significant at five per cent level

** Significant at one per cent level

NS - Not significant

Table 26. Path coefficient analysis in **Acacia nilotica** 4 years old) between component traits

	TH	BD	DBH	Correlation coefficient (r)
(i) With total biomass				
TH	**-0.164**	0.281	0.518	**0.635****
BD	-0.124	**0.371**	0.622	**0.869****
DBH	-0.133	0.360	**0.640**	**0.867****
(ii) With utilizable biomass				
TH	**-0.090**	0.185	0.565	**0.660****
BD	-0.068	**0.244**	0.678	**0.854****
DBH	-0.073	0.238	**0.698**	**0.863****
(iii) With non-utilizable biomass				
TH	**-0.233**	0.454	0.373	**0.594****
BD	-0.177	**0.599**	0.448	**0.870****
DBH	-0.189	0.582	**0.461**	**0.854****

Diagonal values denote the direct effect
** Significant at one per cent level

TH : Tree height
BD : Basal diameter
DBH : Diameter at breast height

Table 27. Estimation of UB, NUB and total biomass of **Acacia nilotica** (4 years old) using regression equations (N = 100)

Yield to be Predicted estimated		Regression equations	R^2 value
UB	i.	$Y = 12.694 + 1.188\ BD^{NS} + 3.480\ DBH^{NS} - 0.748\ TH^{NS}$	0.748**
	ii.	$Y = -17.929 + 4.001\ BD^{**} + 0.254\ TH^{NS}$	0.736**
	iii.	$Y = -10.871 + 4.766\ DBH^{**} - 0.921\ TH^{NS}$	0.742**
	iv.	$Y = -14.952 + 2.894\ DBH^{NS} + 1.410\ BD^{NS}$	0.744**
	v.	$Y = -13.34 + 4.321\ DBH^{**}$	0.740**
	vi.	$Y = -17.325 + 4.112\ BD^{**}$	0.730**
NUB	i.	$Y = -7.222 + 2.180\ BD^{NS} + 1.849\ DBH^{NS} - 1.528\ TH^{NS}$	0.767**
	ii.	$Y = -10.003 + 3.674\ BD^{**} - 0.995\ TH^{NS}$	0.763**
	iii.	$Y = -3.878 + 4.208\ DBH^{**} - 1.846\ TH^{NS}$	0.755**
	iv.	$Y = -11.834 + 0.651\ DBH^{NS} + 2.633\ BD^{NS}$	0.752**
	v.	$Y = -8.824 + 3.315\ DBH^{**}$	0.733**
	vi.	$Y = -12.368 + 3.241\ BD^{**}$	0.762**
Total biomass	i.	$Y = -19.154 + 3.117\ BD^{NS} + 5.652\ DBH^{NS} - 2.420\ TH^{NS}$	0.769**
	ii.	$Y = -27.657 + 7.865\ BD^{**} - 0.792\ TH^{NS}$	0.756**
	iii.	$Y = -14.372 + 9.025\ DBH^{**} - 2.875\ TH^{NS}$	0.763**
	iv.	$Y = -26.459 + 3.755\ DBH^{NS} + 3.835\ BD^{NS}$	0.765**
	v.	$Y = 22.076 + 7.635\ DBH^{**}$	0.754**
	vi.	$Y = -29.539 + 7.340\ BD^{**}$	0.752**

Y - Biomass; TH - Tree height
BD - Basal diameter; DBH - Diameter at breast height
N - No.of trees taken for regression analysis
* Significant at five per cent level
** Significant at one per cent level
NS - Not significant

4.2.7.4. Acacia leucophloea

All the tree component traits had positive significant correlation with UB, NUB and TB (Table 28). Highest direct contribution for TB, UB and NUB was found from DBH, followed by BD and TH. But the linear regression model had shown that both DBH and BD had almost similar prediction capacity for UB, NUB and TB (Table 29).

4.2.7.5. Azadirachta indica

The TH, BD and DBH had significant positive correlation with UB, NUB and TB (Table 30). DBH had exerted more direct effect on UB while tree height was found to contribute more directly to NUB and TB. But neither DBH nor TH found to significantly predict the UB, NUB and TB in stepwise linear regression models developed (Table 31). BD continued to be a significant predictor variable for UB, NUB and TB.

4.2.7.6. Casuarina equisetifolia

All the independent variables tested had positive significant correlation with UB, NUB and TB (Table 32). Maximum direct contribution to the TB, UB and NUB was found to be due to tree height followed by DBH. This result was not reflected in stepwise linear regression models except for UB. The tree height was found to be a significant predictor variable in respect of UB while BD was found to be better significant predictor variable for NUB and TB (Table 33).

Table 28. Path coefficient analysis in **Acacia leucophloea** (4 years old) between component traits

	TH	BD	DBH	Correlation coefficient (r)
		(i) With total biomass		
TH	**0.116**	0.237	0.351	**0.704****
BD	0.084	**0.325**	0.528	**0.937****
DBH	0.074	0.313	**0.549**	**0.936****
		(ii) With utilizable biomass		
TH	**0.203**	0.235	0.315	**0.753****
BD	0.149	**0.321**	0.474	**0.944****
DBH	0.130	0.309	**0.493**	**0.932****
		(iii) With non-utilizable biomass		
TH	**0.016**	0.248	0.377	**0.641****
BD	0.012	**0.340**	0.568	**0.920****
DBH	0.011	0.327	**0.590**	**0.928****

Diagonal values denote the direct effect
** Significant at one per cent level

TH : Tree height
BD : Basal diameter
DBH : Diameter at breast height

Table 29. Estimation of UB, NUB and total biomass of **Acacia leucophloea** (4 years old) using regression equations (N = 100)

Yield to be Predicted estimated	Regression equations	R^2 value
UB	i. Y = $-6.579 + 0.531\ BD^{NS} + 1.948\ DBH^{NS} + 0.883\ TH^{NS}$	0.898**
	ii. Y = $-5.634 + 1.36\ BD^{**} + 0.594\ TH^{NS}$	0.896**
	iii. Y = $-7.258 + 1.567\ DBH^{**} + 1.164\ TH^{NS}$	0.890**
	iv. Y = $-8.964 + 1.772\ DBH^{NS} + 1.617\ BD^{NS}$	0.880**
	v. Y = $-4.501 + 1.916\ DBH^{**}$	0.870**
	vi. Y = $-4.289 + 1.519\ BD^{**}$	0.892**
NUB	i. Y = $-4.55 + 0.530\ BD^{NS} + 1.152\ DBH^{NS} + 0.066\ TH^{NS}$	0.884**
	ii. Y = $-5.228 + 1.720\ DBH^{**} + 0.346\ TH^{NS}$	0.855**
	iii. Y = $-3.459 + 1.487\ BD^{**} - 0.268\ TH^{NS}$	0.853**
	iv. Y = $-4.393 + 1.126\ DBH^{NS} + 0.566\ BD^{NS}$	0.866**
	v. Y = $-4.407 + 1.824\ DBH^{**}$	0.850**
	vi. Y = $-4.066 + 1.415\ BD^{**}$	0.850**
Total biomass	i. Y = $11.281 + 1.060\ BD^{NS} + 2.166\ DBH^{NS} + 0.972\ TH^{NS}$	0.889**
	ii. Y = $-9.230 + 2.859\ BD^{**} + 0.345\ TH^{NS}$	0.884**
	iii. Y = $-12.636 + 3.302\ DBH^{**} + 1.538\ TH^{NS}$	0.886**
	iv. Y = $-8.964 + 1.772\ DBH^{NS} + 1.617\ BD^{NS}$	0.885**
	v. Y = $-9.006 + 3.762\ DBH^{**}$	0.882**
	vi. Y = $-8.45 + 2.951\ BD^{**}$	0.881**

Y - Biomass; TH - Tree height

BD - Basal diameter; DBH - Diameter at breast height

N - No.of trees taken for regression analysis

* Significant at five per cent level

** Significant at one per cent level

NS - Not significant

Table 30. Path coefficient analysis in **Azadirachta indica** (4 years old) between component traits

	TH	BD	DBH	Correlation coefficient (r)
		(i) With total biomass		
TH	**0.285**	-0.288	0.189	**0.912****
BD	0.245	**-0.435**	0.207	**0.909****
DBH	0.249	-0.421	**0.216**	**0.911****
		(ii) With utilizable biomass		
TH	**0.121**	0.149	0.308	**0.935****
BD	0.104	**0.174**	0.339	**0.991****
DBH	0.106	0.167	**0.353**	**0.987****
		(iii) With non-utilizable biomass		
TH	**0.189**	-0.317	0.159	**0.851****
BD	0.163	**-0.369**	0.175	**0.951****
DBH	0.165	-0.354	**0.183**	**0.943****

Diagonal values denote the direct effect
** Significant at one per cent level

TH : Tree height
BD : Basal diameter
DBH : Diameter at breast height

Table 31. Estimation of UB, NUB and total biomass of **Azadirachta indica** (4 years old) using regression equations (N = 100)

Yield to be Predicted/ estimated		Regression equations	R^2 value
UB	i.	$Y = -13.287 + 3.149\ BD^{**} + 0.659\ DBH^{NS} - 0.383\ TH^{NS}$	0.798**
	ii.	$Y = -14.461 + 3.559\ BD^{**}$	0.790**
NUB	i.	$Y = -3.908 + 1.339\ BD^{**} + 0.663\ DBH^{NS} - 0.490\ TH^{NS}$	0.809**
	ii.	$Y = -5.343 + 1.714\ BD^{**}$	0.801**
Total biomass	i.	$Y = -17.221 + 4.49\ BD^{**} + 1.317\ DBH^{NS} - 0.866\ TH^{NS}$	0.837**
	ii.	$Y = -19.812 + 5.273\ BD^{**}$	0.830**

Y - Biomass, TH - Tree height
BD - Basal diameter; DBH - Diameter at breast height
N - No.of trees taken for regression analysis
* Significant at five per cent level
** Significant at one per cent level
NS - Not Significant

Table 32. Path coefficient analysis in **Casuarina equisetifolia** (4 years old) between component traits

	TH	BD	DBH	Correlation coefficient (r)
		(i) With total biomass		
TH	**0.446**	-0.066	0.096	**0.750****
BD	0.280	**-0.105**	0.161	**0.873****
DBH	0.206	-0.081	**0.208**	**0.715****
		(ii) With utilizable biomass		
TH	**0.512**	0.007	0.221	**0.784****
BD	0.322	**0.012**	0.371	**0.784****
DBH	0.236	0.009	**0.480**	**0.778****
		(iii) With non-utilizable biomass		
TH	**0.139**	0.003	0.027	**0.490****
BD	0.087	**0.004**	0.045	**0.774****
DBH	0.064	0.003	**0.058**	**0.581****

Diagonal values denote the direct effect
** Significant at one per cent level

TH : Tree height
BD : Basal diameter
DBH : Diameter at breast height

Table 33. Estimation of UB, NUB and total biomass of **Casuarina equisetifolia** (4 years old) using regression equations (N = 100)

Yield to be Predicted/ estimated	Regression equations	R^2 value
UB	i. $Y = -3.058 + 0.410\ BD^{NS} + 0.476\ DBH^{NS} + 0.490\ TH^{**}$	0.895**
	ii. $Y = -1.29 + 0.787\ TH^{**}$	0.703**
UB	i. $Y = -3.352 + 2.341\ BD^{**} - 0.593\ DBH^{NS} - 0.150\ TH^{NS}$	0.690**
	ii. $Y = -3.828 + 1.824\ BD^{**}$	0.681**
Total biomass	i. $Y = -6.276 + 2.651\ BD^{**} - 0.310\ DBH^{NS} + 0.493\ TH^{NS}$	0.739**
	ii. $Y = -5.723 + 2.910\ BD^{**}$	0.731**

Y - Biomass, TH - Tree height
BD - Basal diameter, DBH - Diameter at breast height
N - No.of trees taken for regression analysis
* Significant at five per cent level
** Significant at one per cent level
NS - Not Significant

PART II STUDY

4.3. EXPERIMENT 3 : Effect of plant densities, ages of first cutting and coppicing durations on the biomass production of Prosopis juliflora (Swartz) DC.

Information on the optimum plant density for higher biomass production, the appropriate age of **Prosopis juliflora** for coppicing, the possibility of increasing the total biomass by coppicing **Prosopis juliflora** at very early stage(s) and their influence on the partitioning of biomass (Leaf/stem ratio) are very much lacking for short rotation plantations of less than three years. Hence, this experiment was conducted.

4.3.1. Establishment of seedling population in the mainfield

Six months old polypot seedlings of **Prosopis juliflora** were planted in the main field. The data on percentage of establishment of seedlings in the mainfield under different plant densities are presented in Table 34.

Table 34. Percentage of seedlings establishment

Plant density	Mean percentage of establishment at 2 MAP
d1 : 4444 plants ha^{-1} (closer spacing)	99.57
d2 : 2500 plants ha^{-1} (medium spacing)	98.95
d3 : 1600 plants ha^{-1} (wider spacing)	99.12

The results of the above table indicated the proper establishment of required seedlings per unit area in the treatments studied.

4.3.2. Adaptation of Prosopis juliflora for moisture stress

The relative water content (RWC) of **Prosopis juliflora** leaves were recorded from 2 to 9 MAP to study the adaptation of **Prosopis juliflora** to soil moisture stress in the mainfield. In general, irrespective of the age of crop, RWC was slightly lesser under higher plant density (d1) followed by medium (d2) and lower (d3) density, throughout the period of observations (2 to 9 MAP) (Fig. 15).

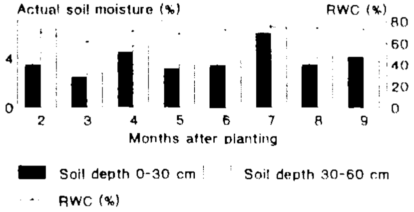
Similarly irrespective of soil depths and actual soil moisture content, the RWC in general, ranged from 61 to 70 per cent, 70 to 72 per cent and 71 to 74 per cent, respectively, under high, medium and lower plant densities, upto 5 MAP.

From 6 MAP onwards, the RWC of the leaves generally got increased beyond 71 per cent. It ranged from 71 to 75 per cent under higher density, 73 to 79 per cent under medium density and 76 to 83 per cent under lower density. The RWC was influenced by the actual soil moisture, with higher RWC when the actual soil moisture was more (Fig. 15).

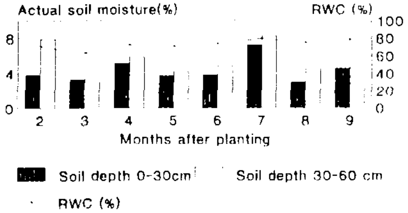
The variations in the RWC of the leaves of **Prosopis juliflora** between earlier (upto 5 MAP) and later

Fig.15 Relationship between soil moisture and RWC of leaves of *Prosopis juliflora*

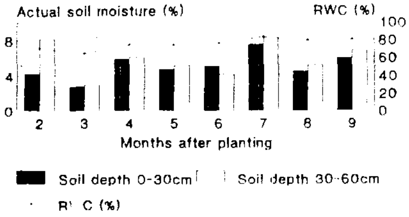
High density



Medium density



Low density



period (6 MAP) was only 5 to 9 per cent under different plant densities. This suggested that **Prosopis juliflora** was able to maintain its RWC at fairly higher level even during the period of moisture stress.

4.3.3. Biometrics (First crop)

4.3.3.1. Tree height, BD and number of primary branches per tree (Table 35)

There was no significant difference between different plant densities studied in influencing the plant height, basal diameter and the number of primary branches per tree of **Prosopis juliflora** at different months after planting (MAP). This indicated that upto 9 MAP, plant densities did not alter the above characters.

4.3.3.2. Biomass (DMP): First crop (Table 36 and 37; Fig.16)

As a result of increased plant density per unit area, the DMP of stem and total biomass of **Prosopis juliflora** were significantly increased. Similarly as the age of the first cutting increased from 9 to 15 MAP, the DMP of stem, and total biomass were also found increased significantly. But in the case of leaf DMP there was an increase upto 12 MAP and thereafter it was comparable with the leaf DMP obtained at 15 MAP. With increase in plant density, the leaf DMP also got increased.

Table 35.1. Mean tree height of **Prosopis juliflora** (cm)

Plant density	Months after planting (MAP)							
	2	3	4	5	6	7	8	9
d1	67.2	78.7	89.5	96.4	106.3	114.6	121.7	129.5
d2	65.3	76.3	87.6	91.6	102.5	111.5	118.8	123.7
d3	64.5	73.5	85.3	89.5	95.5	105.3	116.6	115.8
SE_d	4.2	3.8	4.4	5.3	8.2	6.4	4.0	10.1
CD(P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 35.2. Mean BD of **Prosopis juliflora** (cm)

Plant density	Months after planting (MAP)					
	4	5	6	7	8	9
d1	1.15	1.21	1.35	1.40	1.52	1.61
d2	1.02	1.15	1.36	1.39	1.50	1.59
d3	1.20	1.25	1.34	1.38	1.48	1.57
SE_d	0.08	0.05	0.03	0.04	0.05	0.07
CD(P=0.05)	NS	NS	NS	NS	NS	NS

Table 35.3. Mean number of primary branches per tree in **Prosopis juliflora**

Plant density	Months after planting (MAP)	
	6	9
d1	2.5	3.2
d2	2.8	3.0
d3	2.7	2.9
SE_d	0.55	0.35
CD (P=0.05)	NS	NS

Table 36. Effect of plant densities, ages of first cutting and their interaction effect on DMP of stem, leaf, total biomass and leaf/stem ratio (LSR) of **Prosopis juliflora** (First crop)

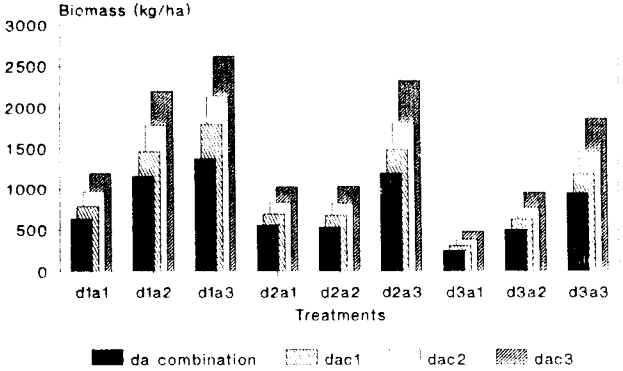
Treatment	Mean biomass production (kg ha^{-1})			Mean LSR
	Stem	Leaf	Total	
Plant density				
d1	638	415	1053	0.7789
d2	505	291	796	0.6976
d3	367	200	568	0.6644
SE$_d$	27	22	30	0.0917
CD(P=0.05)	57	47	63	NS
Age of first cut				
a1	256	224	480	0.8800
a2	401	364	765	0.8776
a3	853	318	1171	0.3833
SE$_d$	27	22	30	0.0917
CD(P=0.05)	57	47	63	0.1943
Interaction effect (d x a)				
SE$_d$	46	39	52	0.1588
CD(P=0.05)	98	82	110	NS

Table 37. Interaction effect of plant densities and ages of first cutting on the mean DMP of leaves of **Prosopis juliflora** (kg ha^{-1}) (First crop)

Plant density	Age of first cutting			Mean
	a1	a2	a3	
d1	313	570	361	415
d2	258	300	316	291
d3	100	224	277	200
Mean	224	364	318	

Source	SE_d	CD (P=0.05 %)
d x a	39	82

Fig. 16 Effect of plant densities ages of 1st cut & coppice durations on the total biomass production of *P.juliflora*



d1 - High density

d2 - Medium density

d3 - Low density

a1 - First cutting 9 MAP

a2 - First cutting 12 MAP

a3 - First cutting 15 MAP

c1 - Coppice for 6 MAFC

c2 - Coppice for 9 MAFC

c3 - Coppice for 12 MAFC

The insight of interaction between the age of first cut and different plant density (Table 37) for leaf biomass had indicated that at higher plant density the leaf biomass production at 9 and 15 MAP were comparable. Similarly under medium population density the leaf biomass production under three ages of first cutting were statistically on par. But in the case of wider spacing, the leaf biomass production at 12 and 15 MAP were comparable.

At 9 and 15 MAP, the higher density and medium density populations were able to produce comparable leaf biomass. While such trend was not observed at 12 MAP wherein the leaf biomass significantly differed with different plant spacings studied.

In the case of stem and total biomass, the interaction revealed the following. In both cases under medium spacing the stem and total biomass production, respectively, were comparable between 9 and 12 MAP. The study on the leaf/stem ratio (LSR) indicated that there was a decrease in LSR with the increase in age of first cut and this was significantly lesser at 15 MAP. However, LSR recorded under 9 and 12 MAP were comparable in registering higher values. Different plant densities failed to influence this parameter. The interaction effect was also absent (Table 36).

4.3.4. Uptake of nutrients (First crop)

4.3.4.1. Macronutrients

The data on the uptake of N, P, K and Na by leaves, stems and the total uptake are presented in Table 38.

In general the uptake of N and K were higher in leaves than in stems while the uptake of P and Na were almost in similar proportions in leaves and stems, irrespective of plant density and ages of first cut.

Different plant densities had significantly influenced the uptake of N, P, K and Na through leaves with maximum uptake under higher plant density (d1). As far as the uptake through stems is concerned, plant densities had altered significantly only the uptake of P and Na.

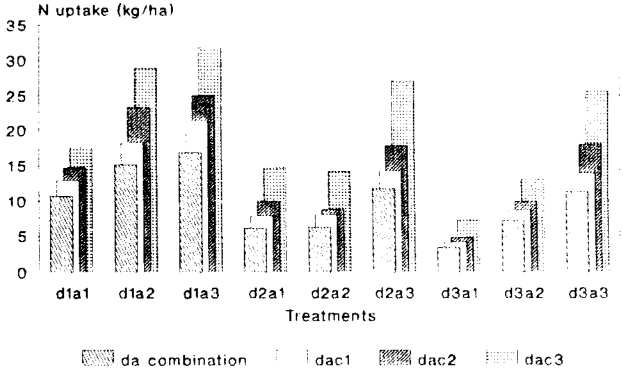
Considering the total uptake, all the nutrients studied viz., N, P, K and Na were significantly influenced due to variations in plant densities as in the case of leaf uptake. The total uptake of N was significantly greater under higher plant density (d1) than in the other two densities (Fig. 17). Similar results were obtained in respect of total uptake of P, K and Na for higher plant density (Fig. 18 to 20) but this was comparable with the uptake under medium plant density (d2). Lowest uptake of all these nutrients was observed under lower plant density (d3).

Table 38. Effect of plant densities, ages of first cut at 9, 12 and 15 MAP and their interaction effect on the uptake of nutrients in **Prosopis juliflora** (First crop)

Treatments	Mean uptake through leaves (kg ha^{-1})				Mean uptake through stems (kg ha^{-1})				Total mean uptake (kg ha^{-1})			
	N	P	K	Na	N	P	K	Na	N	P	K	Na
Plant density :												
d1	9.39	0.50	3.42	0.41	4.81	0.44	1.38	0.46	14.20	0.94	4.81	1.09
d2	4.32	0.26	1.98	0.31	3.74	0.55	1.20	0.36	8.05	0.77	3.17	0.67
d3	4.04	0.21	1.61	0.24	3.29	0.28	0.81	0.27	7.34	0.45	2.42	0.51
SE$_d$	0.51	0.06	0.49	0.05	1.00	0.10	0.30	0.07	1.34	0.12	0.87	0.14
CD(P=0.05%)	1.09	0.12	0.97	0.11	NS	0.21	NS	0.15	2.83	0.26	1.85	0.29
Age of first cut :												
a1	4.77	0.26	1.27	0.26	1.97	0.21	0.41	0.19	6.74	0.47	1.68	0.46
a2	7.01	0.34	3.11	0.35	2.50	0.32	0.72	0.30	9.51	0.59	3.83	0.65
a3	5.98	0.37	2.62	0.35	7.37	0.73	2.26	0.60	13.35	1.10	4.90	1.17
SE$_d$	0.51	0.06	0.49	0.05	1.00	0.10	0.30	0.07	1.34	0.12	0.87	0.14
CD(P=0.05%)	1.09	NS	0.97	NS	2.12	0.21	0.64	0.15	2.83	0.26	1.85	0.29
Interaction effect (d x a) :												
SE$_d$	0.89	0.10	0.80	0.09	1.73	0.17	0.52	0.12	2.31	0.21	1.52	0.24
CD(P=0.05%)	1.88	NS	1.69	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS - Not significant

Fig. 17 Effect of plant densities, ages of 1st cut & coppice durations on the total N uptake of *P.juliflora*



d1 - High density

d2 - Medium density

d3 - Low density

c1 - Coppice for 6 MAFC

c2 - Coppice for 9 MAFC

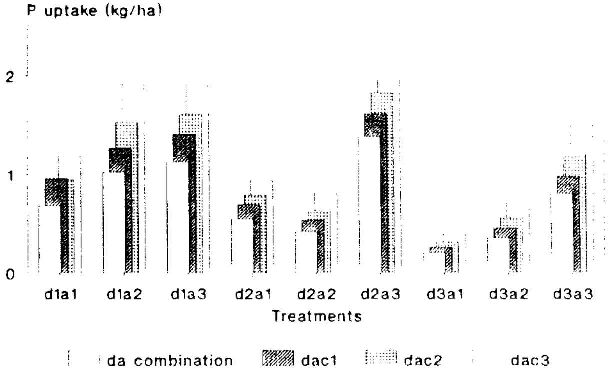
c3 - Coppice for 12 MAFC

a1 - First cutting 9 MAP

a2 - First cutting 12 MAP

a3 - First cutting 15 MAP

Fig. 18 Effect of plant densities, ages of 1st cut & coppice durations on the total P uptake of *P.juliflora*



d1 - High density

d2 - Medium density

d3 - Low density

c1 - Coppice for 6 MAFC

c2 - Coppice for 9 MAFC

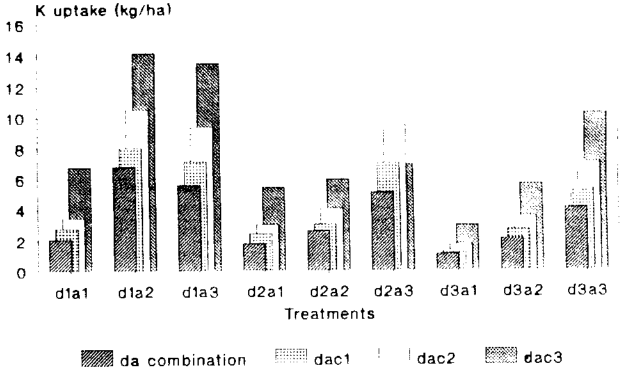
c3 - Coppice for 12 MAFC

a1 - First cutting 9 MAP

a2 - First cutting 12 MAP

a3 - First cutting 15 MAP

Fig. 19 Effect of plant densities, ages of 1st cut & coppice durations on the total K uptake of *P.juliflora*



d1 - High density

d2 - Medium density

d3 - Low density

c1 - Coppice for 6 MAFC

c2 - Coppice for 9 MAFC

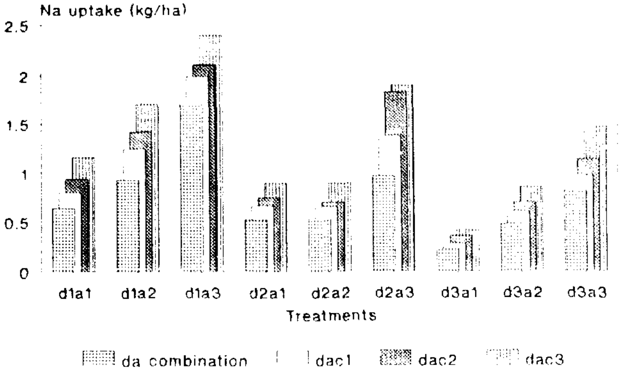
c3 - Coppice for 12 MAFC

a1 - First cutting 9 MAP

a2 - First cutting 12 MAP

a3 - First cutting 15 MAP

Fig. 20 Effect of plant densities, ages of 1st cut & coppice durations on the total Na uptake of *P.juliflora*



d1 - High density

d2 - Medium density

d3 - Low density

c1 - Coppice for 6 MAFC

c2 - Coppice for 9 MAFC

c3 - Coppice for 12 MAFC

a1 - First cutting 9 MAP

a2 - First cutting 12 MAP

a3 - First cutting 15 MAP

Different ages of first cut also did alter the uptake of nutrients studied. The uptake increased with the increase in the age of first cut. However, the uptake of P and Na in leaves was not influenced by different ages of first cut. The total uptake of all the nutrients were the highest at the age of 15 MAP compared to other ages of first cut.

The interaction effect was significant only in respect of leaf N (Table 39) and K (Table 40) uptake. Higher uptake of N and K was observed at the age of 12 MAP (a2) compared to 15 MAP (a3) under higher plant density (d1). Whereas under medium and lower plant densities, there was a trend of increase in uptake with the age. This result clearly indicated that there is a decline in uptake of N and K with advancement of age when the plant density was higher per unit area.

4.3.4.2. Micronutrients (Table 41)

Neither plant density nor the age of first cut or their interaction effect did influence the leaf uptake, stem uptake and total uptake of micronutrients. In general, the uptake of iron was more under different treatments followed by Mn, Zn and Cu (Fig. 21 to 24). Iron uptake was more in stems, while Mn uptake was more in leaves. The Zn and Cu uptake were almost in similar proportions both in leaves and stems.

Table 39. Interaction effect of plant densities and ages of first cutting at 9, 12 and 15 MAP on the mean uptake of N in leaves of **Prosopis juliflora** (kg ha^{-1}) (First crop)

Age of first cut	Plant density			
	d1	d2	d3	Mean
a1	8.01	4.15	2.15	4.77
a2	11.84	4.37	4.81	7.01
a3	8.33	4.45	5.17	5.98
Mean	9.39	4.32	4.04	

Source	SE_d	CD ($P<0.05\%$)
d	0.51	1.09
a	0.51	1.09
d x a	0.89	1.88

Table 40. Interaction effect of plant densities and ages of first cutting at 9, 12 and 5 MAP on the mean uptake of K in leaves of **Prosopis juliflora** (kg ha^{-1}) (First crop)

Age of first cut	Plant density			
	d1	d2	d3	Mean
a1	1.65	1.30	0.87	1.27
a2	5.80	1.83	1.70	3.11
a3	2.81	2.80	2.26	2.62
Mean	3.42	1.98	1.61	

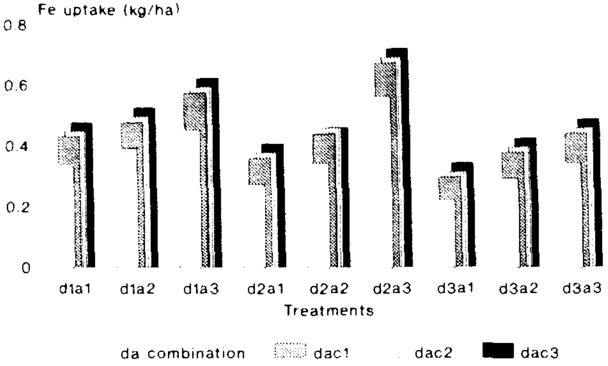
Source	SE_d	CD ($P<0.05\%$)
d	0.49	0.97
a	0.49	0.97
d x a	0.80	1.69

Table 41. Effect of plant densities ages of first cutting at 9, 12 and 15 MAP and their interaction effect on the uptake of micronutrients in **Prosopis juliflora** (First crop)

Treatments	Mean uptake through leaves (kg ha^{-1})				Mean uptake through stems (kg ha^{-1})				Total mean uptake (kg ha^{-1})			
	Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu
Plant density :												
d1	0.185	0.081	0.020	0.024	0.264	0.049	0.021	0.023	0.449	0.130	0.041	0.047
d2	0.125	0.050	0.013	0.015	0.212	0.037	0.019	0.019	0.337	0.387	0.032	0.034
d3	0.084	0.033	0.008	0.011	0.154	0.027	0.018	0.014	0.238	0.060	0.026	0.025
SE$_d$	0.035	0.019	0.005	0.004	0.112	0.022	0.003	0.003	0.124	0.032	0.012	0.010
CD(P=0.05%)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Age of first cut :												
a1	0.087	0.044	0.011	0.014	0.121	0.021	0.009	0.010	0.208	0.065	0.020	0.024
a2	0.162	0.064	0.017	0.018	0.171	0.031	0.016	0.015	0.333	0.095	0.033	0.033
a3	0.147	0.051	0.013	0.016	0.301	0.053	0.034	0.027	0.448	0.104	0.047	0.043
SE$_d$	0.035	0.019	0.005	0.004	0.112	0.022	0.003	0.003	0.124	0.032	0.012	0.010
CD(P=0.05%)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction effect (d x a) :												
SE$_d$	0.043	0.029	0.015	0.014	0.078	0.051	0.039	0.026	0.180	0.050	0.018	0.015
CD(P=0.05%)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS - Not significant

Fig. 21 Effect of plant densities, ages of 1st cut & coppice durations on the total Fe uptake of *P.juliflora*



d1 - High density

d2 - Medium density

d3 - Low density

a1 - First cutting 9 MAP

a2 - First cutting 12 MAP

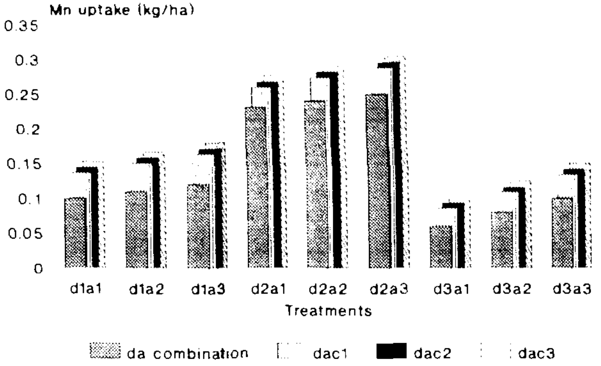
a3 - First cutting 15 MAP

c1 - Coppice for 6 MAFC

c2 - Coppice for 9 MAFC

c3 - Coppice for 12 MAFC

Fig. 22 Effect of plant densities, ages of 1st cut & coppice durations on the total Mn uptake of *P.juliflora*



d1 - High density

d2 - Medium density

d3 - Low density

a1 - First cutting 9 MAP

a2 - First cutting 12 MAP

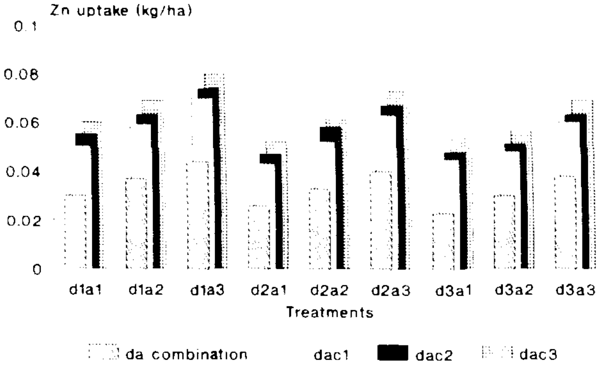
a3 - First cutting 15 MAP

c1 - Coppice for 6 MAFC

c2 - Coppice for 9 MAFC

c3 - Coppice for 12 MAFC

Fig. 23 Effect of plant densities, ages of 1st cut & coppice durations on the total Zn uptake of *P.juliflora*



d1 - High density

d2 - Medium density

d3 - Low density

a1 - First cutting 9 MAP

a2 - First cutting 12 MAP

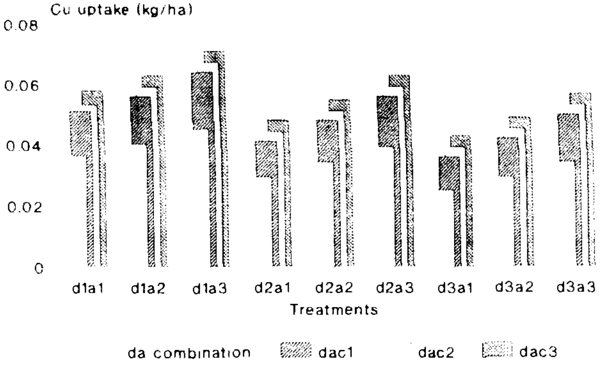
a3 - First cutting 15 MAP

c1 - Coppice for 6 MAFC

c2 - Coppice for 9 MAFC

c3 - Coppice for 12 MAFC

Fig. 24 Effect of plant densities, ages of 1st cut & coppice durations on the total Cu uptake of *P.juliflora*



d1 - High density

d2 - Medium density

d3 - Low density

a1 - First cutting 9 MAP

a2 - First cutting 12 MAP

a3 - First cutting 15 MAP

c1 - Coppice for 6 MAFC

c2 - Coppice for 9 MAFC

c3 - Coppice for 12 MAFC

4.3.5. Biometrics (Coppice crop)

4.3.5.1. Number of coppice shoots per stool (Table 42)

The plant densities failed to alter the numbers of coppice per stool recorded at 1, 3 and 6 MAFC (Months after first cut). Similarly the interaction effect between the plant density and the age of first cut also revealed no statistical difference.

But in the case of different ages of first cut studied, there was an influence on the numbers of coppice per stool due to treatments. In all the months of observations viz., 1, 3 and 6 MAFC, the numbers of coppice shoots increased with the increase in age of first cut.

In all these three months of observations, initiating the first cut at 15 MAP had significantly increased the coppice numbers per stool, followed by first cut at 12 MAP. The first cut given at 9 MAP registered lower coppice numbers per stool.

4.3.5.2. Coppice height (Table 42)

The planting density, age of first cut and their interaction effects had significantly influenced the coppice height right from 1 to 6 MAFC. With regard to plant densities studied, the lower plant density (d3) had shown increased coppice height throughout the period of observations (1 to 6 MAFC) and it was significantly superior to other treatments.

Table 42. Effect of plant densities and ages of first cutting at 9, 12 and 15 MAP and their interaction effect on the number of coppice shoots per stool, coppice height and basal diameter of coppice shoots of **Prosopis juliflora** at 1, 3 and 6 months after first cut (MAFC)

Treatment	Mean No.of coppice stool^{-1}			Mean coppice height (cm)			Mean BD of coppice (cm)		
	1 MAFC	3 MAFC	6 MAFC	1 MAFC	3 MAFC	6 MAFC	1 MAFC	3 MAFC	6 MAFC
Plant density :									
d1	10.67	13.37	13.56	31.6	76.6	118.2	0.44	0.52	0.63
d2	11.33	13.56	13.80	37.4	81.7	123.1	0.45	0.54	0.65
d3	11.03	13.93	14.13	37.7	84.0	132.7	0.46	0.55	0.67
SE_d	0.50	0.67	0.74	0.50	2.76	3.01	0.05	0.07	0.04
CD(P=0.05%)	NS	NS	NS	1.05	5.85	6.38	NS	NS	NS
Age of first cut :									
a1	8.13	10.80	11.00	36.2	75.9	120.8	0.42	0.50	0.61
a2	9.80	14.03	14.24	34.6	84.5	126.2	0.41	0.52	0.64
a3	15.10	16.02	16.27	40.0	81.9	127.1	0.43	0.54	0.65
SE_d	0.50	0.67	0.74	0.50	2.76	3.01	0.05	0.07	0.04
CD(P=0.05%)	1.05	1.42	1.56	1.05	5.85	6.38	NS	NS	NS
Interaction effect (d x a) :									
SE_d	0.86	0.84	0.82	0.86	2.94	4.77	0.09	0.08	0.07
CD(P=0.05%)	NS	NS	NS	1.83	6.23	10.12	NS	NS	NS

The higher and medium plant densities exhibited comparable coppice height next to lesser density treatment during 3 and 6 MAFC.

Different ages of first cut had also influenced the coppice height. The first cut given at 15 MAP (a3) gave significantly higher coppice height as compared to 12 and 9 MAP only in early stage (1 MAFC) and at later stages (3 and 6 MAFC) it was comparable with other ages of first cut viz., 12 and 9 MAP.

This indicated that even though there was significant difference during the early months after first cut, the treatments compensated at later stages. The interaction between plant density and age of first cut (Table 43) which was observed at 6 MAFC indicated that at all the ages of first cut, the lower plant density (d3) was able to increase the coppice height significantly except at early age of first cut (9 MAP). Similarly, at all plant densities studied, in general, the coppice height under each age of first cutting was comparable, except under lower plant density.

4.3.5.3. Basal diameter of coppice shoots (Table 42)

The plant density, age of first cut and their interaction effects did not influence the BD of coppice shoots significantly at all the months of observations.

Table 43. Interaction effect of plant densities and ages of first cutting at 9, 12 and 15 MAP on the mean height growth (cm) of coppice shoots in **Prosopis juliflora** at 6 MAFC

Age of first cut	Plant density			
	d1	d2	d3	Mean
a1	131.9	136.5	140.6	136.3
a2	135.7	138.6	150.7	141.7
a3	141.3	145.9	154.0	147.1
Mean	136.3	140.3	148.4	

Source	SE_d	CD(P=0.05%)
a	4.12	8.73
d	4.12	8.73
a x d	4.77	10.12

4.3.5.4. Biomass (DMP) : Coppice crop (Table 44)

Plant density, age of first cut, coppice duration and their interactions had significantly increased the stem, leaf and total biomass. Higher plant density (d1) significantly proved its potential in registering higher stem, leaf and total biomass at the end of the coppice cropping period as compared to medium (d2) and lower (d3) plant densities. The DMP due to different ages of first cut revealed that cutting at 15 MAP (a3) registered significantly higher stem and total biomass. But with reference to leaf biomass production, it was comparable with the DMP obtained in the first cut at 12 MAP.

The data on coppice duration on the biomass production indicated that with increasing coppice duration, the stem, leaf and total biomass production was increased and the DMP obtained was the highest at longer coppice duration of 12 MAFC compared to the other two coppice durations viz., 6 MAFC and 9 MAFC. Allowing coppice growth for shorter period (6 MAFC) had resulted in the lowest DMP of stem, leaf and total biomass.

In respect of total biomass production of coppice crop (Table 44), at all levels of plant density, the first cut given at 15 MAP was found to register higher total biomass (Fig. 16). However, at medium plant density (d2), the total biomass production at 9 MAP and 12 MAP was on par.

Table 44. Effect of plant densities, ages of first cutting at 9, 12 and 15 MAP, coppicing durations of 6, 9 and 12 MAFC and their interaction effect on the DMP of stem, leaf, total biomass and leaf/stem ratio (LSR) of **Prosopis juliflora** (Coppice crop)

Treatments	Mean biomass production (kg ha^{-1})			Mean LSR
	Stem	Leaf	Total	
Plant density :				
d1	392	213	605	0.6633
d2	289	137	426	0.5856
d3	222	103	325	0.5456
SE$_d$	10	5	14	0.0307
CD(P=0.05%)	21	10	30	0.0652
Age of first cut :				
a1	143	117	260	0.7944
a2	241	173	414	0.6926
a3	519	164	683	0.3074
SE$_d$	10	5	14	0.0307
CD(P=0.05%)	21	10	30	0.0652
Coppice duration :				
c1	142	65	207	0.5896
c2	283	136	419	0.5704
c3	478	253	731	0.6344
SE$_d$	8	6	8	0.0588
CD(P=0.05%)	17	12	17	NS

Interaction effects :

		SE$_d$	CD	SE$_d$	CD	SE$_d$	CD	SE$_d$	CD
d x a :		17	37	8	18	24	51	0.0532	0.1128
d x C :	C at d	15	29	11	21	14	29	0.1018	NS
	d at C	16	32	10	20	18	38	0.0887	NS
a x C :	C at a	15	29	11	21	14	29	0.1018	NS
	a at C	16	32	10	20	18	38	0.0887	NS

At the age of 9 and 15 MAP, all these three plant densities studied significantly differed in registering total biomass (Table 45). But at 12 MAP, the medium density (d2) and lower density (d3) were on par. The interaction effect between plant density and coppicing duration revealed that the highest total DMP was achieved under higher plant density (d1) when allowed to coppice for one year (ie. 12 MAFC) (Table 46).

Similarly interaction between ages of first cut and coppicing duration had shown that maximum total DMP could be obtained by prolonging the age of first cut (ie. 15 MAP) as well as the coppicing duration (12 MAFC) (Table 47).

4.3.5.5. Leaf/stem ratio (LSR) (Table 44)

The LSR among different plant densities and ages of first cut varied significantly, while significance was not obtained for different coppicing durations studied. The interaction effect was absent.

As the plant density decreased, the LSR was found decreasing, and least LSR was observed with lower plant density (d3). In the case of the ages of first cut, the earliest first cut given at 9 MAP was found to register higher LSR and it decreased with the increase in the age of first cut. This indicated that cutting **Prosopis juliflora** at early stages will ultimately give more of leafy biomass than utilizable biomass (stem).

Table 45. Interaction effect between plant densities and ages of first cutting at 9, 12 and 15 MAP on the total DMP (leaf + stem) of **Prosopis juliflora** (kg ha^{-1}) (Coppice crop)

Plant density	Age of first cutting			Mean
	a1	a2	a3	
d1	347	653	816	605
d2	291	308	680	426
d3	141	282	552	325
Mean	260	414	683	

Source	SE_d	CD(P=0.05%)
d	14	30
a	14	30
d x a	24	51

Table 46. Interaction effect between plant densities and coppice durations of 9, 12 and 15 MAP on the total DMP (leaf + stem) of **Prosopis juliflora** (kg ha^{-1}) (Coppice crop)

Plant density	Coppice duration			Mean
	c1	c2	c3	
d1	293	569	954	605
d2	187	389	702	426
d3	142	298	535	325
Mean	207	419	731	

Source	SE_d	CD(P=0.05%)
c	8	17
c at d	14	29
d at c	18	38

Table 47. Interaction effect between ages of first cutting and coppice durations on the total DMP (leaf + stem) of **Prosopis juliflora** (kg ha^{-1}) (Coppice crop)

Age of first cut	Coppice duration			Mean
	c1	c2	c3	
a1	115	243	421	260
a2	189	386	668	414
a3	318	627	1102	683
Mean	207	419	731	

Source	SE_d	CD(P=0.05%)
d	14	30
c	8	17
c at a	14	29
a at c	18	38

4.3.6. Comparison of DMP between first crop and coppice crop of Prosopis (Table 48)

In general, the total biomass production under different plant densities and ages of first cut in the first crop was greater than that of the coppice crop under different coppice durations (Fig. 16). This had been clearly exhibited through the DM increment obtained between 9 and 12 MAP and between 12 and 15 MAP under all plant densities.

The results indicated that coppicing of **Prosopis juliflora** at the early stages viz., 9, 12 and 15 MAP was not beneficial for achieving higher biomass production. For more biomass production through coppicing the age of first cut should be more than 15 MAP as demonstrated from the results of present investigation.

4.3.7. Uptake of nutrients (coppice crop)

4.3.7.1. Macronutrients

The data on the uptake of N, P, K and Na through leaves, stems and the total plant uptake are furnished in Table 49 and Fig. 17 to 20.

Different plant densities had influenced the uptake of all the nutrients through leaves, stems and their total uptake except for the uptake of P in stems. The uptake, in general, was maximum under higher plant density (d1) and lesser under lower plant density (d3).

Table 48. Mean dry matter increment in first and coppice crop of **Prosopis juliflora** at different time interval (Data not analysed statistically)

Spacing and plant density	Age of first cut	Total DMP of the first crop at different age of first cut (kg ha^{-1})	Increment in total DMP of the first crop between ages of first cut (kg ha^{-1})	Total DMP of coppice crop at different coppicing duration (kg ha^{-1})		
				6 MAFC	9 MAFC	12 MAFC
1.5 x 1.5 m	9 MAP	633		152 (24.0)	330 (52.1)	560 (88.5)
4444 plants ha^{-1}	12 MAP	1158	525	297 (25.6)	615 (53.1)	1048 (90.5)
	15 MAP	1367	209	429 (31.4)	763 (55.8)	1255 (91.8)
2.2 x 2.0 m	9 MAP	557		134 (24.1)	269 (48.3)	470 (84.4)
2500 plants ha^{-1}	12 MAP	634	77	141 (22.2)	282 (44.5)	501 (79.0)
	15 MAP	1197	563	287 (24.0)	616 (51.5)	1136 (94.0)
2.5 x 2.5 m	9 MAP	250		59 (23.6)	131 (52.4)	234 (93.6)
1600 plants ha^{-1}	12 MAP	504	254	128 (25.4)	262 (52.0)	455 (90.3)
	15 MAP	949	445	239 (25.2)	502 (53.0)	916 (96.5)

Figures in parenthesis refers to the percentage of DMP to the corresponding DMP in first crop

Table 49. Effect of plant densities, ages of first cutting, coppice durations and their interaction effect on the mean uptake of nutrients in **Prosopis juliflora** (Coppice crop)

Treatments	Uptake through leaves (kg ha^{-1})				Uptake through stems (kg ha^{-1})				Total uptake (kg ha^{-1})			
	N	P	K	Na	N	P	K	Na	N	P	K	Na
Plant density :												
d1	4.02	1.03	2.03	0.23	3.28	0.22	1.54	0.21	7.30	1.31	3.57	0.44
d2	3.09	0.16	1.50	0.25	2.38	0.19	1.36	0.22	5.58	0.36	2.86	0.40
d3	2.38	0.13	1.03	0.11	1.88	0.14	0.92	0.12	4.33	0.26	2.06	0.25
SE$_d$	0.38	0.16	0.24	0.02	0.31	0.03	0.20	0.01	0.44	0.19	0.28	0.04
CD (P=0.05%)	0.81	0.34	0.51	0.03	0.67	NS	0.42	0.03	0.92	0.40	0.59	0.09
Age of first cut :												
a1	2.48	0.95	1.11	0.16	1.15	0.10	0.54	0.12	3.67	1.08	1.65	0.23
a2	3.36	0.18	1.59	0.19	1.87	0.15	0.97	0.11	5.27	0.34	2.56	0.33
a3	3.64	0.20	1.86	0.25	4.52	0.31	2.31	0.33	8.27	0.50	4.28	0.52
SE$_d$	0.38	0.16	0.24	0.02	0.31	0.03	0.20	0.01	0.44	0.19	0.28	0.04
CD (P=0.05%)	0.81	0.34	0.51	0.03	0.67	0.07	0.42	0.03	0.92	0.40	0.59	0.09
Coppice duration :												
c1	1.15	0.09	0.60	0.11	1.01	0.09	0.33	0.25	2.24	1.02	0.93	0.19
c2	2.64	0.18	1.22	0.21	2.18	0.17	0.97	0.12	4.83	0.32	2.30	0.35
c3	5.69	0.25	2.73	0.28	4.34	0.29	2.52	0.19	10.14	0.58	5.26	0.54
SE$_d$	0.45	0.16	0.23	0.03	0.47	0.02	0.19	0.02	0.73	0.18	0.30	0.03
CD (P=0.05%)	0.90	0.32	0.46	0.05	0.95	0.04	0.41	0.04	1.49	0.39	0.61	0.06
Interaction effects :												
d x a	S	S	S	S	NS	NS	NS	S	S	S	S	S
d x c	NS	S	NS	NS	NS	NS	NS	S	NS	S	S	NS
a x c	NS	S	NS	NS	S	S	S	S	S	S	S	S

S : Significant; NS : Not significant

It was observed that different ages of first cut also altered significantly the uptake of all the nutrients in leaves, stems and the total uptake. Similar results were obtained for different coppicing durations of the crop studied.

Uptake of all the nutrients increased with the age of the crop and their uptake was maximum at the age of 15 MAP (a3) except for P. The P uptake was the highest at early stage of the crop (9 MAP) compared to later stages (12 and 15 MAP). Similarly the uptake of all the nutrients increased with the duration of coppicing, with higher uptake at 12 MAFC (c3).

The interaction effect on the uptake of nutrients in stems and leaves was found to be significant for certain nutrients and absent for other nutrients (Table 49). However, the total uptake of all nutrients were significantly influenced by all the interactions studied except d x c interaction in respect of N and Na.

The total uptake of N (Table 50 and 51) and K (Table 54 and 55) were maximum at the age of 15 MAP at all densities and their uptake was also higher at all ages of first cut under higher plant densities (Fig. 17 and 19). Similarly with the advancement of age and coppice duration, the total uptake increased, with maximum uptake being at the age of first cut given 15 MAP (a3) and allowing for longer

Table 50. Interaction effect between plant densities and ages of first cutting at 9, 12 and 15 MAP on the total mean uptake of N in **Prosopis juliflora** (kg ha^{-1}) (Coppice crop)

Age of first cut	Plant density			
	d1	d2	d3	Mean
a1	4.31	4.73	1.96	3.67
a2	8.33	4.13	3.36	5.27
a3	9.26	7.88	7.67	8.27
Mean	7.30	5.58	4.33	

Source	SE_d	CD(P=0.05%)
a	0.44	0.92
d	0.44	0.92
d x a	0.75	1.60

Table 51. Interaction effect between ages first cutting at 9, 12 and 16 MAP and coppice durations of 6, 9 and 12 MAFC on the total mean uptake of N in **Prosopis juliflora** (kg ha^{-1}) (Coppice crop)

Age of first cut	Coppice duration			
	c1	c2	c3	Mean
a1	1.51	3.08	6.41	3.67
a2	2.08	4.51	9.23	5.27
a3	3.14	6.90	14.78	8.27
Mean	2.24	4.83	10.14	

Source	SE_d	CD(P=0.05%)
c	0.73	1.49
c at a	1.27	2.57
a at c	1.12	2.29

coppice duration of 12 MAFC (c3). A similar trend was observed for the total uptake of Na also (Table 56 and 57; Fig. 20).

Total P uptake was greater at the early stage of crop (upto 9 MAP) compared to 12 and 15 MAP under higher plant density (Table 52). Similarly the total P uptake was higher when first cut was done at early age of 9 MAP (a1) and allowed for shorter coppice duration of 6 MAFC (c1) (Table 53).

4.3.7.2. Micronutrients (Table 58; Fig. 21 to 24)

Only the uptake of Fe through leaves, stems as well as its total uptake was found to be significantly influenced by different coppice durations studied. The total uptake of Fe was significantly higher under longer coppice duration of 12 MAFC (c3) compared to other coppicing durations viz., 6 and 9 MAFC. The interaction effect was absent.

The uptake of other micronutrients was not at all altered significantly by any of the treatments and their interaction effect studied. It may be concluded that the uptake of all the nutrients, in general, were more in first crop than in the coppice crop. The uptake of nutrients were in the order of N > K > P > Na. N uptake was nearly two times higher than that of K under all treatments. Among the micronutrients studied, Fe uptake was higher followed by Mn,

Table 52. Interaction effect between plant densities and ages of first cutting at 9, 12 and 15 MAP on the total mean uptake of P in **Prosopis juliflora** (kg ha^{-1}) (Coppice crop)

Age of first cut	Plant density			
	d1	d2	d3	Mean
a1	2.86	0.27	0.12	1.08
a2	0.54	0.25	0.23	0.34
a3	0.52	0.55	0.42	0.50
Mean	1.31	0.36	0.26	

Source	SE_d	CD(P=0.05%)
a	0.19	0.40
d	0.19	0.40
a x d	0.33	0.69

Table 53. Interaction effect between ages of first cutting at 9, 12 and 15 MAP and coppicing durations of 6, 9 and 12 MAFC on the total mean uptake of P in **Prosopis juliflora** (kg ha^{-1}) (Coppice crop)

Age of first cut	Coppice duration			
	c1	c2	c3	Mean
a1	2.67	0.21	0.36	1.08
a2	0.15	0.31	0.56	0.34
a3	0.23	0.44	0.81	0.50
Mean	1.02	0.32	0.58	

Source	SE_d	CD(P=0.05%)
c	0.18	0.39
c at a	0.33	0.67
a at c	0.29	0.63

Table 54. Interaction effect between plant densities and ages of first cutting at 9, 12 and 15 MAP on the total mean uptake of K in **Prosopis juliflora** (kg ha^{-1}) (Coppice crop)

Age of first cut	Plant density			
	d1	d2	d3	Mean
a1	2.23	1.82	0.91	1.65
a2	4.09	1.74	1.85	2.56
a3	4.39	5.02	3.43	4.28
Mean	3.57	2.86	2.06	

Source	SE_d	CD(P=0.05%)
d	0.28	0.59
a	0.28	0.59
d x a	0.48	1.02

Table 55. Interaction effect between ages of first cutting at 9, 12 and 15 MAP and coppicing durations of 6, 9 and 12 MAFC on the total mean uptake of K in **Prosopis juliflora** (kg ha^{-1}) (Coppice crop)

Age of first cut	Coppice duration			
	c1	c2	c3	Mean
a1	0.51	1.05	3.39	1.65
a2	0.73	2.18	4.77	2.56
a3	1.54	3.68	7.62	4.28
Mean	0.93	2.30	5.26	

Source	SE_d	CD(P=0.05%)
c	0.30	0.61
c at a	0.52	1.06
a at c	0.49	1.02

Table 56. Effect of plant densities and ages of first cutting at 9, 12 and 15 MAP on the total mean uptake of Na in **Prosopis juliflora** (kg ha^{-1}) (Coppice crop)

Age of first cut	Plant density			
	d1	d2	d3	Mean
a1	0.33	0.25	0.12	0.23
a2	0.53	0.22	0.24	0.33
a3	0.46	0.72	0.37	0.52
Mean	0.44	0.40	0.25	

Source	SE_d	CD(P=0.05%)
d	0.04	0.09
a	0.04	0.09
d x a	0.07	0.15

Table 57. Interaction effect between ages of first cutting at 9, 12 and 15 MAP and coppicing durations of 6, 9 and 12 MAFC on the total mean uptake of Na in **Prosopis juliflora** (kg ha^{-1}) (Coppice crop)

Age of first cut	Coppice duration			
	c1	c2	c3	Mean
a1	0.12	0.22	0.36	0.23
a2	0.18	0.29	0.51	0.33
a3	0.28	0.53	0.76	0.52
Mean	0.19	0.35	0.54	

Source	SE_d	CD(P=0.05%)
c	0.03	0.06
c at a	0.05	0.11
a at c	0.06	0.12

Table 58. Effect of plant densities, ages of first cutting, coppice durations and their interaction effect on the mean uptake of micronutrients in **Prosopis juliflora** (Coppice crop)

Treatments	Uptake through leaves (kg ha^{-1})				Uptake through stems (kg ha^{-1})				Total uptake (kg ha^{-1})			
	Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu
Plant density :												
d1	0.081	0.029	0.014	0.010	0.079	0.032	0.018	0.014	0.160	0.061	0.032	0.024
d2	0.059	0.018	0.009	0.006	0.066	0.024	0.014	0.011	0.125	0.042	0.023	0.017
d3	0.043	0.013	0.007	0.005	0.044	0.019	0.011	0.009	0.087	0.032	0.018	0.014
SE_d	0.032	0.011	0.005	0.005	0.030	0.010	0.006	0.004	0.052	0.025	0.010	0.012
CD(P=0.05%)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Age of first cut :												
a1	0.047	0.016	0.009	0.006	0.034	0.009	0.007	0.006	0.081	0.025	0.016	0.012
a2	0.068	0.023	0.011	0.008	0.049	0.014	0.012	0.009	0.117	0.037	0.023	0.017
a3	0.066	0.020	0.010	0.007	0.090	0.028	0.025	0.019	0.156	0.048	0.035	0.026
SE_d	0.032	0.011	0.005	0.005	0.030	0.010	0.006	0.004	0.052	0.025	0.010	0.012
CD(P=0.05%)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Coppice duration :												
c1	0.026	0.009	0.005	0.003	0.030	0.012	0.007	0.005	0.056	0.021	0.012	0.008
c2	0.053	0.018	0.009	0.006	0.059	0.024	0.014	0.010	0.112	0.042	0.023	0.016
c3	0.103	0.032	0.016	0.011	0.096	0.039	0.024	0.018	0.199	0.071	0.040	0.029
SE_d	0.036	0.015	0.010	0.007	0.029	0.021	0.011	0.009	0.048	0.034	0.025	0.019
CD(P=0.05%)	0.072	NS	NS	NS	0.058	NS	NS	NS	0.059	NS	NS	NS
Interaction effect :												
d x a	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
d x c	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
a x c	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Zn and Cu. The uptake of all the nutrients increased with the age of the crop and coppice durations. Such increase in uptake was maximum under higher plant density.

4.3.8. Soil fertility changes

The data on available soil macro and micronutrients and also the organic carbon content are presented in Table 59 and 60.

4.3.8.1. Organic carbon (Table 59)

The organic carbon content of the soil at the closure of the experiment did not vary significantly between the different treatments studied viz., plant density, age of first cut, coppice duration and their interactions.

4.3.8.2. Macronutrients (Table 59)

There was significant change in the available soil N between different plant densities and also between different coppice durations studied. Lower plant density (d3) and medium plant density (d2) were on par in registering higher soil N. Similarly longer coppice duration of 9 and 12 MAFC were comparable in respect of higher soil N.

The treatments did not differ significantly for available soil P.

With reference to available soil K, significance was obtained only between different plant densities studied.

Table 59. Effect of plant densities, ages of first cutting, coppicing durations and their interaction effect on the mean organic carbon content and the mean available macronutrients under **Prosopis juliflora** at the end of cropping period (2.7 years)

Treatments	Organic carbon (per cent)	Available nutrients (kg ha^{-1})			
		N	P	K	Na
Plant density :					
d1	0.689	208	1.411	212	173
d2	0.663	214	1.748	232	185
d3	0.615	227	1.811	274	181
SE_d	0.030	6.8	0.199	9.3	12.4
CD(P=0.05%)	NS	14.4	NS	19.8	NS
Age of first cut :					
a1	0.643	214	1.611	243	200
a2	0.657	216	1.667	244	174
a3	0.689	220	1.693	231	166
SE_d	0.030	6.8	0.199	9.3	12.4
CD(P=0.05%)	NS	NS	NS	NS	26.3
Coppice duration :					
c1	0.650	208	1.507	249	190
c2	0.683	217	1.811	230	173
c3	0.695	224	1.652	239	177
SE_d	0.032	5.2	0.151	11.5	10.4
CD(P=0.05%)	NS	10.5	NS	NS	NS

Interaction effects :	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD
d x a :	0.047	NS	11.75	NS	0.345	NS	16.2	NS	21.5	NS
d x c : c at d	0.050	NS	9.00	NS	0.262	0.532	19.9	NS	18.1	36.7
d at c	0.052	NS	10.00	NS	0.292	0.605	18.7	38.4	19.3	39.8
a x c : c at a	0.050	NS	9.00	NS	0.262	NS	19.9	40.3	18.1	36.7
	0.052	NS	10.00	NS	0.292	NS	18.7	38.4	19.3	39.8

Higher available soil K was observed with the treatment d3 (lower density) and it was significantly superior to other plant densities studied.

Different ages of first cut differed significantly for available soil Na while, other factors did not vary. Between different ages of first cut the treatment, a1 (first cut at 9 MAP) and a2 (first cut at 12 MAP) were able to exhibit higher available soil Na. Significantly lesser available soil Na was seen with treatment a3, wherein the first cut was imposed at 15 MAP.

4.3.8.3. Micronutrients (Table 60)

Different treatments studied in the present investigation did not influence significantly the available soil micronutrients viz., Fe, Mn, Zn and Cu.

4.4. EXPERIMENT 4 : Comparative performance of Prosopis juliflora (Swartz) DC. under different soil types (Off Station study)

This study was conducted to evaluate the influence of different soil types on the growth and biomass production of **Prosopis** and the relevant data are presented in Table 61 and Fig. 25.

The parameters taken for this study viz., number of branches per tree, tree height, BD, NUB per tree as well as per hectare were not significantly altered by the different soil types. However, different soil types had

Table 60. Effect of plant densities, ages of first cutting, coppicing durations and their interaction effect on the *mean* available soil micronutrients under **Prosopis juliflora** at the end of cropping period (2.7 years)

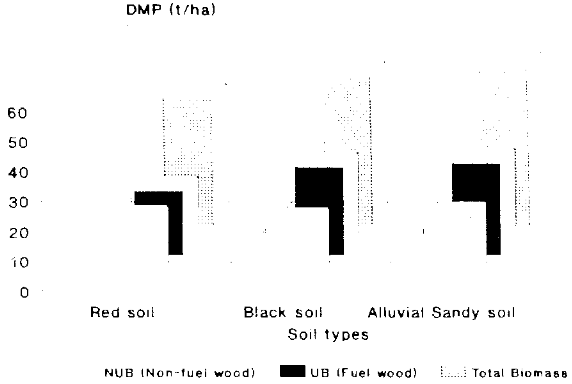
Treatments	Available nutrients (ppm)			
	Fe	Mn	Zn	Cu
Plant density :				
d1	13.11	22.26	0.66	2.03
d2	13.82	22.55	0.61	2.06
d3	14.47	22.38	0.62	2.23
SE_d	0.96	0.11	0.06	0.11
CD(P=0.05%)	NS	NS	NS	NS
Age of first cut :				
a1	14.26	22.09	0.66	2.01
a2	14.14	22.37	0.63	2.17
a3	12.99	22.13	0.60	2.14
SE_d	0.96	0.11	0.06	0.11
CD(P=0.05%)	NS	NS	NS	NS
Coppice duration :				
c1	13.92	22.33	0.62	2.11
c2	13.80	22.10	0.64	2.15
c3	13.56	22.16	0.61	2.07
SE_d	0.42	0.14	0.04	0.07
CD(P=0.05%)	NS	NS	NS	NS

Interaction effects :	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD
d x a :	0.78	NS	0.20	NS	0.10	NS	0.19	NS
d x c : c at d	0.72	NS	0.24	NS	0.07	NS	0.11	NS
d at c	0.74	NS	0.23	NS	0.08	NS	0.14	NS
a x c : c at a	0.72	NS	0.24	NS	0.07	NS	0.11	NS
a at c	0.74	NS	0.23	NS	0.08	NS	0.14	NS

Table 61. Growth and dry biomass production of 4 years old **Prosopis juliflora** under different soil types

Soil type	Mean No.of branches per tree	Mean tree height (m)	Mean BD (cm)	Mean DBH (cm)	Mean UB kg $tree^{-1}$	Mean NUB kg $tree^{-1}$	Total mean biomass kg $tree^{-1}$	Mean UB/NUB ratio	Mean UB t ha^{-1}	Mean NUB t ha^{-1}	Total mean biomass t ha^{-1}
Red soil	2.32	4.34	5.89	3.71	8.39	8.57	16.96	0.98	20.98	21.43	42.41
Black soil	2.41	4.46	5.92	4.24	11.67	8.26	19.93	1.41	29.18	20.65	49.83
Alluvial sandy soil	2.35	4.52	5.90	4.30	12.17	9.06	21.23	1.34	30.43	22.65	53.08
SE_d	0.16	0.19	0.44	0.19	1.13	0.94	0.94	0.14	2.50	2.94	1.65
CD (P=0.05%)	NS	NS	Ns	0.52	2.46	NS	2.62	0.39	6.93	NS	4.56

Fig. 25 DMP (Biomass) of *P.juliflora* (4 years old) under different soil types



influenced the other parameters such as DBH, UB per tree and per hectare, total biomass per tree and per hectare and also the UB/NUB ratio.

Among the three soil types, the influence of red soil was significantly lower as compared to alluvial sandy soil and black soils on the above parameters. The DBH, UB per tree, UB per hectare, total biomass per tree and per hectare of **Prosopis juliflora** were significantly greater in alluvial sandy soil. However, this result was comparable with the values obtained from **Prosopis juliflora** raised in black soil. Eventhough, UB/NUB ratio was the highest for the **Prosopis** raised in black soil, this was also comparable with the **Prosopis juliflora** raised in alluvial sandy soil.

The results indicated the superiority of alluvial sandy soil and black soil over red soil for obtaining better growth and greater biomass from **Prosopis juliflora**.

4.5. EXPERIMENT 5 : Study on the charcoal recovery from Prosopis juliflora (Swartz) DC. fuelwood (Off station study)

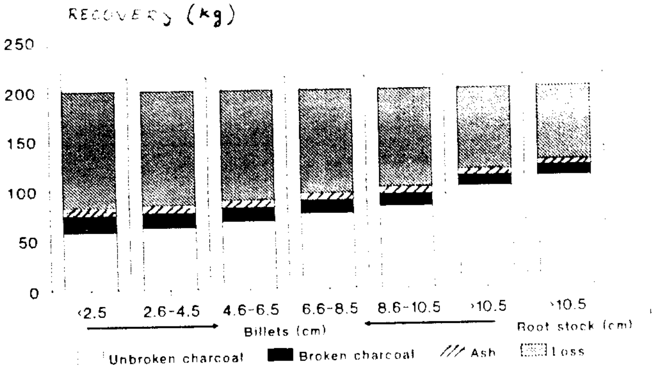
The results on the recovery of utilizable charcoal (UC), non-utilizable charcoal (NUC) and ash obtained from anaerobic burning of 200 kg DM in each of six diameter classes of **Prosopis juliflora** fuelwood billets and one diameter class of **Prosopis** root stock are presented in Table 62 and Fig.26.

Table 62. Mean charcoal yield/recovery from the fuelwood of **Prosopis juliflora** billets/root stocks (kg)*

Diameter of billets/ root stocks	Utilizable charcoal (Unbroken commercial grade)	Non-utilizable charcoal (Broken charcoal)	Ash	Loss
< 2.5 cm billets	57.4 (26.7)	16.4 (8.2)	8.2 (4.1)	118.0 (59.0)
2.6 to 4.5 cm billets	61.4 (30.7)	15.0 (7.5)	7.8 (3.9)	115.8 (57.9)
4.6 to 6.5 cm billets	67.0 (33.5)	14.2 (7.1)	7.4 (3.7)	111.4 (55.7)
6.6 to 8.5 cm billets	74.4 (37.2)	13.8 (6.9)	7.0 (3.5)	104.8 (52.4)
8.6 to 10.5 cm billets	81.0 (40.5)	13.0 (6.5)	6.6 (3.3)	99.4 (49.7)
> 10.5 cm billets	100.6 (50.3)	11.2 (5.6)	6.0 (3.0)	82.2 (41.1)
> 10.5 cm root stocks	110.4 (55.2)	10.0 (5.0)	5.2 (2.6)	74.4 (37.2)

* Refers to quantity obtained from 200 kg DM taken for the study
Figures in parenthesis refers to the percentage recovery.

Fig. 26 Charcoal recovery from the fuel wood of *P.juliflora* billets/root stocks of different diameter classes



The comparison between different billet sizes and root stocks in terms of UC recovery indicated the superiority of the root stocks over the fuelwood billets of same diameter (> 10.5 cm) and fuelwood billets of < 10.5 cm diameter classes studied. Between different billet sizes evaluated, the charcoal recovery in terms of UC increased with the increase in the diameter of billets and it was higher with the billets of > 10.5 cm in diameter. With the increase in the billet diameter the quantity of ash yield as well as the proportion of NUC obtained was also found decreasing indicating lesser losses.

These results suggest that for obtaining higher recovery of commercial grade charcoal, both root stocks and fuelwood billets of > 10.5 cm diameter could be used for anaerobic burning.

PART III STUDY

4.6. EXPERIMENT 6 : Germinability of hot water treated Prosopis juliflora (Swartz) DC. seeds under different times of sowing

The results obtained for the seeds sown upto 15 days after hot water treatment are presented in Table 63. The current recommendation is to sow the hot water treated seeds after shade drying. There seems to be a physical barrier for the adoption of the above technology by the farming community due to their various activities. Hence,

Table 63. Germinability of hot water treated **Prosopis juliflora** seeds at different times of sowing

	Treatments	Mean germination percentage
T_1	Sowing the seeds on the day of HWT	77.3 (61.8)
T_2	Sowing the seeds 1 DAHWT	76.7 (61.4)
T_3	Sowing the seeds 2 DAHWT	75.3 (60.3)
T_4	Sowing the seeds 3 DAHWT	79.3 (63.2)
T_5	Sowing the seeds 4 DAHWT	78.7 (62.7)
T_6	Sowing the seeds 5 DAHWT	78.0 (62.0)
T_7	Sowing the seeds 6 DAHWT	76.0 (60.8)
T_8	Sowing the seeds 7 DAHWT	82.6 (65.5)
T_9	Sowing the seeds 8 DAHWT	80.0 (63.5)
T_{10}	Sowing the seeds 9 DAHWT	74.7 (60.0)
T_{11}	Sowing the seeds 10 DAHWT	76.6 (61.4)
T_{12}	Sowing the seeds 11 DAHWT	77.7 (61.8)
T_{13}	Sowing the seeds 12 DAHWT	77.3 (61.6)
T_{14}	Sowing the seeds 13 DAHWT	75.7 (60.5)
T_{15}	Sowing the seeds 14 DAHWT	77.0 (61.5)
T_{16}	Sowing the seeds 15 DAHWT	75.0 (60.2)
	SE_d	3.7
	CD (P=0.05%)	NS

The figures in parenthesis refer to transformed mean values.
HWT : Hot water treatment
DAHWT : Days after hot water treatment

the viability of seeds was tested upto 15 days after hot water treatment for practicable and acceptable purposes.

Between treatments there was no statistical significance indicating the suitability of the **Prosopis juliflora** seeds for sowing upto 15 days after hot water treatment.

4.7. EXPERIMENT 7 : Effect of seed sizes and depths of sowing on the germination of Prosopis juliflora (Swartz) DC.

The data on the effect of different seed sizes and different depths of sowing on the earliness and the length of germination period is presented alongwith the DMP per plant and DMP per pot recorded 30 days after planting in Table 64.

First germination was observed only on 3rd day after sowing and that too under 2 cm depth of sowing for small and big seeds and 4 cm depth of sowing for big seeds only.

In general, as the depth of sowing increased, the cumulative germination percentage recorded at 16 days after sowing was found decreasing for the small size seeds. But this was different for bigger size seeds wherein there was a hike in germination percentage at 6 cm depth of sowing as

Table 64. Effect of seed sizes and depths of sowing on the earliness and the length of germination period of **Prosopis juliflora** (days) and mean DMP per plant (g) and per pot (g). DS 3.11.93

Seed sizes and depths of sowing	* Germination percentage of Prosopis at different days after sowing														Cumulative germination percentage 16 DAS	Mean DMP (g plant^{-1})	Mean DMP (g pot^{-1})
	3	4	5	6	7	8	9	10	11	12	13	14	15	16			
Small seeds (2.438 g/100 seeds)																	
T_1 2 cm depth	6.00	5.34	12.67	8.67	8.67	6.67	3.34	2.00	-	0.67	0.67	-	1.34	0.67	56.67 (48.9)	0.117	6.630
T_2 4 cm depth	-	0.67	2.67	1.34	5.34	4.00	4.00	2.00	0.67	-	-	-	-	-	26.67 (26.9)	0.103	2.129
T_3 6 cm depth	-	-	2.00	-	0.67	-	3.34	0.66	1.34	0.66	-	-	-	-	8.67 (16.8)	0.094	0.815
T_4 8 cm depth	-	-	0.67	0.67	0.67	-	0.67	-	-	-	0.67	-	-	-	3.34 (8.6)	0.092	0.304
Big seeds (3.070 g/100 seeds)																	
T_5 2 cm depth	4.67	8.67	12.67	9.34	9.34	7.34	3.34	1.34	3.32	1.34	-	-	-	-	60.37 (51.2)	0.190	11.470
T_6 4 cm depth	0.67	0.67	2.00	1.34	2.67	4.00	6.67	1.34	0.67	0.67	2.67	-	-	-	19.34 (26.1)	0.160	3.114
T_7 6 cm depth	-	-	-	3.34	4.00	7.34	2.67	0.67	-	1.34	-	-	-	-	23.3 (28.9)	0.140	3.262
T_8 8 cm depth	-	-	0.67	0.67	-	-	-	1.34	0.67	-	-	-	-	-	3.34 (10.3)	0.160	0.354
SE_d															3.7	0.005	1.945
CD(P=0.05%)															7.8	NS	4.029

Figures in parenthesis refer to transformed values.

* Mean of three replications and data not analysed statistically

compared to 4 cm depth. Considering the seed sizes, big size seeds increased the germination percentage over smaller size seeds.

The first germination was delayed by 2 to 3 days when sown deeper than 4 cm in case of smaller seeds and 6 cm for bigger seeds. The germination continued upto 16th day after sowing for the smaller size seeds sown at 2 cm depth. But such observation was not found for other depths of sowing adopted for smaller seeds and all depths for bigger size seeds.

Nearly 50 per cent of germination was observed between 5 and 6 days after sowing when the seeds were sown at 2 cm depth irrespective of the seed sizes studied. When sown deeper than 2 cm, 50 per cent germination occurred between 7 to 10 days after sowing. However, nearly 75 per cent of total germination was completed 10 days after sowing, irrespective of different seed sizes and depths of sowing.

Thus it is evident that the peak period of germination occurred between 5 to 10 days after sowing under different depths of sowing with different sizes of seeds. However, peak germination was observed on 5 days after sowing for both smaller and bigger seeds sown at 2 cm depth. Different seed sizes and different depths of sowing failed to alter DMP of single plant. But total DMP per pot was significantly influenced by different depths and sizes of the seeds in study.

Between the treatments evaluated, significantly higher DMP per pot was observed for bigger seeds sown at 2 cm depth and this was 73 per cent and 251.6 per cent higher than smaller seeds sown at 2 cm depth and bigger seeds sown at 6 cm depth, respectively.

This treatment of sowing bigger seeds at 2 cm depth was closely followed by small seeds sown at 2 cm depth and bigger seeds sown at 6 cm depth and the latter were comparable. The lowest DMP per pot was observed with bigger seeds sown at 8 cm depth.

4.8. EXPERIMENT 8 : Allelopathic effect of Prosopis juliflora (Swartz) DC on field crops

The data on germination percentage and DMP of test crops are presented in Table 65 and 66; Fig. 27.

Three field crops viz., blackgram, sorghum and sunflower and **Prosopis juliflora** were sown in the soils collected from **Prosopis juliflora** stand and this was compared with the top soil collected from open field wherein **Prosopis juliflora** leaf litter, leaf extract, leaf powder extract and root extracts were added. The aim of the study was to find out the allelopathic effect of **Prosopis juliflora** on crop germination and DMP.

Table 65. Allelopathic effect of **Prosopis juliflora** on the germination of test crops (10 DAS)

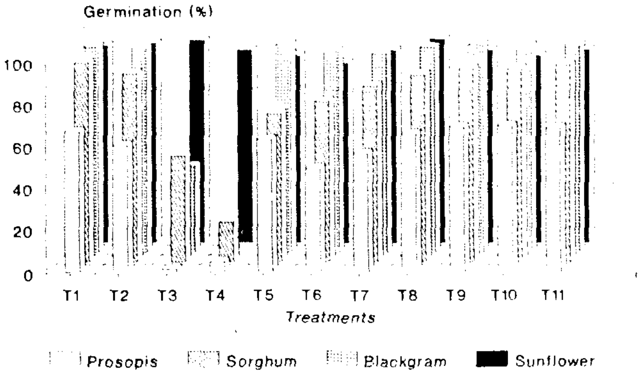
	Treatments	Mean germination percentage			
		Blackgram (Co 5)	Sorghum (Co 26)	Sunflower (Co 2)	Prosopis
T_1	Top soil (UP)	98.0 (81.9)	95.3 (78.0)	94.0 (76.0)	66.7 (54.9)
T_2	Sub soil (UP)	97.3 (80.7)	90.0 (71.7)	95.3 (77.6)	60.0 (50.8)
T_3	Top soil (FL) + PLL 1 per cent	14.0 (18.1)	50.0 (45.0)	96.7 (79.9)	1.3 (3.9)
T_4	Top soil (FL) + PLL 2 per cent	0.0 (0.0)	18.7 (25.5)	92.0 (73.7)	4.7 (9.5)
T_5	Top soil (FL) + PLE 1 per cent	99.3 (87.3)	70.7 (63.2)	89.3 (71.3)	62.7 (52.6)
T_6	Top soil (FL) + PLE 2 per cent	96.0 (83.2)	76.7 (62.8)	86.0 (68.1)	48.7 (50.1)
T_7	Top soil (FL) + PLPE 1 per cent	94.7 (77.1)	84.0 (68.1)	92.0 (73.7)	56.0 (48.5)
T_8	Top soil (FL) + PLPE 2 per cent	98.0 (81.9)	89.3 (71.3)	97.3 (82.6)	65.3 (54.3)
T_9	Top soil (FL) + PRE 1 per cent	99.3 (87.3)	92.0 (73.7)	92.0 (73.7)	68.7 (56.0)
T_{10}	Top soil (FL) + PRE 2 per cent	98.7 (84.6)	92.0 (73.7)	89.3 (71.3)	69.3 (56.5)
T_{11}	Top soil (FL) + Tap water (control)	98.7 (84.6)	94.0 (76.0)	92.0 (73.7)	68.0 (55.5)
	SE_d	5.8	9.1	4.7	5.7
	CD (P=0.05%)	12.3	19.4	10.1	12.2

UP : Under Prosopis, FL : Fallow land, PLL : Prosopis leaf litter : PLE : Prosopis leaf extract
PLPE : Prosopis leaf powder extract, PRE : Proscpis root extract
The figures in parenthesis refer to transformed values

Table 66. Allelopathic effect of **Prosopis juliflora** on the dry matter production of test crops (15 DAS)

	Treatments	DMP (g plant^{-1})			
		Blackgram (Co 5)	Sorghum (Co 26)	Sunflower (Co 2)	Prosopis
T_1	Top soil (UP)	0.065	0.050	0.088	0.032
T_2	Sub soil (UP)	0.063	0.054	0.086	0.035
T_3	Top soil (FL) + PLL 1 per cent	0.080	0.049	0.087	0.019
T_4	Top soil (FL) + PLL 2 per cent	0.000	0.051	0.085	0.019
T_5	Top soil (FL) + PLE 1 per cent	0.066	0.057	0.085	0.027
T_6	Top soil (FL) + PLE 2 per cent	0.068	0.061	0.083	0.033
T_7	Top soil (FL) + PLPE 1 per cent	0.067	0.044	0.086	0.027
T_8	Top soil (FL) + PLPE 2 per cent	0.069	0.050	0.087	0.029
T_9	Top soil (FL) + PRE 1 per cent	0.070	0.052	0.088	0.030
T_{10}	Top soil (FL) + PRE 2 per cent	0.065	0.053	0.077	0.032
T_{11}	Top soil (FL) + Tap water (control)	0.066	0.053	0.085	0.030
	SE_d	0.024	0.025	0.020	0.028
	CD (P=0.05%)	NS	NS	NS	NS

Fig. 27 Allelopathic effect of *P.juliflora* on the germination of test crops (10 DAS)



T1 - Top soil (UP)
T2 - Sub soil (UP)
T3 - Top soil (FL) + PLL 1 per cent
T4 - Top soil (FL) + PLL 2 per cent
T5 - Top soil (FL) + PLE 1 per cent
T6 - Top soil (FL) + PLE 2 per cent
T7 - Top soil (FL) + PLPE 1 per cent
T8 - Top soil (FL) + PLPE 2 per cent
T9 - Top soil (FL) + PRE 1 per cent
T10 - Top soil (FL) + PRE 2 per cent
T11 - Top soil (FL) + Tap water (Control)

Among the crops tested, sunflower germination was not at all affected either by the soil collected from fields under **Prosopis** stand or by the addition of **Prosopis juliflora** leaf litter (Plate 1) and other extracts as indicated in the treatments.

It was observed that both in blackgram and sorghum, the germination was reduced significantly when **Prosopis juliflora** leaf litter was added at 1 per cent and 2 per cent level to the top soil collected from fallow land (Plate 2 and 4). This reduction was higher at 2 per cent level of **Prosopis juliflora** leaf litter. The remaining treatments did not affect the germination percentage of test crops. The same trend was observed in respect of germination of **Prosopis juliflora** seeds sown (Plate 7).

Comparing the different test crops under study, the germination percentage of **Prosopis juliflora** was considerably lower than that of blackgram, sorghum and sunflower.

The other plant extracts of **Prosopis juliflora** such as leaf extract, leaf powder extract and root extract did not exert any significant effect on the germinability of all the test crops including **Prosopis juliflora**, at 1 per cent and 2 per cent, respectively.

It is very interesting to observe that the DMP plant^{-1} of the test crops studied was not significantly

Plate 1. Sunflower: Germination not affected by allelopathic effect of Prosopis leaf litter when sown at the time of leaf incorporation(LI)

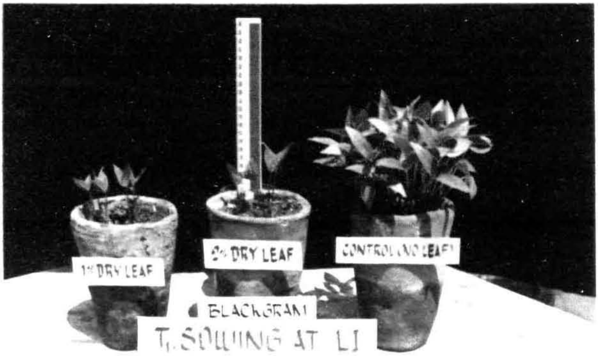


Plate 2. Blackgram : Germination affected by allelopathic effect of Prosopis leaf litter at 1 and 2 percent level when sown at LI.

Plate 3. Blackgram : Germination not affected by allelopathic effect of Prosopis leaf litter when sown one week after leaf incorporation (1 WALI)

Plate 4. Sorghum : Germination affected by allelopathic effect of Prosopis leaf litter at 1 and 2 percent level when sown at LI. But growth increased later

Plate 5. Sorghum : Germination affected by allelopathic effect of Prosopis leaf litter when sown at 1 WALI. But growth increased later.

Plate 6. Sorghum : Germination not affected by allelopathic effect of Prosopis leaf litter when sown at 2 WALI. But growth increased later.

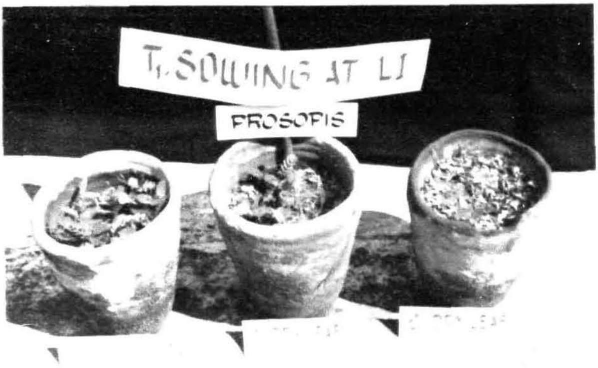


Plate 7. Prosopis:: Germination affected by allelopathic effect of its own leaf litter (autotoxic) at 1 and 2 per cent level when sown at LI.

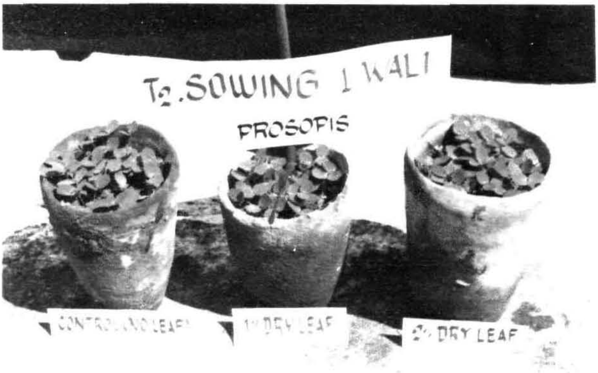


Plate 8. Prosopis : Germination not affected when sown 1WALI

changed even though there was significant variations in the germination of test crops as cited elsewhere (Table 65). After the estimation of the DMP of first sown test crops (15 DAS), the same test crops viz., blackgram, sunflower, sorghum and **Prosopis juliflora** were sown again in the same treatments as residue crops without any external application of the plant materials on 30th day after first crop sowing, leaving 15 days as a *fallow period* between *first* and *second* test crops.

The results on germination percentage of the second test crops (residue crops) are presented in Table 67.

The statistical analysis on germination percentage of blackgram, sunflower, sorghum and **Prosopis juliflora** indicated the absence of significance between treatments evaluated. This suggested that the allelopathic effect of **Prosopis juliflora** leaf litter at 1 and 2 per cent level (Table 65) that was observed in the first crop was absent in the second crop. Thus, it was found that the allelopathic effect seen as a result of leaf litter addition existed only for two to three weeks after the leaf litter incorporation.

After studying the effect of leaf litter of **Prosopis juliflora** on the germinability of test crops, assuming the role of phenolic contents as a cause for allelopathic effect in **Prosopis juliflora**, plant materials such as dried bark, fresh roots, dry leaves, fresh leaves,

Table 67. Allelopathic effect of **Prosopis juliflora** on the germinability of residue test crops on 10 DAS

	Treatments	Mean germination percentage			
		Blackgram (Co 5)	Sorghum (Co 26)	Sunflower (Co 2)	Prosopis
T_1	Top soil (UP)	97.7 (81.3)	94.0 (76.0)	97.0 (80.1)	67.7 (55.4)
T_2	Sub soil (UP)	97.0 (80.1)	93.0 (74.8)	94.0 (76.0)	64.3 (53.3)
T_3	Top soil (FL) + PLL 1 per cent	97.0 (80.1)	92.3 (74.0)	96.7 (79.7)	68.3 (55.8)
T_4	Top soil (FL) + PLL 2 per cent	97.7 (81.3)	92.3 (74.0)	99.0 (85.3)	65.0 (53.7)
T_5	Top soil (FL) + PLE 1 per cent	97.0 (80.1)	92.0 (73.7)	95.0 (77.1)	64.0 (53.1
T_6	Top soil (FL) + PLE 2 per cent	97.3 (81.0)	94.0 (76.0)	96.3 (79.2)	67.9 (55.4)
T_7	Top soil (FL) + PLPE 1 per cent	96.7 (79.7)	94.3 (76.3)	94.7 (76.7)	64.0 (53.1)
T_8	Top soil (FL) + PLPE 2 per cent	97.3 (81.0)	95.3 (77.9)	96.0 (78.7)	68.3 (55.8)
T_9	Top soil (FL) + PRE 1 per cent	98.7 (84.6)	92.7 (74.2)	96.3 (79.6)	65.0 (53.7)
T_{10}	Top soil (FL) + PRE 2 per cent	98.3 (84.2)	94.0 (76.0)	96.3 (79.6)	66.3 (54.9)
T_{11}	Top soil (FL) + Tap water (control)	97.3 (81.0)	93.0 (74.8)	97.0 (80.1)	63.3 (52.7)
	SE_d	3.8	3.6	4.5	2.7
	CD (P=0.05%)	NS	NS	NS	NS

dry leaf powder and stem powder of **Prosopis juliflora** were assessed for the phenolic contents and the data are presented in Table 68.

The phenolic contents varied from 0.950 to 1.500 mg g^{-1} of plant material for different plant parts of **Prosopis juliflora**. Fresh root of **Prosopis juliflora** had shown higher phenolic content followed by dried stem and bark. The dry leaf powder contained lower amount of phenols.

C:N ratio was also estimated for both leaflet and veins of **Prosopis juliflora** leaves and presented in Table 69. The leaflets had 11.02 per cent carbon and 2.2 per cent N (C/N ratio 5:1) while, in the veins the carbon and N contents were 8.0 and 1.5 per cent respectively (C/N ratio 5:1). These results indicate that the C:N ratio of **Prosopis juliflora** leaves is well within the accepted norms.

4.9. EXPERIMENT 9 : Effect of different times of sowing of test crops to mitigate the allelopathic effect of Prosopis juliflora (Swartz) DC. leaf litter on the germination and DMP of test crops

The allelopathic effect of **Prosopis juliflora** leaf litter on the germinability of the test crops viz., blackgram, sorghum and **Prosopis juliflora** was evident from the results of the previous experiment (Table 65) when the test crops were sown at the time of **Prosopis juliflora** leaf incorporation.

Table 68. Phenolic content in different plant parts of **Prosopis juliflora**

Plant parts	Mean Phenolic content mg/g of plant tissue
1. Bark (Dry)	1.370
2. Root (Fresh)	1.500
3. Dry leaves	1.140
4. Fresh leaves	1.040
5. Dry leaf powder	0.950
6. Dry stem powder	1.420

Table 69. C:N ratio of **Prosopis juliflora** leaves

Plant parts	Mean carbon content (per cent)	Mean nitrogen content (per cent)	C:N ratio
Leaflets	11.02	2.20	5:1
Leaf vein	8.00	1.50	5:1

In order to assess the effect of different times of sowing of test crops after **Prosopis juliflora** leaf incorporation, this experiment was conducted. The purpose was to develop a technology against allelopathic effect of **Prosopis juliflora** on field crops. The results on germination percentage of blackgram, sorghum and **Prosopis juliflora** and their DMP on 30 DAS are presented in Table 70 to 73 and Fig. 28.

4.9.1. Germination (Table 70 to 72)

There was significant reduction on the germination percentage of sorghum, blackgram and **Prosopis juliflora** both at 1 and 2 per cent leaf litter incorporation treatments as compared to control (no leaf litter incorporation) when sown at the time of leaf incorporation (Plate 2, 4 and 7). Among the two levels of leaf incorporation, the reduction in germination percentage of all the test crops was higher at 2 per cent than at 1 per cent.

When the sowing was delayed by one week after leaf incorporation, the germination percentage of blackgram and **Prosopis juliflora** was not at all affected (Plate 3 and 8); but rather improved. Whereas, the germination of sorghum was drastically affected upto one week after leaf incorporation (Plate 5). This effect was seen at both 1 and 2 per cent leaf litter incorporation. This indicated the susceptibility of sorghum to **Prosopis juliflora** leaf litter upto one week from its leaf incorporation.

Table 70. Effect of different times of sowing to mitigate the adverse influence of allelopathy of **Prosopis juliflora** leaf litter on the germination of blackgram (Co 5) (10 DAS)

Treatments	Mean germination percentage of blackgram		
	1% LI	2% LI	NLI
T_1 Sowing at LI	22.7 (28.3)	14.7 (22.4)	95.3 (78.4)
T_2 Sowing 1 WALI	90.6 (72.7)	94.0 (76.2)	90.0 (72.2)
T_3 Sowing 2 WALI	93.3 (75.3)	94.5 (76.4)	76.0 (78.7)
T_4 Sowing 3 WALI	96.0 (78.7)	95.3 (78.0)	95.3 (77.6)
T_5 Sowing 4 WALI	94.7 (77.3)	96.0 (78.7)	94.0 (76.3)
T_6 Sowing 5 WALI	94.6 (77.3)	92.0 (73.7)	94.7 (77.3)
T_7 Sowing 6 WALI	96.0 (78.7)	94.0 (76.4)	94.0 (76.7)
SE_d	3.7	2.6	3.7
CD(P=0.05%)	7.8	5.5	NS

LI : Leaf incorporation,
NLI : No leaf incorporation (control)
WALI : Week after leaf incorporation
Figures in the paranthesis indicate transformed values

Table 71. Effect of different times of sowing to mitigate the adverse influence of allelopathy of **Prosopis juliflora** leaf litter on the germination of sorghum (Co 26) (10 DAS)

	Treatments	Mean germination percentage of sorghum		
		1% LI	2% LI	NLI
T_1	Sowing at LI	32.7 (34.8)	10.7 (18.2)	85.0 (67.4)
T_2	Sowing 1 WALI	30.7 (33.4)	11.5 (19.4)	86.0 (69.0)
T_3	Sowing 2 WALI	90.6 (72.4)	90.7 (72.5)	86.5 (69.2)
T_4	Sowing 3 WALI	86.7 (69.4)	90.7 (72.5)	90.7 (72.5)
T_5	Sowing 4 WALI	85.3 (67.7)	90.0 (72.2)	93.3 (75.6)
T_6	Sowing 5 WALI	90.0 (72.6)	93.6 (75.6)	92.0 (73.7)
T_7	Sowing 6 WALI	86.7 (68.8)	90.7 (72.5)	88.7 (71.0)
	SE_d	4.5	3.8	5.2
	CD(P=0.05%)	9.6	8.3	NS

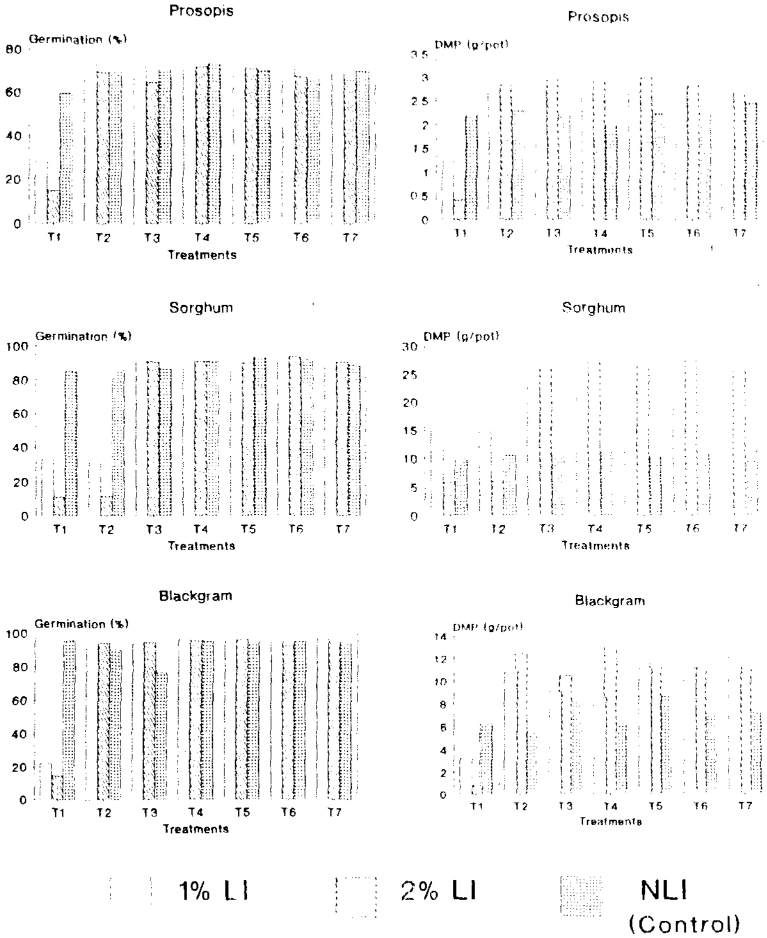
LI : Leaf incorporation,
NLI : No leaf incorporation (control)
WALI : Week after leaf incorporation
*Figures in the paranthesis indicate transformed values

Table 72. Effect of different times of sowing to mitigate the adverse influence of allelopathy of Prosopis leaf litter on the germination of **Prosopis juliflora** seeds (10 DAS)

Treatments		Mean germination percentage of **Prosopis**		
		1% LI	2% LI	NLI
T_1	Sowing at LI	28.0 (31.8)	14.7 (21.3)	59.3 (50.4)
T_2	Sowing 1 WALI	72.7 (58.8)	69.3 (56.6)	69.3 (56.4)
T_3	Sowing 2 WALI	72.0 (58.2)	64.7 (53.5)	70.5 (57.0)
T_4	Sowing 3 WALI	70.0 (56.9)	72.0 (58.2)	73.3 (59.0)
T_5	Sowing 4 WALI	68.0 (55.4)	71.3 (57.7)	70.0 (56.9)
T_6	Sowing 5 WALI	71.0 (57.7)	67.3 (55.2)	66.0 (54.4)
T_7	Sowing 6 WALI	68.6 (55.9)	66.0 (54.4)	70.0 (59.6)
	SE_d	4.3	4.5	5.7
	CD(P=0.05%)	9.3	9.6	NS

LI : Leaf incorporation,
NLI : No leaf incorporation (control)
WALI : Week after leaf incorporation
*Figures in paranthesis indicate transformed values

Fig. 28 Effect of different times of sowing of test crops to mitigate the allelopathic effect of *P. juliflora* leaf litter



T1 - Sowing at LI
T2 - Sowing 1 WALI
T3 - Sowing 2 WALI
T4 - Sowing 3 WALI
T5 - Sowing 4 WALI
T6 - Sowing 5 WALI
T7 - Sowing 6 WALI
LI - Leaf incorporation
NLI - No leaf incorporation
WALI - Week after leaf incorporation

4.9.2. Dry Matter Production (Table 73)

The recorded DMP on 30 DAS for **Prosopis juliflora**, sorghum and blackgram behaved similar to the observations made under germination percentage of the crops tested in the present investigation. In all these crops, the treatment control (No leaf litter incorporation) had not exerted any influence on the DMP of different treatments studied. In the case of **Prosopis juliflora** and blackgram significantly lower DMP was observed when sowing was done immediately after leaf incorporation both at 1 and 2 per cent level. But such effect was not seen for the sowings taken 1 WALI. The DMP of the other test crop viz., sorghum was affected both at 1 and 2 per cent level of **Prosopis juliflora** leaf incorporation even if sowing was taken at 1 WALI and thereafter normality was restored. This trend was similar to the observation made on the germination of sorghum with the leaf litter addition.

One interesting phenomenon was observed in respect of DMP pot^{-1} in all the test crops studied. That is at all the times of sowing treatment except sowing at the time of leaf incorporation, compared to the control (no leaf incorporation), the DMP was in the increasing trend due to leaf litter incorporation both at one and two per cent level and the DM increase was slightly higher at two per cent level. The DM increase was spectacular in sorghum and blackgram compared to **Prosopis juliflora** with 119 to 150 per

Table 73. Effect of different times of sowing to mitigate the allelopathic influence of **Prosopis juliflora** leaf litter on the mean DMP (g pot^{-1}) of test crops (30 DAS)

	Treatments	Prosopis			Sorghum (Co 26)			Blackgram (Co 5)		
		1% LI	2% LI	NLI	1% LI	2% LI	NLI	1% LI	2% LI	NLI
T_1	Sowing at LI	1.218	0.412	2.194	17.184	5.805	9.733	3.167	0.779	6.195
T_2	Sowing 1 WALI	2.763	2.841	2.287	14.721	5.917	10.621	10.781	12.408	5.535
T_3	Sowing 2 WALI	2.628	2.944	2.186	22.559	26.530	10.294	9.050	10.499	8.208
T_4	Sowing 3 WALI	2.590	2.916	1.979	23.106	27.165	11.020	8.496	12.961	6.242
T_5	Sowing 4 WALI	2.686	2.995	2.240	21.752	26.325	10.263	11.127	11.520	8.601
T_6	Sowing 5 WALI	2.769	2.827	2.211	23.625	27.472	10.948	11.021	11.132	7.103
T_7	Sowing 6 WALI	2.686	2.706	2.450	22.850	25.487	12.108	12.096	11.092	7.144
	SE_d	0.419	0.752	0.401	1.911	4.393	1.464	2.332	3.883	2.542
	CD(P=0.05%)	0.875	1.568	NS	3.986	9.163	NS	4.865	8.099	NS

LI : Leaf incorporation;
NLI : No leaf incorporation (control)
WALI : Week after leaf incorporation

cent increase over control in sorghum and 51 to 78 per cent over control in blackgram at different times of sowing (Table 73).

4.10. EXPERIMENT 10 : Effect of leaf litter and plant extracts of Prosopis juliflora (Swartz) DC on weed control

Prosopis root extract, leaf extract and leaf litter at 2 per cent level were taken for the study alongwith one control (tap water) on the germination and DMP of important problematic weeds like haryali, nutgrass and parthenium. The data on germination percentage of weeds and their DMP studied in the present investigation are presented in Table 74.

The germination percentage and DMP of the test weeds were not at all affected by the treatments (root extract, leaf extract and leaf litter incorporation at 2 per cent level) studied. This is in contrast to the observations made on the germination of blackgram, sorghum and **Prosopis juliflora** in the experiment with the addition of **Prosopis juliflora** leaf litter (Table 65).

The comparison of the results furnished in Table 65 and 74 indicated that 2 per cent concentration of **Prosopis** leaf litter incorporation was found to be harmful to the field crops like sorghum, blackgram and **Prosopis juliflora**, but weeds like haryali, nutgrass and parthenium

Table 74. Effect of plant extracts and leaf litter of **Prosopis juliflora** on the germination per cent and DMP of weeds

Treatments		Mean germination per cent (10 DAS)	Mean DMP (g pot^{-1}) (20 DAS)
T_1	HS + PRE	40.0 (39.2)	0.636
T_2	HS + PLE	33.3 (30.0)	0.465
T_3	HS + PLL	53.3 (46.9)	0.436
T_4	HS + tap water (control)	46.7 (43.0)	0.929
T_5	NG + PRF	40.0 (38.2)	0.467
T_6	NG + PLE	30.0 (27.8)	0.856
T_7	NG + PLL	30.0 (27.8)	0.387
T_8	NG + tap water (control)	40.0 (39.2)	0.351
T_9	Parthenium + PRE	18.0 (25.0)	1.488
T_{10}	Parthenium + PLE	14.0 (21.6)	1.694
T_{11}	Parthenium + PLL	14.7 (21.5)	2.428
T_{12}	Parthenium + tap water (control)	14.0 (20.0)	2.305
	SE_d	14.1	0.840
	CD (P=0.05%)	NS	NS

The figures in parenthesis refers to transformed values.

HS : Haryali stolon, NG : Nut grass,

PRE : Prosopis root extract, PLE : Prosopis leaf extract,

PLL : Prosopis leaf litter incorporation were not affected. This indicated the sub-optimal level of **Prosopis juliflora** plant material on the control of weeds in the present investigation.

Hence, a second experiment was conducted with slight modifications (The concentration of leaf and root extracts were increased from 2 to 5 per cent; the leaf litter was added as a mulch at 1 per cent level against 2 per cent incorporation tried in the earlier experiment; sorghum was found to be a susceptible crop for **Prosopis juliflora** leaf litter incorporation as seen in previous experiment and hence this was also included as test crop in addition to weeds). The data on germination percentage and DMP of weeds and sorghum are presented in Table 75.

The germination percentage of parthenium (Plate 9) and sorghum were significantly affected with the application of root extract, leaf extract and leaf litter mulch of **Prosopis juliflora**. In the control also similar reduction was observed. This needs further probing.

With reference to nutgrass, the treatments were comparable with each other in registering higher germination percentage, revealing the failure of the treatments over nutgrass rhizome germination under control.

With reference to haryali, with the introduction of treatments, the germination percentage of stolon was

Plate 5. Parthenium: germination affected by Prosopis leaf litter mulch at 1 per cent.

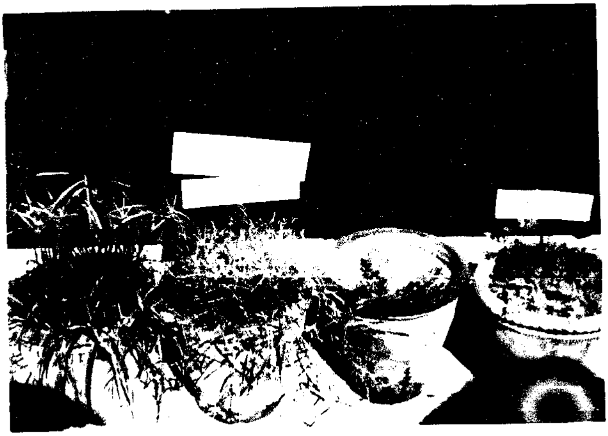


Plate 5. Parthenium: Germination affected by Prosopis leaf litter mulch at 1 per cent.

Table 75. Effect of plant extracts and leaf litter of **Prosopis juliflora** on the germination per cent and DMP of weeds

Treatments	Mean germination per cent (10 DAS)	Mean DMP (g pot^{-1}) (45 DAS)
T_1 HS + PRE	86.7 (68.9)	19.0
T_2 HS + PLE	50.0 (44.9)	14.5
T_3 HS + PLL	80.0 (63.9)	60.3
T_4 HS + tap water (control)	53.3 (47.0)	15.0
T_5 NG + PRE	96.7 (83.9)	15.6
T_6 NG + PLE	96.7 (83.9)	23.4
T_7 NG + PLL	96.6 (83.8)	54.5
T_8 NG + tap water (control)	96.0 (83.6)	16.3
T_9 Parthenium + PRE	40.0 (39.2)	9.2
T_{10} Parthenium + PLE	30.0 (27.8)	9.8
T_{11} Parthenium + PLL	2.7 (9.3)	2.1
T_{12} Parthenium + tap water (control)	47.0 (43.4)	10.5
T_{13} Sorghum + PRE	66.7 (54.8)	13.0
T_{14} Sorghum + PLE	68.7 (56.2)	14.9
T_{15} Sorgnum + PLL	56.0 (48.6)	17.8
T_{16} Sorghum + tap water (control)	76.6 (61.8)	9.3
SE_d	7.8	4.1
CD (P=0.05%)	15.7	8.2

HS : Haryali stolon, NG : Nut grass;
PRE : Prosopis root extract, PLE : Prosopis leaf extract,
PLL : Prosopis leaf litter mulch
Figures in parenthesis refers to transformed values

found higher over its control. This situation also warrants further indepth study.

In respect of DMP of different weeds and sorghum, all treatments exhibited reduction in DMP except **Prosopis juliflora** leaf litter mulching for nutgrass and haryali stolon.

4.11. EXPERIMENT 11 : Effect of leaf incorporation and plant extracts of Prosopis juliflora (Swartz) DC. on the control of root-knot nematode (Meloidogyne incognita (Kofoid and White, 1919) Chitwood, 1949) in tomato (Lycopersicon esculentum Mill.)

Since the leaf litter incorporation was found to affect the germination of field crops and certain abnoxious weeds an innovative study was made in the present experiment to assess the effect of different plant extracts of **Prosopis juliflora** besides dry and fresh leaf material on the control of root-knot nematode. The menace of root knot nematode is increasingly felt in many of the cultivated field crops, especially in tomato. The data collected on nematode population per 200 g of rhizosphere soil, number of egg masses per gram of root, the fruit number and yield per plant of test crop tomato are presented in Table 76.

There was visible difference in the growth of tomato due to different treatments (Plate 10). The nematode population varied significantly between different treatments

Table 76. Effect of leaf incorporation and plant extracts of **Prosopis juliflora** on mean fruit number, fruit yield, nematode population and egg mass at the time of harvest in tomato inoculated with root-knot nematode (4th month)

	Treatments	Mean fruit number plant^{-1}	Mean fruit yield (g plant^{-1})	Mean nematode population (Numbers per 200 g soil)	Mean Egg mass (No.g^{-1} roots)
T_1	Control (No plant extract)	1.7	44.3	313.3	34.7
T_2	Dry stem extract*	1.7	19.6	193.3	24.0
T_3	Fresh bark extract	2.0	45.1	63.3	10.0
T_4	Dry bark extract	3.3	41.2	86.7	12.3
T_5	Charcoal powder extract	2.0	29.8	86.7	12.3
T_6	Dry leaf powder extract	2.1	51.4	80.0	11.3
T_7	Fresh root extract	1.3	17.0	160.0	16.3
T_8	Fresh leaf extract	2.0	30.1	80.0	9.7
T_9	Dry leaf incorporation (1 per cent)	3.7	66.4	36.7	4.7
T_{10}	Fresh leaf incorporation (1 per cent)	3.3	45.6	43.3	4.7
	SE_d	0.6	7.1	19.1	2.2
	CD (P=0.05%)	1.3	14.8	40.1	4.5

* All extracts at 1 per cent concentration

Plate 10. Effect of leaf incorporation and extracts of different plant parts of Prosopis on the growth of tomato inoculated with Meloidogyne incognita (root-knot nematode)

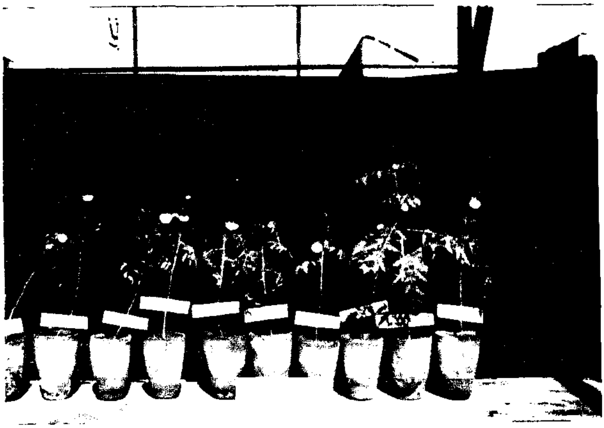


Plate 10. Effect of leaf incorporation and extracts of different plant parts of Prosopis on the growth of tomato inoculated with Meloidogyne incognita (root-knot nematode)

evaluated. As compared to control, the nematode population was reduced greatly under different plant extracts of **Prosopis juliflora**. The reduction was maximum under one per cent incorporation of dry leaves. This reduction was 88.3 per cent over control. This treatment was comparable with the other two treatments viz., fresh leaf incorporation at one per cent level and fresh bark extract at one per cent concentration in controlling the nematode population.

The same trend was observed on the control of egg mass of nematodes present in the roots. In these results dry leaf incorporation as well as fresh leaf incorporation at one per cent level and fresh leaf extract at one per cent concentration were statistically on par in reducing the egg masses of nematode per gram of roots.

As a result of better control of nematode population and egg masses, highest fruit number per plant (tomato) was observed under the treatment dry leaf incorporation at one per cent level. This was comparable with fruit yield obtained under fresh leaf incorporation at one per cent level and dry bark extract at 1 per cent concentration. The lesser fruit yield per plant was registered by the treatments viz., fresh leaf and root extract, dry leaf powder extract, dry stem extract, control, fresh bark extract and charcoal powder extract.

When the fruit yield per plant was reviewed for treatment variations the highest fruit yield was recorded under the treatment dry leaf incorporation at one per cent only. Other treatments were significantly inferior in registering fruit yield per plant.

4.12. EXPERIMENT 12 : Estimation of nutrient addition through **Prosopis juliflora** (Swartz) DC. leaves

The data on the organic carbon content, available NPK, change in EC and pH due to different treatments are presented in Table 77.

The EC of soil and the available P content were not affected by the treatments studied. With reference to pH of the soil it was significantly reduced at 45 days after leaf litter incorporation and thereafter a steady increase in pH was observed upto 90 days.

As a result of **Prosopis juliflora** leaf litter incorporation a spurt in organic carbon content was noticed on 30 days after leaf litter incorporation. Thereafter it got decreased on par with the organic carbon content of control treatment. It indicated that the **Prosopis juliflora** leaves got decomposed within a month.

In the case of available N, significantly higher quantity was observed on 30 days after leaf litter incorporation and statistically same level was maintained upto 60 days after leaf litter incorporation. The increase

Table 77. Change in nutrient contents of the soil after different days of **Prosopis juliflora** leaf litter incorporation

Days after leaf litter incorporation	Mean organic carbon (per cent)	Mean available nutrients (kg ha^{-1})			Mean EC_1 (dSm^{-1})	Mean pH
		N	P	K		
T_1 30 days	0.62	243.1	6.7	181.7	0.29	7.52
T_2 45 days	0.45	239.0	5.8	145.6	0.26	6.74
T_3 60 days	0.43	235.2	4.5	140.7	0.35	6.96
T_4 75 days	0.41	211.3	4.3	134.8	0.30	7.20
T_5 90 days	0.36	207.8	4.3	131.6	0.42	7.22
T_6 Control (No leaf litter)	0.41	215.5	4.5	142.5	0.25	7.29
SE_d	0.08	11.7	1.20	16.5	0.07	0.27
CD(P=0.05%)	0.18	25.5	NS	35.4	NS	0.57

in available soil N on 30 days after leaf litter incorporation was 12.8 per cent over control.

In the case of potassium also significantly higher quantity of available soil K was observed on 30 days after leaf litter incorporation and the increase was 27.5 per cent over control. The available soil K got decreased from 75 days after leaf litter incorporation.

4.13. EXPERIMENT 13 : Enumeration of microbial load in Prosopis juliflora (Swartz) DC. leaf litter collected from the field

Among the three microorganisms cultured in 0.1 per cent tannin incorporated media, only bacteria and fungi were present and the actinomycetes were absent in the washings of the top layers of leaf litter and top soil washings. Whereas, all the three microbes were absent in the culture medium containing 0.25 per cent tannin (Table 78).

The results suggested that microorganisms present in the washings of the **Prosopis juliflora** leaf litter were inhibited by higher concentration of tannin (0.25 per cent). In the top layer of leaf litter collected from Fd. No.37 (Six years old **Prosopis juliflora**), all the three microorganisms were absent while in the bottom layer of leaf litter and the soil below the bottom layer of leaf litter, the bacteria and fungi were present. On the contrary, in Fd.No. 62 (10 years old **Prosopis juliflora**), bacteria and

Table 78. Mean microbial population in **Prosopis juliflora** leaf litter (Number g^{-1} dry leaf)

Treatments	Mean microbial population under tannin based media*					
	0.1 per cent tannin			0.25 per cent tannin		
	Bacteria $\times 10^5$	Fungi $\times 10^3$	Actinomycetes $\times 10^2$	Bacteria $\times 10^5$	Fungi $\times 10^3$	Actinomycetes $\times 10^2$
A. Location I (Fd. No.37)**						
T_1 Top layer of litter	-	-	-	-	-	-
T_2 Bottom layer of litter	191	4	-	-	-	-
T_3 Top soil	46	2	-	-	-	-
B. Location II (Fd. No.62)***						
T_4 Top layer of litter	12	2	-	-	-	-
T_5 Bottom layer of litter	17	3	-	-	-	-
T_6 Top soil	5	1	-	-	-	-

* Data not analysed statistically
** Six years old natural stand of Prosopis (near Fd. No.37)
*** 10 years old natural stand of Prosopis (near Fd. No.62)

fungi were present in both layers of leaf litter and top soil.

The population of bacteria and fungi were relatively higher in the bottom litter and top soil collected from Fd.No.37 compared to that of Fd.No.62. Among the two organisms, the population of bacteria was more than fungi in both locations. This revealed variations in microbial load among different locations as well as age of plantations.

The above results indicated that bacteria and fungi had greater role on the decomposition and mineralization of **Prosopis juliflora** leaf litter, irrespective of the age of the leaves.

DISCUSSION

CHAPTER V

DISCUSSION

Thirteen experiments were conducted on silvicultural and ecological aspects of **Prosopis juliflora.** The results of these experiments have been furnished in the earlier chapter. The discussion made on the results obtained is presented in this chapter.

PART I STUDY

5.1. EXPERIMENT 1. Study on the allometric relationship of the Prosopis juliflora (Swartz) DC. seedlings

Allometric models developed in the present investigation revealed that the above ground DMP (shoot weight) of the **Prosopis juliflora** seedlings could be considered as the most reliable scientific parameter for selecting better planting stocks as the dependence of shoot weight on root weight was evidently proved through simple linear regression model.

The **Prosopis juliflora** seedling attributes such as faster juvenile growth rate, higher number of secondary roots per seedlings and maximum biomass production had been found responsible for the superiority of **Prosopis juliflora** over other tree species evaluated viz., **Acacia auriculiformis, Acacia nilotica, Dalbergia sissoo, Eucalyptus hybrid** and **Terminalia arjuna** in a non-saline sodic soils of Uttar Pradesh as reported by Goel (1987b).

The above ground DMP of **Prosopis juliflora** seedlings (shoot weight) was a result of its root density and volume. The dependence of shoot weight on the root weight might be attributed to the fact that root biomass served as carbohydrate reservoir (source) in the early stage for the above ground biomass (sink). It could also be interpreted that appreciable shoot weight served as an indicator for higher root biomass (root weight). Hence, without destroying the **Prosopis juliflora** seedlings, the aboveground biomass could be estimated using simple linear regression equations with BD and height of the seedlings as independent variables since the regression model computed in experiment 2 (Table 20 and 21) indicated the direct contribution of BD over height to the UB, NUB and TB of **Prosopis juliflora**. This will serve as a non-destructive method for the selection of better root stock for successful plantation.

Eventhough there was a positive correlation between shoot length and root length, it was not significant in the simple regression study which indicated that seedling height was independent of root length. The reason for this behaviour needs further study. However, several workers suggested that height of seedlings in many tree species could be considered as a good measure of growth potential (Nair, 1971; Chavasse, 1977 and Rai **et al.**, 1982). But, this was not observed in the present investigation for **Prosopis juliflora**.

5.2. EXPERIMENT 2. Comparative performance of Prosopis juliflora (Swartz) DC. with other multipurpose tree species (MPTs)

The multipurpose tree species evaluated viz., **Eucalyptus tereticornis, E.camaldulensis, Azadirachta indica, Prosopis juliflora, Casuarina equisetifolia, Acacia nilotica** and **A.leucophloea** were felled down at the close of the 4th year from planting. The data recorded on these trees after felling down are discussed in this section.

5.2.1. Biomass

Total biomass production (DMP) serves as a tool to evaluate the efficiency of any tree sub-system. In the present investigation the growth and yield parameters viz., tree height, BD, DBH, UB (stem), NUB (leaves and branches) and wood density have been found to contribute to the total biomass.

The results showed that the total biomass was higher with **E.tereticornis, E.camaldulensis** and **P.juliflora.** The lowest was observed with **A.leucophloea.** The increased biomass obtained in **E.tereticornis** and **E.camaldulensis** was a result of higher tree height, BD, DBH (Table 7), UB, NUB (Table 10) and wood density (Table 11) obtained from these trees. It was also observed that for the first two years the

CAI (current annual increment) of tree height and BD (Table 8 and 9) were also higher with these trees as compared to other trees evaluated. This indicated the fast juvenile growth potential of **Eucalyptus tereticornis** and **E.camaldulensis**.

The **P.juliflora** tree was comparable in terms of higher total biomass to **E.tereticornis** and **E.camaldulensis.** This performance was mainly due to increased production of NUB from **P.juliflora** (Table 10) as inferred from the partitioning of leaf biomass and branch biomass. Eventhough **E.tereticornis** and **E.camaldulensis** exhibited higher CAI of tree height and BD during the first two years, at the third year **P.juliflora** exhibited increased CAI of tree height and BD and as a result it was comparable to **E.tereticornis** and **E.camaldulensis** in registering higher total biomass.

The highest total biomass thus obtained from **P.juliflora**, **E.tereticornis** and **E.camaldulensis** could be also related to their higher photosynthetic efficiency as reported by Gurumurti **et al.** (1984). According to them, the solar conversion efficiency of **P.juliflora** was higher compared to that of **Albizia lebbeck, Dalbergia sissoo, Eucalyptus hybrid, Cassia siamea, Acacia nilotica** and **Acacia tortilis**. It was reported that the photosynthetic pathway of **Prosopis juliflora** might be similar to C4 plants. But this phenomenon was not reported in any of the trees (Mathur **et al.**, 1984). This might be one among the reasons for higher total biomass production in **Prosopis** juliflora.

Eventhough **Azadirachta indica** and **Acacia nilotica** showed higher CAI of tree height and BD at the third year similar to **Prosopis juliflora**, this was not reflected on the total biomass and hence these two trees exhibited lesser total biomass compared to **P.juliflora**, **E.tereticornis** and **E.camaldulensis**.

The comparison of partitioning of biomass in **P.juliflora** with reference to that of **E.tereticornis** and **E.camaldulensis** revealed the following : partitioning of biomass of **P.juliflora** was comparatively poor due to multistems with more side branches that lack straightness. The UB and NUB contribution to total biomass production were 28.70 and 71.30 per cent, respectively, for **Prosopis juliflora**, while it was 54.60 and 45.21 per cent, respectively, for **E.tereticornis**; 57.88 and 42.12 per cent, respectively, for **E.camaldulensis**.

This indicated the lesser partitioning efficiency of the **P.juliflora** as compared to **Eucalyptus camaldulensis** and **E.tereticornis**. This area needs further probing in order to increase the UB of **Prosopis juliflora** through any silvicultural and/or chemical manipulations since greater

NUB accumulation was observed in leaves and branches of **Prosopis juliflora**.

Among all the MPTs, the least total biomass production was observed in **Acacia leucophloea**. This is attributed to lesser BD, DBH, tree height, MAI of tree height and BD in **A.leucophloea** compared to other MPTs evaluated. Eventhough such characters were observed with **A.leucophloea**, it also had one positive attribute viz., higher wood density on fresh weight basis. However, considering the wood density on dry weight basis, **A.leucophloea** was on par with all other MPTs including **P.juliflora** that recorded the lowest wood density (Table 11).

The observed variations in wood density among different MPTs evaluated is attributed to the inherent wood property (genetic character). However, wood density was also influenced by the moisture content of the wood as confirmed in the present investigation wherein variations in wood density between dry and fresh wood were observed (Table 11). The density of **P.juliflora** on fresh weight basis was higher than that of its dry wood density. This was attributed to highest moisture content of 55.7 per cent in the stem (UB) of **Prosopis juliflora** against 48 to 49 per cent moisture in both the species of **Eucalyptus**, 49.8 per cent in **Azadirachta indica** and less than 45 per cent in other MPTs at the time of felling.

5.2.2. Microbial load

The soil under four years old **Acacia leucophloea** recorded the highest population of bacteria, fungi and actinomycetes per gram of dry soil, followed by **A.nilotica. P.juliflora** ranked third next to them. Lesser microbial population was recorded under both the species of **Eucalyptus camaldulensis** and **E.tereticornis** (Table 12).

The variations in microbial load in the present investigation might be attributed to many factors such as soil moisture, soil temperature, soil organic carbon content, available nutrients, the root exudates in the rhizosphere region, nature of leaf litter over soil surface. soil types and vegetation types as reported by Theodorou (1984).

Comparatively lesser organic carbon content of soil under **E.tereticornis** and **E.camaldulensis** than that of **A.leucophloea, A.nilotica** and **P.juliflora** (Table 17) might have been the reason for lesser microbial population in the soil under **E.tereticornis** and **E.camaldulensis**. The allelopathic effect of **Eucalyptus camaldulensis** and **E.tereticornis** leaves might have been more potent than that of the leaves of other MPTs in inhibiting the growth of microbes as the microbial density on leaf litter was found to depend on types of leaves (species), their physical and chemical properties (Witkamp, 1966). As a result of more organic carbon content of the soil, the activity of microbes might have been induced under **A.leucophloea**, **A.nilotica** and **P.juliflora**. Relatively speaking the allelopathic effect of leaf litter of **A.leucophloea**, **A.nilotica** and **P.juliflora** ought to have been lesser compared to **Eucalyptus camaldulensis** and **E.tereticornis**. This is another favourable factor responsible for increased microbial population under these tree species. It is assumed that with the increase in microbial activity the fertility status of the soil also would be altered favourably as the soil fertility was related to microbial activity (Shankarnarayan, 1988).

5.2.3. Weed flora

There was a shift in weed flora in terms of relative density (RD), relative frequency (RF) and importance value (IV) under the canopies of different MPTs. Maximum number of weed species was recorded under **Casuarina equisetifolia** and **Azadirachta indica** while lesser number was seen under **E.camaldulensis**, **P.juliflora**, **A.nilotica** and **A.leucophloea** (Table 13).

Under the canopy of **P.juliflora** and **C.equisetifolia**, the weeds viz., **Oscimum canum** and **Vernonia cinera** were dominant, while grassy weeds such as **Andropogon pumilus**, **Cymbopogon martini** and **Eragrostis** species were predcminantly seen under all other MPTs as well as in the adjacent open field (control) (Table 13).

The observed shift in weed flora under different MPTs could be attributed to variations in soil moisture, incident PAR under the canopy, differential allelopathic effect of leaf litters and related leachates.

In the 4th year, before felling the trees, more than 80 per cent of crown closure was observed only in **Prosopis juliflora** because of its spreading umbrella like crown and branching nature. Hence, the dominant understorey of **Oscimum canum** and **Vernonia cinera** might be due to their tolerance to more shade. At the same time their dominance under the canopy of **Casuarina equisetifolia** may be due to more incident PAR as well as due to their capability and their wider adaptation under shadeless condition . This indicated the better adaption of **Oscimum canum** and **Vernonia cinera** to both light and shade.

But, the dominance of grassy weeds under all other MPTs as well as in the open field (control) suggested that grassy weeds could grow well under higher incident PAR, as a result of loose and open crowns of these trees.

In respect of DMP of weeds m^{-2}, it was the highest under the canopy of **Casuarina equisetifolia,** followed by **Azadirachta indica** while, the DMP of weeds was the lowest under both the species of **Eucalyptus camaldulensis** and **E.tereticornis.** The DMP of weeds under **P.juliflora** was comparable with that of **A.leucophloea.** The highest DMP of weeds under **Casuarina equisetifolia**, followed by **Azadirachta indica** must be only due to lower allelopathic effect exerted by them as compared to **Eucalyptus camaldulensis** and **E.tereticornis** and other MPTs. In addition, with the receipt of enough sunlight the DMP of weeds was higher under all these species except **Prosopis juliflora.**

More suppression of herbaceous growth under **Leucaena leucocephala, Eucalyptus tereticornis** and lesser suppression under **Casuarina equisetifolia** had been attributed to allelopathic effects rather than physical competition for light, water and nutrients. **E.tereticornis** showed greater allelopathic effect while **C.equisetifolia** had the lowest (Suresh and Rai, 1988). The lesser DMP of weeds under **P.juliflora** must be due to allelopathic effect as *confirmed in the experiment 8* (Table *65 and 66*). Shade effect might have further affected DMP of weeds under **P.juliflora** crown. Lesser number of annuals and perennials as well as their reduced growth and phytomass under **Prosopis juliflora** compared to **P.cineraria** under similar edaphic and climatic conditions was attributed to some unidentified toxin present in the leaves of the former (Srivastava and Hetherington, 1991).

5.2.4. Nutrient uptake

The total uptake of both macro and micronutrients were the highest in **E.camaldulensis**, **E.tereticornis** followed by **P.juliflora** and least with **A.leucophloea** (Table 16). This was mainly due to increased biomass of both leaves and stems recorded under **E.camaldulensis**, **E.tereticornis** and **P.juliflora**.

The nutrient uptake in general was in the order of N > K > P > Na > Fe > Mn > Zn > Cu in all the MPTs evaluated. Though **P.juliflora**, **E.tereticornis** and **E.camaldulensis** were statistically on par with each other in terms of total DMP (Table 10), it was not so in respect of total nutrient uptake. The uptake was higher in **Eucalyptus camaldulensis** and **E.tereticornis** than in **P.juliflora** because of two reasons viz., (i) higher nutrient accumulation was found only in stems than in leaves in **Eucalyptus camaldulensis** and **E.tereticornis** compared to **P.juliflora** (ii) the stem biomass (UB) of **Eucalyptus camaldulensis** and **E.tereticornis** was 94 to 97 per cent higher than that of **P.juliflora** (Table 10) due to increased tree height with straight stems, BD and BH (Table 7). It was also observed that on unit area basis, the maximum amount of all nutrients was found in wood followed by branches and minimum in bark in 10 years old **Eucalyptus globulus** (Negi and Sharma, 1984; George and Varghese, 1991). In the present investigation also maximum amount of all the nutrients studied was found in stem (wood or UB) compared to leaves in all the MPTs except for K in **Prosopis juliflora** and **Azadirachta indica** wherein K accumulation was higher in leaves than in stems (Table 14 and 15).

The total nutrient uptake increased with biomass, especially when the proportion of stem biomass (UB) was higher as in **Eucalyptus camaldulensis** and **E.tereticornis** indicating a positive relationship between total nutrient uptake and UB. This trend is quite obviously seen when we look into the UB and total biomass production of different MPTs (Table 10) and their corresponding level of total uptake of nutrients (Table 16).

The total uptake of N and K in higher quantities compared to other nutrients, in all the tree species, might be due to higher concentrations of these nutrients in the plant parts. The N content ranged from 1.5 to 2.8 per cent, P content from 0.07 to 0.16 per cent and K from 0.43 to 2.01 per cent, in the leaves of different MPTs. Since, the total uptake of the trees is the product of nutrient concentrations and DMP of trees, the uptake of all the nutrients in general, N and K in particular, were found to be in higher quantity in accordance with DMP.

Prosopis juliflora has been considered the most tolerant species to P stress compared to other tree species viz., **Calliandra calothyrsus, Gliricidia sepium** and **Leucaena leucocephala** (Nyami, 1991). In the present investigation, considering the poor status of available soil P of 4.50 kg ha^{-1} in the experimental soil (Table 17), the uptake of P (Table 16), by **Eucalyptus camaldulensis** and **E.tereticornis** as well as **P.juliflora** was high indicating their efficiency in extracting the unavailable fixed P.

5.2.5. Soil fertility

There was significant increase in soil organic carbon build up under different MPTs compared to adjacent open field (control). Similar result was obtained for available NPK also. There was a decrease in available Na under tree cover compared to control (Table 17). The available micronutrients were also in the increasing trend under different MPTs (Table 18). The EC and pH of the soil were not significantly altered by the MPTs evaluated (Table 17).

Inspite of considerable uptake of nutrients from the soil by different tree species, especially by **E.tereticornis**, **E.camaldulensis** and **P.juliflora**, the available nutrients were found increasing under different MPTs compared to control. Similar performance was reported elsewhere (Sharma and Gupta, 1989). This was attributed mainly to nutrient recycling by litter fall on the one hand and by the understorey vegetation such as weeds on the other hand.

The build up of organic carbon under different MPTs was also ascribed to the understorey weeds which adds considerable amount of DM to soil through their roots and shoots decay, besides litter fall and root residues from trees (Shukla and Misra, 1993). Increase in soil organic carbon content and N under different tree cover, including **Prosopis juliflora**, compared to open field (fallow land) had been reported elsewhere (Aggarwal and Lahiri, 1977; Rao **et al.**, 1989). Soil under **Prosopis** species was found to contain 2 to 3 times more organic matter and N than soils collected away from the tree canopies (Rundel **et al.**, 1982; Singh Gurbachan **et al.**, 1990).

The increased available N under leguminous trees such as **A.nilotica, P.juliflora**, **A.leucophloea** and in actinorhizal tree (**Casuarina equisetifolia**) compared to control (Table 17) might be due to dinitrogen fixation through the microbial symbionts, which resulted in increased rates of soil N mineralization and nitrification (Dommergues, 1963; Binkley, 1986. p. 25-36; Montagnini, 1988).

But the increase in the available N under **Eucalyptus camaldulensis** and **E.tereticornis** (Table 17) which are not N_2- fixing trees might be due to their shade influence exerted by the tree canopy, that improved the rate of mineralization of soil nitrogen (Wilson, 1990). A 30 per cent increase in growth of grass (**Paspalam notatum**) within a plantation of non-leguminous **Eucalyptus grandis** compared with the growth of the same grass in an open field was reported in support of this hypothesis (Wilson, 1990). In the present investigation also, more number of grassy weeds viz., **Andropogon pumilus, Cymbopogon martini** and **Eragrostis** species were encountered under the canopy of **Eucalyptus camaldulensis** and **E.tereticornis** (Table 13). However, the DMP of understorey weeds were very less under **Eucalyptus camaldulensis** and **E.tereticornis** compared to that of other MPTs due to allelopathic effect. Though the above three grass species were lesser in numbers under the canopy of **Azadirachta indica** which is also a non-N_2-fixing tree, the overall DMP of understorey weeds was highest under **Azadirachta indica** (Table 13) compared to **Eucalyptus camaldulensis** and **E.tereticornis** due to the presence of other non-grassy weeds. The available soil N was also very high under **Azadirachta indica** (Table 17). This once again confirms the above hypothesis of Wilson (1990). That is improved mineralization of soil N due to shade influence. It is true that bigger crown of **Azadirachta indica** with more foliage did cause more shade.

The significant increase in available P, under different MPTs, especially under **P.juliflora, E.tereticornis**, **E.camaldulensis** and **C.equisetifolia** compared to control (Table 17) may be imputed to the ability of these trees to tap the sub soil P from deeper soil layer in view of their extensive root system/root volume per unit area on the one hand and return of P through litter fall on the other hand. This confirmed the findings of Sereno and Hang (1989) who reported higher P availability in the immediate vicinity of **Prosopis** species compared to the adjacent fallow land.

Besides increase in available NPK, considerable reduction in soil pH, EC, Na content and bulk density had been reported under different tree cover such as **Dalbergia sissoo, Eucalyptus hybrid, Acacia nilotica,** with maximum reduction under **P.juliflora** in a sodic soil (Shukla and Misra, 1993). However, in the present investigation, there was no significant difference in soil pH and EC and available Na under different tree canopies (Table 17). The above result had clearly shown that under saline-sodic soils the tree cover brought down Na, EC and pH levels considerably while, in a non-saline sodic soil such as the one in the present investigation, the above drastic changes could not be expected to happen due to lesser uptake and/or concentration of Na in plants. This is further strengthened by the fact that in two years old **Prosopis juliflora** under sodic soil, the concentration of P, K, Ca, Mg, S, Mn, Zn and Cu had increased. while Na decreased, with the increase in the level of gypsum application (Singh Gurbachan **et al.**, 1989).

The available micronutrients viz., Fe, Mn, Zn and Cu were found to increase under the different tree cover compared to open field. Similar results were reported elsewhere (Muthana **et al.**, 1976). The improvement of micronutrient status of the soil under the crown of 12 years old **Prosopis juliflora** and **P.cineraria** at CAZRI, Jodhpur (Aggarwal **et al.**, 1976) confirmed the above findings. The improvement of micronutrient status under MPTs might be ascribed to tapping of micronutrients from deeper soil layers than from top soil by the extensive root systems/root volume of the trees on the one hand and litter fall nutrients cycling on the other hand.

By harvesting whole trees there might be considerable drain of nutrients. But some of them would be recycled when the leaves along with branches/twigs were left **in situ.** Nutrient budgeting studies in **Eucalyptus hybrid** plantations by George (1977) advocated fertilizer application, in sites where **Eucalyptus** was harvested for whole tree. As an alternative, he had suggested that if certain components like bark and leaves were left in the field at the time of harvesting, the nutrient depletion may not be a serious one. When the biomass production was higher, the nutrient depletion was also more (Table 14, 15 and 16) and in turn the nutrient return through leaves or twigs would also be more. However, the most efficient nutrient recycling was not necessarily associated with the best biomass production (Abrams, 1990). Relatively higher available NPK under **A.leucophloea** and **C.equisetifolia** (Table 17) though they happened to be with lower DMP potential in the present investigation supported the above hypothesis of Abrams (1990).

Due to continuous drain of nutrients without proper nutrient recycling through repeated coppice cropping, there is a possibility of fertile land to become a low productivity site in the long run. At low productivity site, nutrients such as P, Cu, Fe, Zn were found to affect the yield of **Prosopis** species as confirmed by foliar analysis (Wightman and Felker, 1990).

Soil fertility is also dependent on microbial population. A positive relationship between soil fertility and activities of soil microorganism was established in **Prosopis** at CAZRI, Jodhpur (Lahiri, 1981; Shankarnarayan, 1988). Leguminous trees were superior to **Eucalyptus** in building up of soil fertility and this was closely linked with the activities of microbes (Rao **et al.**, 1989). In the present investigation highest microbial population of bacteria, fungi and actinomycetes were seen under the leguminous trees such as **A.leucophloea**, followed by **A.nilotica** and **P.juliflora** (Table 12). But the soil fertility in terms of available NPK and organic carbon under the above leguminous trees was on par with **Eucalyptus camaldulensis** and **E.tereticornis**. These results agreed with the findings of the above researchers that the microbial load increased with soil fertility in respect of all MPTs studied except in both the species of **Eucalyptus**. Though the fertility of soil under both the species **Eucalyptus** was on par with other MPTs, the microbial load was lesser which is imputed to the inhibition of microbial growth by fairly higher allelopathic potential of **E.tereticornis** and **E.camaldulensis** compared to other MPTs evaluated.

5.2.6. Coppicing potential of MPTs

When the trees were cut at 4th year, except **Casuarina equisetifolia** all other MPTs had put forth coppice shoots as observed 10 months after cutting (Table 19). However, coppicing was very poor in **A.leucophloea** as the coppice numbers per stool, coppice height and BD of coppice were lesser compared to other MPTs. In respect of coppice numbers per stool, the trees were ranked in the order of **P.juliflora** > **Azadirachta indica** > **Acacia nilotica** > **E.tereticornis** > **E.camaldulensis** > **A.leucophloea**. But they were all comparable statistically except the last one. Whereas, in respect of coppice height **E.camaldulensis** recorded significantly higher height growth compared to all other MPTs followed by **E.tereticornis** (Table 19).

The variations in the coppicing potential might be attributed to the inherent regenerating capacity of concerned MPTs. The coppice number per stool in **E.tereticornis** had been found to vary with stool diameter and the numbers increased with the increase in stool diameter (Kondas **et al.**, 1976; Rathinam and Surendran, 1982). The higher coppice growth in **E.camaldulensis** and **E.tereticornis** might be ascribed to their greater regenerating vigour compared to other MPTS due to bigger stump size as indicated by the BD of **Eucalyptus camaldulensis** and **E.tereticornis** which was significantly greater than that of other MPTs (Table 7). Bigger stumps are expected to possess higher root biomass and hence they could serve as food reserves. Steinbeck and Brown (1976) while working for fixing the coppice rotation for American Sycamore (**Platanus occidentalis**) stated that large mass of roots acted as carbohydrate reservoirs for trees and were vital for vigorous sprout growth. Basal diameter (stump size) had been found to influence the above ground biomass. This had been confirmed from the path analysis and regression models for different MPTs (Table 20 to 33) wherein the BD of the trees had contributed more directly or indirectly to either UB or NUB or total biomass.

At 15th month after first cut, reduction in the coppice numbers per stool was observed in all the MPTs indicating self thinning under natural condition. This could be confirmed by the observation of Rathinam and Surendran (1982) wherein they had found reduction in the number of coppice shoots irrespective of stool diameter or size with the increase of age of crop.

This is attributed to stiff competition among the coppice shoots in sharing the reserved food from root stock and/or stumps. As per the concept of survival of the fittest, few less vigorous and lanky shoots might have withered not withstanding competition.

5.2.7. Path coefficient and regression analysis

In **Prosopis juliflora**, BD was found to contribute higher for the UB and TB while BN was responsible for the NUB (Table 20). However, the BD and BN together explained more than 60 per cent of variations in biomass yield (Table 21). The low R^2 values for different regression models (0.628 to 0.659) indicated that the four parameters viz., tree height, BD, BN and DBH taken for the present study were not sufficient enough to explain the variations in biomass yield and still some more variables contributing/responsible for the biomass yield need to be incorporated in the regression models for better prediction efficiency (Kalla, 1977). The other parameters such as crown diameter, active root zone around each tree, soil depth, soil fertility, soil moisture, soil type etc., may be included in future for better prediction efficiency.

For trees like **Prosopis juliflora** which is more like a bush due to its branching nature, BD was the most important parameter than average DBH of the branches/shoots and tree height. This is confirmed by the results obtained for some of the shrub species wherein stem diameter at ground level (5 to 15 cm height) was found to be closely correlated with total above ground biomass (Alaback, 1986; Thakur **et al.,** 1993).

For trees such as **Eucalyptus camaldulensis** and **E.tereticornis** having single and straight stem with open/loose crown, the parameters viz., TH, BD and/or DBH were found to contribute more either directly and/or indirectly to the total biomass (Table 22 and 23). When all the three parameters (TH, BD and DBH) were included in the regression model, the individual contribution of either all the three parameters or any two of them though found not significant, the R^2 value of resultant regression equations was found significant (Table 24 and 25). This was mainly due to the fact that either all the three parameters or two of them might have contributed either directly and/or indirectly or some times negatively (Table 22 and 23) and hence their individual contribution became insignificant in this model but the overall prediction efficiency of regression model did increase and became significant with higher R^2 value (Table 24 and 25).

However, stepwise linear regression models revealed that for both **E.tereticornis** and **E.camaldulensis,** DBH alone was sufficient to predict the UB, NUB and TB most reliably with fairly high R^2 values.

Linear regression models developed to predict the DMP of 4, 6, 8 and 10 years old **Eucalyptus hybrid** plantation by Tandon **et al.** (1993) revealed that among the predictor variables tried (D^2H, DBH and D^2), DBH alone was found to give reasonably precise estimate of biomass. This is in good agreement with the results of present investigation.

For trees such as **A.nilotica, A.leucophloea** and **Azadirachta indica** with single stem (which need not necessarily be as straight as in **Eucalyptus**) and bigger crowns, either BD and/or DBH were found to be the better predictor variable(s) of biomass. This is ascribed to the fact that the BD and DBH contributed more directly to the biomass as indicated by path analysis (Table 26, 28 and 30) and their contribution was almost in equal proportion as indicated by stepwise linear regression models (Table 27, 29 and 31). Inclusion of tree height did not influence very much the R^2 value of the regression models (Table 27, 29 and 31).

For straight and single stemmed trees such as **Casuarina equisetifolia** with very light, small and open/lose crown, the tree height (TH) had been found to contribute more directly to the UB, NUB and TB followed by DBH as indicated by path analysis (Table 32). The contribution of TH was confirmed by the stepwise linear regression model only in respect of UB. For NUB and TB only BD was found to be a better predictor variable than DBH and TH (Table 33).

The reason for the highest direct contribution of TH to the UB (fuelwood) is that TH was associated/influenced by BD and DBH and vice-versa. Moreover, only the main stem was used as fuel wood and the side branches of less than 2.5 cm are not used as fuelwood. Hence, naturally higher the TH higher would be the UB yield. In **E.tereticornis** and **E.camaldulensis** also the contribution of tree height to UB was very high due to its strait single stem.

PART II STUDY

5.3. EXPERIMENT 3. Effect of plant densities, ages of first cutting and coppicing durations on the biomass production of Prosopis juliflora (Swartz) DC.

5.3.1. Adaptation

Prosopis juliflora was well adapted and thrived well even under prolonged soil moisture stress when the actual soil moisture content was as low as 2.49 per cent (12% FC). This indicated the ability of **P.juliflora** to maintain fairly higher leaf RWC (Fig. 15). The RWC was slightly lesser under higher plant density of 4444 plants ha^{-1} (1.5 x 1.5 m spacing) compared to the other two plant densities. This was due to greater intra-species competition for moisture, in addition to limited soil moisture availability. Increased depletion of soil moisture under higher plant density with more root volume per unit area in search of moisture was reported by many workers (Malwade, 1986; Chandrasekariah, 1987).

This confirmed the review of Lahiri (1975) that changes in moisture condition in the upper soil layers did influence the transpiration and relative turgidity of seedlings/young trees with limited root system. But such influence was hardly discernible in well established trees due to change in top soil moisture. When the top soil moisture was inadequate, **Prosopis** species had been found to behave like facultative pheratophytes (Wan and Sosebee, 1991). Pheratophytes had been reported to send their roots fairly deeper in search of water (Robinson, 1958).

Reduction in RWC of leaves might lead to reduced water potential as there existed a positive relationship between soil moisture content and pre-dawn water potential of leaf and between soil moisture and average daily stomatal conductance (Ansley **et al.**, 1992). Relationship between RWC and photosynthetic rate had been also established by Catsky (1965). **Prosopis** species had been reported to photosynthesize actively at air temperature of $45^{O}C$ when leaf xylem water potential was as low as minus 4500 KPa (Mooney, 1977).

Serrato Valenti **et al.** (1986) proposed two hypotheses on the water balance of **Prosopis tamarugo** which explains the adaptation of **Prosopis** species, when top soil moisture was inadequate: (i) root absorption deep down in the soil, (ii) foliar absorption of atmospheric moisture. The first hypothesis was supported by Aravena and Acevedo (1985). Mesquite roots commonly reached 7 m depth, occasionally 18 m (Meinzer, 1927) and 50 m depths (Philips, 1963) where moisture is abundant. The second hypothesis was supported by Sudzuki (1985).

Small leaflets of **Prosopis** leaves also seemed to be an adaptation for escaping drought. Martin (1943) suggested that most important advantage of small leaves in a dry environment was that they did not become over heated, therefore, did not transpire excessively when exposed to strong insolation. Wan and Sosebee (1991) reported that **Prosopis glandulosa** had developed mechanisms such as leaf orientation, wax accumulation, and reduction in canopy development to avoid drought, besides stomatal closure.

5.3.2. Biomass production

In general, the total biomass production increased with the increase in plant density, age of first cutting and coppicing duration (Table 36 and 44).

In the first crop when the cut was given at 15 MAP highest total biomass was obtained under higher plant density of 4444 plants ha^{-1} (d1) (Table 36). Similar result was obtained by Rai and Srinivasan (1990) in a high density short rotation 3 years old **E.tereticornis** and **C.equisetifolia**. **Prosopis juliflora** planted at 1 x 1 m (10,000 plants ha^{-1}) accumulated 39 kg DM $tree^{-1}$ and at 2 x 1 m spacing (5000 plants ha^{-1}) it accumulated 32.2 kg DM $tree^{-1}$, after seven years under irrigated condition in sodic soils of Karnal (Singh Gurbachan and Singh, 1993).

Higher biomass under higher plant density in the present study might be attributed to (i) more number of plants per unit area, (ii) better developed root stocks or stumps with more basal diameter as well as increased below ground root biomass or root volume per unit area which served as carbohydrate reservoir, besides helping to extract more soil moisture and nutrients for the better growth of aboveground biomass and (iii) increase in photosynthesis due to increase in crown size and leaf area with the advancement of age.

Similarly, in the coppice crop higher total biomass was obtained when the first crop was cut at the age of 15 MAP (a3) and allowed for longer coppice duration of 12 MAFC (C3) under higher plant density (Table 44). This is ascribed to (i) more number of plants per unit area; (ii) more coppice numbers per stool and better coppice growth (Table 42 and 43, and (iii) increased photosynthesis due to increase in leaf area, crown size and leaf area duration under longer coppice duration of 12 MAFC compared to 6 and 9 MAFC.

Coppicing at 1, 2 and 7 years interval in American sycamore (**Platanus occidentalis**) plantations revealed that very frequent coppicing annually resulted in less root stock mass than those coppiced on longer cycle (Steinbeck and Nwoboshi, 1980). Similar effect might have occurred to the below ground root mass of **P.juliflora** in the present study and this could have been the reason for the less biomass yield recorded when first cut was given at 9 and 12 MAP compared to 15 MAP and when allowed for shorter coppicing duration of 6 and 9 MAFC compared to 12 MAFC.

Studies in 10 years old **E.tereticornis** at Dehradun revealed that the average number of coppice shoots did not vary significantly due to variations in the diameter of the stumps of same age but the height and diameter of coppice shoots were significantly higher in the stumps of larger diameter (Neelay **et al.**, 1984). However, there are reports stating an increase in the number of coppice shoots with increase in stool diameter in **E.tereticornis** at Tamil Nadu (Kondas **et al.**, 1976; Rathinam and Surendran, 1982). But in the present investigation, the coppice number per stump varied with the age and size of the stump and also due to variation in plant density (Table 42). The stump diameter was found to range from 1.57 to 1.61 cm, 1.75 to 1.79 cm, 1.86 to 1.90 cm under different plant densities, at the age of first cut viz., 9, 12 and 15 MAP, respectively. Similarly there was a significant variation in coppice height due to the difference in the age and size of stump but the BD of coppice shoots did not vary (Table 42). Regarding partitioning of biomass both in the first and coppice crops (Table 36 and 44), the leaf biomass increased with the increase in plant density and decreased with increase in the age of first cut and coppice duration as indicated by the LSR (Table 36 and 44).

This was due to more accumulation of photosynthates only in the tender parts of the plants viz., leaves and twigs at the early stages of crop. When the **Prosopis juliflora** was cut at the early ages of 9, 12 and 15 MAP and again allowed to coppice for 6, 9 and 12 MAFC the resultant biomass was only the immature leaves and stems contributing an unutilizable biomass. Singh **et al.** (1983) reported that regular coppicing led to generation of more soft tissues which were not suitable for direct burning or pyrolysing. However, these could find a variety of uses through bioconversion for production of biogas (fuel) and slurry (fertilizer) or for extraction of chemicals including insecticides and pesticides.

Comparison of total biomass production in the first crop of **P.juliflora** and its coppice crop (Table 48) revealed that under all plant densities, at all ages of first cut, the DMP of first crop was higher than that of coppice crop. This had clearly shown that coppicing in **P.juliflora** at early stage upto 15 MAP was not advantageous.

Generally, coppicing is considered advantageous only when the coppice yield is either equal or greater than that of the first crop. Such advantages had been reported in some ornamental plants (Wilkins, 1984. p. 127-147; Giridhar **et al.**, 1985), shrub or bushy plants such as **Ipomea fistulata** and **Adathodo vasica** (Arvind Singh **et al.**, 1987), in **Eucalyptus** species (Pawlick, 1989) and in many other tree species.

Two to three times higher growth and yield was obtained from coppice crop than from seedling origin crop of **Eucalyptus hybrid**, **E.tereticornis** and **E.camaldulensis** at Jabalpur (Ram prasad, 1989). In poplar (**Populus deltoides**), coppice crop gave 30 per cent more yield than the first crop (Cannell, 1980). However, such increase in biomass yield was not obtained in **Prosopis juliflora** when coppiced at early stages in the present investigation. This clearly indicated that the age of first cut for coppicing **P.juliflora** should be more than 15 MAP and also the coppice duration must be more than 12 MAFC to derive the advantageous of coppicing. However, the optimum age of first cut for coppicing and coppicing duration for higher biomass are not within the purview of the present studies. This needs further study.

Though **P.juliflora** had been reported to be a good coppicer, information on the optimum age for coppicing and optimum coppicing duration for higher utilizable biomass (fuelwood) is still very much lacking. Tiwari (1983) reported that **P.juliflora** tolerated annual coppicing right from the second year of planting. The present investigation gave some more added information on these lines. That is **P.juliflora** tolerated coppicing even at the early stage of 9 MAP.

However, pruning of shoot tip of the young plants of **Prosopis chilensis** had increased biomass production by 147 per cent over unpruned control (Kathiresan and Kumaravel, 1990). But in the present investigation, coppicing of **P.juliflora** at early stages did not increase the biomass production compared to uncoppiced crop of same age. This indicated that the resultant effect of pruning and coppicing in **P.juliflora** were quite different. This was attributed to the fact that in pruning only the unwanted side growth or the apical dominance was curtailed and accordingly the growth of **P.juliflora** either in vertical or horizontal dimension was encouraged or stimulated. But in the case of coppicing a new flush of growth was encouraged that may produce either lesser or more biomass compared to the first crop yield which by and large depended on the size and age of the stump.

5.3.3. Nutrient uptake

The total nutrient uptake was in the order of N > K > Na > P in the first crop with Na in third place (Table 38) while it was in the order of N > K > P > Na in coppice crop where Na was in 4th place (Table 49). This suggested that the preference of Na uptake was greater in the first crop than in coppice crop. This might be attributed to higher DMP in the first crop than the coppice crop.

In the first crop the uptake of N and K increased upto 12 MAP and thereafter the uptake declined under higher plant density (d1). But under medium (d2) and lesser (d3) plant density treatments, the uptake was only in increasing trend even with the advancement of age of the crop (Table 39 and 40). This was ascribed to the fact that there was greater competition for N and K among the trees at higher density with advancement of age, especially after one year of growth (12 MAP).

However, in the coppice crop the uptake of N, K and Na except P were in the increasing trend under all plant densities with the advancement of age of first cut and coppice duration (Table 49 and 56). The P uptake decreased with the increase in age of first cut only at higher plant density. The same trend was observed at shorter coppicing duration (Table 49, 52 and 53), with maximum uptake of P at the age of 9 MAP and shorter coppicing period of 6 MAFC (C1) under higher plant density (d1).

The increase in uptake of N, K and Na in the coppice crop with increase in the age of first cut and coppice duration suggested that these nutrients were in demand continuously throughout the coppicing period in higher proportion as against the demand for P only in the early stage(s).

The reason for higher P uptake at early stage of 9 MAP under higher plant density was mainly due to greater foraging of its voluminous root system for P for nodule formation to prepare itself for N_2-fixation. Similarly the higher P uptake at the shorter coppicing duration of 6 MAFC under higher plant density when the plants were given first cut at 9 MAP was due to the fact that when the above ground shoot was cut for coppicing, the below ground root growth would be activated. As a result, increased root biomass with greater food reserve ought to have happened, which subsequently supported the newly sprouting coppice shoots.

Regarding the uptake of micronutrients, neither plant density nor the age of first cut or their interaction effect did influence the leaf, stem and total uptake of the first crop (Table 41). But in the coppice crop, only the uptake of Fe through leaves, stems as well as the total uptake was affected significantly by different coppice durations studied (Table 58). The total uptake of Fe was significantly higher under longer coppice duration of 12

MAFC (C3) compared to other coppicing durations viz., 6 and 9 MAFC. This was attributed to the increased biomass production under longer coppicing period.

5.3.4. Soil fertility

In the present investigation there was no significant difference in soil organic carbon content under different treatments at the end of the experiment (Table 59). Leaf litter was the major source of organic matter build up in the soil under **Prosopis juliflora** in addition to accumulation of died portions of root masses and understorey weeds. The insignificant difference in the soil organic carbon content among different treatments of **P.juliflora** was mainly due to the shorter rotation period of 2.3 years of the experiment conducted. This 2.3 years was too small a period for organic matter build up in the soil, especially, when the crop was not allowed to grow continuously without any interference. In the present experiment the first crop was cut down as per the treatments viz., 9, 12 and 15 MAP and again coppice growth was allowed for a shorter duration of 6, 9 and 12 MAFC. Under these situations, the leaf fall might be insufficient to build up the organic carbon content as expected.

In experiment 12 it was evidently proved that the addition of **P.juliflora** leaf litter (3t ha $^{-1}$) had increased the organic carbon content within a shorter period of 30 days. But this positive performance was not observed in the

2.3 years old **P.juliflora** plantation possibly because of (i) shorter duration of 2.7 years, (ii) lesser fall of leaf litter because of shorter growth durations of the treatments studied and (iii) rapid decomposition of **Prosopis** leaf litter. At this context, if the results of experiment 2 were compared with the results of the present investigation (Experiment 3), in the former because of longer duration of four years, there was an increase in organic carbon content in the soils under **P.juliflora** compared to the open field (Table 17). Rundel **et al.** (1982) was of the opinion that soil under **Prosopis** species did contain 2 to 3 times more organic matter than soils away from tree canopies.

There was significant increase in available N between different plant densities and different coppice durations, with higher available soil N under lower plant density (d3) as well as under longer coppice duration of C3 (15 MAFC). The available soil P was not at all altered. The available K was significantly varying between different plant densities with higher soil K under lesser plant density (d3). The available Na significantly varied under different ages of first cut with higher available Na at the age of 9 MAP.

The lesser availability of N and K in soils under higher plant density is attributed to higher total uptake by these treatments (Table 49) as a result of higher biomass production.

The higher available N at 9 MAP and its decline with the advancement of age of first cut (12 MAP and 15 MAP) was imputed to increased uptake with the advancement of age due to higher DMP.

However, despite the uptake by plants the available N and K were found to be higher while soil available P was lesser in the soil under **Prosopis juliflora** compared to the initial status of the soil (4.5 kg P ha^{-1}) (Table 6). The increase in available N and K was ascribed to nitrogen fixing mechanism of **Prosopis juliflora**, decomposition of understorey weeds and addition of leaf litter to a little extent. A similar trend was observed with the increase in age of **Prosopis juliflora** as observed on 4 years old plantations (Table 17).

N_2-fixation by **Prosopis juliflora** root nodules was also one of the reasons for higher available soil N as cited elsewhere. **Prosopis** species had been found to fix 30 kg N ha^{-1} $year^{-1}$ when their crown coverage was 34 per cent at Californian desert. It had been suggested that upto 100 kg N ha^{-1} $year^{-1}$ might be fixed by **Prosopis** species with greater ground cover and better management practices (Rundel **et al.**, 1982).

The lesser available P under **Prosopis juliflora** (2.3 years old) in this particular experiment was attributed to the depletion of soil P in higher proportion by the roots of **Prosopis juliflora** for its initial establishment before the first cut as well as for the development of new roots after first cut to support the coppice growth put forth from the coppiced stools, besides using P for nodule formation for N_2-fixation. However, when the crop was not coppiced and allowed to grow continuously, with the increase in the age of **Prosopis juliflora** the soil available P was also found increasing. This had been confirmed in the experiment 2, under 4 years old **Prosopis juliflora** (Table 17). This was mainly due to addition of P through litter fall on the one hand and tapping of unavailable fixed P by the deeper root system of **Prosopis juliflora** from sub soil layers on the other hand.

There was no significant difference in the available micronutrients under **Prosopis juliflora** (2.3 years old) due to plant densities, ages of first cutting, coppicing durations and their interaction effect (Table 60). Even at the age of 4 years, there was no significant difference in respect of available micronutrients of soil except for Mn under **Prosopis juliflora** (Experiment 2). The Mn content of the soil increased significantly under **Prosopis juliflora** compared to control (Table 18). In fact the availability of all the other micronutrients were in increasing trend compared to open field (control) but such increase was not significant.

These results suggested that in general, the total uptake of micronutrients was very small in **Prosopis juliflora** at the early stage due to different treatments during the cropping period of 2.3 years (Table 58) and hence there was no significant difference in respect of available micronutrients. However, the uptake of micronutrients increased with the age and DM accumulation of **Prosopis juliflora** as observed under 4 years old **Prosopis juliflora** (Table 16). Despite higher uptake, all the available micronutrients were in increasing trend under 4 years old **Prosopis juliflora** compared to open field (control) (Table 18). This is mainly attributed to addition of micronutrients due to litter fall and the understorey weeds.

5.4. EXPERIMENT 4. Comparative performance of Prosopis juliflora (Swartz) DC. under different soil types (off station study)

The DBH, UB per tree, UB per hectare, total biomass per tree and per hectare and UB/NUB ratio were positively influenced in **Prosopis juliflora** when raised under alluvial sandy soil and black soil over red soil. The increased growth components and yield (DBH, UB per tree, UB per hectare, total biomass per tree and per hectare and UB/NUB ratio) in **Prosopis juliflora** obtained under alluvial sandy soils and black soils might be due to the favourable structure and texture of these two soils. **Prosopis juliflora** has been found to grow well when the soil was relatively deeper with ground water nearer to the surface (Harding and Bate, 1991).

The soil depth, soil moisture content and soil fertility of these two soils were comparatively greater than red soil. The soil depth was 2.0 m and 1.25 m, respectively, for alluvial sandy soil and black soil with a water holding capacity (WHC) of 40 and 50 per cent, respectively. But in the case of red soil, the soil depth and WHC were 0.70 m and 25 per cent, respectively. Soil fertility has been found to be influenced by soil texture. Total soil N was reported to be highest on sites with high clay content and lowest in aeolin sand dunes (Virginia and Jarrell, 1983). Since, the alluvial sandy soil and black soil contained more of clay, naturally the WHC and soil fertility also would be higher. As a result of these favourable soil environments the **Prosopis juliflora** growth and biomass yield were higher under alluvial sandy soil and black soil.

In the case of red soil because of its poor soil characteristics viz., shallow depth, poor WHC and low fertility, the growth and yield of **Prosopis juliflora** was lesser compared to that of alluvial sandy soil and black soil.

5.5. EXPERIMENT 5. Study on the charcoal recovery from Prosopis juliflora (Swartz) DC. fuelwood (off station study)

The utilizable commercial grade charcoal recovery increased with the increase in the diameter of billets. Comparison of fuelwood billets and root stocks of same diameter class (> 10.5 cm diameter) had shown that utilizable charcoal recovery was higher for root stocks than fuelwood billets. With the increase in the diameter of fuelwood the proportion of non-utilizable charcoal (Broken charcoal) and the ash yield were found to decrease and resulted in lesser loss and higher recovery of charcoal. This was attributed mainly to the increase in the proportion of heart-wood with the increase in the diameter of the billets as well as in the root stocks. The hard and heavy heartwood had been found to be responsible for good quality charcoal (Kondas, 1992).

Based on the proximate chemical analysis of logs of **Prosopis juliflora** the ash content was found to vary from 0.29 per cent (Verma, 1987) to 0.52 per cent (Guha **et al.**, 1970). Because of lesser ash content of **Prosopis juliflora** wood, its charcoal had been valued as an excellent charcoal of gun powder quality which is termed as 'Arthracits coal' (Verma, 1987). However, in the present investigation, 2.6 to

4.1 per cent ash was obtained as residual waste at the end of charcoal making process (Table 62).

This was due to some technical snag in the local method of charcoal making known as "Karimoottam" wherein while opening the "Karimoottam" after an anaerobic burning, some of the red hot charcoal came into contact with open air (oxygen) and hence such of those red hot charcoal started burning still faster which resulted in more ash as residue. To put off such burning, cold water is doused by the charcoal maker which resulted in further increased yield in broken charcoal as well as ash. According to Kondas (1992) the charcoal is the residue of wood as a result of heating it to high temperature in a closed space without free access of air and allowing to cool on its own without entry of air. But such practice is not strictly adopted by farmers in the Karimoottam process.

Eventhough root stocks and fuelwood billets of more than 10.5 cm diameter were used, as a result of this local Karimoottam procedure, the charcoal maker obtained poor charcoal quantity because of the technical snag explained above. Hence, a better local technology is to be generated against this local method of charcoal making (Karimoottam).

PART III STUDY

5.6. EXPERIMENT 6. Germinability of hot water treated Prosopis juliflora (Swartz) DC. seeds under different times of sowing

There was no information on the keeping quality of hot water treated **Prosopis juliflora** seeds with reference to its germinability. It was found in the present investigation that the hot water treated **Prosopis juliflora** seeds could be sown without any loss of germination upto 15 days. It was reported by Reynolds and Glendening (1949) that untreated **Prosopis** seeds had been found to be viable in the soil upto 10 years and upto 50 years under dry storage due to hardseededness. Eventhough such advantage existed for untreated **Prosopis** seeds, if it is sown under field condition because of its hard seed coat the germination rarely exceeded 50 per cent. Hence, in order to obtain higher germination percentage, hot water seed treatment has been recommended.

The hot water treatment converted the outer impermeable hard seed coat into soft and permeable layer for the easy entry of soil moisture and gas exchange as reported by Ffolliot and Thames (1983b).

The endosperm of the seed was not at all affected in this process. As a result, increased germination percentage was obtained under hot water treatment. By shade drying of hot water treated seeds of **Prosopis juliflora**, the moisture content of the seeds was brought to the original level without any damage to endosperm. When such treated seeds were sown in soils, as a result of intact endosperm, the germination was not reduced significantly upto 15 days after hot water treatment.

Since the present investigation stopped the testing of germinability of hot water treated **Prosopis juliflora** seeds upto 15 days from the hot water treatment, the fate of the germination of such seeds sown after 15 days after hot water treatment was not known, throwing avenues for further research on this line.

5.7. EXPERIMENT 7. Effect of seed sizes and depths of sowing on the germination of Prosopis juliflora (Swartz) DC.

Germination was early when **Prosopis juliflora** seeds were sown at 2 cm depth, irrespective of big and small sized seeds. When sowing depth was increased to 4 cm, the big sized seeds alone proved to be viable as compared to smaller sized seeds. First germination in these treatments was observed on 3 DAS. Due to the fact that lesser energy required for the plumule of both big and small sized seeds to break open the thin layer of soil surface, higher germination percentage was recorded for these big and small sized seeds when sown at 2 cm depth.

When sowing depth was increased from 4 to 6 cm, small sized seeds, for want of energy, did not come up to the expected level, while big sized seeds came up rightly by pushing dense soil layer. This indicated the benefit of big sized seeds for 4 to 6 cm depth of sowing.

With the increase in the depth of sowing the cumulative germination percentage was found affected. This might be due to rotting of seeds as a result of higher soil moisture and lack of aeration in deep soil layers.

The germination continued upto 16 DAS for small seeds when sown at 2 cm depth and the total germination percentage was 56.67 per cent. Under same depth of sowing, the total germination percentage for big seeds was 60.37 but the germination was over on 12th DAS. Higher germination due to large and medium sized seeds compared to small seeds had been reported in **Colophospermum mopane** (IGFRI, 1988).

At other depths of sowing, the germination period as well as germination percentage was reduced both for small and big seeds. Similar observations had been made by Gupta and Balara (1972) who reported that zero germination was recorded till 4 DAS in **Prosopis juliflora** and the germination period extended upto 17 days of sowing, with total germination percentage of 67. They had also reported that maximum germination was recorded between 6 and 9 DAS.

In the present investigation also the peak period of germination occurred between 5 to 10 days after sowing under different depths of sowing for different sizes of seeds. However, maximum peak germination was observed on 5 DAS for both smaller and big seed sown at 2 cm depth. This indicated that the optimum depth of sowing was 2 cm for quicker and higher germination percentage (Table 64).

The DMP per plant/seedlings did not vary due to different depths of sowing and seed sizes. This was ascribed to the fact that irrespective of the germination percentage, the germinated seeds shared the available growth environment viz., soil moisture, nutrients, sunlight etc., equally for better growth of seedlings. This indicated an auto-adjustment among seedlings in sharing the growth environment profitably. However, the DMP pot^{-1} was significantly altered by different seed sizes and depths of sowing (Table 64). This was due to variations in the population of seedlings per pot as a result of variations in germination percentage.

5.8. EXPERIMENT 8. Allelopathic effect of Prosopis juliflora (Swartz) DC. on field crops

Germination of blackgram, sorghum and **Prosopis juliflora** was reduced significantly when **Prosopis juliflora** leaf litter was incorporated at one and two per cent level to the top soil collected from fallow land. The other treatments viz., leaf extract, leaf powder extract and root extract added to the soil at one and two per cent level did not affect the germination of the above crops. Germination of sunflower was not at all affected by any of the treatments.

The reduction in the germination of the test crops viz., blackgram, sorghum and **Prosopis juliflora** due to **Prosopis** leaf litter was attributed to the allelopathic effect of phenolic compounds present in the leaf litter (Table 68).

The reduction on the germination of **Prosopis juliflora** seeds due to **Prosopis juliflora** leaf litter indicated that there was an autotoxic effect, which might be responsible for the absence of or poor understorey growth of **Prosopis juliflora** seedlings in nature under the crown of well grown **Prosopis juliflora** trees. The lesser understorey weed number and weed biomass under **Prosopis juliflora** in experiment 2 (Table 13) would suggest the allelopathic effect of **Prosopis juliflora**. Especially, when the crown coverage was higher, total absence of regeneration of either understorey weeds or even **Prosopis juliflora** seedlings were noticed due to thick layer of fallen leaf litter and their allelopathic effect on the one hand and lesser or non-availability of sunlight under such crowns on the other hand.

A wide range of phenolic compounds of plant origin had been found to be allelopathic (del Moral and Muller, 1970, Chou and Muller, 1972). In the present investigation though phenolic compounds were present in the extracts of fresh leaves, dry leaf powder and fresh roots (Table 68) they did not affect the germination of the test crops because the phenolic compounds in the extracts added to the surface of the soil might have slowly moved down along with water to the bottom due to inward movement and hence their effect on the germination of plumule or radical might have been reduced in view of lesser contact between radicals and the extracts.

Whereas, the phenolic compounds present in the leaf litter incorporated in the soil might have released the phenolic compounds slowly for longer period of time till all the leaves got decomposed and thereby created a potential toxic level of allelochemical (phenols) besides better contact between radicals and the allelochemicals that could inhibit the germination of all the test crops except sunflower. Sunflower seemed to resist against the inhibitory effect of phenolic compounds of **Prosopis juliflora.** Sunflower was also a plant of higher allelopathic effect. As a result, the allelopathic effect of **Prosopis juliflora** was nullified and hence sunflower had germinated well.

Sometimes, the reduction or failure of germination under leaf mulching was mistaken for allelopathic effect.

The decreased germination of winter wheat due to mulching of straw (Kimber, 1973) and the retardation of the growth of maize due to mulching of **Eucalyptus** leaves (Adams and Attiwil, 1986, Trenbath, 1991) were attributed to temporary immobilization of nutrients as a result of high C/N ratio (*Sanginga and Swift, 1992*).

However, in the present investigation the possibility of temporary immobilization of nutrients as the cause for reduction of germination in the test crops due to high C:N ratio was ruled out as the C:N ratio of **Prosopis juliflora** leaf litter was lesser (5:1) and within the accepted level (Table 69).

It was interesting to note that the DMP plant^{-1} of the test crops studied at 15 DAS did not change significantly even though there was significant variations in the germination of test crops (Table 65). This was ascribed to the fact that the germinated seeds shared the growth environment viz., soil moisture, soil nutrient, sunlight etc., to their fullest advantage indicating a sort of auto-adjustment.

This result once again confirmed the result already obtained (Experiment 7) wherein the DMP plant^{-1} in **Prosopis juliflora** did not vary significantly due to variations in depths of sowing and size of seeds (Table 64).

After estimating the DMP at 15 DAS, same test crops viz., blackgram, sunflower, sorghum and **Prosopis juliflora** were sown as residue crops on 30th day, leaving a fallow period of 15 days, in the respective pots (same treatments) without any further external application of the **Prosopis juliflora** plant materials such as leaf litter and other extracts. On 10th DAS of residue crops, germination count was taken and there was no significant difference in the germination of test crops (Table 67). This had clearly shown that the allelopathic effect of **Prosopis juliflora** leaf litter observed in the first crop was absent in the second crop (Residue crop). Thus it was evident that the allelopathic effect due to leaf litter addition was seen only for a period of two to three weeks after incorporation of **Prosopis juliflora** leaf litter.

5.9. EXPERIMENT 9. Effect of different times of sowing of test crops to mitigate the allelopathic effect of Prosopis juliflora (Swartz) DC. leaf litter on the germination and DMP of test crops

The decrease in germination as well as DMP of blackgram, sorghum and **Prosopis juliflora** (Table 70 to 73) when sown at the time of **Prosopis juliflora** leaf litter incorporation both at 1 and 2 per cent level was mainly due to the allelopathic effect exerted by the **Prosopis juliflora** leaf litter. It has been reported in the earlier experiment

(Experiment 8) that phenolic compounds was one among the chemicals responsible for allelopathic effect.

The satisfactory germination percentage and DMP pot^{-1} of blackgram and **Prosopis juliflora** when sown one week after leaf incorporation (1WALI) was mainly due to two reasons. One might be the disintegration of phenolic compounds into non-harmful substances within a week of leaf litter incorporation that was not toxic to blackgram and **Prosopis juliflora**. The second reason might be the capabilities of both blackgram and **Prosopis juliflora** to tolerate the allelopathic effect even if the phenol was present at lower dose or concentration after one week of leaf litter incorporation.

The spurt in the DMP pot^{-1} of both **Prosopis juliflora** and blackgram when sown one week after leaf incorporation (1 WALI) both at 1 and 2 per cent level might be attributed to the release of growth regulating substance like triacontanol. It was reported by Khan **et al.** (1992) that **Prosopis juliflora** leaf contained triacontanol. When **Prosopis juliflora** leaf litter was incorporated, triacontanol might have been released in a sequence next to phenol. Addition of leaf litter might have also enhanced the soil fertility as evident from the results of experiment 2 and 3. In the present investigation one lab experiment was conducted to estimate the nutrient addition through **Prosopis juliflora** leaf litter (Experiment 12). The result supported the fact that with the addition of **Prosopis juliflora** leaf litter there was a spurt in available NPK (Table 77). Triacontanol was found to influence the DMP or yield of plants by increasing the nutrient uptake (Ries **et al.**, 1977; Patel, 1992).

When the blackgram and **Prosopis juliflora** were sown 1 WALI the germination and DMP were not at all affected but rather the DMP pot^{-1} was increased both at 1 and 2 per cent leaf litter incorporation. This might be due to the fact that these crops might have escaped from the phenol injury with a lapse of one week time and hence higher germination percentage was recorded. But at the same time they benefitted by the growth regulating substance, triacontanol that was released from **Prosopis juliflora** leaf litter after one week of leaf litter incorporation, in addition to nutrient addition by leaf litter. Hence, satisfactory germination and DMP of both **Prosopis juliflora** and blackgram were obtained when sown 1 WALI.

But in the case of sorghum the germination percentage was affected even when sown 1 WALI. This performance was similar to the sorghum crop sown at the time of **Prosopis juliflora** leaf incorporation. This indicated the susceptible nature of sorghum to the lowest level of allelopathic effect of **Prosopis juliflora** leaf litter which was seen one week after leaf litter incorporation.

Eventhough the germination of sorghum was affected 1 WALI, there was enhancement in the DMP pot^{-1} of sorghum at 1 per cent leaf litter incorporation. This might be due to the benefit accrued from the growth promoting substance (triacontanol) released from **Prosopis juliflora** leaf litter. Larson and Schwarz (1980) reported that the leaf litter of wild carrot was found to stimulate the growth of black locust at low concentration and inhibited the growth at higher concentration. This was true in the present investigation wherein at 1 per cent leaf litter incorporation the DMP pot^{-1} of sorghum was increased, while there was reduction in DMP pot^{-1} at 2 per cent leaf litter incorporation, when sorghum was sown 1 WALI.

When the result was probed further it was interestingly observed that by sowing sorghum 2 WALI, the germination was not at all affected (Table 71) and also there was an increase in DMP pot^{-1} both at 1 and 2 per cent leaf litter incorporation compared to control (Table 73). This performance again confirmed the findings in experiment 8 wherein allelopathic effect was found to persist upto two weeks after **Prosopis juliflora** leaf litter incorporation. The results also further indicated that sorghum did not tolerate even the low level of allelopathic effect of **Prosopis juliflora** leaf litter addition that existed upto one week after leaf litter incorporation.

The reasons for persistence of allelopathy for such a shorter period of two weeks might be attributed to the fact that the leaves might have got decomposed quickly within two weeks as a result of microbial activity. Another possibility is that the allelochemicals might have got degraded and converted into a non-toxic substance with the lapse of time. Moreover there was no further addition of leaf litter. Whereas under field conditions, the persistence of allelopathy might be there as long as the tree is there since there will be continuous addition of leaf litter.

The results clearly indicated that sowing blackgram and **Prosopis juliflora** 1 WALI and sowing sorghum *at 2 WALI are the management strategies against the* allelopathic effect of **Prosopis juliflora** leaf litter addition.

5.10. EXPERIMENT 10. Effect of leaf litter and plant extracts of Prosopis juliflora (Swartz) DC. on weed control

Since sorghum was affected due to allelopathic effect of **Prosopis juliflora** leaf litter upto 2 WALI as evident from experiments 8 and 9, the sorghum crop was taken as an indicator plant to compare the control of three important obnoxious weeds viz., parthenium, nutgrass and haryali.

The results indicated the possibility of exploiting **Prosopis juliflora** plant parts for the control of the three weeds tested. With the application of root and leaf extracts and leaf litter mulch, the DMP of both sorghum and parthenium got reduced. Except **Prosopis juliflora** leaf litter mulch, the other treatments viz., leaf extract and root extract of **Prosopis juliflora** had profound influence on the DMP of nutgrass and haryali. Reduction on the DMP of weeds and sorghum might be due to allelopathic effect of **Prosopis juliflora**.

However, the allelopathic effect of leaf litter mulch was found to be inadequate to control the rhizomes of nutgrass and stolon of haryali which were buried deeper in soil away from leaf litter layers due to less or no direct contact. The contact distance between the leaf litter mulch and the stolon and rhizomes of these weeds was very greater and hence the allelopathy of the leaf litter mulch had little effect on the control of nutgrass and haryali. On the other hand as extracts, the root and leaf extracts of **Prosopis juliflora** that percolated down to the rhizome and stolon points through soil water movement and got absorbed in clay complex and as a result there was growth retardation and reduction in the DMP of nutgrass and haryali.

However, a further research is needed under field conditions to test verify the effect of **Prosopis juliflora** plant parts on the control of weeds.

5.11. EXPERIMENT 11. Effect of leaf incorporation and plant extracts of Prosopis juliflora (Swartz) DC. on the control of root-knot nematode (Meloidogyne incognita (Kofoid and White, 1919) Chitwood, 1949) in tomato (Lycopersicon esculentum Mill.)

The root-knot nematode population and their egg masses in tomato were reduced significantly by the incorporation of dry leaves and fresh leaves of **Prosopis juliflora** at one per cent level compared to plant extracts of **Prosopis juliflora** and control (Table 76). This had ultimately reflected in higher fruit numbers and fruit yield of tomato per plant.

Toxic effect of leaf extracts of **Ricinus communis, Leucaena leucocephala, Populus deltoides, Azadirachta indica, Lantana camera** and **Eucalyptus hybrid** on **Meloidogyne incognita** had been reported (Chhabra **et al.**, 1988).

The reduction in nematode population and egg masses due to leaves and plant extracts of **Prosopis juliflora** might be mainly due to the toxic effect of allelochemicals (Phenols) present in **Prosopis juliflora** (Table 68). Phenolic compounds are known to play a major role in the defence mechanism of plants against various external and infectious agents in general, since distinct correlation between the degree of plant resistance and the phenolics present in plant tissues had been well established (Pitcher **et al.**, 1960; Troll and Rhode, 1966, Brueske and Dropkin, 1973). Phenol content may provide resistance to nematode attack either by repelling the larvae or by adversely affecting the development of larvae that entered into the roots (Singh **et al.**, 1983).

Amending soil with neem cake or neem leaves did increase phenolic content in crops like tomato (Singh **et al.**, 1985. p. 108; Ramachandran, 1986) and bhendi (Jonathan, 1988) which might have helped in reducing the nematode population. Similar mechanism might have operated in reducing nematode population and egg masses when **Prosopis juliflora** leaves or extracts were added to tomato crop in the present study.

5.12. EXPERIMENT 12. Estimation of nutrient addition through Prosopis juliflora (Swartz) DC. leaves

Due to the addition of leaf litter of **Prosopis juliflora** there was a spurt in the organic carbon content, available NPK and soil pH on 30 days after leaf incorporation compared to control (no leaf litter) (Table 77). But after 30 days, a decline trend was observed. There was no change in EC of soil.

This might be due to the decomposition of leaf litter before 30 days. At the end of the experiment (90 days after leaf incorporation), the organic carbon content, available NPK and soil pH were on par with control. This might be due to the loss of nutrients through volatilization, fixation in the soil and utilization by soil microbes. Also there was no continuous input of leaf litter to maintain the status quo. However, this trend might change due to continuous addition of leaf litter under field conditions, with the increase in the age of plantations, leading to build up of organic carbon and available NPK as observed in experiment 2 (Table 17) and experiment 3 (Table 59).

5.13. EXPERIMENT 13. Enumeration of microbial load in Prosopis juliflora (Swartz) DC. leaf litter collected from the field

Only bacteria and fungi were found and actinomycetes were totally absent in the washings of top layer of leaf litter of the **Prosopis juliflora** as well as the top soil below the leaf litter under 0.1 per cent tannin incorporated culture media. Whereas all the three microbes were absent in the culture medium containing 0.25 per cent tannin.

This result suggested that the growth of microbes was inhibited when the tannin content was 0.25 per cent in the culture media while microbes (bacteria and fungi) were found growing in 0.1% tannin based media. When **Prosopis juliflora** leaves, bark, root etc., were analysed for the presence of phenolic compounds (since tannin is a polyphenolic compound), it was found that dry leaves contained 0.114 per cent phenol as compared to 0.104 per cent in fresh leaves (Table 68). This facilitated both bacteria and fungi to degrade the **Prosopis juliflora** leaf litter containing approximately 0.1 per cent tannin.

The bacterial and fungal population were relatively higher in the bottom leaf litter compared to the top litter and top soil. This was due to the following reasons: (i) more moisture content in the bottom litter which is in contact with top soil compared to the top litter, (ii) since the bottom litter will be fairly older than top litter, there might be more of organic matter in addition to lesser C:N ratio which acted as a source of energy for more microbial activity.

There was also variation in microbial load between the two locations studied. This was attributed to variations in the age of the leaf litter, soil moisture, soil temperature, the nature of decomposing leaf litter and aeration as reported by Omkar Singh **et al.** (1993).

SUMMARY AND CONCLUSIONS

CHAPTER VI

SUMMARY AND CONCLUSIONS

Investigation on the silvicultural and ecological aspects of **Prosopis juliflora** (Swartz) DC. were carried out both through field and pot culture experiments at Tamil Nadu Agricultural University, Coimbatore. Totally 13 experiments were conducted during the course of investigation as enumerated in Table 1. The summary of the results obtained are presented hereunder.

Studies on the allometric relationship of the **Prosopis juliflora** seedlings revealed that there was a correlation between shoot and root length as well as between shoot and root weight. But the dependence of shoot weight on root weight alone was found significant, while the length was not significant as indicated by the simple linear regression models. The shoot DMP can be taken as a scientific parameter for selection of better planting stocks.

The performance of 4 years old **Prosopis juliflora** was compared with other MPTs of same age. The results indicated that **Eucalyptus camaldulensis** and **E.tereticornis** were found to be fast growing in terms of higher tree height, BD and DBH compared to **P.juliflora** and other MPTs.

The CAI of tree height and BD were higher for **Eucalyptus camaldulensis**, **E.tereticornis** and **Casuarina equisetifolia** during the first and second years, while in the 3rd year, these were higher in **Azadirachta indica**, **Acacia nilotica** and **P.juliflora**. In the 4th year, there was no significant difference between **E.tereticornis**, **E.camaldulensis**, **Casuarina equisetifolia** and **P.juliflora**. The growth of **Acacia leucophloea** was comparatively poorer among the MPTs compared.

Both on per tree and per hectare basis, the NUB was significantly higher under **P.juliflora**. In terms of UB, **E.tereticornis** and **E.camaldulensis** recorded significantly higher biomass than other MPTs. However, in respect of total biomass, **E.tereticornis**, **P.juliflora** and **E.camaldulensis** were comparable and significantly superior to other MPTs evaluated. Comprehensively, based on the UB, MPTs could be rated in the order of **E.camaldulensis** > **E.tereticornis** > **Acacia nilotica** > **P.juliflora** > **Casuarina equisetifolia** > **Azadirachta indica** > **Acacia leucophloea**. However, the UB of **A.nilotica** and **P.juliflora** were statistically on par. The UB of **E.camaldulensis**, **E.tereticornis** and **A.nilotica** were 97.7, 94.5 and 13.0 per cent, respectively, greater than that of **P.juliflora**.

The wood density was the highest for **Acacia leucophloea** and lowest in **Casuarina equisetifolia** on fresh weight basis. However, on dry weight basis, the trend was quite different with **Casuarina equisetifolia** recording maximum wood density and the lowest being with **P.juliflora**.

Highest microbial load in terms of bacteria, fungi and actinomycetes population was found in the soils under **Acacia leucophloea**, followed by **A.nilotica** and **P.juliflora**.

Based on RD, RF and IV, **Oscimum canum** and **Vernonia cinera** were predominant weed species under **P.juliflora** and **Casuarina equisetifolia**. Grassy weeds such as **Andropogon pumilus, Cymbopogon martini** and **Eragrostis** species were predominant under all other MPTs. The DMP of weeds was highest under the canopy of **Casuarina equisetifolia** followed by **Azadirachta indica** and it was lowest under **Eucalyptus camaldulensis** and **E.tereticornis**.

The nutrient uptake increased with the increase in biomass. The total nutrient uptake was the highest in **E.camaldulensis** and **E.tereticornis** followed by **P.juliflora** and lowest uptake was registered with **Acacia leucophloea**. The total nutrient uptake was in the order of N > K > P > Na > Fe > Mn > Zn > Cu in the MPTs studied.

The soil fertility under MPTs had increased significantly in terms of soil organic carbon content and available NPK compared to control (open field). There was no significant difference in the available N and K in the soil under different tree species evaluated, while there was significant difference in respect of available P. Available P was higher under **P.juliflora** which was on par with all other MPTs except **A.nilotica** that recorded the lowest available P. However, there was no significant difference in available Na, EC and pH under different MPTs. Availability of all the micronutrients was in the increasing trend under different MPTs compared to control. But such increase was significantly greater only in respect of Mn.

Except **Casuarina equisetifolia**, all other MPTs had put forth coppice shoots. In respect of coppice numbers per stool, all the MPTs other than **C.equisetifolia** were comparable except **A.leucophloea** which recorded the lowest coppice shoots per stool. **Eucalyptus camaldulensis** recorded maximum coppice height followed by **E.tereticornis**, **A.nilotica** and **P.juliflora** and minimum height was registered with **A.leucophloea**.

Based on path analysis and linear regression models, it was found that in **P.juliflora**, BD contributed more directly to the UB and TB while BN contributed more to the NUB. Both BD and BN were found to be important parameters for prediction of UB, NUB and TB of **P.juliflora**.

For **Eucalyptus tereticornis** and **E.camaldulensis**, DBH alone could be used to predict the UB, NUB and TB. In **Azadirachta indica, Acacia leucophloea** and **A.nilotica** both BD and DBH were found to contribute more directly and almost equally to the UB and NUB. Inclusion of both BD and DBH in the regression model was found to offer better prediction with fairly higher R^2 value.

In **Casuarina equisetifolia**, tree height contributed more directly to the UB, NUB and TB. The tree height for UB and BD for NUB and TB had been found to be the better predictor variables with high R^2 values in regression models.

The RWC of the **P.juliflora** leaves was slightly lesser under higher plant density compared to medium and lower plant densities. The RWC was influenced by the actual soil moisture. **Prosopis juliflora** was able to maintain its RWC fairly at higher level even during the period of soil moisture stress indicating its pheratophytic and xerophytic adaptations through its prolific deeper root system besides its smaller leaves.

The total biomass production of **P.juliflora** increased with the increase in plant density with more biomass under higher plant density of 4444 plants ha^{-1} (1.5 x 1.5 m) followed by medium plant density (2500 plants ha^{-1})

and lower plant density (1600 plants ha^{-1}). Similarly, the total DMP increased with the age of plantation with higher biomass at the age of 15 MAP compared to 9 and 12 MAP. Coppicing **P.juliflora** for longer period of 12 MAFC recorded the highest biomass compared to other coppicing durations of 6 and 9 MAFC respectively. The interaction was significant. Total biomass yield was maximum under higher plant density when cut at the age of 15 MAP and allowed to coppice for 12 MAFC. The leaf biomass, in general increased with plant density and decreased with the advancement of age of first cut and coppice duration as indicated by leaf/stem ratio.

The total biomass production of the first crop was higher than that of coppice crop indicating coppicing **P.juliflora** at the early age of 9, 12 and 15 MAP was not advantageous. Also this study indicated that for coppicing the age of **P.juliflora** must be definitely greater than 15 MAP.

The uptake of NPK and Na as well as the micronutrients were higher in the first crop and lesser in the coppice crop in view of higher DMP in the first crop than that of coppice crop. The uptake of all the nutrients increased with the age and plant density except for P. The P uptake was higher only in the early stages upto 9 MAP. However, the uptake of N and K were found to decline after 12 MAP under higher plant density.

There was no significant difference in the soil organic carbon content under **P.juliflora** due to different plant densities, ages of first cut and coppice durations and their interaction effect. The available N and K decreased with increase in plant density. The available N alone increased with increase in coppice duration. The available P, K, Na and the micronutrients were not influenced by any of the treatments studied for **P.juliflora**.

Comparative performance of **Prosopis juliflora** under different soil types (off station study) was studied. The UB and TB yield were higher when **Prosopis juliflora** was raised in alluvial sandy soil and black soil. **Prosopis juliflora** raised under red soil recorded the lowest UB and TB.

Studies on the charcoal recovery from **P.juliflora** fuelwood (off station study) revealed that the utilizable commercial grade charcoal recovery increased with the increase in diameter of billets. The recovery of charcoal was higher for root stocks than fuelwood billets of same diameter class (> 10.5 cm diameter). With the increase in diameter of the fuelwood billets the yield of broken charcoal and ash decreased and the total loss was lesser.

Germinability of hot water treated **Prosopis juliflora** seeds sown at different times of sowing indicated that the hot water treated **Prosopis juliflora** seeds can be kept upto 15 days without any loss of germination/viability.

Studies on the effect of seed sizes and depths of sowing on the germination of **Prosopis juliflora** suggested that irrespective of seed sizes, sowing at 2 cm depth gave higher germination per cent. However, the germination per cent was higher for big seeds compared to small seeds at 2 cm depth of sowing. Irrespective of seed sizes, the germination decreased with increase in sowing depth. First germination was observed 3 DAS and extended upto 16 DAS. The peak period of germination was 5 to 10 DAS, with peak germination on 5th DAS. The DMP per plant did not vary even though there was variations in population pot^{-1}. But the DMP pot^{-1} varied significantly due to variations in population pot^{-1}.

Allelopathic effect of **Prosopis juliflora** on field crops was studied. Germination of blackgram, sorghum and **Prosopis juliflora** were affected significantly due to allelopathic effect of **Prosopis juliflora** leaf litter both at one and two per cent level, with maximum reduction of germination at two per cent level. The germination of sunflower was not at all affected. The leaf extract, leaf powder extract and root extract did not affect significantly the germination of all the test crops. The DMP plant^{-1} was not altered by **Prosopis juliflora** leaf litter. The allelopathic effect was found to be due to phenolic compounds present in **Prosopis juliflora** leaf litter. The persistence of allelopathic effect was observed upto two weeks as indicated by the residue crops raised.

Studies on mitigation of the allelopathic effect of **Prosopis juliflora** leaf litter on the germination and DMP of test crops indicated that the germination and DMP of **Prosopis juliflora** and black gram was not affected when sowing was done 1 WALI both at 1 and 2 per cent leaf litter. But germination of sorghum was affected even upto one week after leaf incorporation (1WALI) and not affected when sown at 2WALI. The DMP of sorghum was not affected at lesser dose of 1 per cent leaf litter while its DMP was affected drasticaly at 2 per cent leaf litter when sown at 1 WALI. When sorghum was sown at 2 WALI through 6 WALI, the germination and DMP were not affected. Infact the DMP was increased considerably.

Effect of leaf litter and plant extracts of **Prosopis juliflora** on weed control was studied. The germination of parthenium and the test crop sorghum were significantly affected by the root extract, leaf extract (5 per cent) and leaf litter mulch (one per cent) of **Prosopis juliflora**. The germination of other weeds viz., haryali and nut grass were not at all affected by **Prosopis juliflora** leaf litter, root and leaf extracts. The extracts and leaf litter of **Prosopis juliflora** reduced the DMP of parthenium.

Study on the effect of leaf incorporation and plant extracts of **Prosopis juliflora** on the control of root-knot nematode (**Meloidogyne incognita**) in tomato (**Lycopersicon esculentum** Mill.) was made. The nematode population in the soil under tomato and their egg masses in the roots of tomato were significantly reduced by the **Prosopis juliflora** leaf litter and different extracts (dry stem, fresh bark, dry bark, charcoal powder, dry leaf powder, fresh root and leaf extracts) at one per cent concentration, with maximum reduction due to dry leaf and fresh leaf incorporation at one per cent level. This had resulted in increased fruit numbers and fruit yield per plant in tomato, with highest fruit numbers and fruit yield under dry leaf incorporation followed by fresh leaf incorporation.

Studies on nutrient addition through **Prosopis juliflora** leaf litter indicated that there was a spurt in the organic carbon content, available NPK and soil pH on 30 days after leaf incorporation. But after 30 days, a declining trend was observed. After 90 days of leaf incorporation, the organic carbon content, available NPK and soil pH were comparable with the control (no litter addition). There was no significant change in EC of soil throughout the period of investigation.

Enumeration of microbial load in **Prosopis juliflora** leaf litter collected from the field revealed that only bacteria and fungi were present in the washings of the leaf litter. Actinomycetes were absent. This indicated that bacteria and fungi had greater role in the mineralization of **Prosopis juliflora** leaf litter. The growth of bacteria and fungi was inhibited at 0.25 per cent tannin based culture media while, their growth was not inhibited at 0.1 per cent tannin based media. The population of fungi and bacteria were relatively higher in the bottom layer of leaf litter in both locations. However, the variations in the bacterial and fungal population between two locations revealed that microbial load was influenced greatly by the variations in edaphic and climatic conditions besides age of plantations.

Based on the summary of the present investigation the following conclusions have been drawn.

* Shoot biomass of **P.juliflora** seedlings can be taken as a scientific parameter for selecting better planting stocks, as evident in six months old seedlings. Height and BD of seedlings can be used to estimate the shoot biomass without destroying the seedlings.

* **Eucalyptus camaldulensis**, **E.tereticornis**, **P.juliflora**, **Azadirachta indica** and **Acacia nilotica** can be allowed for coppicing after four years of planting.

- Branch numbers and basal diameter (BD) for **P.juliflora**, tree height, BD and DBH for **E.camaldulensis** and **E.tereticornis**, BD and DBH for **A.nilotica**, **Acacia leucophloea** and **Azadirachta indica**; tree height and DBH for **Casuarina equisetifolia** shall be used as better predictor variables to precisely estimate the utilizable biomass (fuelwood) using regression models.

- For a short period plantations of 2.3 years old **P.juliflora**, a combination of higher plant density (1.5 x 1.5 m) with the first cut at 15 MAP and subsequently coppicing for 12 MAFC can be recommended for obtaining higher total biomass.

- Though **P.juliflora** is amenable for coppicing even at the early stages of 9, 12 and 15 MAP, it is not economical because the coppice crop yield was lesser than that of the first crop yield.

- **P.juliflora** can be recommended for areas where soil moisture stress exists for crop production.

- Alluvial sandy soils and black soils can be effectively utilized for raising **P.juliflora**.

- For higher charcoal recovery fuelwood billets and root stock of higher diameter class (> 10.5 cm) are recommended.

* **P.juliflora** seeds could be used for sowing upto 15 days after hot water treatment without any loss of germination/viability.

* **P.juliflora** seeds of bigger size with 100 seed weight of more than 3 g is recommended for early germination and better growth of the seedlings.

* Sowing of **P.juliflora** seeds at 2 to 4 cm depth is recommended for better germination and growth of the seedlings.

* Sowing of **P.juliflora** and blackgram after one week and sorghum after two weeks of **P.juliflora** leaf litter incorporation is recommended against allelopathic effect of **P.juliflora** leaf litter. It needs further confirmation in field studies.

* The leaf litter of **P.juliflora** could also be used as a source of organic manure as it had increased the DMP of sorghum, blackgram and **P.juliflora** crops when they were sown two weeks after the incorporation of **P.juliflora** leaf litter in the soil.

* There is a positive indication that the allelopathic potential of **P.juliflora** could be exploited for the control of abnoxious weed like **Parthenium hysterophorus**. This needs further confirmation under field.

- Incorporation of both fresh and dry leaves (leaf litter) at one per cent (W/W basis) can be recommended for biocontrol of root-knot nematode (**Meloidogyne incognita**) in tomato (**Lycopersicon esculentum**). It warrants further confirmation in field.

- Soil fertility could be improved through **P.juliflora** leaf litter.

FUTUROLOGY

Based on the experiences gained in the present investigation the following future lines are suggested.

- The comparative performance of **P.juliflora** with other MPTs, particularly trees like **E.camaldulensis**, **E.tereticornis**, **A.nilotica** and **Azadirachta indica** in terms of biomass production needs to be evaluated at different age series under different edaphic and climatic conditions.

- Besides tree height, BD, BN and DBH some more new parameters need to be included in the regression model to estimate the biomass yield of **P.juliflora** precisely.

- Optimum plant density for different ages of first cut and for different durations of coppicing to obtain higher UB needs to be fixed.

- The optimum age of first cut of **P.juliflora** for coppicing and optimum coppicing duration for higher fuelwood need to be studied since in the present investigation expected biomass was not obtained, when the age of first cut was too early with shorter coppicing duration.
- A refined method of charcoal making instead of local method (Karimoottam) is very much needed for higher charcoal recovery.
- Detailed indepth studies are needed for exploiting **P.juliflora** as biopesticides to control weeds and root-knot nematodes.

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* Original not seen