SUSTAINABLE INTEGRATED FARMING SYSTEM FOR DRYLAND VERTISOL AREAS OF WESTERN ZONE OF TAMIL NADU

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

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CERTIFICATE

This is to certify that the thesis entitled **"SUSTAINABLE INTEGRATED FARMING SYSTEM FOR DRYLAND VERTISOL AREAS OF WESTERN ZONE OF TAMIL NADU"** 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 is a record of **bonafide** research work carried out by **Mrs. S. RADHAMANI** under my supervision and guidance and that no part of this thesis has been submitted for the award of any other degree, diploma, fellowship or other similar titles or prizes and that the work has not been published in part or full in any scientific or popular journal or magazine.

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ABSTRACT

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SUSTAINABLE INTEGRATED FARMING SYSTEM FOR DRYLAND VERTISOL AREAS OF WESTERN ZONE OF TAMIL NADU

BY

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A field survey was conducted in Avinashi and Palladam taluks of Coimbatore district of western zone to study the existing farming practices, yield of crops, components involved in the farming and production constraints in the existing dryland farming. Among the 50 farmers interviewed, 70 per cent of the farmers were grouped as small farmers (1-5 ac) and 30 per cent were grouped as large farmers (>5 ac). Sorghum was the predominant crop. Sole sorghum (CO 1) was raised and the average grain and straw yields were 205 kg ha^{-1} and 3.02 t ha^{-1}, respectively. Among the components involved in the farming, next to cropping livestock maintenance was the major enterprise followed by raising of perennial trees by few farmers. Cow and goat were the major livestock in the existing farming condition. The production constraints identified were cultivation of low yielding and long duration (125-130 days) traditional sorghum variety (CO 1), adoption of high seed rate, non adoption of management practices like intercropping, application of inorganic fertilizers, *in situ* moisture conservation practices, raising perennial fodder grasses and difficulties in maintenance of the tree seedlings during lean season.

Based on the production constraints identified under the existing dryland farming in western zone, field experiments were conducted at the Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore with an objective to identify suitable sustainable integrated farming system for the dryland vertisol areas of western zone of Tamil Nadu and to sustain the productivity through recycling of resources and residue from the allied component during from March 1999 to February 2001. Non replicated experiments with treatment schedule of conventional cropping system with sole sorghum, *Ailanthus excelsa* + crop + goat, *Ceiba pentandra* + crop + goat and *Emblica officinalis* + crop + goat were carried out to identify the suitable component linkage under drylands of western zone of Tamil Nadu. The cropping systems included were grain sorghum + cowpea, fodder sorghum + cowpea and *Cenchrus glaucus* each in 0.33 ha in integrated farming systems and the remaining 0.01 ha was allotted to the goat component. One unit of Tellichery goats, consisting five females and one male was included in the system. Three tree species *viz.*, *A. excelsa*, *C. pentandra* and *E. officinalis* were evaluated for their performance under dryland situation.

To evaluate suitable practices for the tree seedling growth and maintenance during lean season, treatments were imposed to the tree seedlings during Summer in a replicated experiment with split plot design with main plot being the tree species and sub plots being the moisture conservation and watering methods.

To evaluate the suitable *in situ* moisture conservation practices and nitrogen management on yield of crops in the integrated farming system, replicated field experiments were carried out in split plot design. Trees and moisture conservation practices were assigned to main plots and nitrogen management practices were allotted to the sub plots.

Experimental results on integrated farming system for drylands of western zone of Tamil Nadu revealed that integration of crop with *E. officinalis* and goat resulted in higher productivity than cropping alone with sole sorghum. Integration of cropping *viz.,* grain sorghum + cowpea, fodder sorghum + cowpea and *C. glaucus* each 0.33 ha in *E. officinalis* with goat (0.01 ha) recorded higher gross and net returns, with higher output energy. The additional employment generation was 47 and 55 mandays during first and second year, respectively. Integration of cropping in *E. officinalis* with goat sustained the productivity of soil through the addition of manure from the goat component with better supply of nutrients.

The increase in height and basal diameter of tree seedlings was greater with *E. officinalis* indicating the better response of tree to pitcher irrigation and mulching under drylands. Mulching and pitcher irrigation recorded higher tree seedling height and basal diameter with higher soil moisture and less soil temperature.

The results of the field experiments with different cropping systems with *in situ* moisture conservation and N management practices through recycling of goat manure revealed that higher and comparable growth and yield of sorghum and cowpea, higher total biomass, nutrient uptake and sorghum fodder equivalent yield were recorded with *E. officinalis* in both the years. The grass yield of *C. glaucus* was not influenced by the tree species.

Tied ridges had significant influence on the growth, yield attributes and yield of sorghum and cowpea only during first year, when moisture content of the soil was adequate. The yield of *C. glaucus* was not influenced by tied ridges in both the years. The total biomass accumulation and sorghum fodder equivalent yield and crude protein yield were higher under tied ridges only during 1999.

Application of 50 per cent N through fertilizer and 50 per cent N through goat manure, recorded higher growth, yield attributes, total biomass and sorghum fodder equivalent yield in both the years through higher nutrient availability and uptake by the crop which resulted in higher crude protein yield and also improvement in soil fertility status through substantial improvement in the post harvest available N, P and K.

Higher net return (Rs. 7385) and B:C ratio (2.18) were recorded with grain sorghum and cowpea in *E. officinalis* under tied ridges with 50 per cent N through fertilizer and 50 per cent N through goat manure during first year when rainfall is adequate. During second year, under low rainfall situation the net return (Rs. 1448) and B:C ratio (1.57) were higher under *C. glaucus*.

In **conclusion**, it could be inferred that (i) integration of sorghum + cowpea (for grain), sorghum + cowpea (for fodder) and *C. glaucus* each in 0.33 ha intercropped in *E. officinalis* with Tellichery goat component (5+1) in 0.01 ha resulted in higher productivity, economic returns and provided better employment opportunity and improved soil fertility under drylands of western zone of Tamil Nadu than existing practices of raising sole sorghum alone (ii) growth of *E. officinalis* was better as compared to other trees under vertisol dryland situation, (iii) coir pith mulching and pitcher irrigation increased the tree seedling growth than the control, (iv) tied ridges conserved more moisture and improved the productivity of the crops, (v) application of 50 per cent N through fertilizer and 50 per cent N through goat manure increased the productivity, enhanced the soil fertility and provided better opportunity for recycling of manure to the crops.

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INTRODUCTION

CHAPTER I

INTRODUCTION

Dryland agriculture is practised in most of the arid and semi arid areas. India is predominantly a rainfed country and the drylands constitute about 68 per cent of the total cultivated area of 143.8 mha and contribute 44 per cent of the total food grain production. Keeping in view the ever increasing population and corresponding demand for food, fodder and fuel, there is direct need to exploit the production potential of drylands. The major sources under dryland situation are rainfall and soil. Due to vagaries of monsoon, which is erratic and unpredictable, the productivity levels of dryland crops are very low and unstable. Soils of the drylands are often coarse textured and inherently low in fertility and organic matter. In addition, the dryland farmers generally grow long duration local varieties of crops that do not exactly fit into the growing season. The available soil moisture is not conserved and utilised effectively. In view of diversity of problems an integrated approach has to be adopted to overcome the constraints and to increase the productivity.

Sustainability of food production could be achieved through increased total productivity per unit area in a specified time. The integrated farming systems approach, therefore, assumes greater opportunity for better management of farm resources to enhance the farm productivity, reduce environmental degradation, improve the quality of life of resource poor dryland farmers and to maintain the economic sustainability. Hence, the concept of vertical expansion of plant components to capture maximum solar energy for increasing the biomass production through various alternate land use systems becomes imperative. This systems help in efficient utilisation of resources like land and labour (Singh, 1995). Perennials used in this system impart ecological stability besides utilising the off season rainfall and improve soil fertility. Establishment and maintenance of these components are difficult under drylands. Hence, suitable practices have to be evolved to maintain the tree seedlings under adverse climatic conditions.

To meet out the requirement of 400 million bovines in India, there is scarcity of green fodder than the dry fodder under dryland situations. Inclusion of perennial drought tolerant fodder grasses along with goat rearing not only rescue the farmers at the time of crop failures but also maximise the income of the resource poor dryland farmers.

Less productivity of crops in the dryland agriculture can be mainly attributed to lack of moisture conservation practices and low rate of manure and fertilizer application. In drylands, even the rainfall is high, it is often lost as runoff when the soil surface is not suitably structured. Therefore, in dryland farming systems, it is very much essential to include moisture conservation practices to improve the soil moisture status.

Maintenance of soil fertility is also equally important. Nitrogen is the key element in dryland crop production. All dryland soils are deficient in nitrogen and heavy losses also occur due to runoff and volatilization. Due to high cost of fertilizer nitrogen and risk involved in application of fertilizers during inadequate rainfall years, dryland farmers are often not interested to use the fertilizers. According to Lal *et al.* (1988) environmentally sustainable dryland farming system emphasises on conservation and efficient utilisation of natural resources by adoption of agronomic practices such as conservation tillage and mulching, use of legumes and cover crops to improve nitrogen and efficiently utilise the cattle manure. Addition of organic manures to dryland, improves not only the nutrient availability but also the water holding capacity of the soil.

Several studies on integrated farming practices with cropping and other allied enterprises have been carried out by many researchers under different farming situations. Since farming systems are highly location specific and the information on the possibilities of integration of components such as crops, trees and goat to stabilize the yield, income and to improve the productivity and sustainability of the soil are very limited under dryland situation of western zone of Tamil Nadu, the study has been formulated on the sustainable integrated farming systems for drylands of western zone of Tamil Nadu with the following **objectives**.

i. To identify the production constraints in the existing farming in dryland vertisol areas of western zone of Tamil Nadu,

ii. To develop suitable integrated farming system model for the dryland vertisol areas of western zone of Tamil Nadu,

iii. To evaluate suitable tree species with management practices for maintenance of tree seedlings in lean season under dryland vertisols of western zone of Tamil Nadu and

iv. To study the effect of *in situ* moisture conservation practices and nitrogen management through recycling of goat manure on the yield and economics of cropping.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

The traditional cropping leads to a high degree of uncertainty in yield, income and employment under dryland conditions. The integrated farming systems approach introduces a change in the farming techniques for maximum productivity in farming by optimal utilisation of resources. Judicious mix of agricultural crops and other enterprises suited to the given agroclimatic condition and socio-economic status of the farmer would improve the prosperity in the dryland farming.

The present day trend towards sustainable agriculture encourages the utilisation of residue and waste materials of crop and its allied activities for enrichment of soil nutrients, water retention to protect the environment over a long period. Literature relevant to the farming systems research, contribution by different components, methods of tree seedlings establishment, in situ moisture conservation and integrated nutrient management in the crop production under drylands are reviewed in this chapter.

2.1. Climate, soil and productivity of crops in dryfarming regions

Drylands are characterised by highly fragile resource base and mainly depends upon the prevailing weather conditions. Among them, rainfall is the major deciding factor. Erratic and ill distribution of rainfall coupled with high rates of evaporation in dry climate often lead to periods of water deficit and have serious implications for stability of crop production (Aggarwal and Kumar, 1993). Singh (1995) opined that the total rainfall, its distribution, potential evapotranspiration and soil water storage govern the length of growing season which varies from 60 to 300 days. The important soil groups are vertisols and alfisols and their associated orders, which are characterised by low organic matter and poor nutrient status particularly with nitrogen, phosphorus, sulphur and calcium (Singh, 1995).

The main constraints that limit crop production in drylands are moisture and nutrient stress. Poor soil fertility and low water holding capacity also lead to poor crop yields in dry farming regions.

Tamil Nadu comes under the ecozone of bimodel rainfall tropical area in which the mean annual rainfall is around 700 mm but since this is received during two seasons, there is general scarcity of water and drought is fairly common (Virmani, 1995).

Present farming systems in the dryland area are characterised by low and unpredictable yield due to an inefficient use of rains and the soil, rare use of fertilizers, high yielding varieties and improved soil conservation (Pathak and Laryea, 1995). Efficient resource management including improved water resource management, crop production technologies and alternate land use systems are the key issues to increase the productivity of the dryland areas (Singh, 1995).

2.2. Farming systems research

'Farming' is a process of harnessing solar energy in the form of economic plant and animal products. 'System' implies a set of interrelated practices and processes organised into functional entity i.e., an arrangement of components or parts that interact according to some process and transforms inputs into outputs (Fresco and Westphal, 1988).

According to Singlachar (1987), the farming system approaches for finding a solution should be diverse enough to find various alternatives with ecological relevance. He also stated that any development of the farming system ought to make it possible to move from food security and should achieve stability of production and income.

According to Lal and Miller (1990), farming system is a resource management strategy to achieve economic and sustained production to meet diverse requirement of farm household while preserving resource base and maintaining a high level environmental quality.

Mahapatra and Bapat (1992) viewed the farming system as a complex interrelated matrix of soil, plants, animals, implements, power, labour, capital and other inputs controlled in part by farm families and influenced to varying degrees by political, economic, institutional and social forces that operate at many levels. Farming system designates a set of agricultural activities organised into a functional unit(s) to profitably harness solar energy while preserving land productivity, environmental quality and maintaining desirable level of biological diversity and ecological stability (Rangasamy, 1994).

Integrated farming system is a component of Farming System Research and it deals with whole farm approach to minimise risk and increase the production and profit with better utilisation of wastes and residues (Palaniappan, 1994). Balakrishnan (1994) stated that integrated farming system approach introduces a change in the farming techniques for maximum production in the cropping pattern and takes care of optimal utilisation of resources.

According to Prasad and Reddy (1986), farming systems research was developed because of the disappointing results of traditional agricultural research in influencing the productivity of small farms in developing countries and its primary aim is to increase the overall productivity of the farm. Farming systems research has found acceptance as an effective approach to agricultural research and development and it considers the farmers total farming system which contrasts with the single crop/resource oriented research (Venkatadri, 1993). Maji (1991) opined that the study of farming system needs to be based on small agroecological zones which are homogeneous at least with respect to endowments of natural resources, cropping pattern and socio-economic situation. He also reported that the systems approach provides a useful tool for evaluating the sustainability of agriculture as well as for testing and designing appropriate systems to suit the natural endowments, limited resource base and micro level farming system research should be incorporated in the future plan of a sustainable agriculture.

2.3. Contribution by components in integrated farming system

Farmers irrespective of holding size, keeping livestock or poultry enterprise on a predominantly cropping farm, even on a small scale are better able to stand adverse natural or economic conditions than those who are specialised in crop production. Such a system allows for efficient recycling of farm waste, maintenance of soil fertility, efficient utilisation of byproducts and for the economic security of diversification (Srivastava, 1988).

2.3.1. Economic contribution

Small ruminants like goats and sheep form an important economic and ecological niche in Asian mixed farming systems. Approximately 60 per cent of goats and 20 per cent of sheep population are found in Asia (Devendra, 1998). According to McIntyre *et al.* (1992) one third or more of household income in the semi arid tropics may come from livestock. Oberoi *et al.* (1992) stated that goats were more remunerative than sheep in India. Singh and Sharma (1987) and Prasad (1992) also reported that the integration of livestock into land use systems increased the farm income. Raut and Nadkarni (1974) and Deoghare and Bhattacharya (1993) reported that the goats and sheep provide a most valuable source of income in the semi-arid tropics and the sale of goats contributed 30.1 per cent of thé total farm income in India. Similarly Wimalasuriya *et al.* (1993) also reported that in Sri Lanka, with minimal disturbance to the socio economic environment, the farmers with crop livestock integration could earn an average of 88 per cent more income than farmers with no livestock.

Prabaharan *et al.* (1994) also reported that goats generated higher annual income than dairy cattle and sheep and showed the best economic viability. Chinnaswami (1994) reported that integrated farming system with goat rearing produced an additional income of Rs.3258 and Rs.11,932 over farmers cropping at Paiyur and Aduthurai respectively. In the rainfed black soils of Aruppukottai introduction of tree legumes like subabul, *Acacia senegal*, *Prosopis cineraria* and perennial fodder grass and inclusion of goat rearing yielded an additional income of Rs.2163 to Rs.2556 per year from a farm area of 1.6 ha (Veerabadran, 1994). He also reported that the integrated farming system with crop + horticulture + goat proved to be successful and increased the profit by Rs.2163 to Rs.5206 per hectare over cropping alone.

Studies at Koilpatti revealed that the IFS with alley cropping of subabul with fodder sorghum and cotton and goat rearing in deep litter system yielded an annual income of Rs.8410 per ha compared to Rs.4654 per ha under traditional cropping alone (Veerabadran, 1994). Sivasankaran *et al.* (1995) reported that integrating crops, goat and trees recorded an additional net income of Rs.3747 ha^{-1} yr^{-1} over conventional cropping alone. He also reported that in IFS 54.4 per cent of net income was obtained from crop component and remaining 45.6 per cent was from the animal component.

Santhi *et al.* (1996) reported that highest benefit cost ratio of 1:1.28 was obtained with crop livestock integration than cropping alone. Goat rearing was an appropriate intervention in a capital scarce situation and that can contribute significantly to household income (Saadullah *et al.*, 1997). Among the main occupation of households, the average net income per household per year from livestock farming was 26.6 per cent and from crop farming was 73.3 per cent (Deoghare, 1997). In an integrated silvipastoral based farming system for drylands, among the animal components, rearing goats recorded higher income followed by milch animal (Vairavan *et al.*, 2000).

According to Khanna (1994), the net benefit cost ratio was the highest with fruit forestry model involving aonla plus guava. A horticulture based agroforestry system with subabul, lemon, papaya, turmeric and okra produced a net return of Rs. 10,000-18,000 ha^{-1} yr^{-1} for three years under rainfed condition compared with Rs. 1740 - 4600 ha^{-1} yr^{-1} from agricultural crops of maize - wheat in Shiwalik foot hills (Dyal *et al.*, 1996). According to Gajja *et al.* (1999), the BCR was maximum under hortipasture system followed by silvipasture system.

2.3.2. Employment generation

Round the year gainful provision of employment is possibly one of the major considerations for evolving any cropping system. Dryland farm families remain unemployed for almost two thirds of the time. Change in crops and cropping pattern is one such way of generating additional employment.

Integrated farming system under dryland with sorghum + cowpea, *Leucaena leucocephala* + *Cenchrus ciliaris*, *A. senegal* + grass with goat generated an additional employment of 113 man days ha^{-1} annually (Sivasankaran *et al.*, 1995). Santhi *et al.* (1996) reported that the employment generation through crop + goat mixed farming was 320 man days per year and it was higher than the farmers system due to lower cropping intensity. Singh (1996) reported that highest labour employment of 58.3 per cent was recorded in goat rearing with large flocks especially on grazing. According to Deoghare (1997) the average labour employment per household per year from goat, sheep, buffalo and crop farming were 23.3, 1.9, 33.1 and 41.5 per cent respectively in Uttar Pradesh.

Integrated farming system comprising field and horticultural crops, fishery, poultry, duckery, apiary, mushroom, dairy and agroforestry generated an additional employment of 573 man days on a small piece of land of 1.25 ha (Behera and Mahapatra, 1999). In arid zone of Rajasthan, an additional employment was generated through adoption of silvipasture or hortipastoral system with sheep or goat (Gajja *et al.*, 1999).

2.3.3. Resource recycling

Nutrient cycling refers to transfer of nutrients from one component to another in the soil-plant-animal-environment system. Nutrient transfer occurs through livestock, if they are an integral part of the systems (Rao *et al.*, 1999).

Continuous dairy based farming system increased the organic, humic and fulvic carbon and available N, extractable K, Ca and Mg, Zn, Mn, Fe with time (Das and Singh, 1992). Rangasamy (1994) opined that integration of enterprises like cattle rearing, fishery, poultry and goat rearing, sericulture and mushroom cultivation with cropping could properly recycle the residues for getting maximum compatibility and replenishment of organic matter.

According to Rao *et al.* (1999) stall feeding of livestock through cut and carry system ensures better utilisation of fodder and crop residues and more efficient collection of manure for recycling. The integrated farming system provides excellent opportunity for organic recycling and it reduces farmers dependency on external or market purchased inputs. It offers good scope for recycling of crop components to the animals and animal waste to the crop components (Vairavan *et al.*, 2000).

2.4. Alternate land use system

For providing stability and sustainability to the farming system, tree cum crop farming system will be the most appropriate one. Alternate land use system is a perennial system or practice adopted to replace or modify the traditional land use (Singh and Osman, 1995). Subbian (1999) stated that alternate land use systems are appropriate in areas where subsistence farming is practised in fragile ecosystems and it poses more potentiality and flexibility in land use than the traditional crop production systems.

2.4.1. Agroforesty

Agroforestry is a part of alternate land use system. According to Lundgren and Raintree (1982), it is a collective name of land use systems and technologies where woody perennials are deliberately used from the same land management units as agricultural crops and / or animals in some form of spatial arrangement or temporal sequence.

Rao (1989) and Rao and Mac Dicken (1991) mentioned that, the term agroforestry encompasses any and all techniques that attempt to establish or maintain both forest tree and agricultural production on the same piece of land. According to Deb Roy (1995) agroforestry is an integrated self sustained land management system which involves woody perennials with agricultural crops including pasture / livestock simultaneously or sequentially on the same unit of land meeting ecological as well as socio economic needs of the people.

Agroforestry practices in drylands improve the ecological status of the area through the trees raised along with agriculture, pastoral and other vegetation grown in the area. According to Sivakumar *et al.* (2000), due to low initial cost and ensured seasonal income through intercropping and supply of different kinds of raw materials to support cottage industries, tree keeping in drylands would certainly offset the risky farming under dryland condition.

2.4.1.1. Agrisilvicultural system

2.4.1.1.1. Tree crop interaction

P. cineraria is more suitable than *Acacia tortilis* and *Tecomella undulata* with cluster bean, cowpea and mothbean whereas *A. tortilis* may not be considered suitable for agroforestry because of crop failure (Jindal *et al.*, 1990). According to Deb Roy and Gill (1991) the best grain production (80-82 per cent relative yield) of sorghum, wheat, gram and arhar was observed in association with *Casuarina equisetifolia*, *Emblica officinalis* and *Eucalyptus tereticornis* compared to 79 per cent relative yield in association with *Leucaena* and *Acacia nilotica.* They also reported that there was no definite trend in the yield of crops during the first year whereas the grain production was reduced in the second year in association with trees. Yield of sorghum was on par with sole sorghum when grown in tamarind, neem and silk cotton whereas the yield was drastically reduced with *Ailanthus* and *Casuarina* (Anonymous, 1993). Gill and Deb Roy (1997) tested 12 multipurpose tree species and reported that the yield of wheat was higher from the interspaces of *Hardwickia, Acacia, Casuarina* and *Emblica* than the other tree species. Dhyani and Tripathi (1999) reported an increase in yield as the distance from the tree increased.

The tree growth *viz.*, height and collar diameter was better in agroforestry than in sole tree plantings (Deb Roy and Gill, 1991). Better growth and timber volume in the tree + crop situation was mainly due to the application of fertilizers and weeding (Dhyani and Tripathi, 1999).

2.4.1.1.2. Soil fertility

L. leucocephala with cereal intercropping improved the soil organic carbon status and available N and P but reduced the available K and Ca (Rawat and Hazra, 1991) under dryland condition. Arable crops like castor and redgram could be grown with *Acacia albida* in marginal lands under rainfed conditions with the advantage of enriched site due to the deciduous nature of the tree species (Bheemaiah *et al.*, 1992).

2.4.1.1.3. Economics

According to Grewal *et al.* (1995) agrisilvicultural system with *E. tereticornis* generated an annual cash return of Rs. 5642 ha^{-1} compared with Rs. 2997 ha^{-1} from rainfed crop of turmeric and was thus more economical and viable. Similarly, highest net return per hectare was obtained when sorghum or cowpea were grown in association with *Faidherbia albida* whereas the lowest with sole annual crops (Suresh and Rao, 1998). Further, Suresh and Rao (2000) reported that an eight to nine year old nitrogen fixing tree species of *F. albida, Acacia ferrugienia* and *Albizia lebbeck* reduced the seed and dry fodder yields of cowpea than sole crop whereas the fertilizer nitrogen application produced significantly higher seed and dry fodder yields.

2.4.1.2. Agrihorticultural system

2.4.1.2.1. Tree crop interaction

Maize, sorghum and cowpea were more compatible with trees and they least reduced the tree growth and had the least yield reduction (Dasthagir and Suresh, 1990). Khanna (1994) reported that the total yield per hectare was the highest in guava + ber model followed by aonla + guava. He also reported that the productivity in terms of fruit and fodder was higher with aonla + subabul as compared to guava + subabul model.

Sorghum recorded higher yield than legumes with custard apple, pomegranate and aonla (Anonymous, 1997). In an agrihorticultural system with citrus and wheat, maximum production of wheat was recorded during the establishment year of citrus species and production was affected in the subsequent years (Gill *et al.*, 1999). Singh *et al.* (1999) reported that maximum height, collar diameter and biomass production were attained by *E. officinalis* compared to *Hardwickia binata.*

2.4.1.2.2. Soil fertility

In Northern hill region under moderately slopped land horticultural crops increased the Ca, K and P content of the soils (Prasad, 1992). Newaj *et al.* (1999) reported that the organic carbon content of the soil was increased from 65 to 109 per cent below the canopy of aonla when compared to open canopy due to falling of leaves under rainfed condition.

2.4.1.2.3. Economics

According to Arora and Mohan (1990) fruit based cropping systems not only are known for their economic viability but they also generate lot of employments and gave assurance against crop failure during drought years. Under rainfed conditions of alfisol, agrihorticulture system gave the highest benefit cost ratio of 2.16 compared with 1.95 with annual cropping, 1.69 with agroforestry and 1.52 with agrisilviculture (Das *et al.*, 1993).

Singh and Osman (1995) opined that agrihorticulture system was an ideal option for better sites and produce higher returns with timely management and adequate plant protection measures. Gill *et al.* (1997) reported that agrihorticultural system with mango + wheat with subabul between mango trees was a successful system in Jhansi.

2.4.1.3. Silvi / Hortipastoral system

Hortipasture is one of the agroforestry systems which involves integration of fruit trees with pasture. When a fruit tree is replaced with a top feed tree, it is called as silvipastoral system (Singh and Osman, 1995). *C. ciliaris* is a drought hardy, vigourously growing pasture species capable of producing good quality forage in arid and semi arid areas of India (Rajora, 1998). According to Prasad *et al.* (1995) and Mishra *et al.* (1997), *Cenchrus glaucus* (CO 1 grass) at the flowering stage could meet the maintenance protein needs of sheep when offered as the sole feed.

2.4.1.3.1. Tree crop interaction

The forage yield under *P. cineraria* was the highest whereas it was the least under *A. senegal* (Sharma *et al.*, 1980). *C. ciliaris* + *Macroptilium atropurpureum* produced the highest mean green fodder and dry matter yield of 14.7 and 4.89 t ha^{-1} (Basavaraju and Rao, 1996). In a hortipastoral study, stylo and deenanath were compatible fodder crops with guava, custard apple and mango upto two years after planting (Sekar *et al.*, 1998).

Eighty per cent of mortality was recorded in ber under buffel grass and the growth was also severely affected in the established pasture of buffel grass (Sharma and Vasishtha, 1985). Singh and Osman (1995) also reported that after 18 months pasture establishment, survival and growth of fruit trees was found to be poor with grass than legume association. In a silvipastoral system, the least survival was obtained with *Ailanthus excelsa* whereas maximum with *P. cineraria* (Singh *et al.*, 1996). In the same study maximum biomass production was obtained with *Cenchrus setigerus* while minimum was recorded with *Panicum* sp.

2.4.1.3.2. Soil fertility

Jha (1990) reported that silvipastoral system with napier grass and *L. leucocephala* increased the organic carbon and available K content of the soil (0.49 per cent and 46 kg ha^{-1}, respectively) compared to the initial stage level of 0.40 and 29 kg ha^{-1}, respectively after three years. Prasad (1992) stated that in the North eastern hill regions of India, silvipastoral crops were recommended for the moderately sloped lands which increased the Ca, K and Bray's P content. Robertson *et al.* (1993) reported that the total soil N and organic C were higher under permanent pasture than under sorghum. *L. leucocephala* with *Cenchrus* + *Stylosanthus* improved the organic carbon and available N and phosphorus content of the soil compared to the bare lands (Yadava and Varshney, 1997 and Katyal *et al.*, 1998).

2.4.1.3.3. Economics

Sankaranarayanan *et al.* (1987) reported that higher return was obtained from silvipastoral system of *A. tortilis* with *C. ciliaris* compared to growing pure tree or pure grass. According to Gajja *et al.* (1999) the silvipasture and hortipasture systems were more profitable than arable farming and the BCR was maximum under hortipasture followed by silvipasture. In southern zone of Tamil Nadu, the gross income and B:C ratio obtained from sorghum + tamarind, sorghum + neem, black gram + neem, black gram + tamarind were sustainable (Gururajan, 1999).

2.5. Establishment techniques for tree seedlings

Deficiency of moisture and extremes of temperature in arid and semiarid condition adversely affect the early growth and establishment of trees. The percolated water during the rainy season is not used by the trees in their early establishment. Hence, practices to increase the moisture availability and for checking evaporation losses for efficient utilisation of moisture are very much needed under dryland situation.

2.5.1. Evaporation control through mulching

The surface mulch will be useful when there is plenty of water in the sub surface (Gardener, 1959). The potential for increased water storage and decreased evaporation is greater in wheat residues rather than sorghum or cotton residues as a surface mulch (Unger and Parker, 1976).

Uthaiah *et al.* (1993) reported that application of coir pith, plastic sheeting or paddy husk did not affect the plant height but drip irrigation with coir pith mulch increased the growth of the trees. There was 25 per cent higher moisture in surface and 30-32 per cent higher moisture in the sub surface in coir pith mulching (Singh and Prasad, 1993). Mapa and Kumara (1995) and Subramanian and George (1998) stated that because of high C:N ratio and water holding capacity, coir pith can be effectively used as a mulching material for establishment of plantation forestry. According to Mertia (1993) gravel mulch was effective in checking moisture losses and improving the tree growth of ber.

Soil moisture content was higher under mulched plots than the control (Kumar and Srivastava, 1997; Sarma and Baruah, 1997). Rathore *et al.* (1998) found that straw mulch conserved more water in the soil profile than no mulch. According to Shukla (1998) dry grass mulch not only conserved soil moisture and it also increased the root and shoot growth. Subramanian and George (1998) found that soil moisture in the coir pith mulched plot remained higher than control plot and the fall in moisture per cent was gradual in mulched plot compared to non mulched one.

Gupta (1980) reported that there was reduction in soil temperature by 2-4°C with bajra husk. According to Gupta and Gupta (1985) the maximum temperature of the soil was reduced by 1-9°C during the hot month of June under grass mulch. Application of coir pith mulch reduced the temperature and the reduction was 0.5°C to 6°C (Singh and Prasad, 1993). Kumar and Srivastava (1997) and Sarma and Baruah (1997) reported that organic mulches reduced the soil temperature whereas plastic mulches increased it.

There was an increase in the growth of tree seedlings due to application of mulching material on the soil surface (Mertia, 1993; Rathore *et al.*, 1998; Shukla, 1998) than no mulch.

2.5.2. Moisture management - pitcher irrigation

Pitcher irrigation is a new technique of growing plants using a small amount of water with earthen pots, which usually used for storing drinking water, buried in the soil upto the necks (Mondal, 1974). He also stated that the water requirement of plants grown by this technique was only a fraction of their normal water requirements under normal irrigation. Oswal and Singh (1975) reported that with pitcher method, vegetable could be grown satisfactorily under drylands. Mondal (1978) found that water melon gave economic return with pitcher irrigation and there was greater water economy compared to pot watering (Balakumaran *et al.*, 1982; Sahu, 1984)

Kurian *et al.* (1983) found quick establishment and faster growth of *Prosopis juliflora* with pitcher irrigation. Reddy and Rao (1983) reported that pitcher irrigation gave higher yields of bitter gourd when filled every fourth day compared to basin irrigation.

Sheikh and Shah (1983) found better survival and growth of *Acacia* and *Eucalyptus* with pitcher irrigation than hand watering. In mango saplings, the highest plant height, stem girth, leaf area, dry matter production and root number were obtained with sub soil irrigation via pitcher (Narvane and Desai, 1989) with 3.5 litre pitcher. Akbar *et al.* (1996) also reported that pitcher irrigation is a successful method of plant production under arid environment to establish the tree species like ber and *Acacia*.

According to Chauhan *et al.* (1999) the water loss was found negligible in pitcher method of irrigation since open surface was less which led to low evaporation losses. Mahajan *et al.* (2000) reported that drips are used in order to reduce the drudgery of irrigating orchards and this can result in water savings of over 50 per cent.

2.6. Crop management

2.6.1. *In situ* moisture conservation

Highest sorghum grain yield (0.69 t ha^{-1}) was obtained from plots receiving off season tillage and compartmental bunding compared to control (Kandiannan *et al.*, 1992). Grain yield, total N and P uptake were higher with ridge and furrow sowing compared to normal sowing and compartmental bunding (Shaikh *et al.*, 1995) in rainfed pearl millet. Kaushik and Lal (1998) found that beds with furrow system gave highest yields, water use efficiency and returns in pearl millet under rainfed condition.

The growth, yield attributing characters and grain and fodder yields of rainfed sorghum were the highest with tied ridges followed by ridges and furrows (Kolekar *et al.*, 1998a and 1998b) whereas Bhan *et al.* (1998) reported that ridging and furrowing between the crop rows 3 weeks after sowing increased yield attributes, yield, moisture use efficiency and nitrogen uptake compared with other moisture conservation practices in rainfed sorghum. According to Surakod and Itnal (1998) in dryland rabi sorghum, with both deep and shallow tillage, use of ridges and furrows produced higher yields than with compartmental bunding.

Selvaraju *et al.* (1999) found increased stored soil moisture (14 per cent) and higher grain and straw yields of rainfed sorghum (14 per cent and 11 per cent, respectively) under tied ridges than flat bed method of sowing in alfisol. In vertisols, compartmental bunding and ridges and furrows conserved soil moisture and improved root development, total dry matter production, grain and straw yield and water use efficiency than with flat beds (Patil and Sheelavantar, 2000).

2.6.2. Integrated nutrient management

2.6.2.1. Effect of organic manures

The yield of pasture grasses and corn due to the application of goat manure at 10 t ha^{-1}, was comparable with the yield using 100 per cent inorganic fertilizer

(Baconawa *et al.*, 1987). Badanur *et al.* (1990) recorded highest sorghum grain yield (16.7 q ha^{-1}) with the application of sunnhemp at the rate of 5 t ha^{-1} under dryland sorghum. Gangwar and Niranjan (1991) recorded an increased dry matter production of fodder sorghum (8.2 t ha^{-1}) with the application of 6 t ha^{-1} of FYM compared to farm residues at the same rate of application.

Suri *et al.* (1995) reported that FYM incorporation at the rate of 10 t ha^{-1}, irrespective of the use of NPK, increased maize yields significantly under rainfed situation. Patil *et al.* (1996) found that application of 50 kg N as crop residues of sorghum + *L. leucocephala* cuttings produced the highest mean grain yield of 1.23 t ha^{-1} in dryland *rabi* sorghum.

According to Ravichandra *et al.* (1996) highest grain yield of maize was obtained with coir compost with cattle slurry compared to NPK alone. They also reported that the nutrient availability was also increased in this treatment. Aggarwal *et al.* (1997) reported that addition of cluster bean residues and FYM increased pearl millet grain yield 0.1 to 0.2 t ha^{-1} compared with no residue.

2.6.2.2. Effect of inorganic fertilizers

Abichandani *et al.* (1973) reported that green fodder and crude protein yields were significantly increased upto 90 kg N ha^{-1} in fodder sorghum under rainfed condition. Muddemmanavar *et al.* (1990) found that the total dry matter yield was increased upto 100 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1} with an irrigated main and rainfed ratoon crop of sorghum. Whereas Khot *et al.* (1991) reported that the dry matter and crude protein yields were increased with upto 80 kg N ha^{-1} and there was no further yield increase with 120 kg N ha^{-1} in fodder sorghum.

According to Atkins and Boucher (1992) the improved soil fertility and crop management would increase the dry matter and crude protein yields. They found that application of fertilizers increased the crude protein content by 6.0 per cent compared to control without fertilizer. Naphade *et al.* (1995) found that application of 150 per cent recommended fertilizer gave the highest N, P and K uptake and average yield of sorghum under rainfed vertisol. Whereas Kumbhare *et al.* (1997) reported that recommended rate of N, P_2O_5 and K_2O (100:50:50 kg ha^{-1}) gave the highest dry matter and grain yield of *kharif* sorghum at Akola.

2.6.2.3. Effect of combined application of organic manure and inorganic nutrients

2.6.2.3.1. Productivity

Application of 40 kg N + 20 kg P_2O_5 + 12.5 t ha^{-1} farm yard manure gave the highest grain yield of sorghum when intercropped with *Vigna mungo* under dryland condition (Latha and Subramanian, 1991). Application of 6 t FYM ha^{-1} + 50 per cent recommended dose of fertilizer produced highest grain and fodder yields of sorghum compared to control (Gangwar and Singh, 1992; Niranjan and Arya, 1992). Guldekar *et al.* (1992) found that application of 60 kg N as urea + 60 kg N as FYM produced highest grain and fodder yields compared with control.

According to Madhavi *et al.* (1995) plant height, DMP, yield parameters and yield were higher with 100 per cent recommended rate of NPK + 4.5 t poultry manure ha^{-1} and it was comparable with 50 per cent recommended rate of NPK with same quantity of poultry manure.

In maize, application of 10 t ha^{-1} of FYM with 90:45:20 kg N, P_2O_5 and K_2O resulted in higher grain production (Sharma and Singh, 1996). In pearl millet, crop residues of cluster bean or mung bean plus 20 kg fertilizer N ha^{-1} produced equal grain yield to that of 40 kg N ha^{-1} alone and saved 50 per cent fertilizer N (Aggarwal *et al.*, 1997). In cowpea, 100 per cent recommended NPK with FYM recorded highest dry fodder yield of 0.66 t ha^{-1} (Lal and Singh, 1998).

Bellaki and Badanur (1997) recorded the highest grain yield of sorghum with to meet 50 per cent N with 50 per cent recommended dose of fertilizer. Similarly, *et al.* (2000) reported that half of N as inorganic fertilizer with half as organic manure significantly higher grain and straw yield of sorghum, green fodder and dry matter yield ɔdder crops and sorghum grain equivalent yield than other fertilizer schedules under fed condition.)

.2.3.2. Nutrient uptake

(According to Singh and Rajat (1987) the combination of organic matter and tilizer N increased the P and K uptake more than their application individually. ɹraisamy *et al.* (1990) observed slight improvement in N, P and K uptake by the ıdition of FYM. Guldekar *et al.* (1992) recorded the highest uptake of N, P and K with the ɔplication of 60 kg N as wheat straw with 60 kg N as urea in sorghum. Similar results were lso reported by Aggarwal *et al.* (1997) with the addition of crop residues with FYM.

Lal and Singh (1998) reported that the highest uptake of K was recorded with 100 per cent NPK with FYM. Santhy *et al.* (1998) also reported that application of FYM along with NPK increased the crop yield and nutrient uptake. According to Bellaki and Badanur (1997) the highest N, P and K uptake was recorded with FYM to meet 50 per cent N along with 50 per cent recommended dose of fertilizer in rainfed sorghum.)

2.6.2.3.3. Residual soil fertility

Livestock have a key role in ecological sustainability and maintenance of soil fertility. Manure application increases crop yield and improves soil quality (Pearson *et al.*, 1998). According to Suri *et al.* (1995) application of FYM not only increased the N use efficiency but also improved the fertility status of the soil. Santhy *et al.* (1998) reported that application of FYM along with NPK increased the nutrient status of the soil under finger millet-maize-cowpea rotation. Kathiresan and haskar (1999) found that the residual nutrients and organic carbon content were high ırough the application of sheep manure. Available N, P_2O_5, K_2O and micronutrients ıcreased significantly with organic sources of nutrients either alone or in combination ith inorganic fertilizers (Bellaki and Badanur, 1997; Suresh *et al.*, 1999).

.7. Economics of intercropping

Traditional cropping systems are mostly subsistence in nature. Over the last two ecades, the dry land agricultural research has improved cropping systems which have igh land equivalent ratio than the traditional systems.

According to Bhagavandoss *et al.* (1992) the crop yield of the intercrops was gnificantly greater than the pure stand yield of cereals and the contribution of cowpea to e total biomass was higher in 1:1 ratio than 2:1 ratio. Under rainfed cropping systems, arlmillet and sorghum were the most profitable crops under intercropping system and ve higher net returns than the other crops (Malik *et al.*, 1996). In sorghum cowpea ercrop with paired row system, with recommended rate of NPK produced the highest vpea forage yield (17.81 t ha^{-1}) and sorghum grain yield of 4.5 t ha^{-1} and the highest ss return (Patil *et al.*, 1997).

Arya *et al.* (2000) reported that sorghum + cowpea (*Vigna unguiculata*) gave ificantly highest green fodder and dry matter yields than sorghum + grass in the food / ler alley cropping system. Desale *et al.* (2000) reported that normal planting of hum with 45 cm spacing with one row cowpea intercropped, recorded highest gross n which was 12.75 per cent higher than the sole crop of sorghum.

The available literature clearly reveals that the productivity and income under nd situation could be stabilised by adopting integrated farming systems. Because of iverse ecological situation and socio-economic status, there is a need to develop farming systems suitable to the particular situation. It is also clear from the review that trees, perennial grasses and animal component could sustain the productivity and soil fertility of the system under drylands. With recent thrust on integrated nutrient management and also importance of moisture conservation under dryland situation there is an urgent need to exploit the possible means to the cropping systems. In this context the present experiment was carried out to develop sustainable integrated farming system for the dryland vertisol areas of western zone of Tamil Nadu, to evaluate suitable tree species and its management practices and to study the effect of moisture conservation and nutrient management for cropping under dryland situation.

MATERIALS AND METHODS

CHAPTER III
MATERIALS AND METHODS

A field survey was conducted in western zone of Tamil Nadu to understand the existing farming practices, yield of crops, livestock and perennial tree component adopted in the farming and their production constraints. Based on the survey, field experiments were conducted at Eastern block of the Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore with a view to develop sustainable integrated farming system for the dryland vertisol areas of western zone of Tamil Nadu with suitable tree component and goat integration by recycling of manure from the goat component to the crops during March 1999 to February 2001. The materials used and methods adopted in the field experiments are described in this chapter.

PART - I

3.1. Field survey on existing farming practices

3.1.1. Description of study area

3.1.1.1. Location

Western zone comprises of Erode and Coimbatore districts, Nilakottai and Palani taluks of Dindigul district, Usilampatti, Uthammapalayam and Periyakulam taluks of Madurai district, Karur and Manapparai taluks of Trichy district and Tiruchengode taluk of Namakkal district. The zone is situated between 9°30' and 12' N latitude and 70°30' - 78°E longitude. The altitude of the zone ranges from 160-2700 MSL

3.1.1.2. Climate

Climate in the zone ranges from semi arid to sub humid with frequent occurrence of drought.

3.1.1.3. Soils

The soils of the zone are divided into six groups, *viz.*, red calcareous, red non calcareous, black calcareous, alluvial colluvial mixed soils and associations, forest soil and saline alkali soils.

Red noncalcareous is predominant (37 per cent of the total area) and black calcareous is an important one occupying almost all taluks of this zone. The important feature of the soils are very low fertility under rainfed situation.

3.1.1.4. Rainfall

Annual rainfall varies from 524-1428 mm with an average of 786 mm. Of the total rainfall 48.4 per cent is received during North East Monsoon season and 32.2, 18.6 and 2.8 per cent during South West, Summer and Winter seasons respectively. Important characteristics of this drylands are undependable and low rainfall.

3.1.2. Design of the study

3.1.2.1. Choice of the study area

Avinashi and Palladam blocks of Coimbatore district were selected for the study due to the low rainfall and predominantly vast area under dry farming. A low rainfall of less than 600 mm in Palladam taluk and 700-800 mm in Avinashi taluk is received.

3.1.2.2. Sampling design

From each block, five villages were selected at random and from each village five farmers were selected again at random. Thus the total sample consisted of 50 farms. All the sample farmers were interviewed with a structured questionnaire to get the necessary information.

3.1.2.3. Data collection

The data were collected both from the primary and secondary sources. The primary sources being the interviews from the farmers and the secondary source being the data from records of taluk statistical office.

The total sample of 50 farmers were post stratified into small farmers with an operational holding of 1-5 acres and large farmers with an operational holding of more than 5 acres. Data with regard to land holding, literacy status of the farmers, crops grown, management practices adopted, yield of crops, livestock particulars and tree component were collected.

3.1.2.4. Analysis

Average and percentage analysis were used to examine the size composition of farm holding. cropping pattern, technology adoption, perennial tree component, livestock particulars and yield of the crops.

PART - II

3.2. Field experiment

3.2.1. Materials

3.2.1.1. Field location

Experiments were conducted in the Eastern block, Tamil Nadu Agricultural University, Coimbatore. The geographical location of the experimental site is situated at 11°N latitute and 77°E longitude at an altitude of 427 m above MSL.

3.2.1.2. Weather and climate

The location experiences a mean annual rainfall of 640 mm. The annual mean maximum and minimum temperatures are 31.5°C and 22.2°C respectively. Relative humidity ranges from 61 to 91 per cent and the mean bright sunshine hours per day are

7.4 with a mean solar radiation of 400 cal. cm^{-2}. day^{-1}. The mean weekly weather parameters prevailed during the experimental periods are furnished in **Appendix I** and depicted in **Fig.1 and 2**. Amount of rainfall received during the North East Monsoon seasons of 1999 and 2000 were 422.6 and 291.2 mm, respectively.

3.2.1.3. Field and soil

The experiment was conducted in field No. 36E of the Eastern block of Central Farm, Tamil Nadu Agricultural University. The soil of the experimental site was vertisol having low available nitrogen, medium available phosphorus and high available potassium. The soil characteristics of the experimental site is presented in **Table 1.**

3.2.1.4. Components in the farming system

Based on the results of the field survey, the components of the present farming system investigation were selected in such a way to suit with the existing dryland condition and to evaluate their potentiality to improve the productivity and soil fertility and to get sustainable yield and income.

3.2.1.4.1. Cropping

The crop component in the integrated farming system consists of three different cropping systems *viz.*, (a) sorghum + cowpea, (grain) (b) sorghum + cowpea (fodder) and (c) *Cenchrus glaucus* for serving green fodder requirement of goat. An area of 0.33 ha of the land was allotted to each of the above components. The crop component was raised as intercrops in between the tree species.

3.2.1.4.2. Tree species

Three economically potential tree species were included in the experiment. A brief description of the trees is given below.

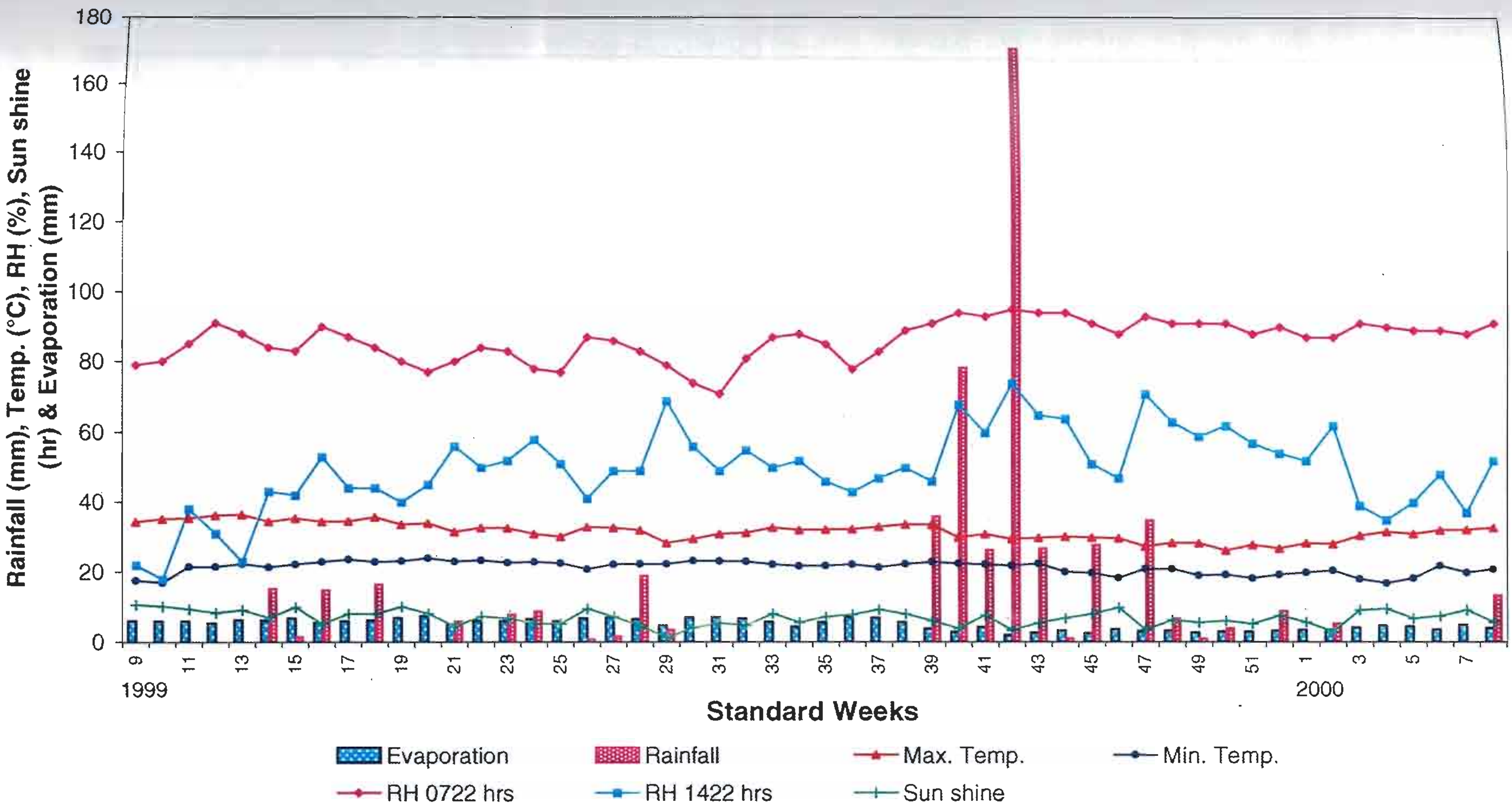


Fig. 1. Weather data during experimental period - 1999-2000

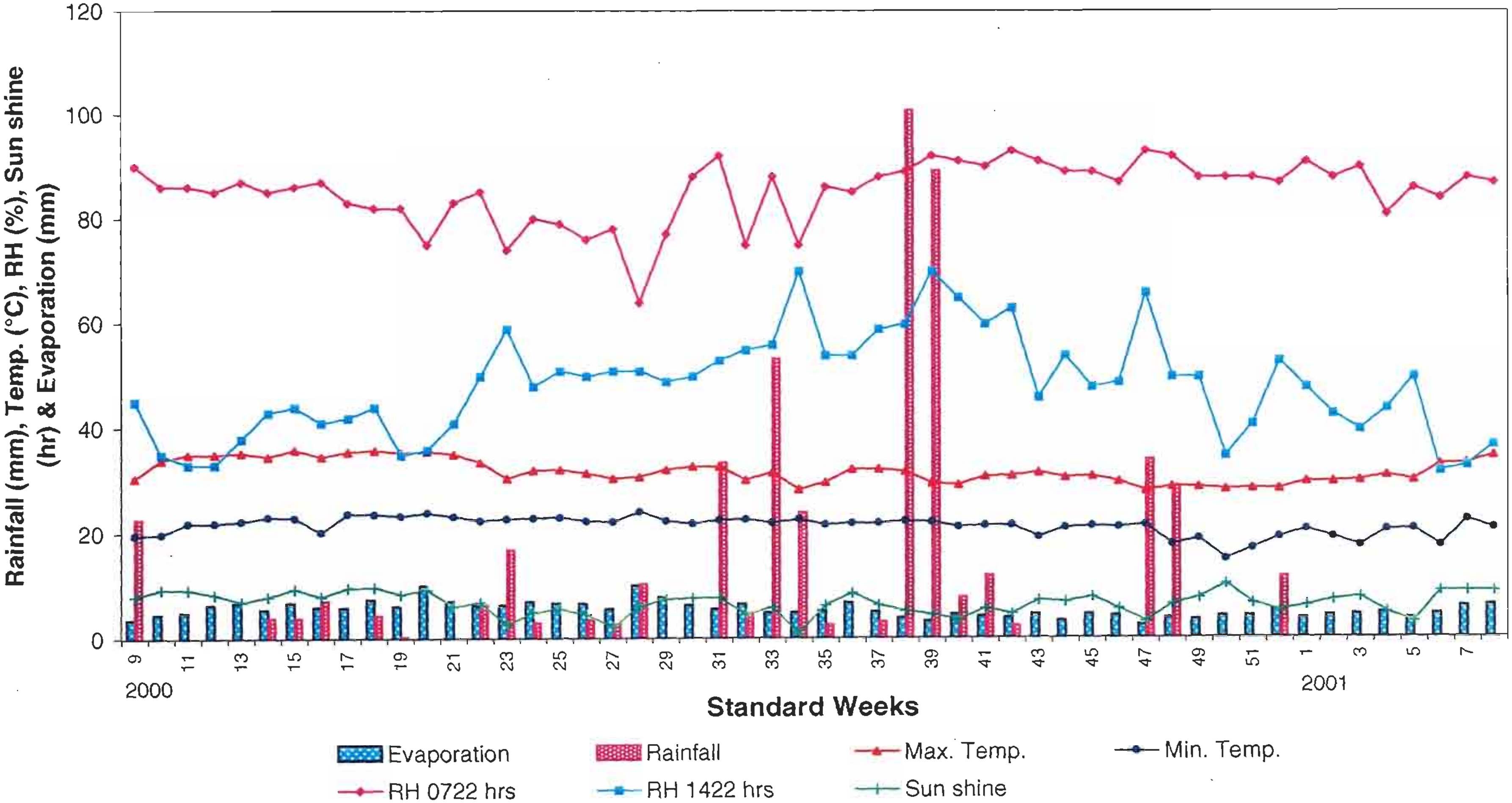


Fig. 2. Weather data during experimental period - 2000-2001

Table 1. Soil characteristics of the experimental site

Particulars	Field No. 36 E
Mechanical composition (Piper, 1966)	
Coarse sand (per cent)	20.40
Fine sand (per cent)	28.40
Silt (per cent)	18.60
Clay (per cent)	32.40
Physical properties (Piper, 1966)	
Bulk density (g. cm^{-3})	1.59
Field capacity (per cent)	22.50
Wilting point (per cent)	10.34
Chemical analysis	
Available nitrogen (kg ha^{-1}) (Subbiah and Asija, 1956)	147
Available phosphorus (kg ha^{-1}) (Olsen *et al.*, 1954)	13.7
Available potassium (kg ha^{-1}) (Stanford and English, 1949)	432
Organic carbon (per cent) (Walkley and Black, 1934)	0.42
EC (1:2 soil water solution) dSm^{-1} (Jackson, 1973)	0.37
pH (1:2 soil water solution) (Jackson, 1973)	7.9

(i) *Ailanthus excelsa* **Roxb.**

It is commonly known as the tree of heaven or match splint tree. A species indigenous to India, *A. excelsa* is found throughout the drier tropical and subtropical parts of India (Champian and Seth, 1968). It grows in almost any soil except heavy clay with poor drainage (Singh, 1982). Main use is as leaf fodder for sheep and goat and timber suitable for preparing match boxes and it is in great demand in South India for the match industry (Hocking, 1993).

(ii) ***Ceiba pentandra*** **Gaertn.**

It is native of South America and now it is grown in Jawa, Sri Lanka and India. In Tamil Nadu, it is grown in Salem, Coimbatore, Dharmapuri besides Madurai where it is grown in very large area of about 40,000 ha. It is used as stuffing material for pillow and bed. It is also used for making tennis ball, boxing gloves and shooting suits. Oil is used for making soap.

(iii) ***Emblica officinalis*** **Gaertn.**

It is commonly known as Indian gooseberry or Aonla. It is found scattered in deciduous forests all over India except the desert regions. It is commonly planted for its fruit which are having several medicinal values. The species tolerates a wide variety of soils including mildly alkaline soils (Singh, 1982).

3.2.1.4.3. Goat

A unit of Tellichery goats comprising of five females and one male in the age group of one year was maintained under deep litter system. A floor space of 10-15 sq. ft per goat is essential for rearing under deep litter system (Gopalakrishnan and Lal, 1984). Hence 90 sq. ft floor space was allotted in the goat shed. The goat shed was provided with good ventilation for free flow of air. To conserve dung and urine and to prevent loss of nutrients, coir pith was spread to a height of 15 cm evenly on the floor and it formed the bedding material. Again once in a week, the coir pith was applied over the bedding material at the rate of 20 kg, in order to remove the wetness on the surfaces.

3.2.2. Methods

The present investigation involves three experimental parts. First being the farming system study, non replicated, to identify the suitable component linkage between trees, crops and goat. Second part of the investigation involves identification of suitable establishment technique for the tree seedlings under dryland situation. The third experiment involves the crop component, to identify suitable moisture conservation practice and nitrogen management through recycling of goat manure for economical and sustainable crop productivity under drylands.

Experiment I

3.2.2.1. Farming system experiment

The farming system experiment included three components *viz*., trees, crops and goat. This experiment was carried out for a period of two years from March 1999 to February 2001.

3.2.2.1.1. Choice of components

The components of this investigation was selected based on the economical and suitability under dryland situation. Sorghum being the major crop in drylands of western zone, was selected as a base crop. The existing variety is CO 1, which is low yielding and having longer duration. Further crop failure is common, since the growth phase will not match the water availability period. Hence grain cum fodder type, CO 26 and fodder type CO 27 varieties of sorghum were chosen for the study. To minimise the risk of crop failure, intercropping of cowpea (CO 4) was resorted. To get green fodder throughout the year, the grass component, *C. glaucus* was included in the system. To utilise the off season rainfall and with an aim to obtain additional economical returns in the future the tree component was included. To utilise the family labour and with less investment and to get additional employment and income, the goat component was also included in the study.

3.2.2.1.2. Farming systems treatment

T_1 Conventional cropping system with crop alone

T_2 IFS with crop + *A. excelsa* + Goat

T_3 IFS with crop + *C. pentandra* + Goat

T_4 IFS with crop + *E. officinalis* + Goat

Cropping

Conventional cropping system – Sole sorghum (CO 1) with recommended practices -1.0 ha.

Cropping system in IFS

i.	Sorghum + cowpea (grain crop)	-	0.33 ha
ii.	Sorghum + cowpea (fodder crop)	-	0.33 ha
iii.	*C. glaucus* (for green fodder)	-	0.33 ha
	Goat shed	-	0.01 ha

Trees

Three species of tree *viz., A. excelsa, C. pentandra* and *E. officinalis* were planted at an espacement of 5m x 5m to get equal number of trees and plot size for the cropping experiment, where the interspaces of the trees were utilised for raising the crop component.

Goat

One unit of Tellichery goats having five females and one male were maintained during the first year. Since sufficient quantity of fodder was obtained from the system to maintain 12 number of goats, the additional 7 kids obtained in the first year were retained and maintained during the second year.

Feeding of goat

Adults were fed with the green grass of *C. glaucus* along with fodder cowpea at 4.0 and 1.0 kg, respectively, per adult per day. During Summer, dry fodder of sorghum and cowpea were used as a substitute to meet the feed requirement along with *C. glaucus*.

The kids were fed with doe's milk upto 2 months age. From the third month upto fourth month, 1.0 kg of green grass and 300 g of cowpea fodder were fed to the kids in addition to milk feeding. The kids were weaned on completion of 3 months of age. From fourth month of age upto fifth month, the kids were provided with 2.0 kg of *C. glaucus* and 500 g of cowpea fodder. In fifth month of age 3.0 kg of *C. glaucus* and 750 g of cowpea fodder were fed to each kid. From sixth month of age, full adult ration was provided.

Experiment II

3.2.2.2. Technology for tree seedlings growth and maintenance

3.2.2.2.1. Choice of treatment

Under dryland condition, considerable amount of rainfall is also received during the off season. By utilising the off season rainfall with limited application of water, the tree seedlings establishment techniques were evaluated during Summer. Since evaporation is the major water loss during Summer, mulching around the trees was included to control the evaporation losses. Coir pith, a waste from the coir industry, having less economic value and high water holding capacity, was used as a mulching material. Pitcher irrigation is a method of drip irrigation, which saves irrigation water compared to other methods. Hence, this method was also included to study the suitability in the establishment of tree seedlings.

3.2.2.2.2. Design and layout

The experiment was laid out in split plot design with nine replications. Tree species were allotted to the main plot and mulching and watering methods assigned to sub plots. The field layout plan is given in **Fig. 3**.

N ←

	R1	R1	R2	R2	R3	R3	R4	R4	R5	R5	R6	R6	R7	R7	R8	R8	R9	R9
T_1	M_1P_1	M_1P_2	M_2P_1	M_2P_2	M_1P_2	M_1P_1	M_1P_2	M_1P_1	M_2P_2	M_2P_1	M_1P_2	M_1P_1	M_2P_1	M_2P_2	M_1P_2	M_1P_1	M_2P_2	M_2P_1
T_1	M_2P_2	M_2P_1	M_1P_2	M_1P_1	M_2P_2	M_2P_1	M_2P_1	M_2P_2	M_1P_1	M_1P_2	M_2P_1	M_2P_2	M_1P_2	M_1P_1	M_2P_1	M_2P_2	M_1P_1	M_1P_2
T_2	M_2P_1	M_2P_2	M_1P_2	M_1P_1	M_2P_1	M_2P_2	M_1P_1	M_1P_2	M_2P_2	M_2P_1	M_1P_1	M_1P_2	M_2P_2	M_2P_1	M_1P_2	M_1P_1	M_2P_1	M_2P_2
T_2	M_1P_1	M_1P_2	M_2P_1	M_2P_2	M_1P_2	M_1P_1	M_2P_2	M_2P_1	M_1P_1	M_1P_2	M_2P_2	M_2P_1	M_1P_1	M_1P_2	M_2P_1	M_2P_2	M_1P_2	M_1P_1
T_3	M_2P_2	M_2P_1	M_1P_1	M_1P_2	M_2P_1	M_2P_2	M_1P_2	M_1P_1	M_2P_1	M_2P_2	M_1P_1	M_1P_2	M_2P_1	M_2P_2	M_1P_2	M_1P_1	M_2P_2	M_2P_1
T_3	M_1P_1	M_1P_2	M_2P_2	M_2P_1	M_1P_2	M_1P_1	M_2P_1	M_2P_2	M_1P_2	M_1P_1	M_2P_2	M_2P_1	M_1P_2	M_1P_1	M_2P_2	M_2P_1	M_1P_1	M_1P_2

10 m

5m

Fig.3. Field layout for tree component

3.2.2.2.3. Treatment details

I. Main plot

(i) Tree species

T_1 – *A. excelsa*

T_2 – *C. pentandra*

T_3 – *E. officinalis*

II. Sub plot

(i) Mulching

M_1 – Mulching with coir pith

M_2 – Without mulching

(ii) Watering methods

P_1 – Pitcher irrigation

P_2 – Control

3.2.2.2.4. Land preparation

Prior to the start of the experiment the land was ploughed with disc plough and then the soil was broken by cultivating with tiller. Then the field was levelled. Pits of size 30 x 30 x 30 cm were dug at an espacement of 5m x 5m.

3.2.2.2.5. Planting

One year old seedlings of the trees were planted in the pits and planting was done during the North East Monsoon season of 1998.

Tree species	**Date of planting**
A. excelsa	23.10.98
C. pentandra	23.10.98
E. officinalis	24.11.98

3.2.2.2.6. After care

After planting of tree seedlings, annual crop components were sown in interspaces during the monsoon season. No additional care was given to the tree seedlings.

During the Summer, weeding was done around the trees and the treatments were imposed. Pitcher pots having 5 lit capacity, were installed as per the treatments, 15 cm from the base of the seedlings in the first year of establishment during Summer. Coir pith was applied 50 cm diameter around the trees at the rate of 5 kg as per the treatments assigned. The pitcher pots were filled after draining the entire water once in a week. A common watering was done to all the seedlings once in 15 days in order to maintain the population. Need based plant protection measures were taken to *A. excelsa* to control leaf feeding caterpillar.

Experiment III

3.2.2.3. Experiment on crop management practices – moisture conservation and nutrient management

This study was carried out to evaluate the moisture conservation practices and nutrient management for the cropping systems adopted in the integrated farming systems.

The cropping systems included are

i. S_1 - Sorghum + cowpea (grain crop)

ii. S_2 - Sorghum + cowpea (fodder crop)

ii. S_3 - *C. glaucus*

Crops were grown as intercrops in between the tree seedlings during North East Monsoon season. During the first year of establishment of trees, crops were raised without imposing any treatments. The treatments were imposed to the crops during the second and third year of the establishment of trees.

3.2.2.3.1. Design and layout

The experiment was laid out in split plot design with three replications. Trees and moisture conservation measures were allotted to the main plot and nutrient management practices were tried in sub plots. The field layout plan is given in **Fig. 4**.

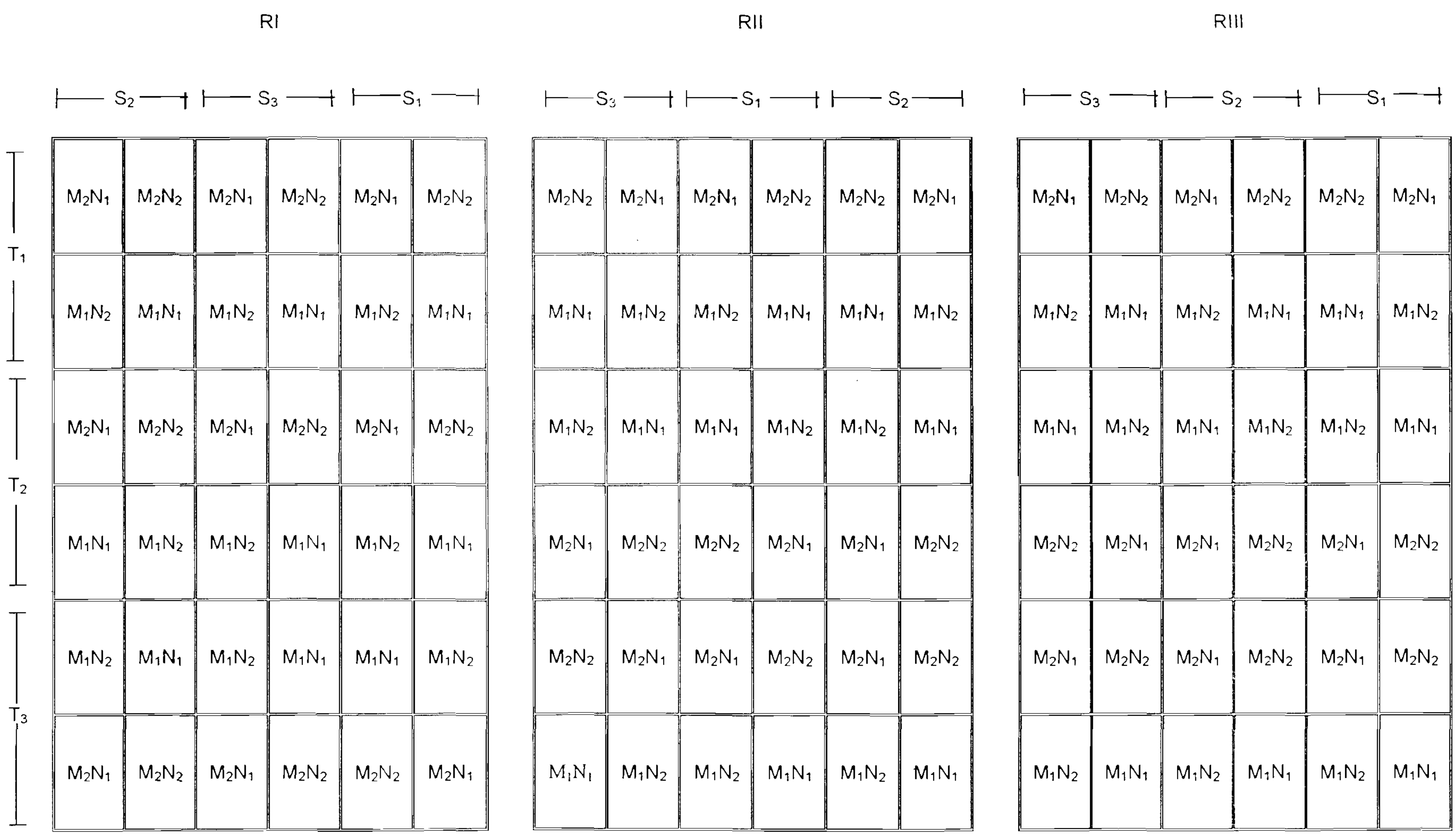


Fig.4. Field layout for crop component

5 m

3.2.2.3.2. Treatment details

The main and sub plot treatments were furnished below

I. Main plot

(i) Tree species

T_1 – *A. excelsa*

T_2 – *C. pentandra*

T_3 – *E. officinalis*

(ii) Moisture conservation practices

M_1 – Tied ridges

M_2 – Flat bed

II. Sub Plot

(i) Nutrient management practices

N_1 – 100 per cent N through fertilizer

N_2 – 50 per cent N through fertilizer + 50 per cent N through goat manure

3.2.2.3.3. Plot size

The plot size adopted for the experiment are given below

Gross plot area	:	10 x 5 m
Net plot area	:	9 x 4 m

3.2.2.3.4. Field preparation

The experimental field was ploughed with tractor drawn disc plough and brought to fine tilth by working with tiller. The plots were marked with pegs. Bunds were formed by using bund former and rectified manually and then again levelled. For *C. glaucus*, at the start of the season, the grass was cut at ground level and then the plots were marked by forming bunds.

3.2.2.3.5. Seeds and sowing

The seeds were soaked in 2 per cent potassium dihydrogen phosphate for six hours and shade dried and then sown in the field. Paired row method (60/30 x 15 cm) of planting was adopted in sorghum + cowpea intercropping. The seeds were sown before the onset of monsoon by dibbling in the levelled plots. Tied ridges were formed at third week after germination as per the treatments. With regard to *C. glaucus*, the rooted cuttings were planted at a spacing of 50 cm between rows and 30 cm between plants. It was established during the first year of planting of tree seedlings, in the North East Monsoon season, 1998.

Crop	Date of sowing		Receipt of first rain		Date of harvest	
	I crop	II crop	I crop	II crop	I crop	II crop
Sorghum (grain)	16.09.1999	12.09.2000	27.09.1999	14.09.2000	20.01.2000	22.01.2001
Cowpea (grain)	16.09.1999	12.09.2000	27.09.1999	14.09.2000	03.01.2000	25.12.2000
Sorghum (fodder)	16.09.1999	12.09.2000	27.09.1999	14.09.2000	16.12.1999	29.11.2000
Cowpea (fodder)	16.09.1999	12.09.2000	27.09.1999	14.09.2000	25.11.1999	10.11.2000

3.2.2.3.6. Manure and fertilizer application

Goat manure was applied basally and incorporated as per the treatment assigned. Recommended dose of nitrogen was adopted to sole inorganic and organic and inorganic combinations.

Table 2. Recommended fertilizer schedule for various crops in the cropping systems

Crops	Fertilizer dose (kg ha^{-1})		
	N	P_2O_5	K_2O
Sorghum (grain)	40	20	-
Sorghum (fodder)	40	20	-
C. glaucus	25	40	20

Nitrogen was applied in two splits, 50 per cent as basal and the remaining 50 per cent at 30 DAS. Entire P was applied basally by making deep lines before sowing. For *C. glaucus* the recommended P_2O_5 and K_2O were applied basally and incorporated.

3.2.2.3.7. After care

Hoeing and weeding were taken up twice. Adequate plant protection measures were given against pest and diseases.

3.2.2.3.8. Harvesting and threshing

For grain component, sorghum earheads were harvested from the net plot, dried and threshed. After cleaning and drying, yield was recorded treatmentwise. Sorghum stalks were sun dried and weighed for recording straw yield. For intercrop cowpea, the pods were harvested after full maturity and threshed, after cleaning and drying, grain yield of cowpea was recorded.

For fodder component, sorghum was harvested at 50 per cent flowering, sun dried in the field itself, weighed for recording fodder yield. Cowpea was harvested at 55 DAS, field dried and the fodder yield was recorded. Both sorghum and cowpea were staked after drying, to feed the goat during lean season.

For *C. glaucus*, the grass was cut at 50 per cent flowering by marking 1.0 m^2 area in the net plot and the green fodder yield was recorded.

3.2.3. Observations

3.2.3.1. Farming system components

3.2.3.1.1. Cropping

3.2.3.1.1.1. Productivity

Productivity in terms of grain and fodder yields were recorded and expressed as kg of sorghum fodder equivalent.

3.2.3.1.1.2. Economic analysis

Parameters like cost of cultivation, gross and net returns were worked out and expressed in Rs. ha^{-1}.

3.2.3.1.1.3. Employment generation

Labour required for different activities were recorded and given in man days ha^{-1} $year^{-1}$. A man working for 8 hours in a day is considered as one man day. A woman working for the same period is treated as 2/3 man days and computed to man days for all purposes.

3.2.3.1.2. Goat

3.2.3.1.2.1. Growth rate

The growth rate of adults and kids were recorded at monthly interval and expressed in kg.

3.2.3.1.2.2. Economics

Economic parameters like cost, gross and net returns were worked out for the goat component and expressed in Rs.

3.2.3.1.2.3. Employment generation

Labour required for management of trees and goat was computed as in the case of crop component and expressed in man days.

3.2.3.1.3. Sorghum fodder equivalents

The productivity of each component was converted into sorghum fodder equivalent yield and expressed as tonnes.

$$\text{Sorghum fodder equivalent (t)} - \frac{\text{Productivity of component(kg) x Cost component (Rs. unit}^{-1})}{\text{Cost of sorghum fodder (Rs. t}^{-1})}$$

3.2.3.1.4. Energy efficiency

Energy input and output were worked out for individual components as per the procedure given by Mittal *et al.* (1985) and Gopalan *et al.* (1976) for the farming systems (**Appendix II**). Based on input and output energies, energy efficiency was also worked out.

3.2.3.1.5. Nutrient balance

Nutrient balance under different farming systems with recycling of goat manure was worked out as per the procedure suggested by Sadanandan and Mahapatra (1973).

$$\text{Nutrient balance} = Y - (X - A) - N$$

Where,

Y = Total amount of nutrients removed by the crops in the sequence

X = Initial soil status of nutrient element.

A = Final soil status of nutrient element.

N = Total quantity of nutrient added through manure and fertilizers.

3.2.3.1.6. Carrying capacity

Based on the quantity of feed available from the system in terms of *C. glaucus* grass equivalent yield in year and requirement of 5 + 1 number of goats, the number of animals can be maintained was worked out and expressed as number of animals.

$$\textit{C. glaucus}\text{ grass equivalent (t)} = \frac{\text{Productivity of component (kg) x Cost of component (Rs.unit}^{-1}\text{)}}{\text{Cost of } \textit{C. glaucus}\text{ (Rs.t}^{-1}\text{)}}$$

3.2.3.2. Trees

3.2.3.2.1. Height

Tree height was recorded from the ground level to the tip of the highest branch and expressed in m.

3.2.3.2.2. Basal diameter

The diameter was measured at 10 cm above the ground level and expressed in cm.

3.2.3.2.3. Soil moisture

Soil moisture content was estimated gravimetrically at 0-15 and 15-30 cm depth around the tree base and expressed in per cent. The samples were drawn with the help of screw auger before filling of pots once in a month.

3.2.3.2.4. Soil temperature

Soil temperature was recorded at 15 and 30 cm depth before watering with the help of soil thermometer once in a month before filling of pots and expressed in °C.

3.2.3.3. Cropping systems

3.2.3.3.1. Growth parameters

3.2.3.3.1.1. Plant height

The sorghum plant height was measured from the ground level to the tip of the top most leaf or earhead. The plant height was measured at 30, 60, 90 DAS and at harvest for grain sorghum and 30, 60 DAS and at harvest for fodder sorghum. In case of cowpea, the height from the ground level to the tip of the terminal bud was measured and given in cm. The height was measured at 30, 60 DAS and at harvest in grain cowpea and 30 DAS and at harvest in fodder cowpea.

3.2.3.3.1.2. Leaf area index

Leaf area per plant was measured by using the leaf area meter (LI-COR-Model LI-3000) at 60 DAS in case of grain sorghum, fodder sorghum and grain cowpea and at harvest in case of fodder cowpea. Leaf area index was worked out by dividing the total leaf area of the plant by the area occupied by the individual plant.

3.2.3.3.1.3. Dry matter production

The plant samples were collected randomly by cutting close to the ground level from the sampling rows of each plot. They were first air dried, then oven dried at 60°C till a constant weight was obtained and the dry matter was expressed in kg ha^{-1} at 30, 60, 90 DAS and at harvest in grain sorghum, 30, 60 DAS and at harvest in fodder sorghum, and grain cowpea and 30 DAS and at harvest in fodder cowpea.

3.2.3.3.2. Yield components of sorghum

3.2.3.3.2.1. Length of earhead

The length of earhead from the base of the lower primary rachis to the tip of the earhead was measured in cm.

3.2.3.3.2.2. Number of grains per earhead

Five randomly selected earheads from each plot were taken and threshed separately and number of grains in each earhead was counted.

3.2.3.3.2.3. Test weight

One thousand grains from each plot were counted, weighed and expressed in g.

3.2.3.3.3. Yield

3.2.3.3.3.1. Grain yield

Earheads from each net plot were dried, threshed and the weight of cleaned grain at 14 per cent moisture was recorded and expressed as kg ha^{-1}.

3.2.3.3.3.2. Straw yield

The stalks were cut at ground level, sundried and the dry weight was recorded for each plot and expressed in kg ha^{-1}.

3.2.3.3.4. Yield components of cowpea

3.2.3.3.4.1. Number of pods per plant

Pod numbers from five tagged plants were counted and the mean number was calculated.

3.2.3.3.4.2. Number of seeds per pod

Five pods from each tagged plant were selected and total number of seeds were counted and the mean number of seeds per pod was calculated.

3.2.3.3.4.3. Pod length

Five pods from each tagged plant was selected and the pod length was measured and the mean pod length was expressed as cm.

3.2.3.3.4.5. Test weight of grain

One hundred seeds randomly selected from each treatment weighed and expressed in g.

3.2.3.3.5. Yield of cowpea

3.2.3.3.5.1. Grain yield

Grain yield from each net plot area was recorded at 14 per cent moisture and expressed in kg ha^{-1}.

3.2.3.3.5.2. Haulm yield

After final picking of pods, the plants were cut at ground level allowed to dry in the field and weight of dried haulms per plot was recorded and expressed in kg ha^{-1}.

3.2.3.3.6. Grass yield of *C. glaucus*

The grass was cut at 50 per cent flowering and the green fodder yield was recorded and expressed as t ha^{-1}.

3.2.4. Soil moisture

Soil samples were collected at weekly interval from the treatments with the help of screw auger at 0-15 cm and 16-30 and 31-45 cm depth from $42^{nd}/43^{rd}$ standard week upto harvest. The soil moisture was estimated by gravimetric method.

3.2.5. Chemical analysis

Chemical analysis of the samples from the experiment was done as follows.

3.2.5.1. Soil analysis

Soil samples were collected before the start of the experiment and after the harvest of each crop and analysed for the available N, P and K as per the methods indicated in Table 3.

3.2.5.2. Plant analysis

The plant samples used for dry matter accumulation were ground into fine powder in a Willey mill. The powdered material was used for estimating the nutrient content. N, P and K uptake was computed by multiplying the nutrient content by dry matter production and expressed in kg ha^{-1}. The plant samples for N, P and K were analysed as per the standard procedures described in **Table 3**.

3.2.5.3. Manure analysis

Content of N, P and K in the manure obtained from the deep litter system was analysed as per the procedure described in **Table 3**.

Table 3. Details of analytical methods adopted in soil, manure and plant analysis

	Name of the estimation	Author(s)
I	**Soil and manure analysis**	
	Available nitrogen	Subbiah and Asija (1956)
	Available phosphorus	Olsen *et al* (1954)
	Available potassium	Stanford and English (1949)
	Total nitrogen	Piper (1966)
	Total phosphorus	Pemberton (1945)
	Total potassium	Stanford and English (1949)
II	**Plant analysis**	
	Nitrogen	Humphries (1956)
	Phosphorus	Jackson (1973)
	Potassium	Jackson (1973)

3.2.6. Crude protein yield

From the nitrogen content of sorghum, cowpea and *C. glaucus* the crude protein content of dry fodder was estimated, using the factor 6.25. Crude protein yield for different cropping systems was worked out and expressed as kg ha^{-1}.

3.2.7. Nutrient balance in the cropping systems

Soil available nutrient balance in the cropping system was computed for different treatments as per the procedure suggested by Sadanandan and Mahapatra (1973).

3.2.8. Sorghum fodder equivalent yield

The productivity of each cropping system was converted into sorghum fodder equivalent yield and expressed as tonnes.

3.2.9. Statistical analysis

The data on various characters studied were statistically analysed as suggested by Gomez and Gomez (1984). Wherever the treatment difference was found the critical difference were worked out at five per cent probability level.

RESULTS

CHAPTER IV

RESULTS

A field survey was conducted in western zone of Tamil Nadu to understand the existing farming and to identify the production constraints under dryland situation. Based on the survey, the field experiments were conducted during 1999 and 2000 to develop suitable integrated farming system for the dryland vertisol areas of western zone of Tamil Nadu. The results are presented in this chapter.

PART - I

4.1. Field survey on existing farming practices

4.1.1. Average land holding (Table 4)

Among the 50 sample farmers 70 per cent were small and the rest of 30 per cent were large. The average land holding in Avinashi block was 3.16 and 7.85 ac in small and large farmers respectively whereas it was 3.79 and 8.13 ac in case of Palladam block.

4.1.2. Literacy status (Table 5)

In Avinashi block, among the small farmers, 38.8 per cent had secondary education. 33.3 per cent of the farmers had primary education and only 16.6 per cent were illiterate. About 11.1 per cent of the farmers had higher education up to graduation. With respect to large farmers, most of them had primary education (57.1 per cent) followed by secondary education (28.8 per cent) and 14.3 per cent of them were illiterate. None of the farmers had education above secondary level.

In Palladam block, most of the small farmers had primary education (52.9 per cent), 23.5 per cent of the farmers were illiterate and only 5.8 per cent had education up to graduate level. With regard to large farmers, 50 per cent of the farmers had primary education and 37.5 per cent had secondary education. Only 12.5 per cent were illiterate.

Table 4. Distribution of farmers and average land holding according to the size group

	Avinashi			Palladam		
	No. of farmers	Per cent to total no. of farmers	Average land holding	No. of farmers	Per cent to total no. of farmers	Average land holding
Small farmer (1-5 ac)	18	72	3.16	17	68	3.79
Large farmer (>5 ac)	7	28	7.85	8	32	8.13

Table 5. Literacy status of the respondents (per cent) according to the size group

	Avinashi					Palladam				
	I	P	S	HS	G	I	P	S	HS	G
Small farmer (1-5 ac)	16.6	33.3	38.8	0.0	11.1	23.5	52.9	17.6	0.0	5.8
Large farmer (>5 ac)	14.3	57.1	28.8	0.0	0.0	12.5	50.0	37.5	0.0	0.0

I – Illiterate, P – Primary, S – Secondary, HS – Higher secondary, G - Graduate

4.1.3. Existing enterprises (Table 6)

With regard to the enterprises as practiced by the farmers, 100 per cent of the respondents both in small and large farmers cultivated annual crops and it constituted the main enterprise. The next predominant enterprise was livestock. In Avinashi block, 77.8 and 71.5 per cent of the small and large farmers maintained cow whereas in Palladam block, 100 per cent of the small and large farmers had cow. Buffaloes were maintained only in Avinashi block, whereas none of the sample farmers owned buffaloes in Palladam. Next to cow, goat rearing was major enterprise both in Avinashi and Palladam. In Avinashi block, 22.2 per cent of the small farmers and 42.8 per cent of the large farmers reared goat, whereas it was 17.6 and 12.5 per cent, respectively in Palladam block. Sheep rearing was the minor enterprise.

With regard to agroforestry, in Avinashi block, 16.6 per cent of the small farmers adopted perennial trees whereas none of the large farmers had tried the agroforestry in their farms. In Palladam block, 5.8 and 25 per cent of the small and large farmers had tree component in their farm. So, the tree planting was adopted by large number of farmers in Palladam block compared to Avinashi block.

4.1.4. Cropping pattern (Table 7)

In Avinashi block, cotton and sorghum were the important crops under rainfed condition. Pulses were grown in very limited area (in cents) for the household purposes. Among cotton and sorghum, sorghum was grown predominantly and the average area was 2.36 and 4.86 ac in small and large farmers, respectively. Cotton was grown only in black soil areas and the average area under cotton were 1.60 and 4.38 ac, respectively under small and marginal farmers.

In Palladam block, sorghum was the only dominant crop. Average area under sorghum was 3.44 and 6.38 ac, respectively in small and large farms. Hence, sorghum was the predominant crop under both blocks under dryland condition.

Table 6. Percentage of farmers possessing different enterprises according to size group

Enterprises	Avinashi		Palladam	
	Small farmer	Large farmer	Small farmer	Large farmer
Crop	100	100	100	100
Cow	77.8	71.5	100	100
Buffalo	22.2	28.5	-	-
Goat	22.2	42.8	17.6	12.5
Sheep	5.5	-	-	-
Agroforestry	16.6	-	5.8	25

Table 7. Cropping pattern and average area under different crops according to the size group

	Avinashi					
	Cotton			Sorghum		
	No. of farmers	Total area (ac)	Average Area (ac)	No. of farmers	Total area (ac)	Average Area (ac)
Small farmers (1-5 ac)	7	11.25	1.60	16	37.75	2.36
Large farmers (>5 ac)	4	17.50	4.38	7	34.00	4.86
	Palladam					
	Sorghum			Horsegram		
	No. of farmers	Total area (ac)	Average Area (ac)	No. of farmers	Total area (ac)	Average Area (ac)
Small farmers (1-5 ac)	17.	58.50	3.44	-	-	-
Large farmers (>5 ac)	8	51.00	6.38	1	5.00	5.00

4.1.5. Existing farming practices for crop production (Table 8 and 9)

With regard to the practices adopted by the dryland farmers, 100 per cent of the large farmers in both blocks, 88 per cent of the small farmers in Avinashi and 94 per cent of the small farmers in Palladam adopted the traditional long duration sorghum variety CO 1, whereas only 6 per cent of the small farmers in Palladam and 12 per cent of the same group in Avinashi cultivated the improved varieties CO 26 and K tall. A thick seed rate of 20-25 kg ac^{-1} was adopted by all the respondents in both size groups of two blocks. Broad casting was the common method of sowing by using tractor or country plough. Required spacing was not adopted. Available quantity of manure in their own farm was applied once in three or four years. None of the farmers in both size groups applied chemical fertilizers and no moisture conservation practices were adopted.

With regard to the yield of sorghum, the farmers obtained an average grain yield of 220 and 190 kg ha^{-1} in small and large farms, respectively. The straw yield was 3.00 and 3.03 t ha^{-1} in small and marginal farmers. On an average the farmers obtained 205 kg of grain and 3.02 t of fodder from one ha of land area.

4.1.6. Livestock enterprise (Table 10 and 11)

With regard to the livestock maintenance, almost all the farmers in both size groups owned cattle. The cattle population was more than goat or sheep in both size groups. About 91.0 per cent of the small farmers and 86.7 per cent of the large farmers expressed that, they maintained cattle mainly to utilise the available labour profitably. Similarly, 97.1 and 93.3 per cent of the small and marginal farmer responded that they got some income from sale of milk and calves. The fodder grown by the farmers was not sufficient to meet all their requirements.

Table 8. Existing practices adopted by the farmers according to the size group

Practices	Avinashi		Palladam	
	Small farmers	Large farmers	Small farmers	Large farmers
Summer ploughing	NA	NA	NA	NA
Variety				
(i) Traditional (CO 1)	88 per cent	100 per cent	94 per cent	100 per cent
(ii) Improved (CO 26 & K-tall)	12 per cent	-	6 per cent	-
Seed rate	20 –25 kg ac^{-1}	20 – 25 kg ac^{-1}	20 – 25 kg ac^{-1}	20 – 25 kg ac^{-1}
Sowing	BC	BC	BC	BC
Spacing	NA	NA	NA	NA
Manuring	Available quantity applied once in 3-4 years			
Fertilizer	NA	NA	NA	NA
Moisture conservation practices	NA	NA	NA	NA

NA – Not adopted

BC – Broad cast method

Table 9. Average yield of sorghum (CO 1) under different size groups

	Avinashi		Palladam		Average	
	Grain (kg ha^{-1})	Straw (t ha^{-1})	Grain (kg ha^{-1})	Straw (t ha^{-1})	Grain (kg ha^{-1})	Straw (t ha^{-1})
Small farmers (1 – 5 ac)	238	2.98	200	3.00	220	3.00
Large farmers (>5 ac)	168	3.30	213	2.73	190	3.03

Table 10. Average number of animals in the farm according to size group

	Cattle	Goats
Small farmers (1 – 5 ac)	1.54	0.17
Large farmers (>5 ac)	2.10	0.46

Table 11. Purpose of livestock maintenance (per cent of the respondents)

	To match with fodder availability	To meet out the manure requirement of the farm	To utilise family labour	To get income
Small farmers (1 – 5 ac)	8.5	4.3	91.0	97.1
Large farmers (>5 ac)	6.7	4.7	86.7	93.3

Table 12. Percentage of the respondents adopted tree component in their farm

	Avinashi	Palladam	Average
Small farmers (1 – 5 ac)	16.6	5.8	11.2
Large farmers (>5 ac)	0.0	25	12.5

Table 13. Reason for lack of adoption of trees in the farm (per cent of the respondents)

	Lack of maintenance	To produce fodder for livestock	Non availability of seedlings	Water scarcity
Small farmers (1 – 5 ac)	62.3	20.0	0.0	97.1
Large farmers (>5 ac)	66.6	53.3	0.0	100.0

4.1.7. Trees in the farming system (Table 12 and 13)

With regard to the cultivation of perennial trees, 11.2 per cent of the small farmers have raised tree species such as tamarind and mango in their field. About 12.5 per cent of the large farmers had grown coconut, tamarind, *Casuarina* and curry leaf in areas of adequate water supply.

The major reason cited by the respondents for not growing trees was water scarcity during lean season followed by difficulties experienced at the earlier year of tree growth since the areas are opened to free grazing by cattle especially during lean seasons without any field crops. However, most of the farmers had few naturally grown trees of *Acacia leucophloea* and *Ailanthus excelsa.*

PART II

4.2. Field Experiment

Experiment 1

4.2.1. Component Linkage in dryland farming systems

Field studies were carried out for two years (1999 and 2000) to evaluate suitable integrated farming system under drylands with integration of components *viz*., crop, trees and goat in non replicated trials. The results on productivity, economics, employment generation, energy budgeting, nutrient balance of the different integrated farming systems tried are presented below.

4.2.1.1. Productivity (Table 14)

Productivity of the different components integrated in each system was converted as sorghum fodder equivalent yield based on the existing unit cost of the produce of each component. Since the trees were only in initial stage, their wood value was very meagre and so the productivity of the tree component was not accounted in the total productivity of the system. Productivity of the systems by integration of cropping with different tree

Table 14. Productivity (sorghum fodder equivalent) of integrated farming systems

Farming systems		Component productivity (tonnes)								
		1999			2000			Mean		
		Crop	Goat	Total	Crop	Goat	Total	Crop	Goat	Total
FS_1 – Conventional cropping - 1.0 ha		9.09	-	9.09	3.59	-	3.59	6.34	-	6.34
FS_2 – *Ailanthus excelsa* + crop + goat	CS_1	9.79			3.31			6.55		
	CS_2	3.93			2.54			3.24		
	CS_3	3.76			3.14			3.45		
	Goat	-	14.1		-	22.6		-	18.35	
	Total	**17.48**	**14.1**	**31.58**	**8.99**	**22.6**	**31.59**	**13.24**	**18.35**	**31.59**
FS_3 – *Ceiba pentandra* + crop + goat	CS_1	8.62			3.41			6.02		
	CS_2	3.80			2.50			3.15		
	CS_3	3.74			3.12			3.43		
	Goat	-	14.1		-	22.6		-	18.35	
	Total	**16.16**	**14.1**	**30.26**	**9.03**	**22.6**	**31.63**	**12.60**	**18.35**	**30.95**
FS_4 – *Emblica officinalis* + crop + goat	CS_1	9.78			3.83			6.81		
	CS_2	4.01			2.97			3.49		
	CS_3	3.74			3.15			3.45		
	Goat		14.1		-	22.6		-	18.35	
	Total	**17.53**	**14.1**	**31.63**	**9.95**	**22.6**	**32.55**	**13.75**	**18.35**	**32.10**

CS_1 - Grain sorghum + cowpea - 0.33 ha
CS_2 - Fodder sorghum + cowpea - 0.33 ha
CS_3 - *Cenchrus glaucus* - 0.33 ha
Goat - 0.01 ha

species along with goats was compared with conventional cropping *viz.*, sole sorghum. The results revealed that integration of cropping with goats resulted in higher productivity than sole sorghum in both the years. Highest productivity of 32.10 t of sorghum fodder equivalent yield was obtained with intercropping of different crops in *Emblica officinalis* with the integration of goats and recycling of goat manure to the crops in the cropping system.

The cropping systems in the integrated farming system tried *viz.*, sorghum + cowpea (grain), sorghum + cowpea (fodder) and *Cenchrus glaucus* totally contributed 54.8 per cent of the total productivity whereas goat component contributed 45.2 per cent during first year. In the second year, the productivity of cropping systems was 29.2 per cent and the goat was 70.8 per cent to the total productivity.

4.2.1.1.1. Productivity of cropping

With regard to the productivity of individual components, cropping with *A. excelsa* produced 92.3 and 150 per cent higher productivity than sole sorghum during 1999 and 2000, respectively. With regard to *Ceiba pentandra* the increase in productivity was 77.8 and 151.0 per cent during first and second year, respectively. Cropping with *E. officinalis* recorded 92.8 and 177.2 per cent increased productivity over sole sorghum during 1999 and 2000, respectively. Among the tree species cropping with *E. officinalis* recorded higher productivity (17.53 and 9.95 t during 1999 and 2000 respectively) than the other tree species.

Contribution of goats to the total productivity of the farming systems was 14.1 and 22.6 t of sorghum fodder equivalent yield during 1999 and 2000, respectively.

4.2.1.1.2. Productivity of goat component (Table 15 and 16)

The total live weight of the six Tellicherry goats increased from 102 kg to 142.8 kg during first year and from 142.8 to 165.5 kg during the second year. The average gain in

Table 15. Live weights and growth rates of adult goats

Period	1999			2000		
	Live weight (kg)	Increase in live weight (kg)	Daily gain per adult (g)	Live weight (kg)	Increase in live weight (kg)	Daily gain per adult (g)
1999						
March	102.000	-	-	145.000	2.200	12.2
April	104.000	2.000	11.1	146.300	1.300	7.2
May	106.000	2.000	11.1	147.600	1.300	7.2
June	108.300	2.300	12.8	148.800	1.200	6.7
July	111.000	2.700	15.0	150.000	1.200	6.7
August	114.000	3.000	16.7	151.200	1.200	6.7
September	117.800	3.800	21.1	152.500	1.300	7.2
October	122.000	4.200	23.3	154.300	1.800	10.0
November	127.000	5.000	27.8	157.000	2.700	15.0
December	132.300	5.300	29.4	160.000	3.000	16.7
2000						
January	138.000	5.700	31.7	162.900	2.900	16.1
February	142.800	4.800	26.7	165.500	2.600	14.4

Table 16. Live weight and growth rate of kids

Period	1999				2000			
	No. of kids	Live weight (kg)	Increase in live weight (kg)	Daily gain per kid (g)	No. of kids	Live weight (kg)	Increase in live weight (kg)	Daily gain per kid (g)
1999								
March	-	-	-	-	7	68.000	9.900	55.3
April	-	-	-	-	7	76.000	8.000	37.3
May	-	-	-	-	9	88.000	12.000	33.3
June	-	-	-	-	9	99.000	11.000	33.3
July	4	10.000	-	-	9	109.800	10.750	25.0
August	5	14.800	4.800	32.0	9	120.800	11.050	25.0
September	5	20.000	5.200	34.7	9	131.900	11.100	24.9
October	5	25.400	5.400	36.0	9	143.200	11.300	24.5
November	5	31.000	5.600	37.3	9	154.500	11.300	23.5
December	7	40.100	9.100	40.4	12	172.500	18.000	24.0
2000								
January	7	50.600	10.500	41.5	12	186.300	13.850	24.4
February	7	58.100	7.500	45.7	16	210.000	23.700	24.5

live weight per day per adult was 20.6 g and 10.5 g during first and second year, respectively. In general, the per day weight gain was higher during October to December than during other months of the year.

Seven kids were born during first year. The total live weight contributed by the seven kids were 58.1 kg at the end of the year. These kids were maintained along with adult goats during second year. Hence the total number of kids delivered by 5+1 number of goat unit was 16 at the end of second year. The total live weight of 16 kids at the end of second year was 210 kg. The rate of gain in weight per day per kid ranged from 32.0 g to 24.5 g at the end of the study.

4.2.1.2. Economics (Table 17 and 18)

Economic analysis of individual components revealed that, the gross return was higher in intercropping with tree species as compared to sole sorghum. The gross returns from the cropping system were higher during first year than the second year. With regard to net return, the highest net return was recorded with cropping with *E. officinalis* (Rs.2096). The gross and net returns for goat component were Rs.13111 and Rs.995 and Rs.12527 and Rs.2123 for the first and second year, respectively.

With regard to the economics of integrated farming systems, the highest gross return (Rs.20470) and net return (Rs.3091) were recorded in the cropping systems with *E. officinalis* along with integration of goat component during first year. The lowest gross and net returns were recorded with sole sorghum (Rs.3816 and Rs.198). Cropping with *E. officinalis* or *A. excelsa* with goat recorded the highest B:C ratio of 1.18 during first year. During second year the highest gross and net return and B:C ratio (Rs.16536, Rs.1143 and 1.07, respectively) were recorded in cropping with *E. officinalis* with goat component.

Table 17. Economic analysis of individual components in integrated farming systems

Farming systems		1999			2000		
		Cost of production (Rs.)	Gross return (Rs.)	Net return (Rs.)	Cost of production (Rs.)	Gross return (Rs.)	Net return (Rs.)
FS_1 – Conventional cropping (1.0 ha)		3618	3816	198	3618	1509	-2109
FS_2 – *A. excelsa* + crop (0.99 ha)							
	CS_1	2230	4112	1882	2230	1391	-839
	CS_2	1569	1650	81	1569	1067	-502
	CS_3	1464	1577	113	1190	1321	131
	Total	5263	7339	2076	4989	3779	-1210
FS_3 – *C. pentandra* + crop (0.99 ha)							
	CS_1	2230	3621	1391	2230	1432	-798
	CS_2	1569	1595	26	1569	1048	-521
	CS_3	1464	1571	107	1190	1308	118
	Total	5263	6787	1524	4989	3788	-1201
FS_4 – *E. officinalis* + crop (0.99 ha)							
	CS_1	2230	4106	1876	2230	1503	-729
	CS_2	1569	1682	113	1569	1183	-386
	CS_3	1464	1571	107	1190	1323	133
	Total	5263	7359	2096	4989	4009	-980
Goat (0.01 ha)		12116	13111	995	10404	12527	2123

CS_1 - Grain sorghum + cowpea - 0.33 ha
CS_2 - Fodder sorghum + cowpea - 0.33 ha
CS_3 - *Cenchrus glaucus* - 0.33 ha

Table 18. Economic analysis of integrated farming systems

Farming systems	1999				2000			
	Cost of production (Rs. ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	B : C ratio	Cost of production (Rs. ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	B : C ratio
FS_1 – Conventional cropping	3618	3816	198	1.05	3618	1509	-2109	0.42
FS_2 – *A. excelsa* + crop + goat	17379	20450	3071	1.18	15393	16306	913	1.06
FS_3 – *C. pentandra* + crop + goat	17379	19898	2519	1.14	15393	16315	922	1.06
FS_4 – *E. officinalis* + crop + goat	17379	20470	3091	1.18	15393	16536	1143	1.07

4.2.1.3. Employment generation (Table 19)

Farming with sole sorghum provided employment for 37 man days ha^{-1} yr^{-1} whereas the cropping systems in integrated farming system generated 44 man days ha^{-1} yr^{-1} during first year and 40 man days ha^{-1} yr^{-1} during second year. Integration of trees generated additional employment opportunity for 17 man days ha^{-1} yr^{-1}. Inclusion of goat component generated employment opportunity for 23 man days during first year and 35 man days during second year. Additional employment of 47 and 55 man days during first and the second year generated through integrated farming systems provided opportunity for the employment of family labour who were idle during the lean season.

Of the total employment generated by the integrated farming system, crop contributed 52.4 per cent and the contribution of trees and goat were 20.2 and 27.4 per cent, respectively in the first year. During second year, the contribution of crop, tree and goat components were 43.5, 18.5 and 38.0 per cent, respectively.

4.2.1.4. Energy budgeting (Table 20 and 21)

Among different systems, cropping with *E. officinalis* with the integration of goat component recorded higher energy output of 76760 and 58144 MJ during 1999 and 2000, respectively. The energy efficiency was also higher in this system. Contribution of individual components in the output energy revealed that cropping and goat recorded 98.7 and 1.3 per cent during first year and 96.8 and 3.2 per cent during second year. However, sole sorghum resulted in higher energy efficiency (14.01 per cent).

4.2.1.5. Nutrient balance through manure recycling (Table 22)

Manure obtained from the deep litter system was 3525 and 6837 kg during first and second year, respectively. The nutrient content of the goat manure from the deep litter system was 1.72 per cent N, 0.97 per cent P_2O_5 and 0.86 per cent K_2O.

Table 19. Employment generation (man days) of integrated farming systems

Farming systems	1999				2000			
	Crop	Tree	Goat	Total	Crop	Tree	Goat	Total
FS_1 – Conventional cropping	37	-	-	37	37	-	-	37
FS_2 – *A. excelsa* + crop + goat	44	17	23	84	40	17	35	92
FS_3 – *C. pentandra* + crop + goat	44	17	23	84	40	17	35	92
FS_4 – *E. officinalis* + crop + goat	44	17	23	84	40	17	35	92

Crop {
- CS_1 - Grain sorghum + cowpea - 0.33 ha
- CS_2 - Fodder sorghum + cowpea - 0.33 ha
- CS_3 - *Cenchrus glaucus* - 0.33 ha

Table 20. **Input and output energy (MJ) of the components in the integrated farming systems**

Farming systems		Input energy (MJ)		Output energy (MJ)	
		1999	2000	1999	2000
FS_1-Conventional cropping		3190	3190	61795	44900
FS_2 – *A. excelsa* + crop					
	CS_1	853	853	22094	13802
	CS_2	837	837	36615	24066
	CS_3	842	830	15347	13045
FS_3 – *C. pentandra* + crop					
	CS_1	853	853	18856	14313
	CS_2	837	837	33147	23502
	CS_3	842	830	15343	12810
FS_4 – *E. officinalis* + crop					
	CS_1	853	853	23938	15352
	CS_2	837	837	36417	27928
	CS_3	842	830	15413	12979
Goat		41384	84432	992	1855

CS_1 - Grain sorghum + cowpea - 0.33 ha
CS_2 - Fodder sorghum + cowpea - 0.33 ha
CS_3 - *Cenchrus glaucus* - 0.33 ha

Table 21. Energy budgeting in integrated farming systems

Farming systems	1999			2000		
	Input energy (MJ)	Energy output (MJ)	Energy efficiency	Input energy (MJ)	Energy output (MJ)	Energy efficiency
FS_1 – Conventional cropping	3190	61795	19.37	3190	44900	14.01
FS_2 – *A. excelsa* + crop + goat	43916	75048	1.71	86952	52768	0.61
FS_3 – *C. pentandra* + crop + goat	43916	68338	1.56	86952	52480	0.60
FS_4 – *E. officinalis* + crop + goat	43916	76760	1.75	86952	58144	0.67

Table 22. Nutrient balance through manure recycling

Farming systems		1999			2000		
		Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})
FS_1-Conventional cropping (1.0 ha)		-15.90	-12.10	13.20	-6.30	-11.60	12.00
FS_2 – *A. excelsa* + crop + goat (0.99 ha)	CS_1	7.59	-1.85	17.16	9.57	-3.73	15.35
	CS_2	8.09	-2.01	30.20	5.78	-3.14	28.88
	CS_3	1.65	-2.01	9.41	2.64	-1.75	14.19
FS_3 – *C. pentandra* + crop + Goat (0.99 ha)	CS_1	7.92	-2.84	10.73	4.79	-3.66	14.19
	CS_2	4.46	-4.06	24.09	2.64	-3.33	30.01
	CS_3	0.50	-2.24	5.12	1.82	-2.28	8.09
FS_4 – *E. officinalis* + crop + Goat (0.99 ha)	CS_1	8.25	-1.55	23.76	13.37	-3.33	19.64
	CS_2	9.74	-1.85	30.03	10.40	-2.48	31.52
	CS_3	1.16	-1.88	8.25	2.81	-1.85	12.71

Crop:
- CS_1 - Grain sorghum + cowpea - 0.33 ha
- CS_2 - Fodder sorghum + cowpea - 0.33 ha
- CS_3 - *Cenchrus glaucus* - 0.33 ha

Recycling of goat manure to substitute 50 per cent of the recommended nitrogen resulted in gain in N content of the soil as compared to the sole sorghum with inorganic fertilizer alone. Among the different cropping systems with tree species the gain in N content was more with *E. officinalis* with cropping as compared to other tree species.

The loss in the P content of the soil was lesser in the cropping systems adopted in integrated farming as compared to the sole sorghum. Among the tree species with cropping in the farming systems, the loss of P was more with *C. pentandra* than the other tree species. Gain in K content of the soil was higher in the cropping systems adopted in farming systems as compared to sole sorghum in both the years. Among the tree species with cropping, the gain in K content was higher with intercropping in *E. officinalis* followed by *A. excelsa.*

4.2.1.6. Carrying capacity (Table 23)

The data revealed that the fodder availability was higher in the integrated farming system (24.196 and 13.03 t during first and second year, respectively) as compared to the sole sorghum alone (10.60 and 4.19 t, respectively in first and second year). The carrying capacity was worked out to 12 and 7 number of goats during first and second year, respectively in integrated farming system whereas it was 5 and 2 goats in the conventional cropping *viz.* sole sorghum.

Experiment – II

4.2.2. Technology for tree seedlings growth and maintenance

To identify suitable practices for tree seedlings growth and maintenance under dryland situation, moisture conservation and watering methods were evaluated in three different tree species. The results on the height, basal diameter of the tree seedlings, influences on soil moisture and soil temperature are presented below.

Table 23. Carrying capacity in integrated farming systems

I. Feed requirement for 5+1 goat unit		
Cenchrus glaucus	8760 kg $year^{-1}$	
Cowpea	2190 kg $year^{-1}$	
II. Fodder availability in different cropping systems in integrated farming systems [in grass equivalent yield (t ha^{-1})]		
	1999	2000
Sorghum + cowpea (grain)	12.446	4.435
Sorghum + Cowpea (fodder)	7.373	4.881
Cenchrus glaucus	4.373	3.714
Total	24.196	13.030
III. Grass equivalent yield in conventional cropping (t ha^{-1})	10.60	4.19
IV. No. of goats can be maintained		
Integrated farming system	12	7
Conventional cropping system	5	2

4.2.2.1. Height (Table 24 and 25)

The data on height of tree seedlings during Summer1999 revealed that, there was significant influence in the height of tree seedlings with regard to the trees, moisture conservation and watering methods. Among the trees *E. officinalis* (T_3) recorded higher tree height than other trees. Mulching with coir pith (M_1) was superior in increasing the tree height over unmulched trees. Pitcher irrigation (P_1) increased the height of tree seedlings significantly over without pitcher irrigation (P_2) . Among the trees the increase in height was the highest (16.6 cm) with *E. officinalis* followed by *C. pentandra.* Coir pith mulching recorded higher tree height increase (11.3 cm) than unmulched trees. The height increase was higher (12.5 cm) with pitcher (P_1) than without pitcher irrigation (P_2).

The same trend was recorded during Summer 2000 also.

There was significant interaction between the treatment combinations in both the seasons. Among the treatment combinations, *E. officinalis* with coir pith mulching and pitcher irrigation ($T_3M_1P_1$) recorded greater height than the other treatment combinations **(Appendix III)**.

With regard to the height of tree seedlings during the North East Monsoon 1999, the tree height was greater with *E. officinalis* (T_3) followed by *C. pentandra* and *A. excelsa*. The increase in the height of tree seedlings was higher during the North East Monsoon 1999 than North East Monsoon 2000. Significant influence on the height of tree seedlings were recorded with trees, moisture conservation and watering methods during 1999. Among the trees, *E. officinalis* (T_3) recorded greater height than other trees. Height of tree seedlings was significantly increased by coir pith mulching and also with pitcher irrigation.

Similar trend was noticed during North East Monsoon 2000 also.

Table 24. Effect of treatments on height (cm) of tree seedlings (Summer 1999 and 2000)

Treatment	Summer 1999			Summer 2000		
	7 months after planting	9 months after planting	Increase in height (cm)	19 months after planting	21 months after planting	Increase in height (cm)
T_1	33.2	40.7	7.5	78.5	85.3	6.8
T_2	46.3	54.2	7.9	129.3	137.8	8.5
T_3	72.2	88.8	16.6	211.8	227.0	15.2
SE_d	0.29	0.34		0.32	0.51	
CD (P=0.05)	0.61	0.72		0.68	1.09	
M_1	51.1	61.9	11.3	148.8	163.6	14.8
M_2	50.0	60.5	10.0	130.9	136.4	5.5
SE_d	0.22	0.26		0.32	0.25	
CD (P=0.05)	0.43	0.52		0.64	0.49	
P_1	49.6	62.9	12.5	158.9	172.8	13.9
P_2	51.5	59.5	8.8	120.8	127.3	6.5
SE_d	0.22	0.26		0.32	0.25	
CD (P=0.05)	0.43	0.52		0.64	0.49	

	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD
T x M	0.39	0.80	0.47	0.96	0.51	1.04	0.59	1.24
M x T	0.38	0.75	0.45	0.90	0.56	1.11	0.43	0.85
T x P	0.39	NS	0.47	0.96	0.51	1.04	0.59	1.24
P x T	0.38	NS	0.45	0.90	0.56	1.11	0.43	0.85
M x P	0.31	0.62	0.36	0.74	0.46	NS	0.35	0.69

Table 25. Effect of treatments on height (cm) of tree seedlings (North East Monsoon 1999 and 2000)

Treatment	North East Monsoon 1999			North East Monsoon 2000		
	12 months after planting	16 months after planting	Increase in height (cm)	24 months after planting	28 months after planting	Increase in height (cm)
T_1	51.9	67.4	15.5	90.0	97.8	7.8
T_2	85.8	113.0	27.2	142.8	152.5	9.7
T_3	116.5	175.9	59.4	243.3	258.8	15.5
SE_d	0.65	1.94		1.88	1.67	
CD (P=0.05)	1.38	4.11		3.98	3.53	
M_1	86.9	125.1	38.2	172.5	185.7	13.2
M_2	82.6	112.4	29.8	144.8	153.7	8.9
SE_d	0.37	1.57		1.17	1.27	
CD (P=0.05)	0.73	3.13		2.33	2.54	
P_1	89.5	128.9	39.4	183.2	196.7	13.5
P_2	79.9	108.6	28.7	134.2	142.7	8.5
SE_d	0.37	1.57		1.17	1.27	
CD (P=0.05)	0.73	3.13		2.33	2.54	

	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD
T x M	0.79	1.65	2.73	5.61	2.36	4.89	2.28	4.70
M x T	0.64	1.27	2.72	4.42	2.03	4.04	2.21	4.40
P x T	0.64	1.27	2.72	5.41	2.03	4.04	2.21	4.40
T x P	0.79	1.65	2.73	5.62	2.36	4.89	2.28	4.70
M x P	0.52	NS	2.21	NS	1.65	3.29	1.80	3.59

With regard to increase in height, *E. officinalis* recorded better increase in height than other trees in both seasons. Coir pith mulched (M_1) trees recorded greater height increase than unmulched trees (M_2). Similarly, pitcher irrigation (P_1) increased the height of tree seedling compared to without pitcher (P_2).

The interaction effect between the treatment combinations found to be significant in all the months in both the seasons except between coir pith mulching and pitcher during North East Monsoon 1999. Among the treatment combinations, *E. officinalis* with coir pith mulching and pitcher irrigation ($T_3M_1P_1$) recorded higher plant height than other treatment combinations in both the seasons **(Appendix IV)**.

4.2.2.2. Basal diameter (Table 26 and 27)

The data on basal diameter of the tree species revealed that during Summer 1999, the basal diameter was the highest with *A. excelsa* (T_1) and it was superior to *C. pentandra* (T_2) and *E. officinalis* (T_3), whereas during Summer 2000, the basal diameter was the highest with *C. pentandra* (T_2) and it was superior to *A. excelsa* (T_1) and *E. officinalis* (T_3). Among the moisture conservation practices, coir pith mulched trees (M_1) recorded the highest basal diameter and it was superior over unmulched trees (M_2). Watering through pitcher irrigation (P_1) recorded significantly higher basal diameter.

The increase in basal diameter was higher with *E. officinalis* (T_3) than other tree species. Mulching with coir pith (M_1) recorded greater height increase than without mulching (M_2). The height increase in pitcher (P_1) was higher than without pitcher irrigation (P_2).

Similar trend was recorded during Summer 2000 also.

The interaction effect between the treatment combinations was found to be significant in all the months during both the years. During Summer 1999, the treatment combination, *A. excelsa* with coir pith mulching and pitcher irrigation ($T_1M_1P_1$) recorded

Table 26. Effect of treatments on basal diameter (cm) of tree seedlings (Summer 1999 and 2000)

Treatment	Summer 1999			Summer 2000		
	7 months after planting	9 months after planting	Increase in dia (cm)	19 months after planting	21 months after planting	Increase in dia (cm)
T_1	1.60	1.83	0.23	3.58	3.87	0.29
T_2	1.57	1.72	0.15	4.83	5.06	0.23
T_3	1.10	1.62	0.52	3.56	3.96	0.40
SE_d	0.02	0.02		0.02	0.02	
CD (P=0.05)	0.04	0.03		0.05	0.04	
M_1	1.47	1.80	0.37	4.38	4.75	0.37
M_2	1.37	1.65	0.24	3.60	3.85	0.25
SE_d	0.01	0.01		0.02	0.02	
CD (P=0.05)	0.02	0.03		0.04	0.04	
P_1	1.43	1.72	0.31	4.56	4.95	0.39
P_2	1.41	1.73	0.30	3.42	3.65	0.23
SE_d	0.01	0.01		0.02	0.02	
CD (P=0.05)	0.02	NS		0.04	0.04	

	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD
T x M	0.02	0.04	0.02	0.05	0.03	0.07	0.03	0.06
M x T	0.02	0.03	0.02	0.05	0.03	0.07	0.03	0.06
T x P	0.02	0.04	0.02	0.05	0.03	0.07	0.03	0.06
P x T	0.02	0.03	0.02	0.05	0.03	0.07	0.03	0.06
M x P	0.01	0.03	0.02	0.04	0.03	0.05	0.03	0.05

Table 27. **Effect of treatments on basal diameter (cm) of tree seedlings (North East Monsoon 1999 and 2000)**

Treatment	North East Monsoon 1999			North East Monsoon 2000		
	12 months after planting	16 months after planting	Increase in diameter (cm)	24 months after planting	28 months after planting	Increase in diameter (cm)
T_1	2.60	3.13	0.53	3.92	4.06	0.14
T_2	2.71	4.14	1.43	5.13	5.24	0.11
T_3	2.02	3.13	1.11	4.22	4.47	0.25
SE_d	0.02	0.02		0.02	0.02	
CD (P=0.05)	0.04	0.04		0.04	0.05	
M_1	2.52	3.72	1.20	4.89	5.09	0.20
M_2	2.37	3.23	0.86	3.96	4.09	0.13
SE_d	0.01	0.02		0.02	0.02	
CD (P=0.05)	0.03	0.04		0.04	0.04	
P_1	2.58	3.90	1.32	5.10	5.31	0.21
P_2	2.31	3.04	0.73	3.75	3.87	0.12
SE_d	0.01	0.02		0.02	0.02	
CD (P=0.05)	0.03	0.03		0.04	0.04	

	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD
T x M	0.03	NS	0.03	0.05	0.03	0.06	0.04	0.07
M x T	0.02	NS	0.03	0.06	0.03	0.06	0.04	0.08
T x P	0.03	0.06	0.03	0.05	0.03	0.06	0.04	0.07
P x T	0.02	0.05	0.03	0.06	0.03	0.06	0.04	0.08
M x P	0.02	0.04	0.02	0.05	0.03	0.05	0.03	0.06

higher basal diameter than other treatment combinations. Whereas in Summer 2000, *C. pentandra* with the same treatment combination (P_1) recorded higher basal diameter than other tree species **(Appendix V)**.

With regard to the North East Monsoon season, during 1999, among the tree species the basal diameter was the highest with *C. pentandra* (T_2) and it was superior to *A. excelsa* (T_1). Similar trend was noticed during North East Monsoon 2000 also.

With regard to the moisture conservation practices coir pith mulched trees (M_1) recorded significantly higher basal diameter in both the years. Pitcher irrigation (P_1) recorded the highest basal diameter and was superior to without pitcher irrigation (P_2) in both the years.

Interaction effects between the treatments were significant in both the years. Among the treatment combinations *C. pentandra* with coir pith mulching with pitcher irrigation ($T_2P_1M_1$) recorded higher basal diameter than other treatment combination in both the years **(Appendix VI)**.

4.2.2.3. Soil moisture (Table 28)

The soil moisture content was varying among the tree species. *E. officinalis* (T_3) recorded higher soil moisture content than *A. excelsa* (T_1) and *C. pentandra* (T_2). Mulching with coir pith (M_1) recorded higher soil moisture content than without mulching (M_2) in both the seasons. With regard to watering, soil moisture content was higher in pitcher (P_1) as compared to without pitcher irrigation. Among the different depths, the soil moisture content was higher in 15-30 cm depth than 0-15 cm depth in both the seasons.

4.2.2.4. Soil temperature (Table 29)

There was noticeable difference in the soil temperature between coir pith mulched and unmulched treatments. Coir pith mulching (M_1) recorded lesser soil temperature than

Table 28. Effect of treatments on soil moisture content (per cent) (Summer 1999 and 2000)

Treatment	Summer 1999						Summer 2000					
	0-15 cm			15-30 cm			0-15 cm			15-30 cm		
	March	April	May	March	April	May	March	April	May	March	April	May
$T_1 M_1 P_1$	13.32	16.91	14.32	18.80	17.25	18.61	15.63	11.08	11.38	15.80	11.27	11.45
P_2	11.94	12.39	11.42	16.90	16.51	16.32	13.10	10.86	10.96	13.52	10.94	10.99
$M_2 P_1$	12.15	16.70	13.14	18.08	17.32	18.44	14.81	11.05	11.18	14.91	11.17	11.24
P_2	10.43	10.50	10.33	16.89	16.40	16.41	11.52	10.53	10.38	12.31	10.61	10.43
$T_2 M_1 P_1$	13.80	15.00	14.70	19.52	18.94	20.01	15.13	11.02	11.85	15.33	11.69	12.32
P_2	10.73	11.00	11.35	15.91	15.75	16.14	12.82	10.88	10.73	12.90	11.37	12.14
$M_2 P_1$	11.61	12.43	12.11	17.90	17.03	19.72	14.54	10.96	11.60	14.91	11.65	12.31
P_2	10.62	10.91	10.83	15.92	15.81	15.90	11.30	10.67	10.52	11.42	10.91	10.74
$T_3 M_1 P_1$	14.95	16.34	16.02	18.80	19.23	20.00	15.83	13.90	11.96	16.11	18.99	12.58
P_2	11.50	10.81	10.90	16.01	16.16	16.03	13.22	12.59	10.40	14.02	13.83	11.89
$M_2 P_1$	12.09	13.72	12.81	17.14	18.42	19.60	14.71	13.71	11.58	14.15	13.92	12.29
P_2	10.91	10.63	10.83	15.92	15.85	15.90	11.44	10.70	10.01	11.52	11.50	10.80

Table 29. Effect of treatments on soil temperature (°C) at 1422 hrs (Summer 1999 and 2000)

Treatment	Summer 1999						Summer 2000					
	15 cm			30 cm			15 cm			30 cm		
	March	April	May	March	April	May	March	April	May	March	April	May
$T_1 M_1 P_1$	31.1	30.1	30.9	28.5	28.6	28.4	30.3	30.5	31.5	29.2	29.5	30.3
P_2	31.9	30.7	31.6	30.0	30.2	30.4	31.1	31.6	32.3	30.6	31.5	31.2
$M_2 P_1$	31.4	30.2	31.3	28.9	29.3	28.3	30.5	30.7	31.8	30.2	30.7	30.9
P_2	32.7	32.8	33.0	30.1	30.4	30.8	32.0	32.4	32.7	31.4	32.1	32.4
$T_2 M_1 P_1$	31.2	30.5	30.8	28.3	28.3	28.0	30.4	30.6	31.6	29.4	29.7	30.4
P_2	32.4	32.6	31.7	30.6	30.2	30.2	31.7	31.9	32.1	30.6	30.8	31.5
$M_2 P_1$	31.6	31.5	31.1	29.3	29.6	28.1	30.8	30.9	31.9	29.7	29.8	30.9
P_2	32.8	32.7	32.7	30.7	30.5	30.4	32.0	32.1	32.9	31.5	32.0	32.5
$T_3 M_1 P_1$	30.8	30.4	30.2	28.5	28.0	28.0	30.0	30.5	31.4	29.1	29.8	30.1
P_2	31.5	32.7	32.8	29.9	29.9	30.2	31.2	31.8	32.5	30.4	30.7	31.1
$M_2 P_1$	31.0	31.0	30.7	30.5	28.5	28.2	30.5	31.0	31.8	29.5	30.1	30.8
P_2	32.5	32.7	32.9	30.5	30.6	30.5	32.1	32.4	32.8	31.2	31.5	32.5

without mulching (M_2). With regard to watering, pitcher irrigation (P_1) recorded lesser soil temperature than without pitcher irrigation (P_2). With regard to different depths, the soil temperature was less in 30cm depth as compared to 15cm depth in both the seasons.

Experiment - III

4.2.3. Experiment on *in situ* moisture conservation and nitrogen management practices

Field experiments with different cropping systems were carried out during North East Monsoon 1999 and 2000 to evaluate *in situ* moisture conservation methods and Nitrogen (N) management practices under dryland condition with three different tree combinations. The results of the field experiments are presented below.

4.2.3.1. Base crop (sorghum)

4.2.3.1.1. Growth parameters

4.2.3.1.1.1. Plant height (Table 30 and 31)

The data on plant height of grain sorghum revealed that the tree species significantly influenced the plant height at all the growth stages during first year and at 60 and 90 days after sowing (DAS) and at harvest during second year. Among the tree species, grain sorghum intercropped in *E. officinalis* (T_3) recorded higher plant height in all the stages but it was comparable with the plant height of grain sorghum in *A. excelsa* (T_1) at 90 DAS and at harvest during 1999. During North East Monsoon 2000, the sorghum plant height in *E. officinalis* (T_3) was the highest in all the stages.

Moisture conservation practices had significant influence on plant height at 60 and 90 DAS and at harvest only during 1999. Among the moisture conservation practices tied ridges (M_1) recorded significantly higher plant height in all the stages as compared to flat bed.

Table 30. Effect of treatments on plant height (cm) of grain sorghum

Treatment	30 DAS		60 DAS		90 DAS		Harvest	
	1999	2000	1999	2000	1999	2000	1999	2000
T_1	64.1	43.5	107.8	75.3	148.5	98.3	158.1	106.2
T_2	79.6	42.8	104.9	93.1	143.2	107.5	151.5	110.5
T_3	85.2	43.7	112.8	110.1	153.9	125.9	167.5	131.0
SE_d	1.21	0.37	0.68	0.51	3.89	0.89	4.85	1.12
CD (P=0.05)	2.70	NS	1.51	1.14	8.65	1.99	10.80	2.51
M_1	76.1	43.6	111.4	93.1	153.1	110.3	165.9	115.5
M_2	76.6	43.0	105.5	92.5	144.0	110.9	152.1	116.3
SE_d	0.99	0.30	0.55	0.42	3.17	0.72	3.96	0.92
CD(P=0.05)	NS	NS	1.23	NS	7.07	NS	8.82	NS
N_1	75.1	42.7	103.0	91.9	142.5	109.3	153.5	114.0
N_2	77.6	44.0	113.9	93.7	154.6	111.8	164.6	117.8
SE_d	0.94	0.27	0.71	0.80	3.90	0.88	1.17	1.00
CD(P=0.05)	2.04	0.59	1.56	1.74	8.49	1.91	2.55	2.18

	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD
T x M	1.71	NS	0.52	NS	1.96	NS	1.72	NS	5.49	NS	1.26	NS	6.85	NS	1.59	NS
M x N	1.36	NS	0.40	NS	0.90	NS	0.90	NS	5.03	NS	1.14	NS	4.12	NS	1.36	NS
N x M	1.32	NS	0.38	NS	1.01	NS	1.13	NS	5.52	NS	1.24	NS	1.65	NS	1.42	NS
N x T	1.62	NS	0.47	NS	1.24	NS	1.39	NS	6.76	NS	1.51	NS	2.02	NS	1.74	NS
T x N	1.67	NS	0.49	NS	1.11	NS	1.11	NS	6.16	NS	1.40	NS	5.05	NS	1.67	NS

Table 31. Effect of treatments on plant height (cm) of fodder sorghum

Treatment	30 DAS		60 DAS		Harvest	
	1999	2000	1999	2000	1999	2000
T_1	98.6	49.5	193.5	142.5	202.3	152.4
T_2	116.9	49.7	180.8	152.0	194.8	168.1
T_3	134.9	49.8	195.4	163.0	202.5	175.4
SE_d	4.83	1.24	1.86	2.19	2.22	4.43
CD (P=0.05)	10.76	NS	4.14	4.89	4.94	9.87
M_1	117.9	49.7	194.7	153.8	205.5	163.7
M_2	115.8	49.5	185.1	151.2	194.3	166.8
SE_d	3.94	1.01	1.52	1.79	1.81	3.61
CD(P=0.05)	NS	NS	3.38	NS	4.03	NS
N_1	118.9	49.0	183.7	149.0	194.2	161.1
N_2	114.7	50.3	196.1	156.0	205.6	169.5
SE_d	2.17	0.85	1.86	1.37	1.24	3.48
CD(P=0.05)	NS	NS	4.06	2.98	2.72	7.57

	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD
T x M	6.83	NS	1.74	NS	2.62	NS	3.10	NS	3.14	NS	6.27	NS
M x N	4.50	NS	1.31	NS	2.40	NS	2.25	NS	2.19	NS	5.02	NS
N x M	3.08	NS	1.20	NS	2.63	NS	1.93	NS	1.76	NS	4.91	NS
N x T	3.77	NS	1.47	NS	3.22	NS	2.36	NS	2.16	NS	6.02	NS
T x N	5.51	NS	1.61	NS	2.94	NS	2.76	NS	2.69	NS	6.14	NS

With regard to N management practices, application of 50 per cent N through inorganic fertilizer and 50 per cent N through goat manure recorded the highest plant height of grain sorghum in all the growth stages in both the years.

In case of fodder sorghum, the data on plant height revealed that during first year, among the tree species, the plant height of fodder sorghum was significantly higher in *E. officinalis* (T_3) at 30 DAS but it was comparable with the plant height of sorghum in *A. excelsa* (T_1) at 60 DAS and at harvest. During second year, the plant height was significantly influenced by the tree species at 60 DAS and at harvest. The plant height was higher in *E. officinalis* (T_3) than the other tree species.

With regard to the moisture conservation practices, there was significant influence on the plant height at 60 DAS and at harvest only during 1999. The plant height of fodder sorghum was significantly superior in tied ridges (M_1).

Nitrogen management practices significantly influenced the plant height at 60 DAS and at harvest during both the years. Application of 50 per cent inorganic N and 50 per cent N through goat manure (N_2) recorded the highest plant height in both the years.

The interaction effect was not significant in both the years for grain and fodder sorghum.

4.2.3.1.1.2. Leaf area index (Table 32 and 33)

The data on Leaf Area Index (LAI) of grain sorghum revealed that during first year the LAI was higher in *E. officinalis* (T_3) but it was comparable with other tree species. Whereas in the second year, the LAI was not significantly influenced by the tree species. Moisture conservation practices significantly influenced the LAI of grain sorghum only during first year. Among the moisture conservation practices, tied ridges (M_1) recorded the highest LAI and was

Table 32. Effect of treatments on Leaf Area Index (LAI) of grain and fodder sorghum at 60 DAS

Treatment	Grain sorghum		Fodder sorghum	
	1999	2000	1999	2000
T_1	3.54	2.98	5.09	3.67
T_2	3.46	2.98	4.56	3.72
T_3	3.63	3.00	5.57	3.86
SE_d	0.053	0.014	0.089	0.003
CD (P=0.05)	0.118	NS	0.199	0.006
M_1	3.61	2.99	5.37	3.74
M_2	3.48	2.98	4.78	3.74
SE_d	0.043	0.012	0.073	0.020
CD (P=0.05)	0.097	NS	0.162	NS
N_1	3.47	2.98	4.92	3.67
N_2	3.62	2.99	5.23	3.83
SE_d	0.024	0.012	0.072	0.002
CD (P=0.05)	0.052	NS	0.157	0.004

	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD
T x M	0.075	NS	0.020	NS	0.126	0.281	0.004	NS
M x N	0.049	0.109	0.017	NS	0.126	NS	0.003	NS
N x M	0.034	0.073	0.017	NS	0.102	NS	0.003	NS
N x T	0.041	0.090	0.021	NS	0.125	0.271	0.003	NS
T x N	0.060	0.134	0.021	NS	0.125	0.276	0.003	NS

Table 33. Interaction effect on LAI of grain and fodder sorghum at 60 DAS (1999)

Treatment	Grain sorghum					Fodder sorghum				
	M_1	M_2	N_1	N_2	Mean	M_1	M_2	N_1	N_2	Mean
T_1	3.58	3.51	3.48	3.61	3.54	5.70	4.48	4.79	5.39	5.09
T_2	3.51	3.40	3.42	3.49	3.46	4.51	4.61	4.58	4.54	4.56
T_3	3.73	3.54	3.50	3.76	3.63	5.91	5.24	5.40	5.75	5.57
M_1			3.49	3.72				5.26	5.48	
M_2			3.44	3.52				4.58	4.97	
Mean	3.61	3.48	3.47	3.62		5.37	4.78	4.92	5.23	

	Grain sorghum SE_d	Grain sorghum CD		Fodder sorghum SE_d	Fodder sorghum CD
T x M	0.075	NS	T x M	0.126	0.281
M x N	0.049	0.109	M x N	0.126	NS
N x M	0.034	0.073	N x M	0.102	NS
N x T	0.041	0.090	N x T	0.125	0.271
T x N	0.060	0.134	T x N	0.125	0.276

superior to flat bed. N management practices significantly influenced the LAI of grain sorghum only during first year. Application of 50 per cent N through fertilizer and 50 per cent N through goat manure (N_2) recorded the higher LAI.

Interaction effect between moisture conservation and N management, N management and tree species were significant. Among the treatments the LAI of grain sorghum was higher in *E. officinalis* under tied ridges with application of 50 per cent N through fertilizer and 50 per cent N through goat manure ($T_3M_1N_2$) than other treatment combinations.

In case of fodder sorghum, the tree species significantly influenced the LAI during both the years. Highest LAI was recorded by fodder sorghum in *E. officinalis* (T_3). With regard to moisture conservation practices, significant influence on LAI was recorded only during first year. Tied ridges (M_1) recorded higher LAI than flat bed. N management practices had significant influence on LAI of fodder sorghum in both the years. Application of 50 per cent N through fertilizer and 50 per cent N through goat manure (N_2) recorded the highest LAI in both the years.

Interaction effect between trees and moisture conservation practices as well as N management were significant. Among the treatment combinations, fodder sorghum in *E. officinalis* under tied ridges with application of 50 per cent N through fertilizer and 50 per cent N through goat manure ($T_3M_1N_2$) recorded higher LAI and it was comparable with *A. excelsa* with same treatment combination.

4.2.3.1.1.3. Dry matter production (Table 34 to 37)

With regard to grain sorghum, tree species had significant influence on the Dry Matter Production (DMP) of grain sorghum at 60 and 90 DAS and at harvest during first year and at all growth stages during second year. Among the trees, grain sorghum intercropped in *E. officinalis* (T_3) recorded the highest DMP in all the growth stages except at

Table 34. Effect of treatments on dry matter production (kg ha^{-1}) of grain sorghum

Treatment	30 DAS		60 DAS		90 DAS		Harvest	
	1999	2000	1999	2000	1999	2000	1999	2000
T_1	1036	874	2727	1314	3695	1612	4118	1882
T_2	1020	890	2604	1391	3196	1639	3698	1939
T_3	1017	954	2790	1564	3999	1853	4389	2144
SE_d	19.5	17.2	43.2	13.9	13.9	22.4	35.2	11.8
CD (P=0.05)	NS	38.3	96.2	30.9	30.8	49.9	78.5	26.3
M_1	1036	905	2760	1421	3930	1699	4370	1985
M_2	1012	908	2655	1425	3330	1704	3766	1992
SE_d	15.9	14.0	35.2	11.3	11.3	18.3	28.7	9.7
CD (P=0.05)	NS	NS	78.5	NS	25.2	NS	64.1	NS
N_1	999	884	2583	1389	3443	1653	3939	1951
N_2	1049	929	2832	1457	3817	1750	4198	2026
SE_d	19.3	21.0	32.8	13.1	14.2	16.1	27.1	6.9
CD (P=0.05)	41.9	NS	71.5	28.5	31.0	35.1	59.0	15.1

	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD
T x M	27.5	NS	24.2	NS	61.0	136.0	19.6	NS	19.6	43.7	31.7	NS	49.8	111.0	16.7	NS
M x N	24.9	NS	25.3	NS	48.1	NS	17.3	NS	18.2	39.9	24.4	NS	39.5	87.2	11.9	NS
N x M	27.2	NS	29.7	NS	46.4	NS	18.5	NS	20.1	43.9	22.8	NS	38.3	83.5	9.8	NS
N x T	33.3	NS	36.4	NS	56.8	123.8	22.6	NS	24.7	53.7	27.9	NS	46.9	102.3	12.0	NS
T x N	30.6	NS	30.9	NS	58.9	130.0	21.1	NS	22.3	48.9	29.9	NS	48.4	106.7	14.5	NS

Table 35. Effect of treatments on dry matter production (kg ha^{-1}) of fodder sorghum

Treatment	30 DAS		60 DAS		Harvest	
	1999	2000	1999	2000	1999	2000
T_1	2125	1688	5803	2862	6247	4526
T_2	2064	1837	4943	2948	5645	4363
T_3	2141	2116	5803	3825	6310	5145
SE_d	24.5	7.0	16.1	46.0	59.9	48.8
CD (P=0.05)	54.7	15.6	35.9	102.5	133.6	108.7
M_1	2132	1884	5846	3196	6325	4644
M_2	2089	1876	5186	3227	5809	4713
SE_d	20.0	5.7	13.2	37.5	48.9	39.8
CD (P=0.05)	NS	NS	29.4	NS	109.0	NS
N_1	2071	1802	5166	3079	5804	4592
N_2	2149	1958	5866	3344	6331	4764
SE_d	20.6	9.7	34.7	24.2	33.1	26.8
CD (P=0.05)	44.8	21.1	75.6	52.9	72.0	58.5

	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD
T x M	34.6	NS	9.9	NS	22.8	NS	65.1	NS	84.8	188.8	34.4	NS
M x N	28.7	NS	11.2	NS	37.1	81.0	44.7	NS	59.1	130.7	33.4	NS
N x M	29.1	NS	13.7	NS	49.0	106.9	34.3	NS	46.7	101.9	37.9	NS
N x T	35.6	NS	16.8	NS	60.1	130.9	42.0	NS	57.3	124.8	46.5	NS
T x N	35.2	NS	13.8	NS	45.5	99.3	54.8	NS	72.3	160.0	40.9	NS

Table 36. Interaction effect on dry matter production (kg ha^{-1}) of grain sorghum (1999)

Treat-ment	60 DAS					90 DAS					Harvest				
	M_1	M_2	N_1	N_2	Mean	M_1	M_2	N_1	N_2	Mean	M_1	M_2	N_1	N_2	Mean
T_1	2711	2743	2602	2853	2727	4055	3336	3539	3851	3695	4570	3666	3972	4264	4118
T_2	2643	2565	2390	2818	2604	3332	3060	3072	3321	3196	3730	3665	3704	3691	3698
T_3	2925	2656	2756	2825	2790	4405	3593	3718	4279	3999	4810	3967	4140	4637	4389
M_1			2604	2916				3641	4220				4058	4682	
M_2			2562	2748				3245	3414				3819	3713	
Mean	2760	2655	2583	2832		3930	3330	3443	3817		4370	3766	3939	4198	

	SE_d	CD		SE_d	CD		SE_d	CD
T x M	61.0	136.0	T x M	19.6	43.7	T x M	49.8	111.0
M x N	48.1	NS	M x N	18.2	39.9	M x N	39.5	87.2
N x M	46.4	NS	N x M	20.1	43.9	N x M	38.3	83.5
N x T	56.8	123.8	N x T	24.7	53.7	N x T	46.9	102.3
T x N	58.9	130.0	T x N	22.3	48.9	T x N	48.4	106.9

Table 37. Interaction effect on dry matter production (kg ha^{-1}) of fodder sorghum (1999)

Treatment	60 DAS					Harvest				
	M_1	M_2	N_1	N_2	Mean	M_1	M_2	N_1	N_2	Mean
T_1	6157	5448	5483	6123	5803	6572	5922	6050	6445	6247
T_2	5262	4624	4476	5409	4943	5755	5535	5421	5869	5645
T_3	6120	5486	5539	6067	5803	6649	5972	5942	6678	6310
M_1			5546	6146	5846			5967	6684	
M_2			4786	5586	5186			5642	5977	
Mean	5864	5186	5166	5866		6325	5809	5804	6331	

60 DAS	SE_d	CD	Harvest	SE_d	CD
T x M	22.8	NS	T x M	84.8	188.8
M x N	37.1	81.0	M x N	59.1	130.7
N x M	60.1	130.9	N x M	57.3	124.8
N x T	49.0	106.9	N x T	46.7	101.9
T x N	45.5	99.3	T x N	72.3	160.0

60 DAS during first year and it was comparable with DMP of grain sorghum in *A. excelsa*. In second year, at all the growth stages the DMP of grain sorghum was the highest with *E. officinalis* (T_3).

Moisture conservation practices had significant influence on DMP of grain sorghum at 60 and 90 DAS and at harvest only during first year. Among the treatments, the highest DMP of grain sorghum was recorded by tied ridges (M_1) at 60 and 90 DAS and at harvest.

With regard to the N management practices, significant difference in the DMP between the treatments was recorded in all the stages during first year and at 60 and 90 DAS and at harvest during second year. The highest DMP of grain sorghum was recorded with application of 50 per cent N through fertilizer and 50 per cent N through goat manure (N_2).

Interaction effect between trees and moisture conservation as well as N management were significant at 60 and 90 DAS and at harvest and moisture conservation and N management at 90 DAS and at harvest. Among the treatment combinations, grain sorghum in *E. officinalis* under tied ridges with application of 50 per cent N through fertilizer and 50 per cent N through goat manure ($T_3M_1N_2$) produced the highest DMP at 90 DAS and at harvest and it was comparable with *A. excelsa* with same N management practice at 60 DAS.

The data on DMP of fodder sorghum revealed that, the tree species had significant influence on the DMP in all the growth stages during both the years. Fodder sorghum intercropped in *E. officinalis* (T_3) recorded the highest DMP in all the growth stages but it was comparable with *A. excelsa* (T_1) in the first year. Moisture conservation practices had significant influence on the DMP of fodder sorghum at 60 DAS and at harvest only during first year. Highest DMP of fodder sorghum was recorded by tied ridges (M_1) at 60 DAS and at harvest. With regard to N management practices, significant influence on the DMP of fodder sorghum was recorded in all the growth stages in both the years. Among the treatments, application of 50 per cent N through fertilizer and 50 per cent N through goat manure (N_2) recorded the highest DMP of fodder sorghum in all the growth stages.

The interaction effect between the moisture conservation and N management and between trees and N management were significant at 60 DAS and between trees and moisture conservation as well as between trees and N management and moisture conservation and N management were significant at harvest. At 60 DAS, the DMP of fodder sorghum was higher in *A. excelsa* with application of 50 per cent N through fertilizer and 50 per cent N through goat manure but it was comparable with *E. officinalis* with same treatment combination. At harvest, *E. officinalis* under tied ridges produced higher DMP but it was comparable with *A. excelsa* under tied ridges. Whereas the DMP of fodder sorghum in *E. officinalis* with 50 per cent N through fertilizer and 50 per cent N through goat manure ($T_3M_1N_2$) was significantly superior to other treatment combinations.

4.2.3.1.2. Yield attributes

4.2.3.1.2.1. Length of earhead (Table 38)

Significant difference in the length of earhead was recorded among the tree species in both the years. The length of earhead was the highest in sorghum intercropped in *E. officinalis* (T_3).

With regard to moisture conservation practices, significant influence on earhead length was recorded only during first year. Tied ridges recorded the highest earhead length. The earhead length was significantly influenced by the N management practices only during North East Monsoon 1999. Application of 50 per cent N through fertilizer and 50 per cent N through goat manure (N_2) was significantly superior to 100 per cent inorganic N alone.

There was no interaction effect between the treatments in both the years.

4.2.3.1.2.2. Number of grains per earhead (Table 38 and 40)

The results revealed that the tree species had significant influence on the number of grains per earhead in both the years. Grain sorghum in *E. officinalis* (T_3) recorded the highest number of grains per earhead in both the years. With regard to moisture conservation practices, the number of grains per earhead was the highest in tied ridges (M_1) only during first year. Application of 50 per cent N through fertilizer and 50 per cent N through goat manure recorded the highest number of grains per earhead in both the years.

Interaction effect between moisture conservation and N management and between trees and N management were significant only during North East Monsoon 1999. The treatment combination, *E. officinalis* under tied ridges with application of 50 per cent N through fertilizer and 50 per cent N through goat manure ($T_3M_1N_2$) recorded the highest number of grains per earhead.

4.2.3.1.2.3. Thousand grain weight (Table 38)

With regard to the tree species, there was significant influence on 1000 grain weight only during first year. Grain sorghum intercropped in *C. pentandra* (T_2) recorded higher 1000 grain weight but it was comparable with *E. officinalis* (T_3). Among the moisture conservation practices, significant difference in 1000 grain weight was recorded only during 1999. Among the treatments, tied ridges (M_1) recorded the highest 1000 grain weight. N management practices had significant influence on 1000 grain weight only during 1999. The test weight was the highest with application of 50 per cent N through fertilizer and 50 per cent N through goat manure.

Interaction effect was not significant in both the years.

4.2.3.1.3. Yield

4.2.3.1.3.1. Grain yield (Table 39 and 40)

In general, grain yield of sorghum was higher during North East Monsoon 1999 as compared to North East Monsoon 2000.

Table 38. Effect of treatments on yield parameters of grain sorghum

Treatment	Length of earhead (cm)		No. of grains earhead^{-1}		1000 grain weight (g)	
	1999	2000	1999	2000	1999	2000
T_1	18.6	10.4	321	73	22.0	20.8
T_2	18.7	10.2	301	73	23.8	20.9
T_3	20.4	11.0	436	81	23.6	21.0
SE_d	0.42	0.24	6.08	2.03	0.17	0.20
CD (P=0.05)	0.95	0.54	13.55	4.54	0.38	NS
M_1	20.0	10.5	382	76	24.2	20.9
M_2	18.5	10.6	323	75	22.1	20.9
SE_d	0.35	0.20	4.97	1.66	0.14	0.16
CD (P=0.05)	0.77	NS	11.07	NS	0.31	NS
N_1	18.3	10.3	302	73	22.3	20.9
N_2	20.1	10.7	403	78	24.1	21.0
SE_d	0.33	0.22	6.54	1.32	0.16	0.18
CD(P=0.05)	0.73	NS	14.26	2.88	0.35	NS

	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD
T x M	0.60	NS	0.34	NS	8.60	NS	2.88	NS	0.24	NS	0.28	NS
M x N	0.48	NS	0.30	NS	8.22	19.17	2.12	NS	0.21	NS	0.24	NS
N x M	0.47	NS	0.32	NS	9.25	20.16	1.86	NS	0.22	NS	0.25	NS
N x T	0.58	NS	0.39	NS	11.33	24.70	2.28	NS	0.27	NS	0.31	NS
T x N	0.59	NS	0.37	NS	10.06	22.11	2.60	NS	0.26	NS	0.30	NS

The data on grain yield revealed that there was significant influence on the grain yield by the tree species. Among the trees, the grain yield was the highest (778 kg ha^{-1}) in *E. officinalis* (T_3) during first year. Whereas during second year, the grain yield in *E. officinalis* was comparable with grain yield of sorghum in *A. excelsa* (T_1).

Moisture conservation practices had significant influence on the grain yield only during 1999. Among the treatments, tied ridges (M_1) recorded the highest grain yield (783 kg ha^{-1}). With regard to the N management practices, significant difference in grain yield was recorded in both the years. Among the treatments, application of 50 per cent N through fertilizer N and 50 per cent N through goat manure (N_2) recorded the highest grain yield (819 kg ha^{-1}) and it was significantly superior to inorganic N alone.

Interaction effect between the trees and moisture conservation, as well as between trees and N management and moisture conservation and N management were significant only during North East Monsoon 1999. Among the treatment combinations, the grain yield was the highest in grain sorghum with *E. officinalis* under tied ridges with application of 50 per cent N through fertilizer and 50 per cent N through goat manure ($T_3M_1N_2$). The grain yield was lowest in *C. pentandra* under flat bed with 100 per cent inorganic N alone ($T_1M_2N_1$).

4.2.3.1.3.2. Straw yield (Table 39 and 40)

Straw yield of sorghum was significantly influenced by the tree species in both the years. Among the tree species, grain sorghum intercropped in *E. officinalis* (T_3) recorded the highest straw yield in both the years (4629 and 3078 kg ha^{-1}, respectively). Lowest straw yield was recorded with sorghum intercropped in *C. pentandra* (T_1) (3767 and 2746 kg ha^{-1}, respectively) in both the years.

With regard to moisture conservation practices, the straw yield was significantly influenced by the treatments only during first year. Among the treatments, the highest

Table 39. Effect of treatments on grain and straw yield (kg ha^{-1}) of grain sorghum

Treatment	Grain yield (kg ha^{-1})				Straw yield (kg ha^{-1})			
	1999		2000		1999		2000	
T_1	740		144		4211		2879	
T_2	677		138		3767		2746	
T_3	778		149		4629		3078	
SE_d	4.95		2.72		18.29		31.31	
CD (P=0.05)	11.03		6.05		40.75		69.78	
M_1	783		142		4527		2905	
M_2	680		145		3877		2897	
SE_d	4.04		2.21		14.93		25.57	
CD (P=0.05)	9.00		NS		33.27		NS	
N_1	644		140		4094		2866	
N_2	819		147		4310		2936	
SE_d	3.38		2.42		19.38		13.12	
CD (P=0.05)	7.36		5.28		42.23		28.59	
	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD
T x M	7.00	15.59	3.84	NS	25.86	57.63	44.29	NS
M x N	5.27	11.63	3.29	NS	24.47	53.76	28.74	NS
N x M	4.78	10.41	3.43	NS	27.41	59.73	18.55	NS
N x T	5.85	12.75	4.20	NS	33.57	73.14	22.72	NS
T x N	6.45	14.24	4.00	NS	29.97	65.84	35.20	NS

Table 40. Interaction effect on no. of grains earhead^{-1}, grain and straw yield of grain sorghum (1999)

Treatment	No. of grains earhead^{-1}					Grain yield (kg ha^{-1})					Straw yield (kg ha^{-1})				
	M_1	M_2	N_1	N_2	Mean	M_1	M_2	N_1	N_2	Mean	M_1	M_2	N_1	N_2	Mean
T_1	355	286	266	375	321	807	673	639	841	740	4674	3748	4101	4321	4211
T_2	334	268	281	320	301	720	637	629	725	677	3928	3607	3706	3828	3767
T_3	457	415	358	513	436	823	732	663	892	778	4980	4278	4476	4781	4629
M_1			324	440				667	900				4280	4775	
M_2			280	366				620	739				3909	3846	
Mean	382	323	302	403		783	680	644	819		4527	3877	4094	4310	

	SE_d	CD		SE_d	CD		SE_d	CD
T x M	8.60	NS	T x M	7.00	15.59	T x M	25.9	57.6
M x N	8.22	19.17	M x N	5.27	11.63	M x N	24.5	53.8
N x M	9.25	20.16	N x M	4.78	10.41	N x M	27.4	59.7
N x T	11.33	24.70	N x T	5.85	12.75	N x T	33.6	73.1
T x N	10.06	22.11	T x N	6.45	14.24	T x N	30.0	65.8

straw yield of 4527 kg ha^{-1} was recorded with tied ridges (M_1). Among the N management practices, application of 50 per cent N through fertilizer and 50 per cent N through goat manure (N_2) recorded the highest straw yield of 4310 and 2936 kg ha^{-1}, respectively in North East Monsoon 1999 and 2000.

The interaction effect between trees and moisture conservation practices as well as between trees and N management practices and moisture conservation and N management practices were significant only during first year. The treatment combination, grain sorghum intercropped in *E. officinalis* under tied ridges with application of 50 per cent N through fertilizer and 50 per cent N through goat manure ($T_3M_1N_2$) recorded the highest straw yield. The lowest straw yield was recorded with sorghum intercropped in *C. pentandra* under flat bed with application of 100 per cent N through fertilizer alone.

4.2.3.1.3.3. Straw yield of fodder sorghum (Table 41 and 42)

The data revealed that the tree species had significant influence on the straw yield of fodder sorghum during both the years. Among the tree species, the straw yield was higher with fodder sorghum intercropped in *A. excelsa* (T_1) (8251 kg ha^{-1}) and it was comparable with straw yield of fodder sorghum in *E. officinalis* (T_2) (8202 kg ha^{-1}). However, in second year straw yield of fodder sorghum in *E. officinalis* (T_3) was the highest (6688 kg ha^{-1}) and was significantly superior to fodder yield in *A. excelsa* (T_1) and *C. pentandra* (T_2).

With regard to moisture conservation practices, significant influence on straw yield of fodder sorghum was recorded only during first year. Tied ridges (M_1) recorded the highest straw yield (8392 kg ha^{-1}) and it was significantly superior to flat bed.

Nitrogen management practices had significant influence on the straw yield of fodder sorghum in both the years. Application of 50 per cent N through fertilizer and 50 per cent N through goat manure (N_2) recorded the highest straw yield of 8262 and 6150 kg ha^{-1} respectively in both the years.

Table 41. Effect of treatments on straw yield (kg ha^{-1}) of fodder sorghum

Treatment	1999		2000	
T_1	8251		5755	
T_2	7687		5671	
T_3	8202		6688	
SE_d	106		56	
CD (P=0.05)	238		125	
M_1	8392		6000	
M_2	7701		6076	
SE_d	87		46	
CD (P=0.05)	194		NS	
N_1	7832		5926	
N_2	8262		6150	
SE_d	87		80	
CD (P=0.05)	191		176	
	SE_d	CD	SE_d	CD
T x M	151	337	79	NS
M x N	123	NS	92	NS
N x M	124	NS	114	NS
N x T	152	332	139	NS
T x N	151	334	113	NS

Table 42. Interaction effect on straw yield (kg ha^{-1}) of fodder sorghum (1999)

Treatment	M_1	M_2	N_1	N_2	Mean
T_1	8553	7949	8150	8352	8251
T_2	7848	7527	7619	7756	7687
T_3	8778	7628	7727	8677	8202
M_1			8084	8701	
M_2			7579	7823	
Mean	8392	7701	7832	8262	

Interaction effect between trees and moisture conservation and between trees and N management were significant. The treatment combination, fodder sorghum intercropped in *E. officinalis* under tied ridges with application of 50 per cent N through fertilizer and 50 per cent N through goat manure ($T_3M_1N_2$) recorded higher straw yield but it was comparable with the straw yield of fodder sorghum in *A. excelsa* with same treatment combination.

4.2.3.2. Intercrop (cowpea)

4.2.3.2.1. Growth parameters

4.2.3.2.1.1. Plant height (Table 43 and 44)

The data showed that tree species had significant influence on growth of grain cowpea. Grain cowpea intercropped with sorghum in *E. officinalis* (T_3) recorded higher plant height but it was comparable with *A. excelsa* (T_1) at all growth stages during first year. During second year, grain cowpea in *E. officinalis* (T_3) recorded the highest plant height but it was comparable with the plant height of grain cowpea in *C. pentandra* (T_2) at 30 DAS.

Moisture conservation practices significantly influenced the plant height of grain cowpea only during first year. Among the treatments, tied ridges was superior to flat bed in all the growth stages and recorded the highest plant height.

With regard to N management practices, application of 50 per cent N through fertilizer and 50 per cent N through goat manure (N_2) recorded the highest plant height in all the stages in both the years.

The interaction effect between the treatments were found to be not significant in both the years.

In case of fodder cowpea, the trees significantly influenced the growth of fodder cowpea at 30 DAS during first year and at harvest during second year. In both the years, cowpea in *E. officinalis* recorded the highest plant height.

Table 43. Effect of treatments on plant height (cm) of grain cowpea

Treatment	30 DAS		60 DAS		Harvest	
	1999	2000	1999	2000	1999	2000
T_1	35.0	20.9	52.9	32.3	60.1	35.3
T_2	32.7	23.5	50.6	35.6	57.7	39.3
T_3	35.3	24.4	54.7	38.2	61.0	41.4
SE_d	0.42	0.72	0.86	0.58	0.96	0.88
CD	0.93	1.61	1.92	1.30	2.13	1.96
M_1	35.3	23.7	53.9	35.7	61.0	39.2
M_2	33.4	22.2	51.6	35.1	58.2	38.2
SE_d	0.34	0.68	0.70	0.48	0.78	0.71
CD	0.76	NS	1.56	NS	1.74	NS
N_1	33.6	21.8	52.0	32.8	58.8	36.0
N_2	35.1	24.1	53.5	38.0	60.4	41.3
SE_d	0.32	0.34	0.58	0.56	0.65	0.61
CD	0.70	0.75	1.28	1.22	1.42	1.32

	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD
T x M	0.59	NS	1.02	NS	1.22	NS	0.82	NS	1.36	NS	1.24	NS
M x N	0.47	NS	0.68	NS	0.91	NS	0.74	NS	1.02	NS	0.94	NS
N x M	0.46	NS	0.49	NS	0.83	NS	0.79	NS	0.92	NS	1.85	NS
N x T	0.56	NS	0.60	NS	1.01	NS	0.97	NS	1.13	NS	1.05	NS
T x N	0.58	NS	0.84	NS	1.12	NS	0.90	NS	1.25	NS	1.15	NS

Table 44. Effect of treatments on plant height (cm) of fodder cowpea

Treatment	30 DAS				Harvest			
	1999		2000		1999		2000	
T_1	38.0		34.1		57.7		35.8	
T_2	35.9		35.2		56.6		42.9	
T_3	40.3		35.2		58.5		44.4	
SE_d	0.79		0.80		1.70		0.61	
CD	1.76		NS		NS		1.37	
M_1	38.8		35.0		59.3		40.8	
M_2	37.4		34.7		55.9		41.3	
SE_d	0.64		0.66		1.39		0.50	
CD	NS		NS		3.09		NS	
N_1	37.1		33.9		55.5		39.1	
N_2	39.0		35.7		59.7		42.9	
SE_d	0.74		0.56		1.16		0.35	
CD	1.60		1.22		2.53		0.76	
	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD
T x M	1.12	NS	1.62	NS	3.66	NS	0.87	NS
M x N	0.98	NS	1.41	NS	3.72	NS	0.61	NS
N x M	1.04	NS	1.35	NS	3.52	NS	0.49	NS
N x T	1.27	NS	1.59	NS	2.78	NS	0.60	NS
T x N	1.20	NS	1.57	NS	2.69	NS	0.75	NS

Moisture conservation practices had significant influence on the growth of fodder cowpea at harvest only during first year. Among the treatments, tied ridges (M_1) was significantly superior to flat bed. Application of 50 per cent N through fertilizer and 50 per cent N through goat manure (N_2) recorded the highest plant height in all the stages in both the years.

The interaction effect was not significant.

4.2.3.2.1.2. Leaf area index (Table 45 and 46)

With regard to grain cowpea, tree species significantly influenced the LAI of grain cowpea in both the years. The highest LAI was recorded with grain cowpea in *E. officinalis* (T_3). Moisture conservation practices had significant influence on LAI of grain cowpea only during North East Monsoon 1999. Among the treatments, tied ridges (M_1) was superior to flat bed which recorded the highest LAI. In both the years, application of 50 per cent N through fertilizer and 50 per cent N through goat manure (N_2) recorded the highest LAI.

Interaction effect between trees and N management was significant only during 1999. Among the treatment combinations, grain cowpea in *A. excelsa* recorded higher LAI but it was comparable with the LAI of grain cowpea in *E. officinalis*.

With regard to fodder cowpea, the tree species had significant influence on the LAI only during North East Monsoon, 2000. Among the treatments, the LAI was the highest with fodder cowpea in *E. officinalis* (T_3). Moisture conservation practices had significant influence on LAI of fodder cowpea only during first year. Among the treatments, tied ridges (M_1) recorded the highest LAI. With regard to N management practices, application of 50 per cent N through fertilizer and 50 per cent N through goat manure (N_2) recorded the highest LAI of fodder cowpea in both the years.

The interaction effect was found to be not significant.

Table 45. Effect of treatments on Leaf Area Index (LAI) of grain and fodder cowpea at 60 DAS

Treatment	Grain cowpea		Fodder cowpea	
	1999	2000	1999	2000
T_1	2.80	1.59	3.06	1.84
T_2	2.78	1.60	3.06	1.85
T_3	2.81	1.62	3.06	1.89
SE_d	0.003	0.004	0.009	0.005
CD (P=0.05)	0.007	0.009	NS	0.011
M_1	2.80	1.60	3.10	1.86
M_2	2.79	1.60	3.02	1.86
SE_d	0.003	0.003	0.008	0.004
CD (P=0.05)	0.006	NS	0.017	NS
N_1	2.77	1.59	3.03	1.83
N_2	2.82	1.62	3.09	1.89
SE_d	0.003	0.003	0.006	0.004
CD (P=0.05)	0.007	0.007	0.014	0.008

	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD
T x M	0.005	NS	0.005	NS	0.013	NS	0.007	NS
M x N	0.004	NS	0.004	NS	0.010	NS	0.006	NS
N x M	0.005	NS	0.005	NS	0.009	NS	0.005	NS
N x T	0.006	0.012	0.006	NS	0.011	NS	0.006	NS
T x N	0.005	0.012	0.005	NS	0.012	NS	0.007	NS

Table 46. Interaction effect on LAI of grain cowpea (1999)

	M_1	M_2	N_1	N_2	Mean
T_1	2.80	2.80	2.77	2.83	2.80
T_2	2.78	2.78	2.75	2.81	2.78
T_3	2.81	2.80	2.79	2.82	2.81
M_1			2.77	2.82	
M_2			2.77	2.81	
Mean	2.80	2.79	2.77	2.82	

4.2.3.2.1.3. Dry matter production (Table 47 to 49)

The data revealed that tree species had significant influence on the DMP of grain cowpea in all the growth stages in both the years except 30 DAS in first year. During first year at 60 DAS, the DMP of grain cowpea was the highest in *A. excelsa* (T_1) but it was comparable with *E. officinalis*. However, at harvest the DMP of grain cowpea in *E. officinalis* (T_3) was higher and it was comparable with *A. excelsa* (T_1). During second year, the DMP of grain cowpea was the highest in *E. officinalis* (T_3) in all the growth stages.

Moisture conservation practices had significant influence on DMP of grain cowpea only during North East Monsoon 1999. In all the stages, tied ridges (M_1) recorded the highest DMP. Application of 50 per cent N through fertilizer and 50 per cent N through goat manure (N_2) recorded the highest DMP in all the growth stages in both the years.

Interaction effect between trees and N management was significant at 60 DAS during 1999. Among the treatment combinations, the DMP of grain cowpea in *A. excelsa* with 50 per cent N through fertilizer and 50 per cent N through goat manure recorded the highest DMP followed by *E. officinalis* with same N management practice. At 90 DAS, the interaction effect was significant between trees and moisture conservation and between trees and N management. Among the treatment combinations, the DMP of grain cowpea was higher in *A. excelsa* with tied ridges and application of 50 per cent N through fertilizer and 50 per cent N through goat manure, but it was comparable with the DMP of grain cowpea in *E. officinalis* with same treatment combination.

In case of DMP of fodder cowpea, significant influence on the DMP was recorded by the tree species. During first year, the DMP of fodder cowpea in *A. excelsa* (T_1) was the highest in all the growth stages followed by *E. officinalis* (T_3). During second year, the DMP was the highest in *E. officinalis* (T_3). Moisture conservation practices significantly

Table 47. Effect of treatments on dry matter production (kg ha^{-1}) of grain cowpea

Treatment	30 DAS		60 DAS		Harvest	
	1999	2000	1999	2000	1999	2000
T_1	425	284	747	505	2168	1085
T_2	417	276	675	475	2106	1084
T_3	419	299	728	546	2171	1129
SE_d	4.91	1.96	9.67	6.05	19.92	6.21
CD (P=0.05)	NS	4.37	21.60	13.47	44.38	13.84
M_1	427	287	738	508	2232	1104
M_2	413	286	696	509	2065	1096
SE_d	4.01	1.60	7.90	4.94	16.26	5.07
CD (P=0.05)	8.93	NS	17.59	NS	36.24	NS
N_1	414	279	650	486	2006	1086
N_2	427	294	784	532	2291	1113
SE_d	2.56	2.63	14.55	4.50	16.11	3.87
CD(P=0.05)	5.58	5.72	31.69	9.81	35.11	8.44

	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD
T x M	6.94	NS	2.77	NS	13.68	NS	8.55	NS	28.17	62.76	8.79	NS
M x N	4.76	NS	3.08	NS	16.55	NS	6.68	NS	22.89	NS	6.38	NS
N x M	3.62	NS	3.71	NS	20.57	NS	6.36	NS	22.78	NS	5.48	NS
N x T	4.43	NS	4.55	NS	25.19	54.9	7.79	NS	27.91	60.81	6.71	NS
T x N	5.82	NS	3.77	NS	20.27	44.4	8.18	NS	28.04	61.79	7.82	NS

Table 48. Interaction effect on dry matter production (kg ha^{-1}) of grain cowpea

Treatment	60 DAS					Harvest				
	M_1	M_2	N_1	N_2	Mean	M_1	M_2	N_1	N_2	Mean
T_1	767	728	653	842	747	2403	1933	1944	2393	2168
T_2	691	660	628	723	675	2153	2058	1992	2219	2106
T_3	756	699	670	787	728	2140	2203	2082	2260	2171
M_1			663	814				2074	2391	
M_2			638	753				1939	2191	
Mean	738	696	650	784		2232	2065	2006	2291	

	60 DAS SE_d	60 DAS CD		Harvest SE_d	Harvest CD
T x M	13.68	NS	T x M	28.17	62.76
M x N	16.55	NS	M x N	22.89	NS
N x M	20.57	NS	N x M	22.78	NS
N x T	2319	54.90	N x T	27.91	60.81
T x N	20.27	44.4	T x N	28.04	61.79

Table 49. Effect of treatments on dry matter production (kg ha^{-1}) of fodder cowpea

Treatment	30 DAS		Harvest	
	1999	2000	1999	2000
T_1	794	621	2403	1201
T_2	715	638	1996	1198
T_3	769	704	2134	1441
SE_d	6.04	7.35	40.30	4.25
CD (P=0.05)	13.45	16.38	89.79	9.47
M_1	783	651	2366	1288
M_2	737	658	1988	1272
SE_d	4.93	6.00	32.90	3.47
CD (P=0.05)	10.98	NS	73.32	NS
N_1	729	629	2104	1224
N_2	790	680	2250	1337
SE_d	9.05	3.88	28.42	6.33
CD (P=0.05)	19.72	8.45	61.92	13.80

	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD
T x M	19.02	NS	10.39	NS	86.99	NS	6.01	NS
M x N	10.31	NS	7.15	NS	43.48	NS	7.22	NS
N x M	12.80	NS	5.49	NS	40.19	NS	8.96	NS
N x T	15.68	NS	6.72	NS	56.34	NS	10.97	NS
T x N	12.62	NS	8.75	NS	63.19	NS	8.84	NS

influenced the DMP of fodder cowpea only during 1999. Among the treatments, tied ridges (M_1) recorded the highest DMP. Application of 50 per cent N through fertilizer and 50 per cent N through goat manure (N_2) recorded the highest DMP in all the growth stages in both the years.

The interaction effect was not significant in both the years.

4.2.3.2.2. Yield parameters

4.2.3.2.2.1. Number of pods per plant (Table 50 and 52)

The data revealed that the number of pods per plant was the highest with grain owpea in *E. officinalis* (T_3) in both the years. Moisture conservation practices had ignificant influence on number of pods per plant only during 1999. Among the reatments, tied ridges (M_1) recorded the highest number of pods per plant. Application of 50 per cent N through fertilizer and 50 per cent N through goat manure (N_2) recorded the highest number of pods per plant in both the years. The interaction effect was significant between trees and moisture conservation as well as N management and between moisture conservation and N management during 1999 only. The treatment combination, grain cowpea with *E. officinalis* under tied ridges with application of 50 per cent N through fertilizer and 50 per cent N through goat manure ($T_3M_1N_2$) recorded the highest number of pods per plant.

4.2.3.2.2.2. Pod length (Table 50)

Among the tree species, pod length of grain cowpea in *E. officinalis* (T_3) was higher and it was comparable with *A. excelsa* (T_1) in both the years. Moisture conservation practices had significant influence on pod length only during 1999. Among the treatments, the highest pod length was recorded by tied ridges (M_1). N management practices had significant influence only during first year. Application of 50 per cent N through fertilizer and 50 per cent N through goat manure recorded the highest pod length.

4.2.3.2.2.3. Number of seeds per pod (Table 50)

The results revealed that the tree species had no significant influence on the number of seeds per pod in both the years. Moisture conservation practices had significant influence on number of seeds per pod only during 1999. Among the treatments, tied ridges (M_1) recorded the highest number of seeds per pod. Application of 50 per cent N through fertilizer and 50 per cent N through goat manure (N_2) recorded the highest number of seeds per pod in both the years.

The interaction effect was not significant in both the years.

4.2.3.2.2.4. 100 seed weight (Table 50)

With regard to tree species, significant influence on 100 seed weight was recorded only during 1999. Among the trees, the 100 seed weight of grain cowpea was the highest in *E. officinalis* (T_3). Moisture conservation practices significantly influenced the 100 seed weight only during 1999. Among the treatments, tied ridges (M_1) was superior to flat bed (M_2) and it recorded the highest 100 seed weight. The N management practices had significant influence on 100 seed weight only during North East Monsoon 1999. Among the treatments, application of 50 per cent N through fertilizer and 50 per cent N through goat manure (N_2) recorded the highest 100 seed weight.

The interaction effect was not significant.

4.2.3.2.3. Yield

4.2.3.2.3.1. Seed yield (Table 51 and 52)

The results revealed that tree species had significant influence on seed yield of grain cowpea in both the years. Among the tree species, the seed yield of cowpea was the highest (349 and 166 kg ha^{-1}, respectively) in *E. officinalis* (T_3) in both the years. Moisture conservation practices significantly influenced the grain yield of cowpea only during 1999.

Among the treatments, tied ridges (M_1) recorded the highest grain yield (349 kg ha^{-1}). Application of 50 per cent N through fertilizer and 50 per cent N through goat manure recorded the highest grain yield in both the years (354 and 150 kg ha^{-1} respectively).

The interaction effect between trees and moisture conservation as well as between trees and N management and moisture conservation and N management were significant only during 1999. Among the treatment combinations, *E. officinalis* under tied ridges with application of 50 per cent N through fertilizer and 50 per cent N through goat manure ($T_3M_1N_2$) recorded the highest seed yield.

4.2.3.2.3.2. Haulm yield (Table 51 and 52)

The highest haulm yield was recorded with *E. officinalis* (T_3) in both the years. Moisture conservation practices had significant influence on the haulm yield only during 1999. Among the treatments, tied ridges (M_1) was superior to flat bed. Application of 50 per cent N through fertilizer and 50 per cent N through goat manure (N_2) recorded the highest haulm yield in both the years.

The interaction effect between trees and moisture conservation as well as between trees and N management and moisture and N management were significant only during 1999. The treatment combination $T_3M_1N_2$ (*E. officinalis* under tied ridges with application of 50 per cent N through fertilizer and 50 per cent N through goat manure) recorded higher haulm yield than the other treatments.

4.2.3.2.3.3. Dry fodder yield of fodder cowpea (Table 53)

The data showed that the tree species had significant influence on dry fodder yield of fodder cowpea only during 2000. Highest dry fodder yield was recorded with fodder cowpea in *E. officinalis* (T_3). Moisture conservation practices significantly influenced the dry fodder yield only during 1999. Among the treatments, tied ridges (M_1) recorded the highest dry fodder yield.

Table 50. Effect of treatments on yield parameters of grain cowpea

Treatment	No. of pods plant^{-1}		Pod length (cm)		No. of seeds pod^{-1}		100 seed weight (g)	
	1999	2000	1999	2000	1999	2000	1999	2000
T_1	10.3	4.8	17.7	15.6	17.3	14.4	9.75	8.41
T_2	9.8	4.8	17.4	15.4	17.0	14.6	9.13	8.39
T_3	11.0	5.6	17.7	15.7	17.4	14.6	9.86	8.36
SE_d	0.19	0.04	0.12	0.05	0.16	0.16	0.05	0.04
CD (P=0.05)	0.41	0.09	0.26	0.12	NS	NS	0.11	NS
M_1	11.2	5.1	17.9	15.5	17.5	14.6	9.64	8.41
M_2	9.6	5.1	17.2	15.6	17.0	14.5	9.52	8.37
SE_d	0.15	0.03	0.10	0.05	0.13	0.13	0.04	0.03
CD(P=0.05)	0.34	NS	0.22	NS	0.29	NS	0.09	NS
N_1	9.7	4.9	17.0	15.5	16.8	14.0	9.34	8.40
N_2	11.0	5.2	18.2	15.6	17.8	15.1	9.83	8.38
SE_d	0.15	0.03	0.13	0.06	0.14	0.15	0.05	0.01
CD(P=0.05)	0.33	0.06	0.29	NS	0.30	0.32	0.11	NS

	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD
T x M	0.26	0.59	0.06	NS	0.37	NS	0.06	NS	0.51	NS	0.22	NS	0.07	NS	0.06	NS
M x N	0.22	0.47	0.04	NS	0.16	NS	0.07	NS	0.19	NS	0.20	NS	0.06	NS	0.04	NS
N x M	0.22	0.47	0.04	NS	0.19	NS	0.09	NS	0.19	NS	0.21	NS	0.07	NS	0.02	NS
N x T	0.26	0.56	0.05	NS	0.23	NS	0.11	NS	0.24	NS	0.26	NS	0.09	NS	0.03	NS
T x N	0.26	0.58	0.05	NS	0.20	NS	0.09	NS	0.23	NS	0.24	NS	0.08	NS	0.05	NS

Table 51. Effect of treatments on seed and haulm yield (kg ha^{-1}) of grain cowpea

Treatment	Seed yield				Haulm yield			
	1999		2000		1999		2000	
T_1	347		140		529		211	
T_2	309		131		455		205	
T_3	349		166		573		236	
SE_d	1.45		1.70		2.01		2.02	
CD (P=0.05)	3.24		3.79		4.49		4.51	
M_1	349		145		566		218	
M_2	321		147		472		217	
SE_d	1.19		1.38		1.64		1.65	
CD (P=0.05)	2.65		NS		3.66		NS	
N_1	316		142		490		207	
N_2	354		150		548		228	
SE_d	1.72		2.22		1.81		2.49	
CD (P=0.05)	3.74		4.85		3.94		5.42	
	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD
T x M	2.05	4.58	2.40	NS	2.85	6.34	2.86	NS
M x N	2.09	4.58	2.62	NS	2.44	5.38	2.98	NS
N x M	2.43	5.29	3.14	NS	2.56	5.57	3.52	NS
N x T	2.98	6.48	3.85	NS	3.13	6.82	4.30	NS
T x N	2.56	5.61	3.21	NS	2.99	6.59	3.66	NS

Table 52. Interaction effect on no. of pods plant^{-1}, grain and haulm yield (kg ha^{-1}) of grain cowpea

Treatment	No. of pods plant^{-1}					Grain yield (kg ha^{-1})					Haulm yield (kg ha^{-1})				
	M_1	M_2	N_1	N_2	Mean	M_1	M_2	N_1	N_2	Mean	M_1	M_2	N_1	N_2	Mean
T_1	11.1	9.6	9.8	10.9	10.3	350	343	330	363	347	575	482	496	561	529
T_2	10.2	9.4	9.1	10.5	9.8	340	278	288	330	309	491	419	427	483	455
T_3	12.2	9.9	10.4	11.7	11.0	356	343	331	368	349	633	514	546	601	573
M_1			10.2	12.1				325	372				521	611	
M_2			9.3	9.9				308	335				459	485	
Mean	11.2	9.6	9.7	11.0		349	321	316	354		566	472	490	548	

	SE_d	CD		SE_d	CD		SE_d	CD
T x M	0.26	0.59	T x M	2.05	4.58	T x M	2.85	6.34
M x N	0.22	0.47	M x N	2.09	4.58	M x N	2.44	5.38
N x M	0.26	0.58	N x M	2.98	6.48	N x M	3.13	6.82
N x T	0.22	0.47	N x T	2.43	5.29	N x T	2.56	5.57
T x N	0.26	0.58	T x N	2.56	5.61	T x N	2.99	6.59

Table 53. Effect of treatments on dry fodder yield (kg ha^{-1}) of fodder cowpea

Treatment	1999		2000	
T_1	3094		1541	
T_2	3054		1561	
T_3	2950		1895	
SE_d	103		48	
CD (P=0.05)	NS		109	
M_1	3225		1677	
M_2	2841		1655	
SE_d	84		39	
CD (P=0.05)	188		NS	
N_1	2925		1585	
N_2	3141		1747	
SE_d	66		34	
CD (P=0.05)	144		76	
	SE_d	CD	SE_d	CD
T x M	146	NS	69	NS
M x N	107	NS	53	NS
N x M	94	NS	49	NS
N x T	115	NS	60	NS
T x N	131	NS	65	NS

Application of 50 per cent N through fertilizer and 50 per cent N through goat manure (N_2) recorded the highest dry fodder yield in both the years.

The interaction effect was found to be not significant in both the years.

4.2.3.3. Total grass yield of *Cenchrus glaucus* (Table 54)

The data revealed that the tree species had no significant influence on the total grass yield of *C. glaucus* in both the years. There was no significant influence on grass yield with regard to moisture conservation practices. Among the N management practices, application of 50 per cent N through fertilizer and 50 per cent N through goat manure (N_2) recorded the highest total grass yield in both the years.

The interaction effect was not significant in both the years.

4.2.3.4. Evaluation of cropping systems

4.2.3.4.1. Total dry matter production (Table 55 and 56)

The results revealed that the total DMP of grain sorghum + cowpea was significantly influenced by the tree species. Highest total DMP was recorded with *E. officinalis* (T_3) and it was superior to *A. excelsa* (T_1).

Moisture conservation practices had significant influence only during 1999. Among the treatments, tied ridges (M_1) recorded the highest total DMP. Application of 50 per cent N through fertilizer and 50 per cent N through goat manure (N_2) recorded the highest total DMP in both the years.

The interaction effect between trees and moisture conservation and between moisture conservation and N management were significant only during 1999. Among the treatment combinations, the total DMP was higher in *A. excelsa* under tied ridges with application of 50 per cent N through fertilizer and 50 per cent N through goat manure ($T_1M_1N_2$) but it was comparable with *E. officinalis* with same treatment combination ($T_3M_1N_2$).

Table 54. Effect of treatments on total green grass yield (kg ha^{-1}) of *Cenchrus glaucus*

Treatment	1999	2000
T_1	12797	10618
T_2	12718	10561
T_3	12697	10614
SE_d	66	110
CD (P=0.05)	NS	NS
M_1	12751	10628
M_2	12724	10567
SE_d	53	90
CD (P=0.05)	NS	NS
N_1	12235	10106
N_2	13240	11089
SE_d	87	58
CD (P=0.05)	190	127

	SE_d	CD	SE_d	CD
T x M	93	NS	156	NS
M x N	102	NS	107	NS
N x M	123	NS	82	NS
N x T	151	NS	101	NS
T x N	125	NS	131	NS

Table 55. Effect of treatments on total dry matter production (kg ha^{-1}) of the cropping systems

Treatment	Sorghum + cowpea (grain)		Sorghum + cowpea (fodder)		*Cenchrus glaucus*	
	1999	2000	1999	2000	1999	2000
T_1	6286	2985	8649	5725	3570	2995
T_2	5678	3022	7778	5561	3561	2961
T_3	6562	3292	8316	6586	3542	2978
SE_d	109	91	79	76	91	86
CD (P=0.05)	242	203	176	169	NS	NS
M_1	6604	3094	8697	5941	3566	2990
M_2	5747	3106	7799	5973	3550	2966
SE_d	89	74	65	62	74	70
CD (P=0.05)	198	NS	144	NS	NS	NS
N_1	5863	3049	7916	5814	3390	2818
N_2	6488	3150	8580	6101	3726	3138
SE_d	92	42	44	86	111	113
CD (P=0.05)	200	92	97	188	242	247

	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD
T x M	154	342	128	NS	112	249	107	NS	129	NS	122	NS
M x N	128	281	101	NS	78	174	106	NS	134	NS	133	NS
N x M	130	283	99	NS	63	137	122	NS	157	NS	160	NS
N x T	159	NS	121	NS	77	168	149	NS	192	NS	196	NS
T x N	156	NS	124	NS	96	212	130	NS	164	NS	163	NS

Table 56. Interaction effect on total dry matter production (kg ha^{-1}) of the cropping systems (1999)

Treatment	Sorghum + cowpea (grain)					Sorghum + cowpea (fodder)				
	M_1	M_2	N_1	N_2	Mean	M_1	M_2	N_1	N_2	Mean
T_1	6973	5599	5916	6657	6286	8989	8310	8422	8877	8649
T_2	5883	5472	5446	5910	5678	8061	7496	7521	8036	7778
T_3	6955	6169	6227	6897	6562	9042	7591	7804	8829	8316
M_1			6134	7073				8278	9116	
M_2			5591	5903				7553	8044	
Mean	6604	5747	5863	6488		8697	7799	7916	8580	

	SE_d	CD		SE_d	CD
T x M	154	342	T x M	112	249
M x N	128	281	M x N	78	174
N x M	130	283	N x M	77	168
N x T	159	NS	N x T	63	137
T x N	156	156	T x N	96	212

With regard to fodder sorghum + cowpea, during first year, the total DMP was higher in *A. excelsa* (T_1) followed by *E. officinalis* (T_3) whereas during second year, *E. officinalis* (T_3) recorded the highest total DMP. Moisture conservation practices had significant influence only during 1999. Among the treatments, tied ridges (M_1) recorded the highest total DMP. Application of 50 per cent N through fertilizer and 50 per cent N through goat manure (N_2) recorded the highest total DMP in both the years.

The interaction effect between trees and moisture conservation as well as between trees and N management and moisture conservation and N management were significant only during 1999. The treatment combination, *E. officinalis* under tied ridges with application of 50 per cent fertilizer N and 50 per cent N through goat manure ($T_3M_1N_2$) recorded higher total DMP but was comparable with *A. excelsa* with same treatment combination ($T_1M_1N_2$).

In case of *C. glaucus*, the tree species and moisture conservation practices had no significant influence on the total DMP in both the years. Among the N management practices, application of 50 per cent N through fertilizer and 50 per cent N through goat manure (N_2) recorded the highest total DMP in both the years.

The interaction effect was found to be not significant in both the years.

4.2.3.4.2. Sorghum fodder equivalent yield (Table 57)

With regard to grain sorghum + cowpea, the tree species had significant influence on the sorghum fodder equivalent yield. Among the tree species, the highest sorghum fodder equivalent yield was recorded by *E. officinalis* (T_3) in both the years. Moisture conservation practices had significant influence on the sorghum fodder equivalent yield only during 1999. Among the treatments, tied ridges recorded the highest sorghum fodder equivalent yield. Application of 50 per cent N through fertilizer and 50 per cent N through goat manure (N_2) recorded the highest sorghum fodder equivalent yield in both the years.

Table 57. Sorghum fodder equivalent yield (t ha^{-1}) of the cropping systems

Treatment	Sorghum + cowpea (grain)		Sorghum + cowpea (fodder)		*Cenchrus glaucus*	
	1999	2000	1999	2000	1999	2000
T_1	27.32	9.67	11.78	7.52	10.97	9.10
T_2	24.28	10.09	11.18	7.45	10.90	9.05
T_3	27.34	11.35	11.57	8.74	10.89	9.10
SE_d	0.79	0.24	0.42	0.18	0.36	0.16
CD (P=0.05)	1.76	0.53	NS	0.40	NS	NS
M_1	27.82	10.38	12.07	7.92	10.94	9.11
M_2	24.81	10.36	10.94	7.89	10.90	9.06
SE_d	0.63	0.19	0.34	0.15	0.29	0.13
CD (P=0.05)	1.40	NS	0.75	NS	NS	NS
N_1	24.15	10.08	11.17	7.74	10.49	8.66
N_2	28.48	10.66	11.85	8.07	11.35	9.50
SE_d	0.73	0.22	0.28	0.14	0.27	0.12
CD (P=0.05)	1.59	0.48	0.61	0.31	0.59	0.26

	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD
T x M	1.31	NS	0.54	NS	0.60	NS	0.36	NS	0.54	NS	0.26	NS
M x N	0.90	NS	0.30	NS	0.48	NS	0.21	NS	0.40	NS	0.19	NS
N x M	1.03	NS	0.34	NS	0.47	NS	0.24	NS	0.38	NS	0.19	NS
N x T	1.29	NS	0.38	NS	0.57	NS	0.28	NS	0.47	NS	0.23	NS
T x N	1.09	NS	0.36	NS	0.62	NS	0.26	NS	0.49	NS	0.23	NS

With regard to fodder sorghum + cowpea, the tree species had significant influence on the sorghum fodder equivalent yield only during second year. Highest sorghum fodder equivalent yield was recorded by *E. officinalis* (T_3). Moisture conservation practices significantly influenced the sorghum fodder equivalent yield only during 1999. Among the treatments, tied ridges (M_1) recorded the highest fodder equivalent yield. Application of 50 per cent N through fertilizer and 50 per cent N through goat manure (N_2) recorded the highest sorghum fodder equivalent yield in both the years.

With regard to *C. glaucus*, the tree species and moisture conservation practices had no significant influence on the sorghum fodder equivalent yield. Application of 50 per cent N through fertilizer and 50 per cent N through goat manure recorded the highest sorghum fodder equivalent yield in both the years.

The interaction effect was found to be not significant in both the years.

4.2.3.5. Quality parameters

4.2.3.5.1. Total crude protein content (Table 58)

The data revealed that tree species and moisture conservation practices had no significant influence on the total crude protein content of different cropping systems in all the years. With regard to N management practices, significant influence on the crude protein content was recorded in grain sorghum + cowpea and fodder sorghum + cowpea only during 1999. In both the systems, application of 50 per cent N through fertilizer and 50 per cent N through goat manure (N_2) recorded the highest crude protein content in all the years.

4.2.3.5.2. Total crude protein yield (Table 59 and 60)

The data showed that in grain sorghum + cowpea, the tree species had significant influence on total crude protein yield in both the years. Among the treatments, *E. officinalis* (T_3) recorded the highest crude protein yield in both the years. Moisture conservation practices had significant influence only during 1999. Highest crude protein yield was recorded by tied

Table 58. Effect of treatments on total crude protein (per cent) of the cropping systems

Treatment	Sorghum + cowpea (grain)		Sorghum + cowpea (fodder)		*Cenchrus glaucus*	
	1999	2000	1999	2000	1999	2000
T_1	17.6	16.8	13.1	12.5	6.93	6.83
T_2	17.1	16.7	12.7	12.3	6.87	6.84
T_3	17.9	17.3	13.5	12.7	6.91	6.85
SE_d	0.45	0.69	0.55	0.47	0.04	0.11
CD (P=0.05)	NS	NS	NS	NS	NS	NS
M_1	17.9	17.0	13.4	12.5	6.94	6.85
M_2	17.2	16.9	12.8	12.5	6.87	6.84
SE_d	0.36	0.57	0.45	0.38	0.03	0.09
CD (P=0.05)	NS	NS	NS	NS	NS	NS
N_1	16.8	16.8	12.8	12.3	6.89	6.83
N_2	18.3	17.0	13.5	12.6	6.92	6.86
SE_d	0.27	0.35	0.18	0.49	0.02	0.04
CD (P=0.05)	0.58	NS	0.39	NS	NS	NS

	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD
T x M	0.63	NS	0.98	NS	0.78	NS	0.67	NS	0.06	NS	0.15	NS
M x N	0.45	NS	0.67	NS	0.48	NS	0.63	NS	0.04	NS	0.10	NS
N x M	0.38	NS	0.50	NS	0.25	NS	0.70	NS	0.03	NS	0.06	NS
N x T	0.46	NS	0.61	NS	0.31	NS	0.86	NS	0.03	NS	0.07	NS
T x N	0.55	NS	0.82	NS	0.59	NS	0.77	NS	0.05	NS	0.12	NS

Table 59. Effect of treatments on total crude protein yield (kg ha^{-1}) of the cropping systems

Treatment	Sorghum + cowpea (grain)		Sorghum + cowpea (fodder)		*Cenchrus glaucus*	
	1999	2000	1999	2000	1999	2000
T_1	488	226	484	295	244	205
T_2	380	225	426	281	244	202
T_3	536	264	476	351	243	204
SE_d	14.9	4.8	5.1	12.0	3.6	2.1
CD (P=0.05)	33.2	10.8	11.4	26.6	NS	NS
M_1	482	234	501	309	244	205
M_2	454	242	422	308	243	203
SE_d	12.1	3.9	4.2	9.8	2.9	1.7
CD (P=0.05)	26.9	NS	9.3	NS	NS	NS
N_1	426	238	436	297	232	192
N_2	510	239	488	321	255	215
SE_d	15.9	3.2	4.4	5.6	2.3	2.6
CD (P=0.05)	34.6	NS	9.7	12.3	5.0	5.7

	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD
T x M	29.4	65.5	11.2	NS	7.2	16.1	16.9	NS	5.0	NS	3.0	NS
M x N	23.2	51.3	9.1	NS	6.1	NS	11.3	NS	3.7	NS	3.1	NS
N x T	27.5	59.9	8.8	NS	7.7	16.7	9.8	NS	4.0	NS	4.5	NS
N x M	22.5	48.9	8.5	NS	6.3	NS	8.0	NS	3.2	NS	3.7	NS
T x N	28.5	62.8	9.5	NS	7.5	16.4	13.8	NS	4.5	NS	3.8	NS

Table 60. Interaction effect on total crude protein yield (kg ha^{-1}) of the cropping systems (1999)

Treatment	Sorghum + cowpea (grain)					Sorghum + cowpea (fodder)				
	M_1	M_2	N_1	N_2	Mean	M_1	M_2	N_1	N_2	Mean
T_1	554	422	440	537	488	515	453	462	507	484
T_2	350	410	307	452	380	446	405	408	444	426
T_3	542	530	532	540	536	542	410	439	512	476
M_1			409	555				473	529	
M_2			444	464				399	447	
Mean	482	454	426	510		501	423	436	488	

	SE_d	CD		SE_d	CD
T x M	29.4	65.5	T x M	7.2	16.1
M x N	23.2	51.3	M x N	6.1	NS
N x M	22.5	48.9	N x M	6.3	NS
N x T	27.5	59.9	N x T	7.7	16.7
T x N	28.5	62.8	T x N	7.5	16.4

ridges (M_1). N management practices significantly influenced the crude protein yield only during 1999. Application of 50 per cent N through fertilizer and 50 per cent N through goat manure (N_2) recorded the highest crude protein yield of grain sorghum + cowpea.

Interaction effect between trees and moisture conservation as well as between trees and N management and moisture conservation and N management were significant only during 1999. Among the treatment combinations, grain sorghum + cowpea in *E. officinalis* under tied ridges with application of 50 per cent N through fertilizer and 50 per cent N through goat manure ($T_3M_1N_2$) recorded comparable crude protein yield with *A. excelsa* with same treatment combination ($T_1M_1N_2$).

In case of fodder sorghum + cowpea, tree species had significant influence on crude protein yield in both the years. During first year, the crude protein yield was higher in *A. excelsa* (T_1) but it was comparable with crude protein yield in *E. officinalis* (T_3). During second year, *E. officinalis* (T_3) recorded the highest crude protein yield. Moisture conservation practices had significant influence only during 1999. Among the treatments, tied ridges (M_1) recorded the highest crude protein yield. Application of 50 per cent N through fertilizer and 50 per cent N through goat manure (N_2) recorded significantly the highest crude protein yield in both the years.

Interaction effect between trees and moisture conservation as well as between N management were found to be significant only during 1999. The treatment combination, *E. officinalis* under tied ridges with application of 50 percent N through fertilizer and 50 per cent N through goat manure recorded higher crude protein yield than other treatments.

With regard to *C. glaucus*, tree species and moisture conservation practices had no significant influence on the total crude protein yield in both the years. Application of 50 per cent N through fertilizer and 50 per cent N through goat manure (N_2) recorded the highest crude protein yield in both the years.

The interaction effect was not significant in both the years.

4.2.3.6. Soil Moisture (Table 61 to 66)

The soil moisture content in terms of percentage at a depth of 0 - 15, 16 - 30 and 31 - 45 cm were estimated at weekly intervals. However, the moisture content was computed to 0 - 45 cm depth.

In general the available soil moisture was higher during first year than second year. The soil moisture reached wilting point at 70 DAS during second year.

With regard to grain sorghum + cowpea, the variation in soil moisture was recorded in both years among the tree species. The soil moisture was higher in *E. officinalis* (T_3) whereas it was lower in *C. pentandra* (T_2) in both the years.

Among the moisture conservation practices, tied ridges (M_1) recorded higher soil moisture than flat bed during first year only whereas during second year variation in available soil moisture was not observed. Application of 50 per cent N through fertilizer and 50 per cent N through goat manure (N_2) recorded higher soil moisture than inorganic N alone in both the years.

With regard to fodder sorghum + cowpea the same trend was recorded as that of grain sorghum + cowpea.

In case of *C. glaucus* variation in soil moisture was recorded only during first year. *E. officinalis* (T_3) recorded higher soil moisture than other tree species. Moisture conservation practices with tied ridges increased the soil moisture content only during first year. Application of goat manure recorded higher soil moisture as compared to inorganic N alone only during 1999 whereas there was no variation in soil moisture during second year.

4.2.3.7. Nutrient uptake studies

4.2.3.7.1. Total nitrogen uptake (Table 67 and 70)

With regard to N uptake of grain sorghum + cowpea, tree species had significant influence on the N uptake in both the years. Significantly higher N uptake was recorded

Table 61. Soil moisture content (cm) at weekly intervals to a depth of 0-45 cm in grain sorghum + cowpea (1999)

Treatment	Standard weeks										
	43	44	45	46	47	48	49	50	51	52	1
$T_1 M_1 N_1$	10.6	10.5	11.7	9.0	11.4	9.8	8.7	8.3	8.0	7.4	6.7
N_2	10.7	10.5	11.9	9.1	11.6	10.0	8.9	8.4	8.2	7.7	6.8
$M_2 N_1$	9.8	10.2	10.1	8.0	9.8	9.4	8.5	7.7	7.3	6.7	6.4
N_2	10.0	10.2	10.2	8.0	9.8	9.5	8.5	7.8	7.3	6.7	6.5
$T_2 M_1 N_1$	10.8	10.6	11.5	8.8	11.7	9.7	8.8	8.3	7.8	7.3	6.3
N_2	10.9	10.4	11.6	8.8	11.9	9.8	8.9	8.4	7.8	7.3	6.4
$M_2 N_1$	9.8	10.3	9.8	7.8	9.5	9.0	8.3	7.7	7.4	6.8	6.3
N_2	10.2	10.3	10.0	7.8	9.5	9.0	8.4	7.8	7.4	6.9	6.4
$T_3 M_1 N_1$	10.7	10.6	11.9	8.9	11.7	9.7	9.2	8.8	8.0	7.6	6.9
N_2	10.8	10.6	12.1	9.0	11.8	9.8	9.3	8.8	8.1	7.7	7.0
$M_2 N_1$	10.1	10.0	10.7	8.0	9.1	8.6	8.5	7.8	7.3	7.0	6.7
N_2	10.1	10.1	10.7	8.0	9.2	8.8	8.5	7.8	7.4	7.1	6.7

Table 62. **Soil moisture content (cm) at weekly intervals to a depth of 0-45 cm in grain sorghum + cowpea (2000)**

Treatment	Standard weeks											
	42	43	44	45	46	47	48	49	50	51	52	1
$T_1 M_1 N_1$	8.1	7.5	6.3	5.8	5.0	5.2	5.1	x	x	x	x	x
N_2	8.2	7.6	6.3	5.8	5.1	5.1	5.2	x	x	x	x	x
$M_2 N_1$	8.1	7.5	6.2	5.7	5.0	5.2	5.2	x	x	x	x	x
N_2	8.2	7.5	6.3	5.8	5.0	5.2	5.1	x	x	x	x	x
$T_2 M_1 N_1$	8.0	7.4	6.2	5.6	5.0	5.1	5.2	x	x	x	x	x
N_2	8.1	7.4	6.4	5.7	5.1	5.1	5.2	x	x	x	x	x
$M_2 N_1$	8.0	7.5	6.3	5.7	5.1	5.0	5.1	x	x	x	x	x
N_2	8.1	7.4	6.3	5.6	5.0	5.0	5.1	x	x	x	x	x
$T_3 M_1 N_1$	8.2	7.5	6.3	5.7	5.1	5.1	5.2	x	x	x	x	x
N_2	8.3	7.6	6.4	5.8	5.1	5.2	5.2	x	x	x	x	x
$M_2 N_1$	8.1	7.5	6.3	5.8	5.1	5.2	5.1	x	x	x	x	x
N_2	8.2	7.5	6.3	5.8	5.0	5.2	5.2	x	x	x	x	x

x - below wilting point

Table 63. **Soil moisture content (cm) at weekly intervals to a depth of 0-45 cm in fodder sorghum + cowpea (1999)**

Treatment	Standard weeks						
	43	44	45	46	47	48	49
$T_1 M_1 N_1$	10.5	10.5	11.6	9.0	11.5	9.7	8.6
N_2	10.6	10.5	11.7	9.1	11.5	9.7	8.7
$M_2 N_1$	10.1	10.2	10.0	7.9	9.7	9.4	8.4
N_2	10.2	10.2	10.2	8.1	9.6	9.4	8.4
$T_2 M_1 N_1$	10.7	10.5	11.4	8.8	11.8	9.8	8.8
N_2	10.8	10.5	11.6	8.7	11.8	9.8	8.8
$M_2 N_1$	10.1	10.2	9.9	7.8	9.4	8.9	8.3
N_2	10.3	10.2	10.0	7.9	9.5	8.9	8.4
$T_3 M_1 N_1$	10.5	10.6	12.0	9.0	11.8	9.9	9.3
N_2	10.7	10.6	12.0	8.9	11.8	9.9	9.3
$M_2 N_1$	10.3	10.0	10.5	8.0	9.1	8.7	8.4
N_2	10.3	10.0	10.6	8.0	9.2	8.6	8.4

Table 64. Soil moisture content (cm) at weekly intervals to a depth of 0-45 cm in fodder sorghum + cowpea (2000)

Treatment	Standard weeks						
	42	43	44	45	46	47	48
$T_1 M_1 N_1$	8.0	7.4	6.3	5.8	5.4	5.1	5.2
N_2	8.1	7.4	6.4	5.7	5.4	5.2	5.2
$M_2 N_1$	8.0	7.4	6.3	5.8	5.3	5.2	5.1
N_2	8.0	7.4	6.3	5.8	5.4	5.1	5.2
$T_2 M_1 N_1$	8.1	7.3	6.3	5.7	5.3	5.1	5.1
N_2	8.0	7.4	6.3	5.5	5.3	5.1	5.2
$M_2 N_1$	8.0	7.3	6.2	5.6	5.2	5.2	5.2
N_2	8.1	7.3	6.3	5.5	5.3	5.2	5.2
$T_3 M_1 N_1$	8.1	7.4	6.3	5.8	5.4	5.2	5.2
N_2	8.0	7.5	6.4	5.7	5.4	5.2	5.2
$M_2 N_1$	8.1	7.4	6.4	5.8	5.3	5.2	5.2
N_2	8.0	7.4	6.4	5.8	5.3	5.2	5.2

Table 65. Soil moisture content (cm) at weekly intervals to a depth of 0-45 cm in *Cenchrus glaucus* (1999)

Treatment	Standard weeks										
	43	44	45	46	47	48	49	50	51	52	1
$T_1 M_1 N_1$	10.5	10.6	11.5	9.2	11.4	9.6	8.7	8.3	7.9	7.3	6.6
N_2	10.5	10.6	11.6	9.3	11.5	9.7	8.7	8.3	7.9	7.3	6.7
$M_2 N_1$	10.0	10.3	10.3	8.1	9.6	9.3	8.4	7.8	7.3	6.7	6.4
N_2	10.1	10.3	10.0	8.1	9.6	9.4	8.4	7.8	7.3	6.7	6.4
$T_2 M_1 N_1$	10.7	10.7	11.5	8.9	11.6	9.7	8.8	8.3	7.7	7.3	6.2
N_2	10.8	10.7	11.6	9.0	11.6	9.7	8.9	8.3	7.8	7.4	6.2
$M_2 N_1$	10.2	10.4	10.0	7.9	9.3	8.9	8.4	7.6	7.3	6.6	6.2
N_2	10.3	10.4	10.1	8.0	9.5	8.9	8.5	7.7	7.3	6.6	6.2
$T_3 M_1 N_1$	10.7	10.7	11.9	9.1	11.8	9.6	9.3	8.7	7.8	7.3	6.8
N_2	10.8	10.7	12.0	9.1	11.9	9.6	9.3	8.7	7.9	7.3	7.0
$M_2 N_1$	10.1	10.2	10.5	7.9	9.1	8.6	8.4	7.8	7.3	6.9	6.6
N_2	10.3	10.4	10.5	7.9	9.1	8.7	8.4	7.8	7.3	6.9	6.6

Table 66. Soil moisture content (cm) at weekly intervals to a depth of 0-45 cm in *Cenchrus glaucus* (2000)

Treatment	Standard weeks											
	42	43	44	45	46	47	48	49	50	51	52	1
$T_1 M_1 N_1$	7.9	7.1	6.2	5.7	5.3	5.0	5.0	x	x	x	x	x
N_2	7.9	7.2	6.1	5.8	5.2	5.0	5.0	x	x	x	x	x
$M_2 N_1$	8.0	7.1	6.1	5.7	5.0	5.1	4.9	x	x	x	x	x
N_2	7.9	7.1	6.1	5.7	5.0	5.1	5.0	x	x	x	x	x
$T_2 M_1 N_1$	7.9	7.1	6.0	5.7	5.0	5.1	5.0	x	x	x	x	x
N_2	7.8	7.0	6.1	5.8	5.1	5.0	5.0	x	x	x	x	x
$M_2 N_1$	7.9	7.1	6.1	5.7	5.1	5.0	5.0	x	x	x	x	x
N_2	8.0	7.1	6.0	5.7	5.0	5.0	4.9	x	x	x	x	x
$T_3 M_1 N_1$	7.9	7.0	6.1	5.7	5.3	5.1	5.0	x	x	x	x	x
N_2	7.9	7.1	6.1	5.8	5.4	5.0	4.9	x	x	x	x	x
$M_2 N_1$	7.8	7.1	6.0	5.7	5.2	5.1	5.0	x	x	x	x	x
N_2	7.9	7.1	6.1	5.7	5.4	5.1	5.0	x	x	x	x	x

x - below wilting point

with *E. officinalis* (T_3) in both the years. Moisture conservation practices had significant influence on N uptake of grain sorghum + cowpea only during first year. Among the treatments, tied ridges (M_1) recorded the highest N uptake. Application of 50 per cent N through fertilizer and 50 per cent N through goat manure (N_2) was superior in increasing the N uptake in both the years.

Interaction effect between trees and moisture conservation practices and between moisture conservation and N management were significant only during 1999. Among the treatment combinations, sorghum + cowpea in *E. officinalis* under tied ridges with application of 50 per cent N through fertilizer and 50 per cent N through goat manure ($T_3M_1N_2$) recorded higher N uptake but it was comparable with *A. excelsa* with same treatment combination ($T_1M_1N_2$).

With regard to N uptake of fodder sorghum + cowpea, the tree species had significant influence on the N uptake in both the years. Among the tree species, during first year, the N uptake was higher in *A. excelsa* (T_1) but it was comparable with *E. officinalis* (T_3) whereas during second year, *E. officinalis* recorded the highest N uptake. Moisture conservation measures had significant influence on N uptake during first year only. Highest N uptake was recorded with tied ridges (M_1) and it was superior to flat bed (M_2). Application of 50 per cent N through fertilizer N and 50 per cent N through goat manure (N_2) recorded significantly the highest N uptake in both the years.

The interaction effect was not significant in both the years.

With regard to *C. glaucus*, the trees and moisture conservation practices had no significant influence on N uptake in both the years. Application of 50 per cent N through fertilizer and 50 per cent N through goat manure (N_2) recorded the highest N uptake in both the years.

The interaction effect was not significant in both the years.

4.2.3.7.2. **Total phosphorus uptake (Table 68 and 70)**

With regard to grain sorghum + cowpea, the tree species had significant influence on Phosphors (P) uptake in both the years. Highest total P uptake was recorded with *E. officinalis* (T_3) in both the years. The total P uptake was significantly influenced by the moisture conservation practices only during 1999. Among the treatments, tied ridges (M_1) recorded the highest P uptake. Application of 50 per cent N through fertilizer and 50 per cent N through goat manure (N_2) recorded the highest total P uptake in both the years.

Interaction effect between moisture conservation and N management practices was significant only during 1999. The treatment combination, tied ridges with 50 per cent N through inorganic fertilizer and 50 per cent N through goat manure recorded the highest P uptake.

With regard to the total P uptake of fodder sorghum + cowpea, the highest total P uptake was recorded with *E. officinalis* (T_3) in both the years but it was comparable with *A. excelsa* (T_1) during 1999. Tied ridges (M_1) recorded the highest total P uptake only during 1999. Application of 50 per cent N through fertilizer and 50 per cent N through goat manure (N_2) recorded the highest total P uptake in both the years.

The interaction effect was not significant in both the years.

With regard to the total P uptake of *C. glaucus*, the tree species and moisture conservation practices had no significant influence on total P uptake in both the years. Highest total P uptake was recorded with application of 50 per cent N through fertilizer and 50 per cent N through goat manure (N_2).

The interaction effect was not significant in both the years.

4.2.3.7.3. **Total potassium uptake (Table 69 and 70)**

The data showed that the total Potassium (K) uptake of grain sorghum + cowpea significantly influenced by the tree species. Among the trees, grain sorghum + cowpea in *E. officinalis* (T_3) recorded the highest K uptake in both the years.

Table 67. Effect of treatments on total nitrogen uptake (kg ha^{-1}) of the cropping systems

Treatment	Sorghum + cowpea (grain)		Sorghum + cowpea (fodder)		*Cenchrus glaucus*	
	1999	2000	1999	2000	1999	2000
T_1	79.6	36.0	77.4	47.4	39.1	32.8
T_2	68.0	36.0	68.0	45.4	38.9	32.4
T_3	87.1	40.1	76.6	55.8	38.9	32.6
SE_d	2.07	0.61	3.00	1.92	2.23	1.90
CD (P=0.05)	4.62	1.37	6.70	4.27	NS	NS
M_1	86.8	37.5	80.5	50.2	39.1	32.7
M_2	69.7	37.3	67.6	48.9	38.8	32.5
SE_d	1.69	0.50	2.45	1.56	1.82	1.55
CD (P=0.05)	3.77	NS	5.47	NS	NS	NS
N_1	70.6	36.5	69.7	47.6	37.0	30.7
N_2	85.8	38.2	78.3	51.5	40.9	34.5
SE_d	2.18	0.66	1.73	1.00	1.75	1.10
CD (P=0.05)	4.74	1.43	3.76	2.19	3.81	2.40

	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD
T x M	2.93	6.54	0.87	NS	4.25	NS	2.71	NS	3.16	NS	2.68	NS
M x N	2.76	6.06	0.83	NS	3.00	NS	1.85	NS	2.53	NS	1.90	NS
N x M	3.08	6.71	0.93	NS	2.44	NS	1.42	NS	2.47	NS	1.56	NS
N x T	3.77	NS	1.14	NS	2.99	NS	1.74	NS	3.03	NS	1.91	NS
T x N	3.38	NS	1.01	NS	3.67	NS	2.28	NS	3.09	NS	2.33	NS

Table 68. Effect of treatments on total phosphorus uptake (kg ha^{-1}) of the cropping systems

Treatment	Sorghum + cowpea (grain)		Sorghum + cowpea (fodder)		*Cenchrus glaucus*	
	1999	2000	1999	2000	1999	2000
T_1	10.69	4.65	12.12	7.54	11.3	9.4
T_2	9.28	4.67	10.32	7.83	11.2	9.3
T_3	11.79	5.37	12.92	9.43	11.3	9.4
SE_d	0.41	0.28	0.70	0.41	0.56	0.37
CD (P=0.05)	0.90	0.63	1.56	0.90	NS	NS
M_1	11.80	4.90	12.94	8.02	11.1	9.4
M_2	9.37	4.88	10.64	8.51	11.4	9.4
SE_d	0.33	0.23	0.57	0.33	0.46	0.30
CD (P=0.05)	0.74	NS	1.27	NS	NS	NS
N_1	9.44	4.61	10.80	7.81	11.1	8.9
N_2	11.73	5.18	12.77	8.71	11.4	9.9
SE_d	0.37	0.22	0.56	0.36	0.52	0.34
CD (P=0.05)	0.80	0.48	1.21	0.79	NS	0.74

	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD
T x M	0.57	NS	0.40	NS	0.99	NS	0.57	NS	0.79	NS	0.51	NS
M x N	0.50	1.09	0.32	NS	0.80	NS	0.49	NS	0.69	NS	0.45	NS
N x M	0.52	1.14	0.31	NS	0.79	NS	0.51	NS	0.74	NS	0.48	NS
N x T	0.64	NS	0.38	NS	0.96	NS	0.63	NS	0.91	NS	0.59	NS
T x N	0.61	NS	0.39	NS	0.98	NS	0.60	NS	0.85	NS	0.55	NS

Table 69. Effect of treatments on total potassium uptake (kg ha^{-1}) of the cropping systems

Treatment	Sorghum + cowpea (grain)		Sorghum + cowpea (fodder)		*Cenchrus glaucus*	
	1999	2000	1999	2000	1999	2000
T_1	70.3	32.9	70.3	52.4	28.8	24.2
T_2	66.2	33.3	61.9	51.2	28.1	23.9
T_3	81.3	37.4	75.6	62.6	30.0	24.1
SE_d	1.72	1.42	1.81	1.24	1.42	1.24
CD (P=0.05)	3.84	3.16	4.04	2.76	NS	NS
M_1	79.8	34.6	77.1	55.4	29.7	24.1
M_2	65.4	34.4	61.4	55.4	28.2	24.0
SE_d	1.41	1.16	1.48	1.01	1.16	1.02
CD (P=0.05)	3.13	NS	3.30	NS	NS	NS
N_1	67.9	33.4	63.2	52.5	27.7	22.8
N_2	77.3	35.7	75.3	58.3	30.2	25.3
SE_d	1.46	0.83	1.25	1.00	0.83	1.00
CD (P=0.05)	3.17	1.82	2.72	2.17	1.81	2.18

	Sorghum + cowpea (grain) 1999		Sorghum + cowpea (grain) 2000		Sorghum + cowpea (fodder) 1999		Sorghum + cowpea (fodder) 2000		*Cenchrus glaucus* 1999		*Cenchrus glaucus* 2000	
	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD
T x M	2.56	5.71	2.00	NS	3.43	NS	1.75	NS	2.00	NS	1.76	NS
M x N	1.94	4.28	1.43	NS	2.02	NS	1.42	NS	1.43	NS	1.43	NS
N x M	1.77	3.85	1.18	NS	2.06	NS	1.41	NS	1.17	NS	1.42	NS
N x T	2.16	NS	1.45	NS	2.52	NS	1.73	NS	1.44	NS	1.73	NS
T x N	2.37	NS	1.75	NS	0.48	NS	1.74	NS	1.75	NS	1.75	NS

Table 70. Interaction effect on total N, P and K uptake of grain sorghum (1999)

Treatment	N uptake ($kg\ ha^{-1}$)					P uptake ($kg\ ha^{-1}$)					K uptake ($kg\ ha^{-1}$)				
	M_1	M_2	N_1	N_2	Mean	M_1	M_2	N_1	N_2	Mean	M_1	M_2	N_1	N_2	Mean
T_1	91.0	68.3	71.4	87.8	79.6	12.41	8.97	9.25	12.13	10.69	82.4	58.3	62.5	78.1	70.3
T_2	72.7	63.2	62.3	73.6	68.0	9.88	8.67	8.84	9.74	9.28	66.0	57.8	57.8	66.0	61.9
T_3	96.7	77.6	78.5	96.1	87.1	13.12	10.46	10.23	13.36	11.79	83.0	68.1	69.2	81.9	75.6
M_1			76.8	96.7				10.07	13.53				69.1	85.2	
M_2			64.4	74.9				8.81	9.93				57.3	65.5	
Mean	86.8	69.7	70.6	85.8		11.80	9.37	9.44	11.73		77.1	61.4	63.2	75.3	

	N uptake SE_d	N uptake CD	P uptake SE_d	P uptake CD	K uptake SE_d	K uptake CD
T x M	2.93	6.54	0.57	NS	2.56	5.71
M x N	2.76	6.06	0.50	1.09	1.94	4.28
N x M	3.08	6.71	0.52	1.14	1.77	3.85
N x T	3.77	NS	0.64	NS	2.16	NS
T x N	3.38	NS	0.61	NS	2.37	NS

Significantly higher total K uptake was recorded with tied ridges (M_1) only during 1999. In both the years, application of 50 per cent N through fertilizer and 50 per cent N through goat manure (N_2) recorded the highest total K uptake.

Interaction effects were significant between trees and moisture conservation and between moisture conservation with N management only during 1999. The treatment combination *E. officinalis* under tied ridges with application of 50 per cent N through fertilizer and 50 per cent N through goat manure recorded higher total K uptake but it was comparable with same treatment combination in *A. excelsa*.

With regard to fodder sorghum + cowpea, the same trend was noticed as in case of grain sorghum + cowpea.

The interaction effect was not significant in both the years.

With regard to *C. glaucus*, the tree species and moisture conservation practices had no influence on total K uptake. Among the N management practices, the highest total K uptake was recorded with application of 50 per cent N through fertilizer and 50 per cent N through goat manure (N_2) in both the years.

Interaction effect was not significant in both the years.

4.2.3.8. Post harvest nutrient status of soil

4.2.3.8.1. Available soil nitrogen at harvest (Table 71)

The results revealed that in grain sorghum + cowpea, the post harvest soil available N was significantly influenced by the tree species only during second year. Among the tree species, *E. officinalis* (T_3) recorded the highest soil available N. Moisture conservation practices had no significant influence on the soil available N at harvest in both the years. Application of 50 per cent N through fertilizer and 50 per cent N through goat manure (N_2) recorded the highest soil available N in both the years.

Table 71. **Effect of treatments on post harvest soil available nitrogen (kg ha[-1]) of the cropping systems**

Treatment	Sorghum + cowpea (grain)		Sorghum + cowpea (fodder)		*Cenchrus glaucus*	
	1999	2000	1999	2000	1999	2000
T_1	164.3	128.8	125.0	145.8	132.3	135.0
T_2	163.0	128.0	118.0	138.9	129.8	133.5
T_3	163.8	132.3	125.8	152.3	129.3	133.0
SE_d	4.81	0.75	1.76	1.59	2.95	3.31
CD (P=0.05)	NS	1.67	3.94	3.53	NS	NS
M_1	167.0	129.2	128.7	144.3	132.7	134.7
M_2	160.3	130.3	117.2	147.0	128.2	133.0
SE_d	3.93	0.61	1.44	1.30	2.41	2.70
CD (P=0.05)	NS	NS	3.21	NS	NS	NS
N_1	154.1	125.6	118.2	143.6	127.2	129.8
N_2	173.2	133.9	127.7	147.7	133.7	137.8
SE_d	2.66	1.34	2.57	1.66	2.32	2.33
CD (P=0.05)	5.79	2.93	5.60	3.63	5.06	5.08

	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD
T x M	6.80	NS	1.06	NS	4.50	NS	2.24	NS	4.17	NS	4.68	NS
M x N	4.74	NS	1.47	NS	2.95	NS	2.11	NS	3.34	NS	3.56	NS
N x M	3.76	NS	1.89	NS	3.63	NS	2.35	NS	3.28	NS	3.29	NS
N x T	2.60	NS	2.33	NS	4.45	NS	2.88	NS	4.02	NS	4.03	NS
T x N	5.81	NS	1.81	NS	3.61	NS	2.58	NS	4.09	NS	4.37	NS

With regard to fodder sorghum + cowpea, among the tree species, *E. officinalis* (T_3) recorded higher soil available N in both the years than the other treatments. Tied ridges (M_1) recorded the highest soil available N status only during 1999. Among the N management practices, application of 50 per cent N through fertilizer and 50 per cent N through goat manure (N_2) improved soil available N content significantly in both the years.

In case of *C. glaucus*, the trees and moisture conservation practices had no significant influence on the post harvest soil N status. Highest soil available N was recorded with the application of goat manure (N_2) to supply 50 per cent of the recommended N.

Interaction effect was not significant in both the years in all the cropping systems.

4.2.3.8.2. Available soil phosphorus at harvest (Table 72)

With regard to grain sorghum + cowpea, tree species had significant influence on the post harvest soil P content only during second year. Among the trees, *E. officinalis* (T_3) recorded the highest available P status of the soil. Tied ridges (M_1) recorded the highest soil available P status only during 1999. Application of 50 per cent N through fertilizer and 50 per cent N through goat manure (N_2) recorded the highest available P status of the soil in all the years.

In case of fodder sorghum + cowpea during 1999, the highest available P status at harvest was recorded with *A. excelsa* (T_1) followed by *E. officinalis* (T_3). Whereas during 2000, the available P status was higher in *E. officinalis* (T_3) but it was comparable with *A. excelsa* (T_1). Moisture conservation practices had no significant influence on the soil available P status at harvest. Among the N management practices application of goat manure to substitute 50 per cent recommended N (N_2) significantly increased the available P content in both the years.

Table 72. Effect of treatments on post harvest soil available phosphorus (kg ha^{-1}) of the cropping systems

Treatment	Sorghum + cowpea (grain)		Sorghum + cowpea (fodder)		*Cenchrus glaucus*	
	1999	2000	1999	2000	1999	2000
T_1	14.20	16.40	14.27	15.24	15.72	17.09
T_2	13.78	15.88	10.18	14.60	14.87	16.05
T_3	14.20	16.85	12.05	15.48	15.72	16.84
SE_d	0.20	0.31	0.78	0.23	0.86	0.60
CD (P=0.05)	NS	0.38	1.74	0.50	NS	NS
M_1	14.57	16.37	12.60	15.22	15.48	16.82
M_2	13.55	16.38	11.73	15.13	15.39	16.50
SE_d	0.19	0.25	0.64	0.18	0.70	0.50
CD (P=0.05)	0.41	NS	NS	NS	NS	NS
N_1	13.50	16.08	11.27	14.92	14.99	16.23
N_2	14.62	16.67	13.07	15.43	15.88	17.09
SE_d	0.17	0.14	0.54	0.18	0.40	0.33
CD (P=0.05)	0.37	0.30	1.17	0.39	0.87	0.72

	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD
T x M	0.32	NS	0.43	NS	2.18	NS	0.32	NS	1.20	NS	0.87	NS
M x N	0.25	NS	0.29	NS	2.08	NS	0.26	NS	1.20	NS	0.66	NS
N x M	0.24	NS	0.20	NS	2.07	NS	0.25	NS	1.30	NS	0.61	NS
N x T	0.30	NS	0.24	NS	2.20	NS	0.31	NS	1.60	NS	0.76	NS
T x N	0.31	NS	0.35	NS	2.19	NS	0.31	NS	1.40	NS	0.82	NS

With regard to *C. glaucus*, trees and moisture conservation practices had no significant influence on the post harvest soil P content. Application of goat manure improved the soil available P status significantly over inorganic N alone.

The interaction effect was found to be not significant in all the cropping systems in both the years.

4.2.3.8.3. Available soil potassium at harvest (Table 73)

With regard to grain sorghum + cowpea, the tree species had significant influence on soil available K status at harvest in both the years. Among the tree species, the highest soil available K status was recorded in *E. officinalis* (T_3). Moisture conservation practices had significant influence on the soil available K status only during 1999. Among the treatments, tied ridges (M_1) recorded the highest available K content of the soil at harvest. Application of goat manure to supply 50 per cent of the recommended N (N_2) recorded the highest soil available K in both the years.

With regard to fodder sorghum + cowpea, tree species had significant influence on soil available K only during first year. Higher soil available K at harvest was recorded with *A. excelsa* (T_1) and it was comparable with *E. officinalis* (T_3). Among the moisture conservation practices soil available K was the highest in tied ridges (M_1) only during 1999. Application of goat manure to substitute 50 per cent of the inorganic N (N_2) significantly improved the available K content in both the years.

In case of *C. glaucus*, the soil available K status at harvest was significantly influenced by the tree species. During first year, *C. glaucus* with *A. excelsa* (T_1) recorded higher available K content but it was comparable with *E. officinalis* (T_3). During second year, *A. excelsa* (T_1) recorded significantly the highest K content of the soil. Moisture conservation practices had no significant influence on the soil available K status at harvest in both the years. Application of 50 per cent N through fertilizer and 50 per cent N through goat manure (N_2) recorded the highest soil available K content in both the years.

Table 73. Effect of treatments on post harvest soil available potassium (kg ha^{-1}) of the cropping systems

Treatment	Sorghum + cowpea (grain)		Sorghum + cowpea (fodder)		*Cenchrus glaucus*	
	1999	2000	1999	2000	1999	2000
T_1	400.5	447.0	449.7	476.5	445.5	468.5
T_2	388.3	444.3	433.0	470.6	430.0	451.8
T_3	413.1	453.1	440.8	480.4	437.0	459.8
SE_d	4.13	2.51	5.05	9.14	4.69	2.98
CD (P=0.05)	9.21	5.59	11.25	NS	10.44	6.65
M_1	414.0	448.3	456.1	475.2	438.5	462.0
M_2	387.0	447.9	426.2	476.5	436.5	458.0
SE_d	3.38	2.05	4.12	7.46	3.82	2.44
CD (P=0.05)	7.52	NS	9.19	NS	NS	NS
N_1	392.0	445.1	426.2	472.5	430.0	452.2
N_2	409.0	451.2	456.1	479.2	445.2	467.8
SE_d	4.11	2.09	3.10	2.81	3.76	2.54
CD (P=0.05)	8.95	4.56	6.76	6.11	8.20	5.54

	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD	SE_d	CD
T x M	5.84	NS	3.55	NS	7.14	NS	12.91	NS	6.63	NS	4.22	NS
M x N	5.32	NS	2.92	NS	5.16	NS	7.97	NS	5.37	NS	3.53	NS
N x M	5.81	NS	2.96	NS	4.39	NS	3.97	NS	5.32	NS	3.59	NS
N x T	7.11	NS	3.62	NS	5.37	NS	4.86	NS	6.51	NS	4.40	NS
T x N	6.81	NS	3.58	NS	6.32	NS	9.76	NS	6.57	NS	4.31	NS

4.2.3.8.4. Nutrient balance (Table 74)

The data revealed that there was gain in N with the application of goat manure (N_2) in all the cropping systems in both the years. Whereas the N balance was found to be negative when no organic manure (N_1) was applied. The gain in N was higher in grain sorghum + cowpea followed by fodder sorghum + cowpea and *C. glaucus*.

With regard to P balance, the magnitude of loss of P was lower with application of goat manure (N_2) as compared to inorganic fertilizer alone (N_1). The loss of P was less in *C. glaucus* as compared to grain / fodder sorghum + cowpea. With regard to K status, application of goat manure (N_2) recorded higher gain in K. Among the different cropping systems the gain in K was higher with fodder sorghum + cowpea followed by grain sorghum + cowpea and *C. glaucus*.

4.2.3.9. Economics (Table 75 and 76)

4.2.3.9.1. Gross return

The data showed that during first year, grain sorghum + cowpea with the treatment combination $T_3M_1N_2$ (*E. officinalis* under tied ridges with application of 50 per cent N through fertilizer and 50 per cent N through goat manure) recorded higher gross return (Rs.13620) followed by $T_1M_1N_2$ (*A. excelsa* under tied ridges with application of 50 per cent N through fertilizer and 50 per cent N through goat manure). During second year, grain sorghum + cowpea with the same treatment combination ($T_3M_1N_2$) recorded the highest gross return (Rs.4750).

4.2.3.9.2. Net return

Among the treatment combinations, grain sorghum + cowpea with *E. officinalis* under tied ridges and application of 50 per cent fertilizer N and 50 per cent N through goat manure recorded the highest net return of Rs.7385 during first year followed by *A. excelsa* with tied ridges and application of 50 per cent N through fertilizer and

Table 74. Net nutrient balance (kg ha^{-1})

Treatment	Nitrogen						Phosphorus						Potassium					
	CS I		CS II		CS III		CS I		CS II		CS III		CS I		CS II		CS III	
	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
$T_1 M_1 N_1$	6	15	23	6	-3	-2	-8.6	-12.3	-6.8	-10.5	-7.9	-7.2	42	40	90	84	16	34
N_2	23	42	40	17	7	10	-2.6	-11.3	-4.4	-9.1	-5.5	-5.1	81	46	96	89	29	46
$M_2 N_1$	-1	-7	-9	5	-8	-3	-11.4	-12.4	-10.4	-10.8	-7.7	-7.7	8	35	70	81	16	20
N_2	23	16	9	18	3	9	-8.6	-11.3	-7.8	-9.2	-6.6	-5.5	23	47	87	86	28	40
$T_2 M_1 N_1$	1	-2	1	3	-4	-4	-10.4	-13.3	-13.4	-12.1	-8.1	-8.0	15	35	70	80	4	9
N_2	28	20	17	6	6	5	-7.2	-11.4	-11.3	-10.4	-6.8	-6.8	56	42	85	89	18	22
$M_2 N_1$	-1	-10	-11	-1	-10	-5	-10.8	-12.9	-14.8	-11.1	-8.5	-8.2	8	36	57	76	5	13
N_2	20	9	10	10	-3	6	-9.9	-11.9	-13.3	-9.7	-6.8	-6.9	9	44	61	93	13	27
$T_3 M_1 N_1$	9	-19	16	21	-8	-5	-7.4	-11.1	-11.1	-8.6	-7.8	-7.7	63	50	89	95	6	17
N_2	34	54	47	33	5	10	-1.8	-10.1	-2.3	-7.6	-5.5	-5.2	98	61	98	99	27	42
$M_2 N_1$	18	11	-14	22	-11	-4	-10.0	-11.2	-13.1	-8.3	-8.3	-7.8	20	46	59	87	1	10
N_2	16	27	12	30	2	7	-7.6	-10.1	-8.4	-7.3	-5.8	-6.0	46	58	84	92	23	35

CSI - Sorghum + cowpea (grain)
CSII - Sorghum + cowpea (fodder)
CSIII - *Cenchrus glaucus*

Y_1 - 1999
Y_2 - 2000

Table 75. Economic analysis (Rs. ha^{-1}) of the cropping systems (1999)

Treatment	Sorghum + cowpea (grain)				Sorghum + cowpea (fodder)				*Cenchrus glaucus*			
	Cost of cultivation	Gross return	Net return	B:C ratio	Cost of cultivation	Gross return	Net return	B:C ratio	Cost of cultivation	Gross return	Net return	B:C ratio
$T_1 M_1 N_1$	6435	10877	4442	1.69	4130	5034	904	1.22	3738	4425	687	1.18
N_2	6235	13135	6900	2.10	3930	5146	1216	1.31	3614	4777	1163	1.32
$M_2 N_1$	6210	10101	3891	1.62	3905	4763	858	1.22	3513	4446	933	1.27
N_2	6010	11788	5778	1.94	3705	4857	1152	1.31	3389	4781	1392	1.41
$T_2 M_1 N_1$	6435	9930	3495	1.54	4130	4659	529	1.13	3738	4414	676	1.18
N_2	6235	11828	5593	1.89	3930	5224	1294	1.33	3614	4774	1160	1.32
$M_2 N_1$	6210	8922	2712	1.44	3905	4454	549	1.14	3513	4383	870	1.25
N_2	6010	10120	4110	1.68	3705	4440	735	1.20	3389	4745	1356	1.40
$T_3 M_1 N_1$	6435	10711	4276	1.66	4130	4887	757	1.18	3738	4385	647	1.17
N_2	6235	13620	7385	2.18	3930	5484	1554	1.40	3614	4770	1156	1.32
$M_2 N_1$	6210	10335	4125	1.66	3905	4361	456	1.12	3513	4377	864	1.25
N_2	6010	11263	5253	1.87	3705	4710	1005	1.27	3389	4752	1363	1.40

Table 76. Economic analysis (Rs. ha^{-1}) of the cropping systems (2000)

Treatment	Sorghum + cowpea (grain)				Sorghum + cowpea (fodder)				*Cenchrus glaucus*			
	Cost of cultivation	Gross return	Net return	B:C ratio	Cost of cultivation	Gross return	Net return	B:C ratio	Cost of cultivation	Gross return	Net return	B:C ratio
$T_1 M_1 N_1$	6435	3896	-2539	0.61	4130	3104	-1026	0.75	2906	3665	759	1.26
N_2	6235	4198	-2037	0.67	3930	3236	-694	0.82	2782	3999	1217	1.43
$M_2 N_1$	6210	3914	-2296	0.63	3905	3056	-849	0.78	2681	3622	941	1.35
N_2	6010	4235	-1775	0.70	3705	3232	-473	0.87	2557	4005	1448	1.57
$T_2 M_1 N_1$	6435	4128	-2307	0.64	4130	3093	-1037	0.75	2906	3650	744	1.26
N_2	6235	4302	-1933	0.69	3930	3163	-767	0.80	2782	3965	1183	1.43
$M_2 N_1$	6210	4140	-2070	0.67	3905	3076	-829	0.79	2681	3629	948	1.35
N_2	6010	4376	-1634	0.73	3705	3191	-514	0.86	2557	3963	1406	1.55
$T_3 M_1 N_1$	6435	4631	-1804	0.72	4130	3590	-540	0.87	2906	3627	721	1.25
N_2	6235	4750	-1485	0.76	3930	3763	-167	0.96	2782	4052	1270	1.46
$M_2 N_1$	6210	4679	-1531	0.75	3905	3576	-329	0.92	2681	3638	957	1.36
N_2	6010	4359	-1651	0.73	3705	3408	-297	0.92	2557	3968	1411	1.55

50 per cent N through goat manure (Rs.6900). Whereas during second year, *C. glaucus* in *A. excelsa* under flat bed with application of 50 per cent N through fertilizer and 50 per cent N through goat manure ($T_3M_2N_2$) recorded the highest net return (Rs.1448). This was followed by *C. glaucus* in *E. officinalis* with same treatment combination (Rs.1411).

4.2.3.9.3. B:C ratio

During first year, the highest B:C ratio of 2.18 was recorded with grain sorghum + cowpea in *E. officinalis* under tied ridges with application of 50 per cent N through fertilizer and 50 per cent N through goat manure ($T_3M_1N_2$). This was followed by grain sorghum + cowpea in *A. excelsa* with same treatment combination (2.10). During second year, the highest B:C ratio of 1.57 was recorded with *C. glaucus* in *A. excelsa* under flat bed ($T_1M_2N_2$) with application of 50 per cent N through fertilizer and 50 per cent N through goat manure followed by *C. glaucus* with *E. officinalis* or *C. pentandra* with same treatment combination (1.55).

DISCUSSION

CHAPTER V

DISCUSSION

The results of the survey conducted in western zone to understand the existing farmin practices, the components linked and their production constraints and the results of the fiel experiments to develop suitable integrated farming system for dryland vertisol areas o western zone of Tamil Nadu are discussed below.

5.1. Identification of existing farming practices

5.1.1. Crop management practices under existing farming

Predominant crop raised by both small and large farmers under dryland condition of western zone was sorghum. The variety adopted was CO 1, locally called as 'periya manjal cholam'. This variety has medium duration of 125-130 days. Even though this traditional variety is drought tolerant, disease resistant with thin stem, it produced low grain yield of 220 and 190 kg ha^{-1} under small and large farmers condition. Reason for the adoption of local variety was lack of awareness about the newly released short duration and high yielding varieties. Apart from this, farmers have their own seed reserves and they did not want to take risk of changing the traditional variety. Further the variety is highly drought tolerant and it has an ability to withstand the drought during dry period and to grow after the receipt of subsequent rains.

It was found that the major reasons for low yield of crops were thick seed rate and the broadcast method of sowing. Because of this the spacing was not maintained which produced lean and lanky seedlings. This resulted in heavy competition and the yield was very much affected. Only the available farm yard manure was applied once in 3 or 4 years. None of the farmers applied inorganic fertilizer in both blocks which might have resulted in poor soil fertility resulting in reduced biomass production of sorghum (3.01 t ha^{-1}). Due to uneven distribution of rainfall in most of the years, sole crop of sorghum resulted in crop failure. No intercropping was practised by the respondents, which may minimise the risk of crop failure. None of the farmers interviewed in both size groups adopted moisture conservation practices. This would have led to increased runoff and soil nutrient loss during heavy downpour. Because of the above reasons, the rainfall was not utilised efficiently by the crops and so the total biomass production was also less under the present survey conducted in dry farming situation of western zone.

5.1.2. Livestock component

Among the subsidiary enterprises, cattle is the dominant enterprise followed by goat. An average of 89.0 per cent of the small farmers and 86.0 per cent of the large farmers possessed cow and 20 and 28 per cent of the small and large farmers possessed goats. Family labour was utilised for the maintenance of animals in the farm. The main aim of the farmers to possess cattle was to get additional income by utilising the available family labour. Considering the fodder availability, the fodder production was not sufficient to meet the requirement of the cattle in all the years. This component was found to be less economical under dryland condition as per the farmers views. The reason for the less adoption of goats was lack of availability of green grass during lean season. None of the perennial drought tolerant fodder grasses were raised by the farmers in their farm. One of the possible ways to get more income might be maintenance of goats by growing perennial fodder grasses suited to dryland condition with less initial investment and by utilising the family labour.

5.1.3. Perennial component in the system

An average of 11.2 per cent of the small and 12.5 per cent of the large farmers raised tree component in their farm, where water supply was limited. The major reasons cited by both group of farmers for less adoption of trees were water scarcity and difficulties in maintenance due to uncontrolled grazing during lean season, which caused damage to the growing seedlings. Pot watering during lean season also resulted in less survival of the seedlings. Farmers required drought tolerant remunerative tree species and simple technologies to conserve water and to maintain the tree seedlings during lean season.

Hence the following production constraints were identified under the present dryland situation in western zone.

(i) Farmers in both size group adopted mostly traditional sorghum variety (CO 1) with 125 – 130 days duration and length of growing period did not match the water availability period. This resulted in poor and uneconomic yield of crop.

(ii) Sole crop of sorghum was raised by broadcast method of sowing and with high seed rate. This resulted in poor crop growth.

(iii) No intercropping was done with short duration pulses to minimise the risk of crop failure.

(iv) Inadequate quantity of farm yard manure was applied once in 3 or 4 years.

(v) Inorganic fertilizers were not applied.

(vi) *In situ* moisture conservation practices were not adopted to reduce the run off and increase the infiltration.

(vii) Off season rainfall was not utilised and lost as runoff.

(viii) Lack of green fodder during lean season to maintain small ruminants like goats.

(ix) Lack of adoption of management practices to maintain the tree seedlings during lean season with regard to moisture conservation and watering.

5.2. Field experiment

Based on the production constraints identified under the existing farming in drylands, the experiments were conducted at Tamil Nadu Agricultural University, Coimbatore during 1999 and 2000 to identify suitable integrated farming system for the drylands of western zone of Tamil Nadu with the integration of cropping, trees and goat and the results are discussed below.

5.2.1. Integrated farming system in drylands

5.2.1.1. Component contribution in integrated farming systems

Investigations on integrated farming systems involving different components *viz.*, cropping, trees and goat were studied to identify suitable integrated farming system for drylands, in an area of 0.55 ha, however the results obtained were projected to one hectare to have uniformity in expressing the results. Out of 0.55 ha, 0.54 ha was allotted to cropping, where three cropping systems *viz.*, sorghum + cowpea (grain), sorghum + cowpea (fodder) and *Cenchrus glaucus* were allotted with 0.18 ha each with three different tree species (*Ailanthus excelsa, Ceiba pentandra* and *Emblica officinalis*) and the remaining 0.01 ha was allocated to the goat component. To compare the integrated farming system with conventional cropping system (sole sorghum) an area of 0.18 ha was allotted for raising the crop with sole sorghum under conventional cropping system. The contribution of different components was evaluated mainly on the basis of productivity, economics and employment generation.

Among different components, cropping is the basic activity in the integrated farming system. Contribution of crops to the total productivity was higher during first year (54.8 per cent) whereas the contribution to the total productivity was less (29.2 per cent) during second year. The reason attributed to the decreased productivity was poor and ill distributed rainfall which caused decreased grain and fodder yields during second year. Though there was decreased productivity of crops, it was well compensated by the inclusion of goat component and the total productivity was increased in the second year than the first year. Highest productivity of crops was recorded with the tree component, *E. officinalis*. This might be due to decreased competition posed by the tree species for moisture and nutrients on the crops as compared to other trees. Higher biomass productivity in the cropping systems resulted in higher amount of total output energy of the system.

Productivity of goats was higher during second year, as a result of increased number of animals with the available feed obtained from the system. The cropping systems adopted in integrated farming system with sorghum + cowpea for grain and fodder and with *C. glaucus* to supply green and dry fodder for goat had visible advantage over sole sorghum under conventional cropping. The grass component contributed green fodder for goats almost round the year. This might have supplied sufficient nutritional requirement of goat which in turn reflected on the productivity of goats. Prasad *et al.* (1995) and Mishra *et al.* (1997) also reported that at the flowering stage CO 1 grass (*C. glaucus*) can meet the maintenance protein needs of sheep when offered as the sole feed. Apart from the feed from *C. glaucus,* cowpea also added to the nutritive value of the feed. During Summer, the reduction in the green fodder from *C. glaucus* was managed with the preserved hay from sorghum and cowpea and excess grass during monsoon season.

Inclusion of legume *viz.*, cowpea offered added advantage of increasing the total productivity of crops compared to the sole sorghum through the increased productivity of grain and protein rich fodder. Reasons for the higher productivity of cropping in integrated farming system might also be due to the adoption of improved varieties, intercropping with cowpea and recycling of goat manure from the deep litter system which improved the soil nutrient availability and in turn the yield.

The gross and net returns of cropping were higher in the integrated farming system than sole sorghum during first year whereas during second year due to decreased crop yields there was considerable reduction in net return with sorghum and cowpea cropping systems. Even then, higher net return and B:C ratio were recorded with grass system which compensated the loss in the sorghum grain and fodder system, ultimately increasing the total returns of the cropping under integrated farming system than the sole sorghum.

The economics of rearing Tellichery goats under deep litter system showed that rearing goats with 4.0 kg of grass and 1.0 kg of leguminous fodder for each goat per day would be more economical and profitable and would be best suited for small and marginal farmers. According to Prabaharan *et al.* (1994) goats generated higher annual income than dairy cattle and showed the best economic viability. Vairavan *et al.* (2000) also reported that in an integrated silvipastoral based farming system for drylands, among the animal components, rearing goats recorded higher income followed by milch animal.

In dryland farming, employment opportunity is seasonal and only during north east monsoon season in the western zone. Cropping systems adopted in integrated farming systems involved more labour and generated additional employment because of the inclusion of intercrop cowpea as against sole sorghum in the conventional cropping system. Inclusion of goats as a component, generated additional employment opportunity of 23 mandays during first year and 35 mandays during second year. This provided employment opportunity throughout the year, which can be effectively met with the available family labour. Inclusion of tree component in the farming system generated additional employment opportunity of 17 mandays in a year. This additional employment from tree component might be due to the initial establishment of trees for a minimum of 3 – 4 years. Then the labour involvement will be reduced and the tree can utilise the natural resources effectively for its growth. Inclusion of tree component has other advantages like added income, utilisation of off-season rainfall and improved soil fertility through the addition of leaf litter to the soil.

Additional employment generation through the inclusion of crop, tree and livestock was also reported by Sivasankaran *et al.* (1995), Singh (1996) and Deoghare (1997).

Apart from additional income and employment generation from the goat component, it has an added advantage of recycling of the manure to the crops. The dung and urine are effectively conserved under deep litter system with coir pith bedding material without any loss. This manure was effectively utilised for the production of cropping which in turn reduced the cost of fertilizer apart from getting additional yield and improving soil fertility. According to Rao *et al.* (1999) stall feeding of livestock through cut and carry system ensures better utilisation of fodder and crop residues and more efficient collection of manure for recycling. Vairavan *et al.* (2000) also opined that integrated farming system offers good scope for recycling of crop components to the animals and animal waste to the crop components.

With the available feed from integrated farming system 12 number of Tellichery goats can be maintained as compared to five in the conventional cropping system. This might be due to higher biomass production under integrated farming system. Even with minimum quantity of rainfall, with the available feed seven number of goats can be maintained whereas in conventional cropping only two number can be maintained.

5.2.1.2. Component linkages in integrated farming system

Integration of appropriate components in the farming has resulted in higher income, employment generation and opportunity for resource and residue recycling. Cropping with *E. officinalis* with the integration of goat component recorded higher productivity as compared to other tree species during both the years (**Fig.** 5). Higher crop productivity in first year was due to higher rainfall received during the cropping period. Due to less quantity and poor distribution of rainfall, the crop productivity was very much affected during second year. Even though the rainfall was less, the productivity of cropping in integrated farming system was higher as compared to conventional cropping. This indicated the efficiency of improved crop management practices on increasing the grain and fodder yields. Among the tree species the productivity of cropping in terms of sorghum fodder equivalent yield was higher (92.8 and 177.2 per cent) than sole sorghum with *E. officinalis* in first and second year. This further added the suitability of *E. officinalis* with cropping under dryland condition. The possible reason might be the sparse crown and deciduous nature of tree which resulted in lesser competition for the resources. Apart from this, the tree responded better to pitcher irrigation with

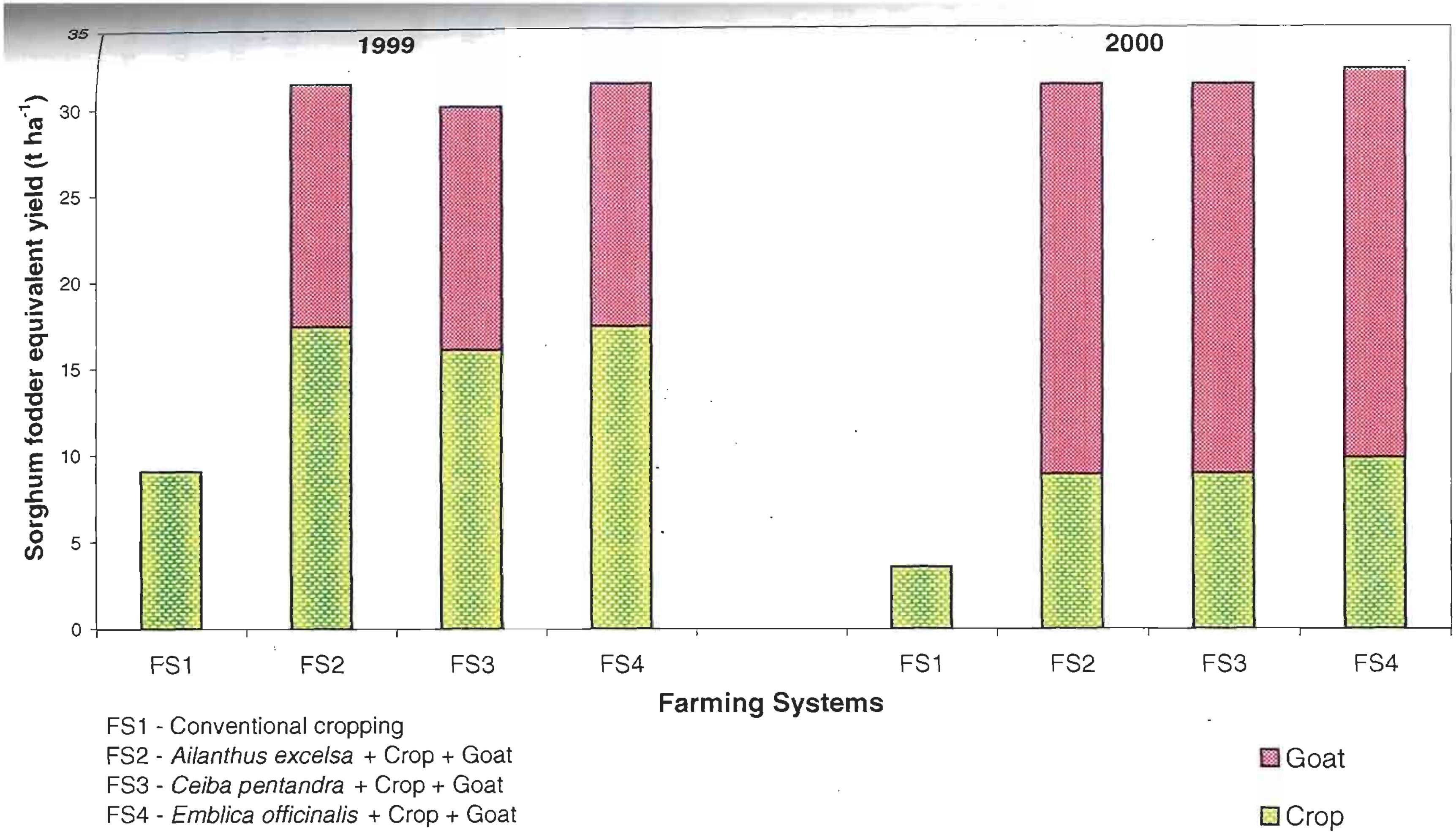


Fig. 5. Productivity (sorghum fodder equivalent) of integrated farming systems

coir pith mulching and the enhancement in height was also better than other tree species. Sivakumar *et al.* (2000) also reported the advantage of inclusion of tree component under dryland condition. Gill *et al.* (1997) reported that agrihorticulture system with mango was a successful system in Jhansi. Establishing the trees with little initial care, in the long run may produce better ecological balance by protecting the soil and environment which are all very fragile under dryland ecosystem. It also ensures seasonal income through intercropping and supplies different kind of raw materials and provide additional income to the farm.

Higher gross (Rs. 20470) and net returns (Rs. 3091) were recorded with *E. officinalis* + crop + goat. However the B:C ratio (1.18) was equal with *A. excelsa* during first year. Whereas during second year, the highest gross (Rs. 16536) and net return (Rs. 1143) and B:C ratio (1.07) were recorded with *E. officinalis* + crop + goat. Due to inadequate rainfall the productivity of crop, gross return and net return and B:C ratio were less under conventional cropping of sole sorghum (**Fig. 6**). Through inclusion of goat as a component under integrated farming system, the productivity of the system as a whole was increased which in turn increased the returns of the system. Even though there was decreased crop yield in the second year, inclusion of livestock sustained the productivity of the system thereby the net return was increased. Veerabadran (1994) reported that integrated farming system with crop + horticulture + goat proved to be sustainable and increased the profit over cropping alone. Similar results were also reported by Chinnaswami (1994) and Sivasankaran *et al.* (1995) with the integration of crop, trees and goat under dryland farming.

Apart from increasing the income of the farm, the employment generation was also increased with the integration of goat component providing employment year round. Inclusion of goat component provided opportunity for recycling of the resources from cropping and residue to the crop. This improved the soil nutrient status as compared to sole sorghum. Among the different systems, *E. officinalis* + crop + goat resulted in higher

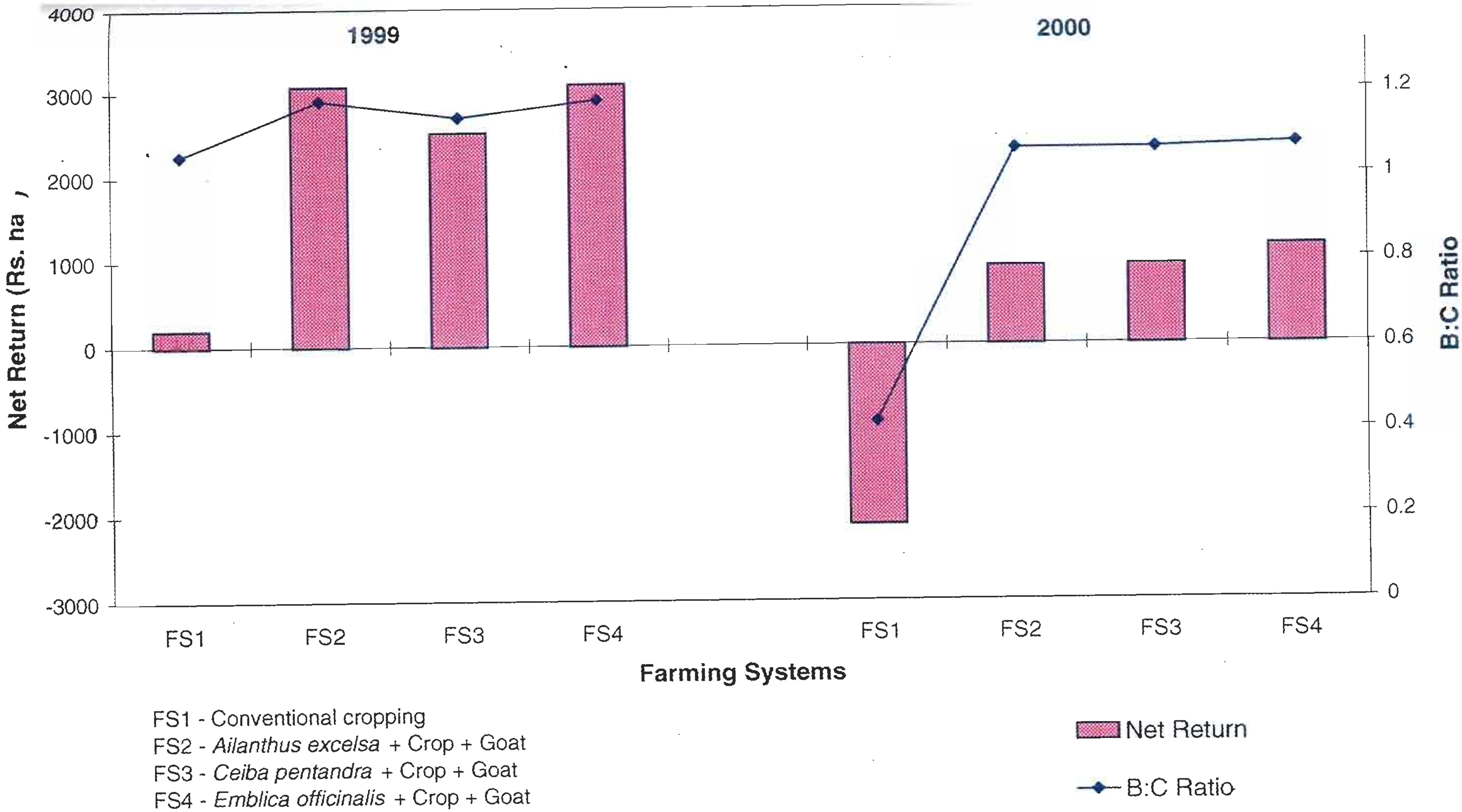


Fig. 6. Economic analysis of integrated farming systems

soil available nutrients and gain in nutrients was also higher. This may improve the soil nutrient status in the long run. Proper utilisation of residues by recycling in the system will lead to sustainable agriculture by conserving the natural resource base and protecting the environment.

From the available feed in the integrated farming system more number of goats can be maintained than conventional cropping. This in turn increased the income of the farm and improves the sustainability of the dryland farming.

5.2.2. Growth of tree seedlings

The tree seedlings were planted during the North East Monsoon 1998 and were established with the help of rainfall received during that season. A total of 428 mm rainfall was received during the North East Monsoon of 1998. The total rainfall received during 1999 and 2000 were 536.4 and 557.7 mm, respectively. Among the total rainfall, 54.3 and 20.0 mm of rainfall was received during Summer 1999 and 2000, respectively. Greater increment in growth of trees was recorded during North East Monsoon 1999 than North East Monsoon 2000 which might be due to availability of higher moisture. The growth of trees was better with moisture conservation and pitcher irrigation as compared to control during Summer. Among the trees, the *E. officinalis* recorded greater increment in height as compared to *C. pentandra* and *A. excelsa* in all the seasons. Results are in accordance with the findings of Solanki *et al.* (1999) who reported better growth of aonla with various *in situ* moisture conservation techniques.

Higher basal diameter was recorded with *A. excelsa* during 1999 which was followed by *C. pentandra* and *E. officinalis*. Whereas during second year the basal diameter was the highest with *C. pentandra* followed by *A. excelsa* and *E. officinalis*. Though the height was greater with *E. officinalis*, the basal diameter was less. *C. pentandra*, which recorded lower height than *E. officinalis* had greater basal diameter with compact crown.

With coir pith mulching and pitcher irrigation, the increment in height as well as basal diameter was greater with *E. officinalis* than other tree species during Summer. This indicated the better response of *E. officinalis* for the mulching and pitcher irrigation.

Increased height and basal diameter with pitcher irrigation might be due to higher moisture availability at the root zone which in turn helped in efficient utilisation of the applied water by reduced water loss through evaporation. Similar views were also reported by Chauhan *et al.* (1999). Narvane and Desai (1989) also reported that the plant height, stem girth and leaf area of mango saplings were highest with sub soil irrigation through pitcher.

Application of coir pith mulching recorded the highest tree seedling height and basal diameter. This might be due to higher soil moisture content and lower soil temperature which would have created favourable environment in the root zone, in turn increasing the growth of the tree seedlings. According to Subramanian and George (1998) coir pith can be effectively utilised as a mulching material for establishing plantation forestry. They also reported that soil moisture in the coir pith mulched plot remained higher than control and the fall in moisture per cent was also gradual in mulched plots. Reduction in soil temperature through the application of coir pith was also reported by Singh and Prasad (1993), who recorded 0.5°C to 6°C reduction in soil temperature in coir pith mulching. According to Kasper and Bland (1992) below ground temperature affects growth, branching, orientation and turn over of roots of trees. He also reported that as soil warming advances downward in dry regions deeper soil layers progressively become more suitable for tree growth. Hence, increased moisture content with less temperature under pitcher irrigation with mulching might have favoured the growth of tree seedlings.

5.2.3. Moisture conservation and nutrient management practices in the cropping systems

5.2.3.1. Seasonal influence

Climate is the major environmental factor affecting the crop growth and yield. Among the weather parameters, rainfall plays an important role in rainfed crop cultivation. North East Monsoon is found to be most favourable for dryland farming in Coimbatore as maximum amount of rainfall is being received during this season. The rainfall received during North East Monsoon 1999 and 2000 were 422.6 mm in 29 rainy days and 291.2 mm in 22 rainy days, respectively. Estimation of soil moisture content at weekly intervals indicated that soil moisture availability was optimum for raising a successful crop, which in turn resulted in higher grain and straw yields during first year. Better distribution of rainfall during first year for entire crop growth period had favoured the growth and resulted in higher grain, fodder and grass yields. Similarly, significance of distribution of rainfall in determining the sorghum yield rather than total rainfall was earlier reported by Rao and Vijayalakshmi (1986). During second year, out of total rainfall, 72.1 per cent of the rainfall was received in 13 rainy days during vegetative phase (0-35 days) and moisture stress was observed during flowering (36 to 70 DAS) to maturity phases (71 to 110 DAS). This moisture stress caused severe impact on yield of grain sorghum and grain cowpea. Baker and Norman (1975) reported that inadequate rainfall during crop growth period might frequently limit the crop production as a result of non-availability of soil moisture.

5.2.3.2. Growth attributes

Better growth attributes such as plant height, Leaf Area Index (LAI) and Dry Matter Production (DMP) of sorghum were recorded with *E. officinalis* and were comparable with *A. excelsa* during 1999. Distribution of rainfall and adequate soil moisture availability during the crop growth period, might have caused little competition between the trees and crops for moisture and nutrients which in turn increased the plant height of sorghum and cowpea during first year. Non receipt of rainfall after the vegetative phase in the second year, might have created competition between the trees and crops which resulted in decreased plant height as compared to the first year. Among the trees, plant height of sorghum and cowpea was higher with *E. officinalis* in both the years. This indicated the compatibility of the tree species for intercropping with sorghum under dryland condition. The LAI of crops was also higher with *E. officinalis* which might be attributed to little competition between trees and crops and increased uptake of moisture and nutrients. Increased plant height and LAI might have contributed to higher DMP of sorghum with *E. officinalis*. The DMP of intercropped cowpea in both grain and fodder sorghum was higher in *A. excelsa* but was comparable with *E. officinalis* during first year. The possible reason might be due to better growth of sorghum which might have utilised more moisture and nutrients. Similar results were also reported by Chittapur *et al.* (1994), who reported lesser cowpea forage yield in maize + cowpea intercropping due to vigorous growth of maize and consequent shadowing due to availability of more moisture.

Higher growth attributes of sorghum and cowpea were recorded under tied ridging only during first year. The possible reason might be higher availability of soil moisture which in turn increased the uptake of moisture and nutrients by the crops. Kolekar *et al.* (1998a and 1998b) reported better growth attributes of rainfed sorghum with tied ridges. Selvaraju *et al.* (1999) also reported increased stored soil moisture under tied ridges than flat bed method of sowing. Decreased growth attributes under tied ridges during second year might be due to poor rainfall after the formation of tied ridges which did not increase the growth of crops to a significant level.

Application of 50 per cent nitrogen (N) through fertilizer and 50 per cent N through goat manure recorded better growth attributes and was superior to application of 100 per cent N through fertilizer alone. The primary effect of applied N coupled with N released from the goat manure and also due to the other nutrients supplied from goat manure might have contributed to enrichment of soil and also improved the physical condition of the soil resulting in enhanced uptake of nutrients with the combined application of 50 per cent inorganic N and 50 per cent N through goat manure, which promoted higher growth attributes. Since the plant height and LAI are the major growth parameters that determine the DMP, increase in DMP might be attributed to high rate of photosynthesis. Madhavi *et al.* (1995) reported an increased plant height and DMP with 50 per cent recommended rate of NPK with 4.5 t of poultry manure ha^{-1}. Arya *et al.* (2000) also reported increased dry matter yield of fodder sorghum with half inorganic fertilizer and half organic source under rainfed condition.

5.2.3.3. Yield parameters

Less competition between the trees and crops and increased uptake of moisture and nutrients which favoured the increased DMP of the plants resulted in better yield parameters of sorghum and cowpea during first year with *E. officinalis*. Increased test weight of sorghum under *C. pentandra* might be due to lesser number of grains per earhead which resulted in bolder grains but was comparable with the test weight of sorghum with *E. officinalis*. Higher yield attributes under *E. officinalis* during second year might be due to decreased competition posed by the tree component on the crops. Higher yield attributes in turn increased the grain and straw yield of sorghum and grain and haulm yield of cowpea. Deb Roy and Gill (1991) reported that the best grain production of sorghum, wheat, gram and arhar was in association with *E. officinalis* compared to *Leucaena* and *Acacia nilotica*. Gill and Deb Roy (1997) also reported that the yield of wheat was higher from the interspaces of *Emblica* than the other tree species.

The dry fodder yield of fodder sorghum was higher under *A. excelsa* but it was comparable with *E. officinalis* during 1999 whereas during second year *E. officinalis* recorded higher dry fodder yield. The possible reason might be decreased competition between the tree and crop component because of higher availability of soil moisture during first year. *A. excelsa* have competed for more moisture and nutrients during second year which have decreased the growth attributes and the dry fodder yield. Khanna (1994) reported that the productivity in terms of fodder was higher with aonla + subabul as compared to guava + subabul model.

The grass yield of *Cenchrus* was not influenced by the tree species in both the years. Higher and uniform availability of soil moisture throughout the crop growth period helped in better development of panicle without any stress. The increased DMP have favoured for the accumulation of more assimilates and increased the yield attributes and yield. 15.1 and 8.7 per cent higher grain yield of sorghum and cowpea and 9.0 per cent higher dry fodder yield of fodder sorghum was recorded under tied ridges than flat sowing. Similar results of increased yield were also reported by Kaushik and Lal (1998), Surakod and Itnal (1998) and Patil and Sheelavantar (2000) under ridges and furrows. Kolekar *et al.* (1998a) reported that the improvement in grain and fodder yield might be attributed to optimum moisture availability in the soil during critical growth stages in the tied ridges. Growth and yield parameters of the crops were not influenced by the different moisture conservation practices during second year. Moisture stress during the crop growth period resulted in decreased uptake of nutrients which in turn affected the DMP of crops. Low available soil moisture caused moisture stress during flowering and grain filling which in turn affected the grain setting and development. This is the possible reason for the low yield during second year. Sharma *et al.* (1982) reported that the most sensitive phase of sorghum to moisture stress was post anthesis to early grain filling stage. Turk *et al.* (1980) reported that flowering and pod filling stage were more susceptible to moisture stress and reduced the cowpea yield to a greater extent.

The efficiency of combined application of inorganic fertilizer and organic manure resulted in 27.2 per cent higher grain yield in grain sorghum, 5.5 per cent higher fodder yield in fodder sorghum and 8.2 per cent higher grass yield in *C. glaucus* during first year.

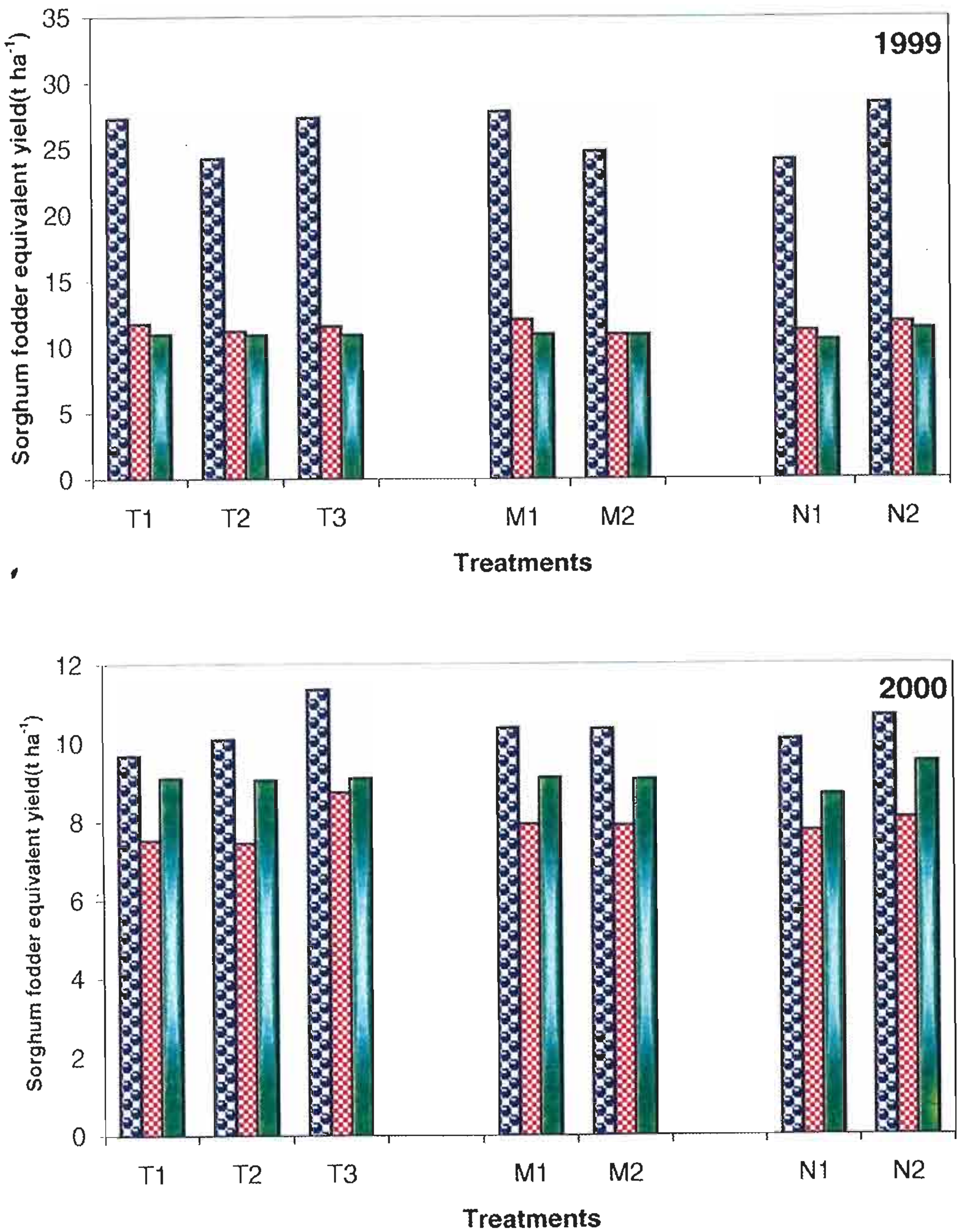
Through the combined application of inorganic fertilizer along with organic manure, the nutrient requirement of the crop at the peak demand stage could also be met with. In addition, the soil moisture status was also higher at all the growth stages, consequently all these factors increased the plant height, LAI and DMP and grain and fodder yield of the crops during first year. Inadequate moisture supply limited the nutrient uptake and plant growth ultimately reducing the yield of crops during second year.

5.2.3.4. Productivity of cropping systems

Higher sorghum fodder equivalent yield was recorded with grain sorghum and cowpea as compared to fodder sorghum and cowpea and *C. glaucus* (**Fig.** 7). This is due to higher value of grain crops than the fodder crop. Higher sorghum fodder equivalent yield during first year was because of higher grain and fodder yield of crops with adequate supply of moisture. Crops grown with *E. officinalis* recorded higher sorghum fodder equivalent yield is attributed to increased grain and fodder yield of crops. Similarly higher yield of crops under tied ridges and application of 50 per cent inorganic N and 50 per cent N through goat manure recorded higher sorghum fodder equivalent yield. Arya *et al.* (2000) also reported that higher sorghum grain equivalent yield was obtained with combined application of both organic and inorganic nutrients.

Higher total DMP recorded under grain sorghum with cowpea in *E. officinalis* (**Fig. 8**) might be the reason for improved crude protein yield. The total crude protein yield of sorghum with cowpea was higher than with *C. glaucus*. This was because of the inclusion of legume component in the system. This aspect is of significance in dry land farming systems where integration of crop and livestock husbandry is practised. Similar results were also reported by Veerabadran (1989) with sorghum and cowpea intercropping.

Higher DMP recorded with tied ridges improved the total crude protein yield during first year only. Due to decreased DMP under different cropping systems in the second year the crude protein yield was also less.



CS1 CS2 CS3

T1 - *Ailanthus excelsa*

T2 - *Ceiba pentandra*

T3 - *Emblica officinalis*

M1 - Tied ridges

M2 - Flat bed

N1 - 100 per cent N through fertilizer

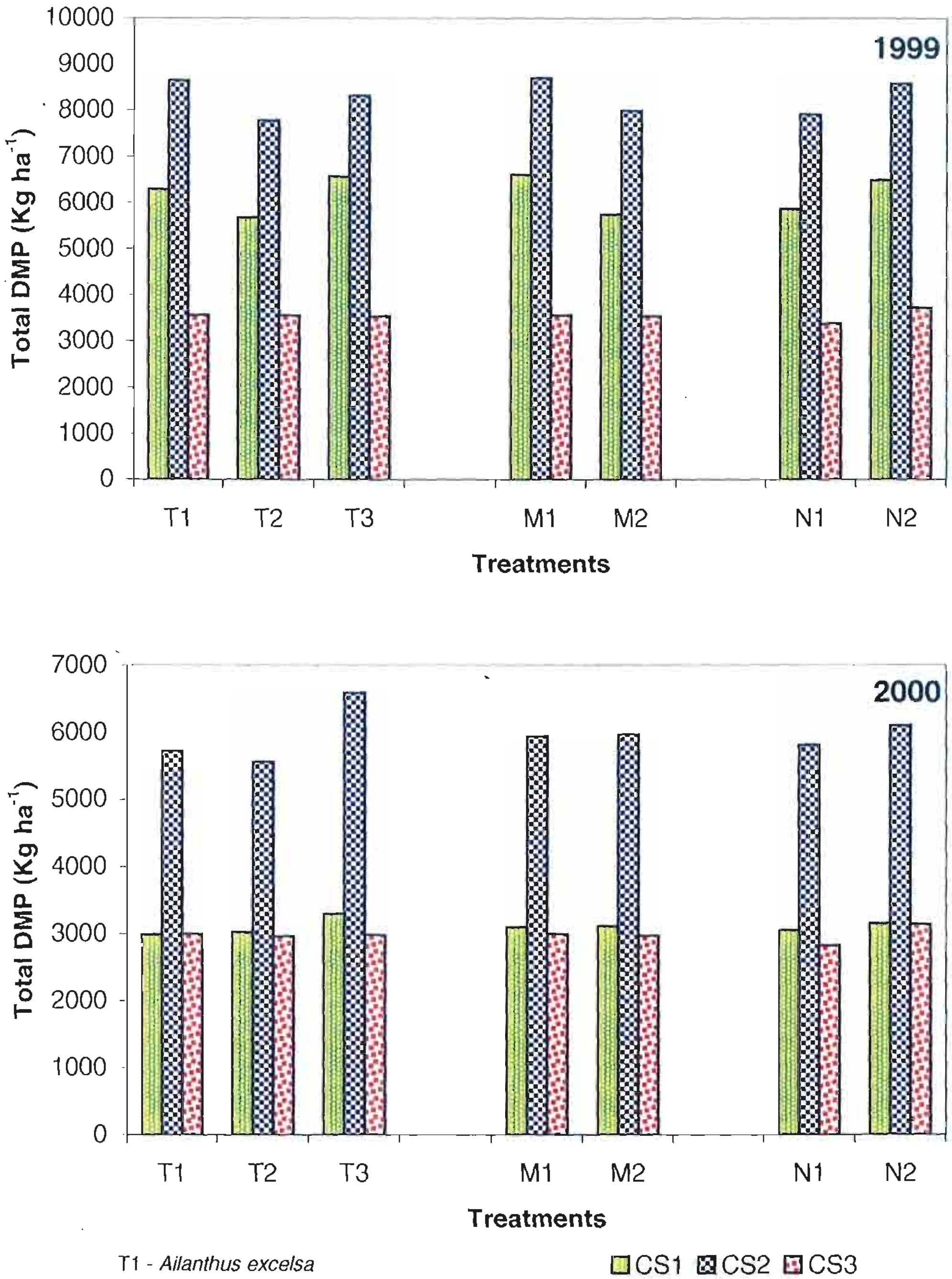
N2 - 50 per cent N through fertilizer + 50 per cent N through goat manure

CS1 - Sorghum + cowpea (grain)

CS2 - Sorghum + cowpea (fodder)

CS3 - *Cenchrus glaucus*

Fig. 7. Sorghum fodder equivalent yield of the cropping systems



T1 - *Ailanthus excelsa*
T2 - *Ceiba pentandra*
T3 - *Emblica officinalis*
M1 - Tied ridges
M2 - Flat bed
N1 - 100 per cent N through fertilizer
N2 - 50 per cent N through fertilizer + 50 per cent N through goat manure

CS1 - Sorghum + cowpea (grain)
CS2 - Sorghum + cowpea (fodder)
CS3 - *Cenchrus glaucus*

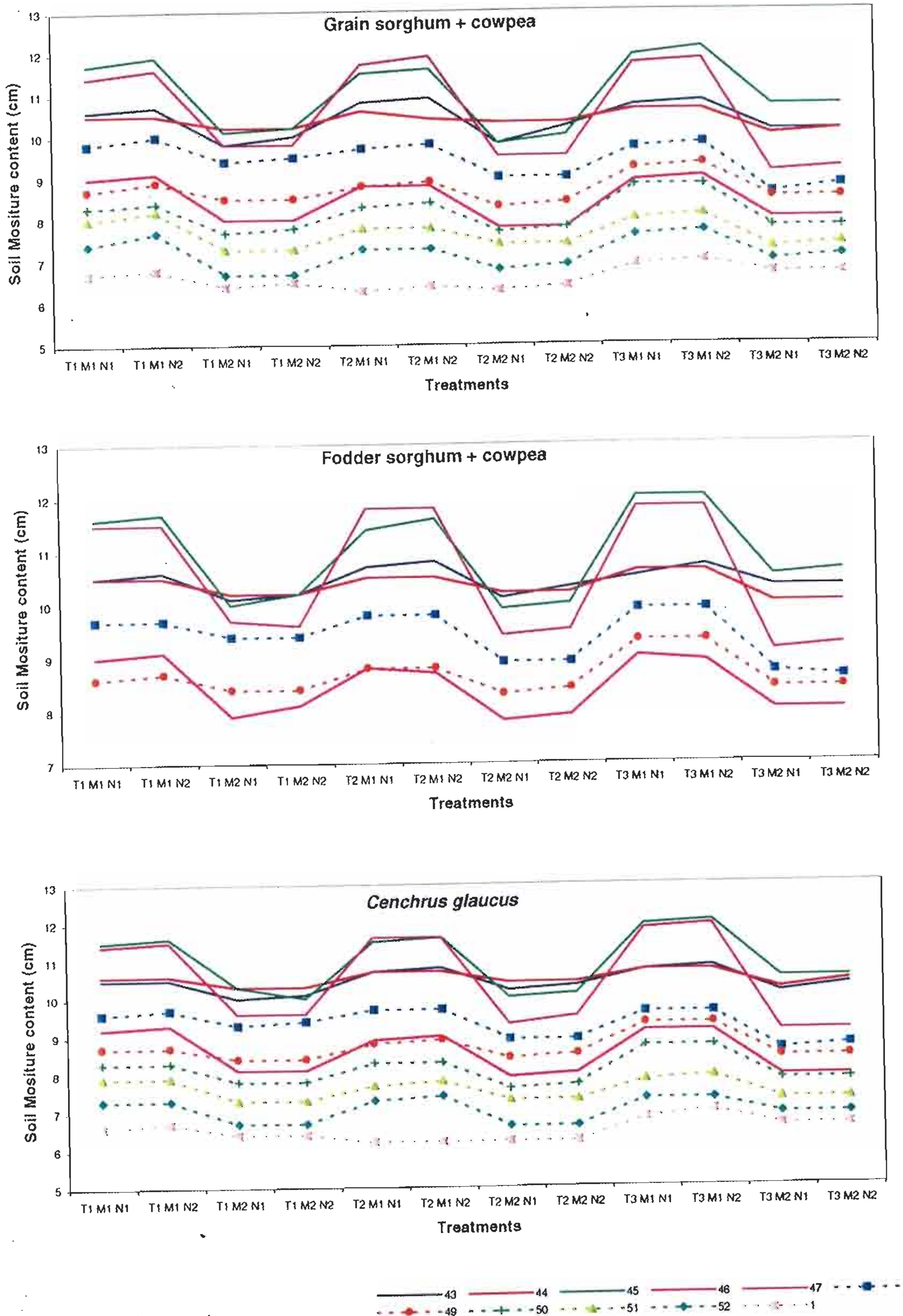
Fig. 8. Total dry matter production (DMP) of the cropping systems

Nutrient management practices had significant influence on the total crude protein yield of grain sorghum with cowpea only during first year which was favoured by increased DMP and crude protein per cent. The decreased total crude protein yield in the second year was attributed to lesser DMP. In case of fodder sorghum and *C. glaucus*, the increased DMP with higher crude protein content favoured the higher crude protein yield in combined application of organic and inorganic nutrients.

5.2.3.5. Soil moisture analysis

Higher soil moisture content was recorded with *E. officinalis* than the other tree species in all the cropping systems **(Fig. 9 and 10)**. This might be due to less competition among the plants and *E. officinalis* for moisture. Among the tree species, *E. officinalis* has comparatively less moisture uptake for its growth than *A. excelsa* and *C. pentendra* which was exhibited through the soil moisture status. Lower available soil moisture was recorded with *C. pentandra* which might have utilised more moisture for its growth and produced higher basal diameter with compact crown. Jackson *et al.* (1996) reported that 70 per cent of the root biomass of tropical deciduous trees was located within the top 30 cm of soil. Odhiambo *et al.* (1999) also reported that 60 and 55 per cent of the root biomass of *Gliricidia* and *Grevillea* was within the top 30 cm of soil. These results revealed the influence on soil moisture supplies.

Soil moisture content was higher under tied ridges than flat sowing during first year. Less runoff and more opportunity time for infiltration might have favoured the better infiltration of water into the soil depth which in turn increased the soil moisture status under this treatment. During second year, not much variation between the moisture conservation practices was recorded. The probable reason might be non receipt of rainfall after the formation of tied ridges. Bhan and Singh (1979) and Robinson *et al.* (1986) reported an increase in soil moisture content under ridges and furrows. Kolekar *et al.* (1998a) also reported that tied ridges recorded higher moisture content and increased the crop yield.



T1 - *Ailanthus excelsa*

T2 - *Ceiba pentandra*

T3 - *Emblica officinalis*

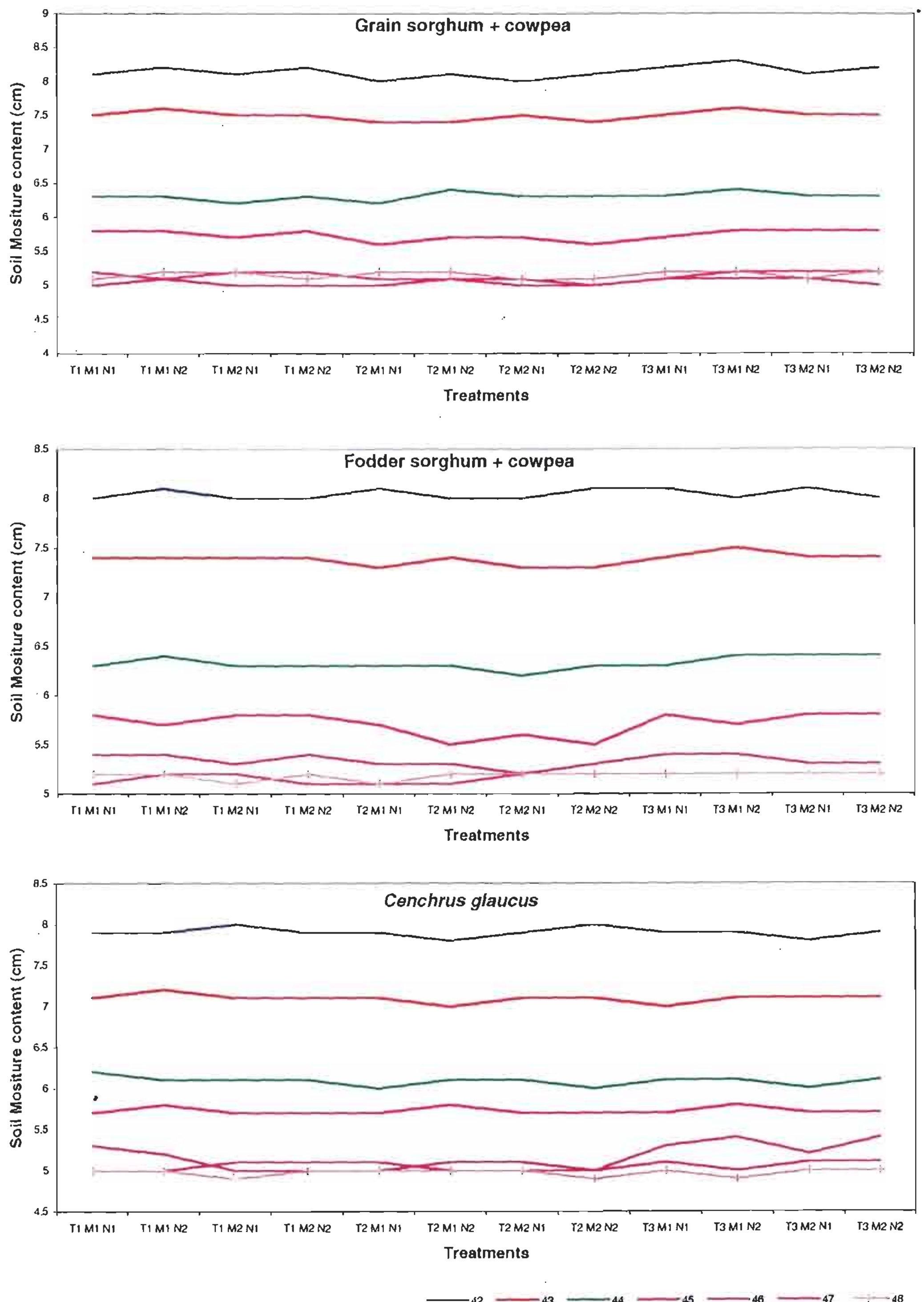
M1 - Tied ridges

M2 - Flat bed

N1 - 100 per cent N through fertilizer

N2 - 50 per cent N through fertilizer + 50 per cent N through goat manure

Soil moisture content at weekly intervals (0-45 cm depth)



T1 - *Ailanthus excelsa*
T2 - *Ceiba pentandra*
T3 - *Emblica officinalis*
M1 - Tied ridges
M2 - Flat bed

N1 - 100 per cent N through fertilizer
N2 - 50 per cent N through fertilizer + 50 per cent N through goat manure

Fig. 10. Soil moisture content at weekly intervals (0-45 cm depth) in the cropping systems - 2000

Application of goat manure along with inorganic fertilizer conserved higher soil moisture throughout the crop period due to high water holding capacity of soil which caused increase in absorption and retention of rain water. This might have reduced the bulk density of soil and increased infiltration rate and hydraulic conductivity, thereby improving water holding capacity of soil as earlier reported by Mayalagu *et al.* (1983) under rainfed condition. Similarly Sugandaraj (1990) also reported higher soil moisture content with the application of enriched farm yard manure under rainfed vertisols.

5.2.3.6. Crop and soil nutrient studies

The increased total nutrient uptake of the crops with *E. officinalis* might be attributed to less competition between the tree and crop component as compared to the other tree species. Higher total nutrient uptake in sorghum + cowpea cropping systems was recorded with tied ridges than flat sowing during first year. The possible reason might be the availability of higher moisture during all the growth stages which in turn increased the uptake of nutrients by sorghum and cowpea. Similar results were reported by several authors. Shaikh *et al.* (1995) reported that total N and P uptake were higher with ridges and furrow sowing compared to normal sowing in rainfed pearl millet. Bhan *et al.* (1998) also reported that ridging and furrowing increased the N uptake of rainfed sorghum. Non receipt of rainfall after the formation of tied ridges and also inadequate soil moisture at critical growth stages of the crop might have reduced the uptake of nutrients which in turn reduced total nutrient uptake during second year.

The nutrient uptake was increased with application of 50 per cent N through fertilizer and 50 per cent N through goat manure. Higher nutrient uptake might be due to continuous and steady availability of nutrients due to chelation effect of organic acids released during decomposition of organic matter (Mathur and Sankar, 1980; Tomar *et al.*, 1984). The addition of basal dose of N along with goat manure could have narrowed down the

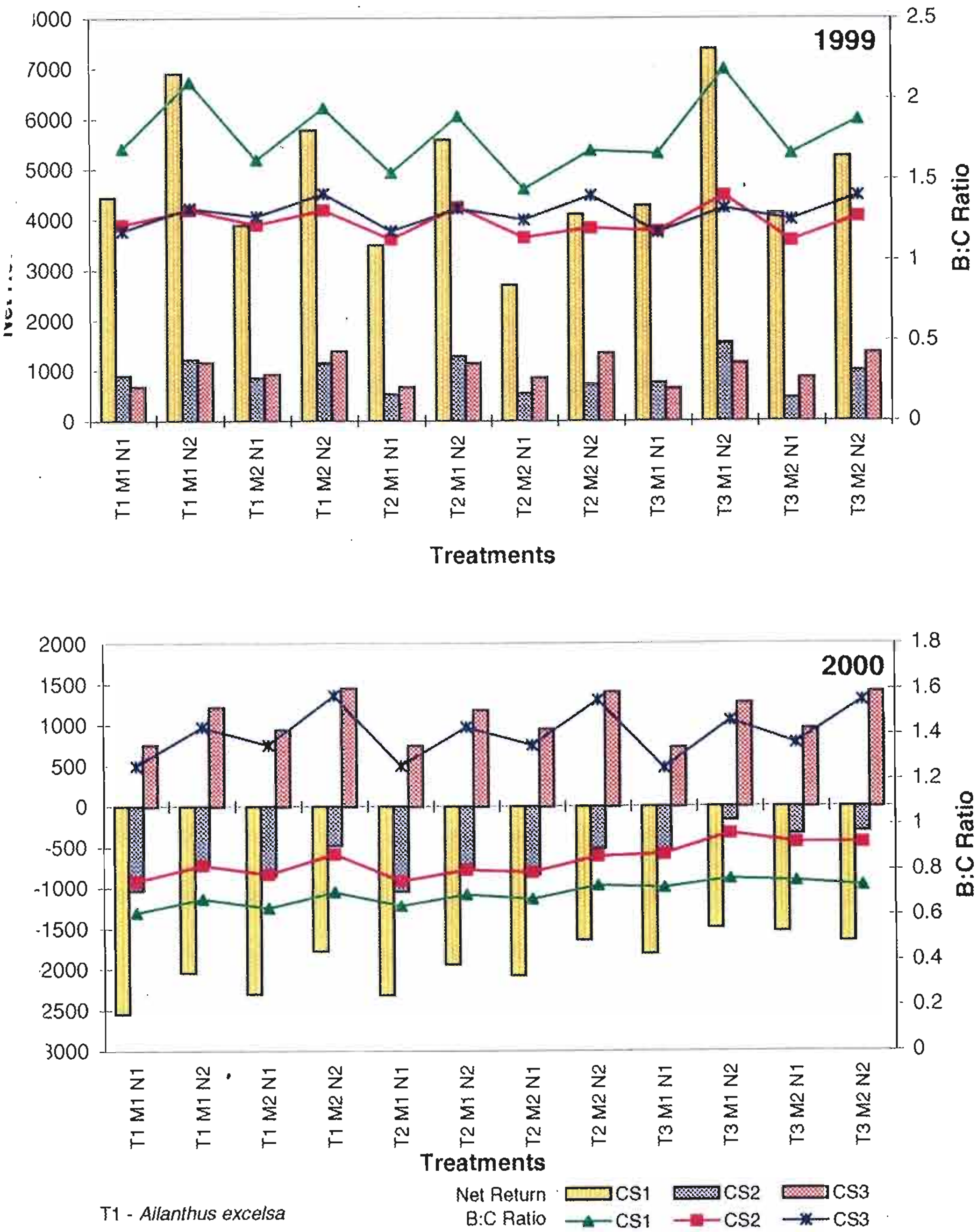
C:N ratio and increased the N availability as reported by Hofman *et al.* (1986). Higher P uptake might be due to availability of moisture and better root growth created by application of goat manure. Increased P uptake coupled with N uptake in sorghum plant was reported by Roy and Wright (1974). Increased P uptake was attributed to the increased solubilisation of insoluble P fraction during humification and reduced P fixation in the soil particles due to the protective action of manure by releasing organic acids during the decomposition. Increased uptake of N and P might have helped to extract more K from the soil resulting in higher K uptake under the application of goat manure. Higher amount of K entering into the soil solution helps the K ions to enter into the plant system through mass flow.

Higher post harvest soil available nutrients with *E. officinalis* as compared to other tree species might be due to less removal of nutrients with this tree component. Inclusion of cowpea with sorghum recorded higher available N, P and K content of the soil which might be due to the legume which fixes atmospheric nitrogen in the soil. Application of goat manure recorded higher available nutrient content of soil due to higher contribution of nutrient to soil under combined source.

Improvement in the soil N and K status was observed with the combined application of organic and inorganic source. The magnitude of loss of P was lowered with the application of goat manure to supply 50 per cent of the recommended N as compared to 100 per cent N through inorganic N alone. Less gain under inorganic source might be due to loss of N by volatilization.

5.2.3.7. Economic analysis

The highest net return and return per rupee invested was higher with the grain sorghum + cowpea during first year (**Fig. 11**). This was due to higher grain and straw yield of sorghum and also from the grain yield of cowpea which have higher monetary



T1 - *Ailanthus excelsa*

T2 - *Ceiba pentandra*

T3 - *Emblica officinalis*

M1 - Tied ridges

M2 - Flat bed

N1 - 100 per cent N through fertilizer

N2 - 50 per cent N through fertilizer + 50 per cent N through goat manure

CS1 - Sorghum + cowpea (grain)

CS2 - Sorghum + cowpea (fodder)

CS3 - *Cenchrus glaucus*

Fig. 11. Economic analysis of the cropping systems

value than the fodder or grass component. Balasubramanian *et al.* (1982) reported that sorghum intercropped with two rows of cowpea under paired row system gave the highest net return. The highest net return (Rs. 7385) and B:C ratio (2.18) was obtained under grain sorghum with cowpea intercropped in *E. officinalis* under tied ridges with application of 50 per cent N through fertilizer and 50 per cent N through goat manure. This was due to higher grain yield produced by sorghum and cowpea. It could be inferred that less competition posed by *E. officinalis* and improved moisture status of the soil by tied ridges along with combined application of organic manure and inorganic fertilizer utilised the resources in better way and produced higher grain yield during first year, which in turn increased the gross return, net return and B:C ratio. Similarly fodder sorghum and cowpea produced higher net return (Rs. 1554) and B:C ratio (1.40) with the above treatment. Due to decreased cost of cultivation and comparable yield with the other treatments, flat sowing with *A. excelsa* with 50 per cent inorganic N and 50 per cent N through goat manure recorded higher B:C ratio (1.41) with the *C. glaucus* during first year.

Because of inadequate rainfall and soil moisture during reproductive and maturity phases the grain yield was reduced in the grain sorghum and cowpea which in turn reduced the net return and B:C ratio during second year. Even with less rainfall, grass produced substantial yield and also due to less cost of cultivation the grass system recorded higher gross return, net return and B:C ratio during second year as compared to grain and fodder sorghum + cowpea.

FUTURE LINE OF WORK

- Studies on tree crop interaction
- Period of compatibility of trees with crops for the economical crop cultivation
- Economic analysis of the tree component

SUMMARY AND CONCLUSION

CHAPTER VI
SUMMARY AND CONCLUSION

A field survey was conducted in western zone of Tamil Nadu to study the existing farming practices, yield of crops, components linkage in the farming, adoption of perennial tree components in the system and the production constraints in the existing farming. Avinashi and Palladam taluks of Coimbatore district were selected for the study because of low rainfall and predominantly vast area under dryfarming.

The climate of this zone ranges from semi arid to sub humid with frequent occurrence of drought. Red non-calcareous and black calcareous are the predominant soil groups under rainfed condition. Average rainfall of this zone is 786 mm. Of the total rainfall 48.4 per cent was received during North East Monsoon season. Important characteristics of this drylands are soils with very low fertility and undependable and low rainfall. Only one crop is raised under rainfed condition. Millets and pulses are the predominant crops. Livestock rearing is an important enterprise.

Among the 50 farmers interviewed, 70 per cent were grouped as small (1-5 ac) and 30 per cent were grouped as large farmers (> 5 ac). The average land holding of small farmers was 3.16 and 3.79 ac in Avinashi and Palladam blocks respectively. It was 7.85 and 8.13 ac respectively in Avinashi and Palladam blocks in large farmers. In both groups, majority of the farmers had either primary or secondary education. Cropping was the main enterprise. Sorghum was the major crop under dryland condition. CO 1, the traditional long duration variety (125-130 days) was predominantly grown. The average grain yield was 205 kg ha^{-1} and the straw yield was 3.02 t ha^{-1}.

Livestock was the next important enterprise adopted by the farmers. Cow and goat were the major livestock in the existing farming condition. Apart from this, agroforestry was also adopted by few farmers in both blocks.

The production constraints identified are as follows :

Farmers in both size group adopted the traditional sorghum variety (CO 1) with 125-130 days duration and the length of growing period did not match with the moisture availability period. Sole crop of sorghum was raised with high seed rate resulted in poor crop growth. Intercropping was not practiced with legumes. Application of organic manure was practiced once in 3 or 4 years. No inorganic fertilizer was applied to the crops. *In situ* moisture conservation practices were not adopted by the respondents. Perennial drought tolerant fodder grasses were not raised in the farm to meet the fodder requirement of the cattle. Difficulties in management to maintain the tree seedling during lean season resulted in poor growth.

Based on the production constraints identified under existing farming situation in western zone with a view to improve the productivity of crops, to maintain soil fertility and to sustain the income of dryland farming, field experiments were conducted at the Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore, to identify suitable integrated farming system model for the dryland vertisol areas of western zone of Tamil Nadu and to sustain the productivity through efficient recycling of resources and residue from the allied component during 1999 and 2000. Non replicated experiment with treatment schedule of conventional cropping system with sole sorghum, *Ailanthus excelsa* + crop + goat, *Ceiba pentandra* + crop + goat and *Emblica officinalis* + crop + goat were carried out to identify the suitable component linkage under dryland condition of western zone of Tamil Nadu. Cropping systems tried were (i) grain sorghum + cowpea, (ii) fodder sorghum + cowpea and (iii) *Cenchrus glaucus* each in 0.33 ha in integrated farming system and the remaining 0.01 ha was allotted to the goat component. One unit of Tellichery goats consisted of five female and one male was included in the system. Three tree species *viz.*, *A. excelsa, C. pentandra* and *E. officinalis* were included in the system.

To evaluate suitable practices for the tree seedling growth and maintenance during lean season, treatments were imposed to the tree seedlings during Summer in a replicated experiment with split plot design. The tree species were allotted to main plots and moisture conservation and watering methods were allotted to the sub plots.

To evaluate the suitable *in situ* moisture conservation practices and N management on the yield of crops in the cropping systems through recycling of manure from the goat component to the crops grown in between the tree seedlings, replicated field experiments were carried out in split plot design. Trees and moisture conservation practices were assigned to main plots and N management practices were allotted to the sub plots.

Experimental results on integrated farming systems for drylands of western zone revealed that integration of crop with *E. officinalis* and goat resulted in higher productivity than cropping alone. Integration of cropping *viz.*, grain sorghum + cowpea, fodder sorghum + cowpea and *C. glaucus* each in 0.33 ha with goat component (0.01 ha) recorded higher sorghum fodder equivalent yields than conventional cropping alone with sole sorghum. During first year, the cropping systems in integrated farming systems totally contributed 54.8 per cent of the total productivity whereas goat component contributed 45.2 per cent of the total productivity. In the second year, the productivity of cropping systems was 29.2 per cent and goat was 70.8 per cent of the total productivity.

Highest gross return (Rs. 20470 and Rs. 16536) and net return (Rs.3091 and Rs. 1143) were recorded in the cropping systems with *E. officinalis* along with integration of goat component in first and second year respectively. Highest B:C ratio of 1.18 was recorded with cropping in *E. officinalis* or *A. excelsa* with goat component during first year whereas during second year cropping in *E. officinalis* with goat recorded higher B:C ratio of 1.07.

Integration of cropping with trees and goat generated additional employment of 47 and 55 mandays during first and second year respectively. Of the total employment generated, crop contributed 52.4 per cent and contribution of trees and livestock were

20.2 and 27.4 per cent respectively during first year. During second year, the contribution of components to the total employment generation was 43.5, 18.5 and 38.0 per cent for crops, trees and goat, respectively.

Highest total output energy and energy efficiency was recorded by integration of cropping in *E. officinalis* with goat. However cropping alone with sole sorghum resulted in higher energy efficiency than the integrated farming systems.

Integration of cropping in *E. officinalis* with goat recorded higher gain in N and K content than sole sorghum and the loss of P content of the soil was lesser in this system thus resulted in improved soil fertility.

The carrying capacity was worked out to 12 and 7 number of goats during first year and second year respectively in the integrated farming system, whereas it was five and two goats in the conventional cropping system *viz.*, sole sorghum.

The results of the field experiment to evaluate the suitable practices for growth and maintenance of tree species during Summer 1999 and 2000 indicated that *E. officinalis* recorded greater height than other tree species in both the years. Higher basal diameter was recorded with *A. excelsa* during 1999 and *C. pentandra* during 2000. The increase in height and basal diameter was greater with *E. officinalis* in both Summer 1999 and 2000 indicating the better response of tree to pitcher irrigation and mulching.

Coir pith mulching and pitcher irrigation recorded greater height and basal diameter of tree seedlings than control. Higher soil moisture content was recorded with *E. officinalis* under coir pith mulching and pitcher irrigation. The soil moisture content was higher in 15-30 cm depth than 0-15 cm depth. The soil temperature was lesser in coir pith mulching and pitcher irrigation. Among the different depths, the soil temperature was less in 30 cm depth as compared to 15 cm depth.

The inference of the field experiments with different cropping systems *viz.*, grain sorghum + cowpea, fodder sorghum + cowpea and *C. glaucus* to evaluate the *in situ* moisture conservation and nitrogen management practices carried out are as follows.

Higher plant height, Leaf Area Index (LAI) and Dry Matter Production (DMP) of both grain and fodder sorghum were recorded with *E. officinalis* but it was comparable with *A. excelsa* during 1999. During second year, the growth attributes were higher with *E. officinalis*. Higher plant height, LAI and DMP of grain and fodder cowpea were recorded with *A. excelsa* but it was comparable with *E. officinalis*. During second year *E. officinalis* recorded higher plant height, LAI and DMP of grain and fodder cowpea.

Length of earhead and number of grains per earhead of grain sorghum were higher in *E. officinalis*. Thousand grain weight of grain sorghum was higher in *C. pentandra* and it was comparable with *E. officinalis*. Higher grain and straw yields of grain sorghum were recorded with *E. officinalis* than other tree species. The straw yield of fodder sorghum was higher in *E. officinalis* in both the years but it was comparable with *A. excelsa* during first year. Higher grain and haulm yields of grain cowpea and dry fodder yield of fodder cowpea were recorded with *E. officinalis* than other tree species.

Higher growth and yield attributes and grain and straw yield of grain sorghum, straw yield of fodder sorghum, grain and haulm yield of grain cowpea and dry fodder yield of fodder cowpea were recorded under tied ridges only during first year.

Application of 50 per cent N through fertilizer and 50 per cent N through goat manure recorded higher growth and yield attributes and yield of grain sorghum and cowpea and straw yield of fodder sorghum and dry fodder yield of fodder cowpea and total grass yield during both the years.

Total DMP of grain sorghum + cowpea was higher with *E. officinalis* during both the years. The total DMP of fodder sorghum + cowpea was higher with *A. excelsa* during first year and it was comparable with *E. officinalis*. During second year, *E. officinalis* recorded higher sorghum fodder equivalent yield. Tied ridges recorded higher total DMP only during first year. Application of 50 per cent N through fertilizer and 50 per cent N through goat manure recorded higher total DMP of all cropping systems in both the years.

Higher sorghum fodder equivalent yield of grain sorghum + cowpea and fodder sorghum + cowpea was recorded in *E. officinalis*. Tied ridges recorded higher sorghum fodder equivalent yield only during first year. Application of 50 per cent N through fertilizer and 50 per cent N through goat manure recorded higher sorghum fodder equivalent yield of all cropping systems in both years. Trees and moisture conservation practices had no significant influence on the sorghum fodder equivalent yield of *C. glaucus*.

Higher crude protein per cent and protein yield was recorded with application of 50 per cent N through fertilizer and 50 per cent N through goat manure. The total crude protein yield of grain sorghum + cowpea was higher in *E. officinalis* in both the years. The higher total crude protein yield of fodder sorghum + cowpea was recorded with *A. excelsa* during first year and it was comparable with *E. officinalis* during second year. Higher total crude protein yield was recorded under tied ridges only during 1999. Tree species and moisture conservation practices had no significant influence on the total crude protein yield of *C. glaucus* in both the years.

The available soil moisture was higher during first year than during second year. Higher soil moisture content was recorded in *E. officinalis* in all the cropping systems. Tied ridges recorded higher soil moisture status only during 1999. Application of 50 per cent N through fertilizer and 50 per cent N through goat manure recorded higher soil moisture in both the years in all the cropping systems.

The total nutrient uptake by both grain and fodder sorghum + cowpea was higher in *E. officinalis* than other tree species. Tied ridges recorded higher total nutrient uptake only during 1999. Application of 50 per cent N through fertilizer and 50 per cent N through goat manure recorded higher total nutrient uptake of all cropping systems in both the years. Trees and moisture conservation practices had no significant influence on total nutrient uptake of *C. glaucus*.

Higher soil available N, P and K content at harvest of grain sorghum + cowpea were recorded with *E. officinalis*. In fodder sorghum + cowpea, higher soil available N was recorded with *E. officinalis* and the soil available P and K content at harvest was higher with *A. excelsa* but it was comparable with *E. officinalis*. Tied ridges recorded higher soil available N, P and K content of the soil in grain and fodder sorghum + cowpea. Application of 50 per cent N through fertilizer and 50 per cent N through goat manure recorded higher nutrient status of soil in all the cropping systems in both the years.

Gain in N and K was recorded with the application of goat manure in all the cropping systems in both the years. Magnitude of loss of P was lower with application of goat manure.

Higher gross (Rs. 13620), net return (Rs. 7385) and B:C ratio (2.18) were recorded with grain sorghum and cowpea in *E. officinalis* under tied ridges with application of 50 per cent N through fertilizer and 50 per cent N through goat manure during first year. During second year, higher gross return (Rs. 4052) was recorded with *C. glaucus* in *E. officinalis* under tied ridges and application of 50 per cent N through fertilizer and 50 per cent N through goat manure and higher net return (Rs.1448) and B:C ratio (1.57) were recorded with *A. excelsa* with flat sowing and application of 50 per cent N through fertilizer and 50 per cent N through goat manure.

In **conclusion**, the field experimental results revealed that integration of sorghum + cowpea (for grain), sorghum + cowpea (for fodder) and *C. glaucus* each in 0.33 ha intercropped in *E. officinalis* with goat component (5+1) in 0.01 ha resulted in higher productivity of 31.63 and 32.10 t ha^{-1} of sorghum fodder equivalent yield with better economic returns (gross and net returns of Rs.20470 and Rs.3091, respectively in first year and Rs.16536 and Rs.1143, respectively in second year) and provided better employment opportunity (84 and 92 mandays, respectively during first and second year) for the family labour round the year with higher output energy under dryland situation of western zone of Tamil Nadu. Even in the year of lower and early withdrawal of rainfall with lesser economic yield of sorghum and cowpea, inclusion of fodder grass with goat sustained the productivity of the system and produced higher economic returns. Integration of goat component provided better opportunity for recycling of manure to the crops and enhanced the soil fertility.

Coir pith mulching with pitcher irrigation produced better growth of tree seedlings under dryland situation and among the trees, *E. officinalis* had better response to mulching and pitcher irrigation under dryland situation.

Intercropping in *E. officinalis* with tied ridges and application of 50 per cent N through fertilizer and 50 per cent N through goat manure produced higher yield and economic returns and B:C ratio under normal rainfall year. However, under low and early withdrawal of rainfall, inclusion of grass component in the system produced higher B:C ratio. In both years, application of 50 per cent N through fertilizer and 50 per cent N through goat manure improved the soil fertility with sustained productivity of crops.

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* Originals not seen.

APPENDICES

Appendix I
Weekly weather during experimental period (1999-2001)

Standard weeks	Period	Temperature (°C)		Relative Humidity (%)		Evaporation (mm)	Wind velocity (km h^{-1})	Rainfall (mm)	Rainy days	Solar radiation (cal. cm^{-2})	Sun shine (hrs)
		Maximum	Minimum	0722 hrs.	1422 hrs.						
1999											
9	26-4 Mar.	34.2	17.6	79	22	6.1	8.8	-	-	491.4	10.7
10	5-11	35.1	17.0	80	18	5.9	6.2	-	-	449.9	10.3
11	12-18	35.3	21.5	85	38	6.0	6.3	-	-	437.8	9.4
12	19-25	36.1	21.5	91	31	5.4	5.2	-	-	407.0	8.4
13	26-1 Apr.	36.3	22.4	88	23	6.3	6.1	-	-	437.9	9.2
14	2-8	34.4	21.4	84	43	6.2	7.3	15.4	2	399.1	7.0
15	9-15	35.3	22.3	83	42	6.7	10.9	1.5	-	428.9	10.0
16	16-22	34.4	22.9	90	53	5.5	8.9	14.9	3	335.2	5.1
17	23-29	34.5	23.6	87	44	6.0	9.5	-	-	407.0	8.1
18	30-6 May	35.7	23.0	84	44	6.2	10.1	16.5	1	386.0	8.0
19	7-13	33.6	23.2	80	40	6.9	10.5	-	-	458.7	10.1
20	14-20	33.9	24.0	77	45	7.3	14.0	-	-	421.5	8.1
21	21-27	31.5	23.1	80	56	5.0	17.8	6.0	2	324.3	4.4
22	28-3 Jun.	32.6	23.4	84	50	6.1	14.8	-	-	394.1	7.3
23	4-10	32.5	22.7	83	52	5.9	14.3	-	-	373.8	6.7

Standard weeks	Period	Temperature (°C)		Relative Humidity (%)		Evaporation (mm)	Wind velocity (km h^{-1})	Rainfall (mm)	Rainy days	Solar radiation (cal. cm^{-2})	Sun shine (hrs)
		Maximum	Minimum	0722 hrs.	1422 hrs.						
24	11-17	30.9	22.9	78	58	6.5	25.6	7.9	2	357.4	5.3
25	18-24	30.1	22.6	77	51	5.9	21.7	8.9	1	358.5	5.3
26	25-1 Jul.	32.9	20.8	87	41	6.8	14.1	-	-	446.6	9.6
27	2-8	32.6	22.2	86	49	7.0	19.4	0.8	-	400.6	7.2
28	9-15	31.9	22.4	83	49	6.5	20.4	1.6	-	348.5	4.6
29	16-22	28.3	22.4	79	69	4.7	24.2	19.0	4	251.6	1.2
30	23-29	29.5	23.3	74	56	7.0	36.9	3.5	1	324.5	4.1
31	30-5 Aug.	30.9	23.2	71	49	7.0	27.6	-	-	264.9	5.4
32	6-12	31.2	23.1	81	55	6.6	28.0	-	-	324.6	4.8
33	13-19	32.7	22.3	87	50	5.7	14.8	-	-	266.2	8.2
34	20-26	32.0	21.8	88	52	4.3	13.4	17.8	1	336.9	5.6
35	27-2 Sep.	32.2	21.9	85	46	5.6	17.6	-	-	388.1	7.2
36	3-9	32.3	22.3	78	43	7.1	23.3	-	-	421.7	7.9
37	10-16	33.0	21.4	83	47	6.9	20.3	-	-	440.0	9.3
38	17-23	33.7	22.4	89	50	5.6	12.9	-	-	394.3	8.0
39	24-30	33.5	22.9	91	46	3.7	8.2	36.0	3	351.4	6.1
40	Oct 1-7	29.9	22.5	94	68	2.8	6.0	78.4	4	282.7	3.7
41	8-14	30.9	22.3	93	60	4.2	3.1	26.5	3	386.1	7.7
42	15-21	29.5	21.9	95	74	1.9	2.7	170.4	6	282.7	3.4
43	22-28	29.8	22.5	94	65	2.6	-	26.9	3	456.7	5.5
44	29-4 Nov.	30.2	20.2	94	64	3.2	-	1.0	-	389.6	6.9
45	5-11	29.9	19.8	91	51	2.5	-	27.8	2	421.4	8.0
46	12-18	29.7	18.4	88	47	3.6	1.7	-	-	463.2	9.9
47	19-25	27.4	21.0	93	71	3.0	3.3	34.9	3	292.3	3.5

Standard weeks	Period	Temperature (°C)		Relative Humidity (%)		Evaporation (mm)	Wind velocity (km h^{-1})	Rainfall (mm)	Rainy days	Solar radiation (cal. cm^{-2})	Sun shine (hrs)
		Maximum	Minimum	0722 hrs.	1422 hrs.						
48	26-2 Dec.	28.4	21.0	91	63	3.2	3.5	6.7	1	373.8	6.3
49	3-9	28.3	19.1	91	59	2.7	2.2	1.0	-	388.3	5.6
50	10-16	26.2	19.3	91	62	2.9	1.9	4.0	1	308.1	6.1
51	17-23	27.9	18.3	88	57	2.9	3.0	-	-	322.0	5.2
52	24-31	26.8	19.3	90	54	3.2	4.4	9.0	1	416.3	7.6
2000											
1	Jan 1-7	28.3	19.9	87	52	3.4	4.9	-	-	379.2	5.7
2	8-14	28.1	20.5	87	62	3.5	6.1	5.4	1	281.5	2.9
3	15-21	30.5	18.1	91	39	4.1	6.2	-	-	405.9	9.2
4	22-28	31.6	16.9	90	35	4.7	4.1	-	-	500.7	9.5
5	29-4 Feb.	31.0	18.3	89	40	4.4	6.8	-	-	420.6	6.7
6	5-11	32.0	21.9	89	48	3.5	4.4	-	-	406.6	7.4
7	12-18	32.2	19.9	88	37	4.9	5.4	-	-	425.7	9.2
8	19-25	32.7	20.9	91	52	4.0	4.5	13.5	1	366.2	5.7
9	26-4 Mar.	30.5	19.6	90	45	3.6	4.8	22.7	3	383.7	8.0
10	5-11	33.9	19.8	86	35	4.6	3.6	-	-	418.0	9.4
11	12-18	35.0	21.9	86	33	4.9	4.6	-	-	425.7	9.3
12	19-25	35.0	21.9	85	33	6.4	6.2	-	-	451.9	8.4
13	26-1 Apr.	35.3	22.3	87	38	6.8	6.7	-	-	391.8	7.0
14	2-8	34.6	23.1	85	43	5.5	3.5	4.0	1	378.5	8.0
15	9-15	35.9	22.9	86	44	6.8	7.1	4.0	1	418.3	9.5
16	16-22	34.6	20.2	87	41	5.9	5.8	7.2	1	382.1	8.0
17	23-29	35.5	23.7	83	42	5.8	6.9	-	-	439.6	9.6
18	30-6 May	35.8	23.6	82	44	7.4	9.2	4.4	2	444.9	9.8

Standard weeks	Period	Temperature (°C)		Relative Humidity (%)		Evaporation (mm)	Wind velocity (km h^{-1})	Rainfall (mm)	Rainy days	Solar radiation (cal. cm^{-2})	Sun shine (hrs)
		Maximum	Minimum	0722 hrs.	1422 hrs.						
19	7-13	35.4	23.3	82	35	6.1	6.6	0.4	0	412.3	8.5
20	14-20	35.7	23.9	75	36	10.0	15.1	-	-	443.8	9.3
21	21-27	35.1	23.2	83	41	7.1	8.9	-	-	392.0	6.1
22	28-3 Jun.	33.6	22.5	85	50	6.2	9.1	6.4	1	369.0	6.9
23	4-10	30.5	22.8	74	59	6.3	21.9	17.0	3	277.5	2.6
24	11-17	32.0	22.9	80	48	7.0	16.5	3.0	1	361.3	4.9
25	18-24	32.2	23.1	79	51	6.7	15.9	-	-	362.8	5.6
26	25-1 Jul.	31.5	22.4	76	50	6.6	16.6	3.6	-	337.9	4.5
27	2-8	30.5	22.2	78	51	5.6	15.4	2.8	1	307.3	2.1
28	9-15	30.8	24.2	64	51	10.1	32.6	10.4	1	380.0	6.1
29	16-22	32.2	22.5	77	47	7.8	17.6	-	-	417.7	7.5
30	23-29	32.8	21.9	88	50	6.3	7.5	-	-	394.1	7.7
31	30-5 Aug.	32.8	22.6	92	53	5.6	6.0	33.6	2	380.4	7.8
32	6-12	30.2	22.8	75	55	6.5	21.1	4.8	1	339.5	4.5
33	13-19	31.6	22.1	88	56	4.8	7.2	53.4	1	374.4	5.9
34	20-26	28.4	22.8	75	70	4.9	25.4	24.1	3	255.9	0.8
35	27-2 Sep.	29.8	21.8	86	54	5.2	17.0	2.6	1	402.5	6.3
36	3-9	32.8	22.1	85	54	6.8	9.3	-	-	431.3	8.7
37	10-16	32.3	22.1	88	59	5.0	4.9	3.2	1	382.1	6.4
38	17-23	31.9	22.5	89	60	3.8	3.8	100.9	3	328.9	5.2
39	24-30	29.6	22.3	92	70	3.2	3.8	89.2	5	288.2	4.5
40	Oct. 1-7	29.3	21.4	91	65	4.5	4.0	7.9	2	303.0	3.5
41	8-14	30.9	21.6	90	60	4.1	3.0	12.1	3	339.0	5.7
42	15-21	31.1	21.7	93	63	3.9	2.5	2.4	1	338.9	4.7

Standard weeks	Period	Temperature (°C)		Relative Humidity (%)		Evaporation (mm)	Wind velocity (km h^{-1})	Rainfall (mm)	Rainy days	Solar radiation (cal. cm^{-2})	Sun shine (hrs)
		Maximum	Minimum	0722 hrs.	1422 hrs.						
43	22-28	31.7	19.4	91	46	4.5	3.1	-	-	378.4	7.3
44	29-4 Nov.	30.8	21.2	89	54	3.3	2.6	-	-	360.3	7.0
45	5-11	31.0	21.5	89	48	4.5	5.2	-	-	420.2	7.9
46	12-18	30.0	21.4	87	49	4.3	6.2	-	-	368.4	5.7
47	19-25	28.2	21.8	93	66	2.4	4.8	34.3	3	243.5	3.2
48	26-2 Dec.	29.0	18.0	92	50	3.7	6.3	29.2	2	357.1	6.5
49	3-9	28.9	19.1	88	50	3.5	5.1	-	-	410.1	7.8
50	10-16	28.5	15.2	88	35	4.2	5.1	-	-	515.5	10.5
51	17-23	28.7	17.3	88	41	4.2	5.2	-	-	450.0	8.8
52	24-31	28.6	19.4	87	53	5.3	6.4	12.0	2	334.1	5.3
2001											
1	1-7 Jan.	30.0	20.9	91	48	3.7	1.1	-	-	371.7	6.3
2	8-14	30.0	19.4	88	43	4.3	5.1	-	-	419.9	7.4
3	15-21	30.2	17.8	90	40	4.5	7.3	-	-	446.8	7.9
4	22-28	31.2	20.8	81	44	4.8	5.6	-	-	386.8	5.0
5	29-4 Feb.	30.2	21.0	86	50	3.7	-	-	-	321.5	3.0
6	5-11	33.3	17.8	84	32	4.6	4.5	-	-	466.2	9.1
7	12-18	33.4	22.7	88	33	6.1	5.3	-	-	411.6	9.1
8	19-25	34.9	21.1	87	37	6.3	3.8	-	-	424.1	9.0
9	26-4 Mar.	34.3	20.6	87	33	7.1	6.2	-	-	451.3	9.6

APPENDIX II

Energy unit conversion equivalents for direct and indirect sources of energy

	Particulars	Units	Equivalent Energy (MJ)
I. Inputs			
Human labour	Man	Man hour	1.96
	Woman	Woman hour	1.57
	Child	Child hour	0.98
Animals	Bullocks	Pair hour	10.1
Petrol		Litre	48.23
Machinery	Farm machinery	kg	16.416
Chemical fertilizers	Nitrogen	kg	60.0
	Phosphorus	kg	11.1
	Potassium	kg	6.7
Organic manure	Goat manure	kg (dry wt.)	0.3
Chemicals	Superior chemicals	kg	120.0
Seed	All crop seeds	kg (dry wt.)	14.7
II. Outputs			
Grain	Sorghum, cowpea	kg (dry weight)	14.7
Straw	Stover and grasses	kg (drt wt.)	12.5
	Cowpea haulm	kg (dry wt.)	18.0
Goat meat		kg (dry wt.)	4.94

Mittal *et al.*, 1985 and Gopalan *et al.*, 1976

Appendix IV

Interaction effect on height (cm) of tree seedlings (North East Monsoon season)

North East Monsoon 1999

Treatment	12 months after planting					16 months after planting				
	M_1	M_2	P_1	P_2	Mean	M_1	M_2	P_1	P_2	Mean
T_1	52.5	51.4	54.3	49.5	51.9	70.1	64.7	73.6	61.2	67.4
T_2	87.6	83.9	92.0	79.6	85.8	122.0	104.1	125.6	100.4	113.0
T_3	120.6	112.4	122.2	110.7	116.5	183.2	168.6	187.7	164.1	175.9
M_1			91.3	82.4				134.9	115.2	
M_2			87.7	77.4				123.0	101.9	
Mean	86.9	82.6	89.5	79.9		125.1	112.4	128.9	108.6	

	SE_d	CD		SE_d	CD
T x M	0.79	1.65	T x M	2.73	5.61
M x T	0.64	1.27	M x T	2.72	4.42
T x P	0.79	1.65	T x P	2.73	5.62
P x T	0.64	1.27	P x T	2.72	4.42
M x P	0.52	NS	M x P	2.22	NS

North East Monsoon 2000

Treatment	24 months after planting					28 months after planting				
	M_1	M_2	P_1	P_2	Mean	M_1	M_2	P_1	P_2	Mean
T_1	95.5	84.5	104.5	75.5	90.0	103.5	92.0	113.0	82.5	97.8
T_2	157.5	128.0	159.5	126.0	142.8	168.5	136.5	172.0	133.0	152.5
T_3	264.5	222.0	285.5	201.0	243.3	285.0	232.6	305.1	212.5	258.8
M_1			202.3	142.7				220.7	150.7	
M_2			164.0	125.7				172.7	134.7	
Mean	172.5	144.8	183.2	134.2		185.7	153.7	196.7	142.7	

	SE_d	CD		SE_d	CD
T x M	2.36	4.89	T x M	2.28	4.70
M x T	2.03	4.04	M x T	2.21	4.40
T x P	2.36	4.89	T x P	2.28	4.70
P x T	2.03	4.04	P x T	2.21	4.40
M x P	1.65	3.29	M x P	1.80	3.59

Appendix III

Interaction effect on height (cm) of tree seedlings (Summer season)

Summer 1999

Treatment	7 months after planting					9 months after planting				
	M_1	M_2	P_1	P_2	Mean	M_1	M_2	P_1	P_2	Mean
T_1	37.6	28.7	32.0	34.4	33.2	44.7	36.8	40.4	41.1	40.7
T_2	46.3	46.4	45.3	47.3	46.3	49.6	58.8	49.7	58.6	54.2
T_3	69.5	75.0	71.6	72.9	72.2	87.4	90.1	88.5	89.0	88.8
M_1			49.5	52.7				56.3	64.8	
M_2			49.7	50.3				62.7	61.1	
Mean	51.1	50.0	49.6	51.5		60.5	61.9	59.5	62.9	

	SE_d	CD		SE_d	CD
T x M	0.39	0.80	T x M	0.47	0.96
M x T	0.38	0.75	M x T	0.45	0.90
T x P	0.39	NS	T x P	0.47	0.96
P x T	0.38	NS	P x T	0.45	0.90
M x P	0.31	0.62	M x P	0.36	0.74

Summer 2000

Treatment	19 months after planting					21 months after planting				
	M_1	M_2	P_1	P_2	Mean	M_1	M_2	P_1	P_2	Mean
T_1	81.7	75.3	89.3	67.7	78.5	89.6	81.1	98.3	72.3	85.3
T_2	139.5	119.1	145.0	113.6	129.3	151.4	124.2	152.6	123.1	137.8
T_3	225.2	198.5	242.6	181.1	211.8	250.0	204.0	267.5	186.5	227.0
M_1			167.9	129.7				189.5	137.7	
M_2			150.1	111.8				156.0	116.8	
Mean	148.8	131.0	159.0	120.8		163.6	136.4	172.8	127.3	

	SE_d	CD		SE_d	CD
T x M	0.51	1.04	T x M	0.59	1.24
M x T	0.56	1.11	M x T	0.43	0.85
T x P	0.51	1.04	T x P	0.59	1.24
P x T	0.56	1.11	P x T	0.43	0.85
M x P	0.46	NS	M x P	0.35	0.69

Appendix V

Interaction effect on basal diameter (cm) of tree seedlings (Summer season)

Summer 1999

Treatment	7 months after planting					9 months after planting				
	M_1	M_2	P_1	P_2	Mean	M_1	M_2	P_1	P_2	Mean
T_1	1.71	1.49	1.58	1.62	1.60	1.98	1.68	1.80	1.87	1.83
T_2	1.61	1.52	1.62	1.52	1.57	1.80	1.65	1.78	1.67	1.72
T_3	1.08	1.11	1.10	1.10	1.10	1.63	1.60	1.57	1.67	1.62
M_1			1.52	1.42				1.83	1.78	
M_2			1.34	1.40				1.60	1.69	
Mean	1.47	1.37	1.43	1.41		1.80	1.65	1.72	1.73	

	SE_d	CD		SE_d	CD
T x M	0.02	0.04	T x M	0.02	0.05
M x T	0.02	0.03	M x T	0.02	0.05
T x P	0.02	0.04	T x P	0.02	0.05
P x T	0.02	0.03	P x T	0.02	0.05
M x P	0.01	0.03	M x P	0.02	0.04

Summer 2000

Treatment	19 months after planting					21months after planting				
	M_1	M_2	P_1	P_2	Mean	M_1	M_2	P_1	P_2	Mean
T_1	4.03	3.13	4.25	2.91	3.58	4.27	3.47	4.63	3.10	3.87
T_2	5.48	4.18	5.71	3.95	4.83	5.64	4.48	5.87	4.25	5.06
T_3	3.64	3.48	3.73	3.40	3.56	4.33	3.59	4.33	3.59	3.96
M_1			5.11	3.65				5.64	3.86	
M_2			4.02	3.19				4.26	3.44	
Mean	4.38	3.60	4.56	3.42		4.75	3.85	4.95	3.65	

	SE_d	CD		SE_d	CD
T x M	0.03	0.07	T x M	0.03	0.06
M x T	0.03	0.07	M x T	0.03	0.06
T x P	0.03	0.07	T x P	0.03	0.06
P x T	0.03	0.07	P x T	0.03	0.06
M x P	0.03	0.08	M x P	0.03	0.05

Appendix VI

Interaction effect on basal diameter (cm) of tree seedlings (North East Monsoon season)

North East Monsoon 1999

Treatment	12 months after planting					16 months after planting				
	M_1	M_2	P_1	P_2	Mean	M_1	M_2	P_1	P_2	Mean
T_1	2.67	2.53	2.72	2.48	2.60	3.40	3.88	3.55	2.73	3.14
T_2	2.80	2.63	2.81	2.62	2.71	4.48	3.80	4.88	3.40	4.14
T_3	2.09	1.94	2.20	1.83	2.02	3.27	3.00	3.27	2.99	3.13
M_1			2.62	2.42				4.20	3.23	
M_2			2.53	2.20				3.60	2.85	
Mean	2.52	2.37	2.56	2.31		3.71	3.23	3.90	3.04	

	SE_d	CD		SE_d	CD
T x M	0.03	NS	T x M	0.03	0.05
M x T	0.02	NS	M x T	0.03	0.06
T x P	0.03	0.06	T x P	0.03	0.06
P x T	0.02	0.05	P x T	0.03	0.05
M x P	0.02	0.04	M x P	0.02	0.05

North East Monsoon 2000

Treatment	24 months after planting					28 months after planting				
	M_1	M_2	P_1	P_2	Mean	M_1	M_2	P_1	P_2	Mean
T_1	4.33	3.51	4.71	3.14	3.92	4.50	3.62	4.87	3.25	4.06
T_2	5.72	4.55	5.96	4.31	5.13	5.84	4.64	6.09	4.38	5.24
T_3	4.63	3.81	4.64	3.80	4.22	4.93	4.02	4.96	3.99	4.47
M_1			5.80	3.98				6.04	4.13	
M_2			4.40	3.51				4.57	3.61	
Mean	4.89	3.96	5.10	5.75		5.09	4.09	5.31	3.87	

	SE_d	CD		SE_d	CD
T x M	0.03	0.06	T x M	0.04	0.07
M x T	0.03	0.06	M x T	0.04	0.08
T x P	0.03	0.06	T x P	0.04	0.07
P x T	0.03	0.06	P x T	0.04	0.07
M x P	0.03	0.05	M x P	0.03	0.06

PLATES

Plate - 1

An overall view of the experimental field of the crop component

Plate - 2

Sorghum + Cowpea (grain) in *Emblica officinalis* under tied ridges with 50 per cent fertilizer N and 50 per cent N as goat manure

Plate - 3

Sorghum + Cowpea (fodder) in *Emblica officinalis* under tied ridges with 50 per cent fertilizer N and 50 per cent N as goat manure

Sorghum + Cowpea (grain)

Sorghum + Cowpea (fodder)

Plate - 4

Intercropping of Sorghum + Cowpea

Before cutting

After cutting

Plate - 5

Plate - 6

***Emblica officinalis* with coir pith mulching and pitcher irrigation**

Stall feeding

A Tellichery Kid

Plate - 7

Tellichery Goats (5+1) as animal component in farming system