PERFORMANCE OF THREE NEWLY INTRODUCED LEGUMINOUS TREE SPECIES IN AGROFORESTRY SYSTEMS OF MIZORAM AND THEIR EFFECT ON AGRICULTURAL CROPS

MALSAWMDAWNGLIANI FANAI

Thesis
submitted in fulfillment of the
requirements for the degree of

Doctor of Philosophy in Forestry

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Performance of three newly introduced leguminous tree species in agroforestry systems of Mizoram and their effect on agricultural crops

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By

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Affectionately dedicated to
my husband and my dearest children
from whom I take
so much more than I give

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CERTIFICATE

This is to certify that the thesis entitled "Performance of three newly introduced leguminous tree species in agroforestry systems of Mizoram and their effect on agricultural crops" submitted by Ms. Malsawmdawngliani Fanai for the degree of Doctor of Philosophy in Forestry embodies the record of original investigations carried out by her under my supervision. She has been duly registered and the thesis presented is worthy of being considered for the award of the degree. This work has not been submitted for any degree of any other university.

Date : 25.7.2012

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DECLARATION

I, Malsawmdawngliani Fanai, hereby declare that the subject matter of this thesis entitled "Performance of three newly introduced leguminous tree species in agroforestry systems of Mizoram and their effect on agricultural crops" is the record of the work done by me, that the contents of this thesis did not form basis for the award of any previous degree or to anybody else, and that I have not submitted the thesis in any other university/institute for any other degree.

This is being submitted to the Mizoram University for the degree of Doctor of Philosophy on Forestry.

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CONTENTS

&&&&&&&&

LIST OF TABLES

&&&&&&&&

LIST OF FIGURES

&&&&&&&&

CHAPTER -1

INTRODUCTION

CHAPTER – I

INTRODUCTION

1.1 General

Agriculture is the mainstay of Indian economy, it provides raw material for a large number of industries in the country. It contributes nearly 12.3 per cent of gross domestic product, and the total workforce in agriculture sector as per 2001 census was about 58 per cent of employment in the country (Anon.,2012). As rice is the staple food of vast majority of Indian, foodgrains production is equally important as other sectors. In 2008-09, foodgrains production in the country reached record level of 234.47 million tonnes, but in 2009-2010 the production declined to 218.11 million tonnes (Anon., 2011) mainly due to severe drought in several parts of the country.

At present, India is the leading producer of milk and pulses, and second largest producer of rice, wheat, sugarcane, fruits, vegetables, tea, egg and culture fishery in the world (Ravi, 2012); it has a second largest arable land and irrigated area next to China. These achievements in production were made with the right combination of appropriate technology, institutional support, policy and the farmers themselves. However India has the second largest population in the world, about 16 per cent of world population to feed, while economic liberalization and disinvestment policy of the government is gaining popularity in the Indian economy, agriculture development on the one hand must not be neglected for sustainable and balanced growth.

While sustainable land management and sufficient production are among first priority in agriculture, per unit area production should be enhanced so as to utilize available resources to the maximum. According to a study, while per unit area production of maize and paddy in USA is as high as 8900 kg/ha and 7500 kg/ha, in India per unit area production is 2100 kg/ha and 3000 kg/ha respectively (Ravi, 2012). With the growing population and high percentage of people below poverty line in rural India who are dependent on agriculture; institutional support, credit facilities, appropriate technologies, infrastructural development, etc., may be made available to them so that they will be able to survive occurrence of unproductive years due to unfavourable climatic condition.

The extensive use of land, chemical fertilizer and water resources for achieving high production potential caused various type of degradation of land and water resources(Srivastava and Khan, 2008). According to World Bank estimates, more than 1.6 billion people depend on forests for their livelihoods. The UN's Food and Agriculture Organization (FAO) estimates that every year 130,000 km^2 of the world's forests are lost due to deforestation, conversion to agricultural land, unsustainable harvesting of timber, unsound land management practices, creation of human settlements are the most common reasons for this loss of forested areas (Anon., 2005). In 2007, total forest cover in India was 69.09 million hectare which accounts for 21.02 per cent of the total geographical area of the country (Anon., 2009a).

1.2 Land use pattern in North East India

The north eastern region of India comprises the states of Assam, Manipur, Meghalaya, Nagaland, Sikkim, Tripura, Arunachal Pradesh and Mizoram. In all the eight states, permanent cultivation in the plains and shifting cultivation in hills are the two predominant patterns of land use, the cropping pattern remained highly specialized or specific in foodgrains production. In most of the states, jhum cultivators have no land-right excepting the right to use the land for a particular period. Similarly, the average operational holdings are also very small for sustainable growth of agriculture in the region. The major problem in north eastern hilly region is that the available land is subjected to heavy soil erosion and land degradation resulting from deforestation and heavy rains. Unabated deforestation has led to serious degradation of soils, water flora and fauna. India State of Forest Report 2009 highlighted decrease in forest cover in Tripura, Arunachal Pradesh, Assam states in North-East India mainly due to felling of trees for shifting cultivation, and increase in forest cover in Mizoram, Manipur and Meghalaya. The main reason put forward by the report for this increase in forest cover is effective protection of forest by Joint Forest Management and regeneration of abandoned shifting cultivation areas.

Valley agriculture is practiced throughout the hilly terrain both at low and high elevations. The land utilization for double or multiple cropping is rather poor and monocropping is practiced in general mainly due to non-existence of irrigation during dry season. Paddy field is usually kept fallow for about six months after harvest of rice crop. However, there are areas where double cropping is practiced with the help of farm manure, fertilizers and artificial irrigation during dry season. Bench terraces are well adapted in some areas more particularly in river valleys and mild slope with assured irrigation facilities.

1.3 Shifting Cultivation

Shifting cultivation is a type of farming system in which the land under cultivation is periodically shifted so that fields that were previously cropped are left fallow and subject to the encroaching forest (fig. 4.9 & 4.10). In India shifting cultivation also known as *Jhumming* has been widely practiced by tribal communities in Andhra Pradesh, Orissa and tribal communities of north eastern hilly region of India like Garo, Khasi, Naga, Arunachali, Mizo, etc. Agriculture in these areas mostly consists of small farms with intensive production, where varieties of crops are grown in mixtures.

In North-East India the cycle of agricultural operations in jhumming is by and large similar following successive stages, selection of forested hill lands before December by entire village on the basis of rotation of fields; cleaning the forest tract by cutting down the jungle during December to January leaving felled leaves and twigs to dry till February; burning the dried debris into ashes around February to mid-March before the onset of monsoon and sowing seeds of various crops as mixed cropping by using hand hoe, dao, dibbling stick or sharp knives, followed by weeding, watching, and protecting of crops, harvesting, threshing and storing.

The most significant feature of shifting cultivation is that all essential crops like maize, tapioca, colocasia, beans, pumpkin, cowpea, cucurbits, sweet potato, ginger, finger millet, cotton, tobacco and many others are grown along with rice in the same field as mixed land use. Though rice is the main crop, vegetables and other crops are harvested all-round the year contributing subsidiary income to the farmers during working season. The fire ashes correct the soil acidity and make the soil fertile for a short period thereby improving crop growth. The large number of crop species over both space and time are effectively managed due to sequential harvesting all over the year. Initial opening of forested land, burning of dried forest, weeding are the most strenuous and labour consuming part of shifting cultivation, at least three weedings are necessary.

Men and women participated equally from the beginning. In some society, men in the family would take care of intense hard work like cutting down the forest as site preparation, making fire line and burning of dried jungle.

Utilization of simple tools such as dao, dibbling sticks, small hand hoe, absence of tillage or use of machine, non-existence of artificial irrigation, little initial investments are some other distinguishing features of shifting cultivation making the system simple and manageable even without scientific method. Shifting cultivation supplemented by harvest of flora and fauna from surrounding forests forms a complete unique economic system and a way of life for hill people. The whole social, political and cultural life of the hill people is interwoven with the practices with the result that they are reluctant to change into modern method of cultivation.

During burning of jhumland, accidental forest fire accelerated by dry season sometime caused huge loss of flora and fauna, it so happened many times in the past that human lives not to mention animal were lost in forest fire. The field is used for a year for mixed cropping and subsequently, it is either abandoned or cultivated with one or two select crops; occasionally some residual crops are collected from the abandoned fields. Owing to leaching, erosion and loss of fertility after one or two years, the cultivated area is abandoned, a new piece of land is then selected to repeat the process leaving the old one under forest fallow for years to recuperate. The land area remains under effective control of village authorities, mode of land allotment varies from tribe to tribe. The average size of jhum plot varies from 1.0 to 2.0 ha and the average family consists of two adults and three to four children (Borthakur, 1992).

Under the pure jhum economy in rural areas people hardly offer labour for hire during intense working season and they sell or purchase very little. However, with the awakening of the world in electronic and modern technology, rural economy has also been conscious of money economy gradually leaving barter system. Government servants working in rural areas play an important role in the availability and used of hard cash in rural areas as a medium of selling and purchasing. Selling of farm produce is important as it makes subsidiary income for the farmers, sustaining the need for children's education, health care, etc.

Several studies were carried out by various workers on shifting cultivation and its impact on rural economy, forest, biodiversity with recommendations. Some workers opined that this system is considered ecologically and economically efficient agricultural practice provided that the fallow period is sufficiently long (Anon., 2009b; Bruun, *et al*., 2009; Cairns and Garrity 1999; Craswell *et al*.,1997; Mertz *et al*., 2009; Ramakrishnan, 1992; Ziegler *et al*., 2009). However, the length of jhum cycle reported from different regions show decline in jhum cycle from 20 or more years earlier to 4-5 years thereby making the system uneconomical and unsustainable. It has reached critical limit in parts of Arunachal Pradesh, Assam and Mizoram where it is as low as 2 to 3 years even though on the maximum it ranges from 4 to 10 years. This has adversely affected economic yield with gradual decline in yield over a period of time when short cycles are imposed on infertile land (Verma *et* *al.*,2001). There may be several reasons for this; it may be inferred that population pressure, industrial policies, forest policies, injudicious collection of timber, firewood are among the reasons for this shortening of jhum cycle.

It was estimated that even with those with good soil base, the natural forest needs 30 years or more to generate. Apart from losing vegetation and bio-mass due to the practice of shifting cultivation, one of the serious adverse effects is soil erosion, which is mainly of splash and wash types. As the soils in the upper reaches in a ridge are exhausted in the process, the cultivators move to the adjoining lower elevations, the process continues till the entire ridge is exhausted leaving the land barren and uncultivable. Further, since the forested hill tops and upper catchments are the source of water, deforestation and soil erosion in the hills have led to shrinkage of the sources of water, siltation of riverbeds and causing floods in the valleys. There is a substantial runoff in high rainfall area like Mizoram and the soils get depleted at a faster rate.

1.4 Shifting cultivation and land use pattern in Mizoram

Agriculture occupies a very important place in the economy of Mizoram, as per Census 2001 about 53.91 per cent of the people are cultivators and 5.85 per cent are agricultural labourers (Anon., 2002). Those cultivators are engaged in agricultural activities mostly by practicing shifting cultivation; both production and productivity are relatively low. In 2009-2010 Agriculture accounts for 16.17 per cent share of Gross State Domestic Product and per capita income at current price was Rs. 32,488.00. In 2009-2010 total production of paddy irrespective of kharif and rabi was 66,132 metric tonnes and the area under paddy cultivation was 47,204 ha. During the same year total food grains distributed through Public Distribution System at a subsidised rate was 1,74,832.36 metric tonnes. This shows that Mizoram is not self-sufficient in rice production though it continues to remain the chief food crop and the staple food of the Mizo. Of the total cropped area of 1.33 lakh hectares, 35.43 per cent is put on paddy and only 3,000 ha are sown more than once (Anon., 2010a). The forest production is mainly timber, bamboo, broom-sticks, etc. The common crops grown in the State are paddy, cowpea, mustard, pumpkin, maize, sesame, ginger, etc., and cabbage, mustard, cauliflower, bean, etc., during winter where irrigation facility is available. India State of Forest Report, 2009 shows increase of forest cover in the state during 2005 - 2007 which is most likely due to re-growth in the abandoned shifting cultivation areas and regeneration of bamboo in bamboo flowering areas. In 2009 –2010, Mizoram has a total forest covered of 19,240 km^2 comprising 134 km^2 of very dense forest; 6,251 km^2 of moderately dense forest and 12,855 km^2 of open forest (Anon., 2010a).

The general landscape of Mizoram is one of the most unique and rather beautiful hilly rugged terrains in north eastern part of India. Shifting cultivation has been the method of farming system practiced by Mizo people as far as history of Mizo is concerned, in the past seasonal intercultural operations were intertwined with festivals and rituals of Mizo people. Even today, customary distribution of community land to jhum cultivators on year to year basis is being practiced by Village Councils in rural areas. Upland cultivation is usually carried out without fertilizers and irrigation, the land would be abandoned after one year and a new site will be selected again for the same purpose.

Mizoram has a pleasant climate as the state lies in the sub-tropical to temperate zone avoiding extreme climate in winter and summer. The State is marked by numerous freshwater rivers and streams, plenty of monsoon rain put the State vulnerable to frequent road blockage due to landslides during rainy season. The settlement areas are normally found high on the hillside thus creating innumerable inconveniences in gathering basic necessities for a living, water supply, road construction and the like. Farm mechanization is almost impossible due to this reason, small patch of flat lands are found in valley lands, where terracing are being practised.

Agricultural communities with limited land holdings usually supplement their income by collecting minor forest produce and growing vegetables, rearing of poultry, pig, goat, sheep etc. at home scale level. In rural Mizoram, growing of upland paddy has been more like a tradition than for their basic livelihood since the last few years due to the fact that Indian government had launched innumerable poverty alleviation schemes for development of rural India, some of them being livelihood development programmes, wage employment, rural housing, wasteland development through peoples' participation, self-employment, etc. While the rural people can go for alternative livelihood activities rather than traditional farming they are very much adhered to the system, complete abandoning of the system is rather a sensitive issue and it will require intensive thematic campaign.

The area under Jhum cultivation in Mizoram during last ten years is presented in the table below.

Table 1.1 : The area utilized for Jhum Cultivation during last 10 years

Sl.No.	Year	Area under Jhum in Ha.
1.	1997-1998	68,114
2.	1998-1999	68,392
3.	1999-2000	36,285
4.	2000-2001	35,798
5.	2001-2002	40,305
6.	2002-2003	41,356
7.	2003-2004	43,447
8.	2004-2005	40,969
9.	2005-2006	40,100
10.	2006-2007	41,465

Source: Anonymous, 2010b

1.5 Need for sustainable farming system in Mizoram

The unsuitability of shifting cultivation begins with the reduction in jhum cycle, land degradation due to soil erosion, runoff, nutrient losses; loss of bio-diversity, deforestation, etc. Shifting cultivation is still prevalent in tribal areas in different parts of India including North-East India. In the 1993, 1995 and 1997 reports of forest survey of India, it was clearly mentioned that among other factors, shifting cultivation played a major role in the rapid deforestation in North-East India. Nevertheless, studies have shown declining trend in areas covered and number of families engaged in shifting cultivation in Mizoram. The need for sustainable farming system in Mizoram are summarised as below:

1.5.1 Land degradation

The cultivation along the hill slope without conservation measures and rapid loss of tree cover from mountain have rendered the land susceptible to accelerated soil erosion, loss of soil nutrients, landslides and loss of habitat. The rehabilitation of mountains and proper management of its resources, particularly the common resources of forests required special attention in the present situation. It is well recognized that apart from natural causes, improvident and unscientific land and water management practices have resulted unproductive, barren and waste lands. With the same amount of input and effort put in the process, decline in per area production due to unproductive land makes the present farming system unattractive. Farmers have to opt for alternative livelihood activities.

1.5.2 Decline in jhum cycle

The State’s economy is largely agricultural with almost 60 per cent of the total work force engaged either directly or indirectly in agriculture. In the olden days with availability of vast area of land including forest land, smaller size of population, jhum practice was more or less in harmony with natural cycle. But the impact of increased pressure on forest land for different purposes like dwelling, mini industry, grazing, timber, firewood, etc., have led to shrinkage of jhum cycle lowering productivity and production thus rendering jhum practice uneconomical.

1.5.3 Availability of essential commodities and alternative livelihood options

Various developmental activities also generate avenues for easier livelihood options like chow making, agarbati stick, candle, plantation of cash crops, oilseed crops, etc., under the aegis of Government, and wage earnings from construction works, rural artistry, handloom, handicraft, groceries and other activities different from hard work involved in jhum practices. Transportation of provisions from other states by private vendors and availability of essential commodities at a subsidised rate through Public Distribution System make the jhumming system appears less economical, as a result farmers are subjected to choose alternative options like growing of commercial crops to increase purchasing power. However, scientific and modern intervention is required at this stage as long as land based activities are opted for sustainable income generating activities.

1.5.4 Technical constraints

There are various technical and implementation constraints to agricultural development in Mizoram. Upland farming in different agroclimatic zones does not permit the uniform package of practices for agricultural development. Rather location specific technology and varieties of crops are needed. The rugged terrain and slope creates difficulty in promoting mechanised agriculture on sloping land. Improved varieties of seeds and planting materials are not readily available to farmers.

1.5.5 Declining crop yields

Available reports indicated that the overall soil fertility status throughout the state is poor and the soil in the hills are strongly acidic in reaction (Anon.,2010b). This is compounded by the fact that farming is generally practice on sloping farmlands, aggravating soil erosion and associated nutrient losses and wet rice cultivation in river valley on continual basis. The productivity of farmlands in the upland areas has been recording either a steady decline or stagnation in crop yields. In lowland wet rice cultivation soil fertility is maintained mainly by the application of compost, manure, and fertilizers. Long term use of inorganic fertilizers alone in wet rice cultivation resulted in poor and low inherent fertility thereby causing yield reduction. In Mizoram, irrespective of wet rice cultivation and jhum land, drastic yield declined of paddy was observed in 2006-2007 and 2007-2008 due to bamboo flowering and it associated problems like incidence of insect pest, rodents. The total yield of paddy in 2009-2010 was still lower than paddy yield before bamboo flowering particularly paddy yield in 2005-2006 (Anon.,2009c).

1.6 Jhum control initiatives

Various attempts have been made by the Government of India as well as State Governments to settle the tribals involved in shifting cultivation. In view of the need to have comprehensive plan for development of wastelands on watershed basis in the country, Integrated Wastelands Development Programme (IWDP) was introduced in 1994 and subsequently revised in 2001 by the Ministry of Rural Development. Likewise the Ministry of Agriculture, Government of India sanctioned watershed development projects under NWDPRA (National Watershed Development Project for Rainfed Areas) and WDPSCA (Watershed Development Project in Shifting Cultivation Areas) as centrally sponsored schemes to cover rain-fed areas and shifting cultivation areas in 1990 and 1994 respectively. The broad objective of Integrated Watershed Management Programme is to treat degraded lands with the help of low cost and locally accessed technologies such as in-situ soil and moisture conservation measures, afforestation etc. through participatory approach.

WDPSCA was particularly launched by the Ministry of Agriculture and Cooperation, Government of India in the seven north eastern states with 100 per cent grant. The scheme aimed at overall development of jhum areas on watershed basis, reclaiming the land affected by shifting cultivation and socio-economic upgradation of jhum cultivators living in these areas so as to encourage them to go in for settled agriculture. These developmental schemes have however, not yielded the desired results perhaps due to ignorance of the authorities about the socio-economic and agro-ecological conditions of different regions coupled with poor publicity of the programmes. The programmes are implemented by agriculture department, soil conservation, forestry etc., in relative isolation without proper coordination through a multi-disciplinary approach.

In Mizoram, the scheme IWDP started in the year 1999-2000. To further simplify the procedures a new guidelines called Hariyali was issued in 2003 by the Government of India. The IWDP / Hariyali is implemented in all 8 districts of Mizoram, at present there are 52 ongoing projects under IWDP / Hariyali in the State. The guidelines of these programmes being revised and modified according to lessons learnt from past experiences, all these programmes are now converged into Integrated Watershed Management Programme (IWMP) under the common Guidelines for Watershed Development Projects 2008, also known as Integrated Watershed Management Programme. There are 49 sanctioned projects under this new guidelines in Mizoram at present.

Policies have also been formulated by the Government of Mizoram for settled and permanent farming system several times in the past. To name some of them, garden colony, new land use policy(NLUP), jhum control, contour trench method, Mizoram intodelhna project (Mizoram Self Sufficiency Project), Newly designed new land use policy, etc. However, major changes in rural economic scenario, the likely beneficial result as a whole is perhaps yet to be known. In the past, it was reported that some families were benefited by the scheme particularly NLUP and gave up jhum practices and managed to set up sustainable, alternative livelihood activities (Anon.,2010b). But, it is likely that the controversy may remain whether those families would have possibly successful even without the aid of government scheme or they were genuinely benefited by the schemes.

In general, people in rural Mizoram are attached to traditional method of jhum cultivation, may be due to lack of know-how or unavailability of reliable and sustainable alternative or income oriented systems. Though it is very difficult to say whether the area under shifting cultivation is increasing or decreasing during the last ten years, it can be said that the number of families engaged in shifting cultivation have declined. However, in some areas shifting cultivation continues for production of non-cereal crops like turmeric, chilli, ginger, etc. Therefore, an alternative system to jhum practice, friendly to hill people is necessary for gradual transformation to permanent landuse practices and change rural economy in Mizoram.

1.7.1 Agroforestry as a sustainable farming system

There may be many and diverse methods as alternative to jhumming. As presented earlier several initiatives were made by the government as a government policy and researchers and scholars have recommended several alternative systems as well. It is crucial to increase food production per unit area to meet the unfulfilled demand of vegetables and food crops of rising population of the state, with practically no scope with shifting cultivation, due attention should be paid to sustainable cropping systems. For such hilly regions the adoption of improved, efficient and sustainable systems like agroforestry system may be an appropriate option to improve the economic scenario of Mizoram.

According to Upadhyaya and Jha (1997), apart from being eco-friendly and sustainable, agroforestry regime is about 18 times as lucrative as shifting cultivation. Various scholars and researchers have defined the term agroforestry differently depending on the focus of work but the general principle have always been land-use systems and technologies where woody perennials are deliberately or intentionally mix or retain and combine with crops/animals production on the same land management. Agroforestry aims at systematic land use systems and practices where positive interaction between crops and trees is maximized.

1.7.2 Use of legumes in farming system

The nitrogen contribution of legumes can be vital for maintaining the productivity of sloping lands over long periods, because this benefits other ground vegetation, both crops and non-crops. To acquire nitrogen-fixing capability, legumes form symbiotic association with nitrogen-fixing organisms, usually nodule forming soil bacteria of the genus *Rhizobium* or actinomycete of the genus *Frankia* (Partap and Watson, 1994). The results of an experiment conducted on the use of leguminous cover crops in Nigeria revealed that total biomass and litter were three times higher in *Tephrosia candida* plots fallowed for 2 year than in the natural fallow. Nutrient (nitrogen, phosphorus, calcium, magnesium and potassium) yields in leaves of *T. candida* fallow for 2 year were on average 200–300% higher than in leaves of other fallows. Soil chemical changes showed significant increases in nitrogen and carbon concentrations after 2 years fallowing and a year of cropping. Conversely, soil pH, available phosphorous and the exchangeable cations, especially calcium were lower (Ikpe *et al*. 2003).

Despite their biological potential to fix nitrogen, not all legumes have the capability to fix nitrogen and species vary in their rates of nitrogen fixation. Some are exceptionally good while others are poor nitrogen fixers. Besides, there are several other factors that influence the fixation of nitrogen by a legume. The most common reasons for poor nitrogen fixing by a legume may be absence of appropriate nodulating bacteria in certain cases and adverse habitat conditions for nitrogen fixation. *Leucaena* is poorly nodulated at pH below 5.5. However, there are some species of *Leucaena* which are tolerant to acidity (Anon., 1977). There are legumes like *Mimosa* which bear healthy nodules even in some of the very high acidic soil of the highlands (Rekasem and Rekasem, 1993).

1.7.3 Principles and functions of hedgerows

The hedgerow in general comprised of tree or shrub either nitrogen fixing tree species or suitable shrub species managed in a shrubby form to be employed as natural or live fence like structure. The main functions are soil fertility maintenance, rehabilitation of degraded lands, natural terrace building through accumulation of top soils and litter fall. In hedgerow intercropping, the hedges provide semi-permeable barriers, thereby checking detached particles of top soils, retain moisture, while their prunings augment soil cover by returning the nutrients back to the soil. In an alley cropping study in Zambia, the soil moisture content was higher under the hedge rows of *Leucaena leucocephala* and *Flemingia macrophylla* than in Maize rows during dry period (Chirwa *et al*., 1994). It was also reported that the higher yield of agricultural crops under trees was attributed to improvement of soil fertility and conservation of moisture (Puri *et al*., 1994; Jaimini and Tikka, 1998). Kang *et al.* (1999) also reported greatly enhanced total biomass yield/ha, higher soil organic carbon, phosphorus and potassium levels under nitrogen fixing hedgerow species of *Gliricidia sepium* and *Leucaena leucocephala* in a long-term alley cropping trial undertaken in south western Nigeria.

1.8 Agroforestry models in Mizoram

Many research works on agroforestry have been carried out all over the world with significant results and few have been tried successfully in Mizoram.

Agroforestry models which are regarded to have special relation with the present investigation and experimented in Mizoram are presented briefly in the subsequent paragraphs.

1.8.1 Tree-green hedge-crop farming system or *Zo Tech*

Jha (2000) had conducted on farm demonstration-cum-trial in four villages which he called 'Tree-green hedge-crop farming system (TGhCFS)' or *Zo Tech* which is reported as a new and alternative to jhum cultivation in Mizoram. Nitrogen fixing tree species viz. *Leucaena leucocephala* and C*ajanus cajan* and non-Nitrogen species *Manihot esculenta* were planted at closer spacing to establish hedges, crops were grown in between hedge rows. The research finding indicates that the TGhCFS may be a suitable agroforestry base cropping system for hill farming system or to rehabilitate jhum land.

1.8.2. Sloping Agricultural Land Technology vis-à-vis Alley cropping system

In southern Mizoram, Baptist Church of Mizoram, having in mind sustainable development of rural people through improved farming system has been advocating Sloping Agricultural Land Technology (SALT), an imported technology from the Philippines by the Church which is one form of alley cropping or hedgerow intercropping system. The salient features of SALT - I for foodgrains production is similar with alley cropping system up to certain extent. The complete system of SALT is rather complicated and intensive integrating foodgrains production, livestock rearing, timber, fruits and plantation crops production. In SALT system, densely populated double or triple rows of woody legumes or hedge forming nitrogen fixing trees are grown along the contour lines and managed to form hedges which later will perform different functions of hedgerows. The hedgerows are the key element of the entire system (Partap and Watson, 1994).

Alley cropping system involved planting of perennial trees or bamboo or shrubs yielding forage in rows at some distances in association with agricultural crops. It is an agroforestry practice, which emerged as an alternative to shifting cultivation in humid tropics. It is a system in which food crops are grown in the alleys formed by hedge rows of trees and shrubs. The primary purpose of alley cropping is to maintain or increase crop yields by improvement of soil fertility (through legume tree component and mulching) and microclimate (Singh, 1995). Alley cropping with tree rows aligned along contours will prove to be an effective means of erosion control and also impart stability to production. The hedge rows are cut back at planting of arable crops and kept pruned during the cropping period so as to prevent shading and reduce competition with food crops. When there are no crops, the hedge rows are allowed to grow freely or cut to meet the fodder needs.

1.8.3 Contour trench farming system

The contour trench farming system with contour trenching as mechanical conservation measure was initiated in Mizoram by the Department of

Agriculture, Government of Mizoram. The trenches are dug along the contour at an interval varying from 20-50m according to percentage of slope. The trenches are dug normally by cutting a trench of 30cm deep and around 45cm wide. The function of the contour trench is to break the slope and convert surface water into subsurface. Detached top soil due to rain and cultural operations gets accumulated with decayed biomass in the trench, which are scooped out from the trench and utilized as compost manure to the crops (Thansanga, 1997).

As discussed earlier, Mizoram is prone to landslides, soil erosion; high run-off attributed by steep hills, heavy rainfall, land degradation and deforestation due to faulty land management, there has been no known proper information about complete system of any identified model of agroforestry system being in practice in Mizoram until very recently. However, government policy for sustainable development and low returns from the uneconomical practices of farming, people started going for some form of agroforestry since a few years back. Though economic returns from these practices were not systematically analyzed, but subsidiary income have been made from the system which stabilizes income of farmers during lean period.

Scope of the present study

The various farming systems in Mizoram need to be analysed to see how well they protect the land, particularly at the critical periods of the year when erosion risk is highest. It is important to study whether the soil fertility be maintained over the long term using leguminous crops as hedgerows? Can the crop productivity be maintained by continuously cultivating such lands in this way? Is this practice economically viable? Which nitrogen-fixing shrub species are most appropriate to the different slopes, soil-types and climatic conditions that occur across the region? Properly designed trials with appropriate controls to specifically test species differences in performance on a variety of slopes under the various climates and soil-types that occur across Mizoram are urgently needed. Such trials, if successful, would also be a critically important resource in disseminating this technology to local farmers. Finally, the growth performance of nitrogen-fixing trees viz. *Leucaena leucocephala*, *Tephrosia candida* and *Flemingia microphylla* and their effects on the growth and yield of agricultural crops in hill slopes of Mizoram need to be studied.

Objectives of the present study

The present study, therefore, aims to investigate the growth performance and yield of rice and maize as affected by leguminous tree species planting as double hedgerows without external application of fertilizers and manuring in the upland condition of Mizoram. It is expected that the present study would also help in determination of changes in the nutrient status of soil, growth and yield attribute of agricultural crops as affected by tree-crop interactions and growth performance of leguminous tree species.

The present experiment has been designed to achieve the following specific objectives:

1. To study the effect of leguminous tree species on the growth and yield of agricultural crops.
2. To study the effect of pruning of leguminous tree species on the growth and yield of agricultural crops.
3. To determine changes in the nutrient status of soil as affected by tree-crop interactions.
4. To determine the most suitable tree species for contour hedgerows cropping system.

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CHAPTER -2

REVIEW

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LITERATURE

CHAPTER – 2

REVIEW OF LITERATURE

2.1 General

Several research works have been carried out on the suitability of intercropping of leguminous trees and agriculture crops, use of woody legumes in agroforestry system in general, hedgerow or alley cropping, and shifting cultivation and its associated problems. In this chapter, an attempt has been made to review relevant literatures available in India and abroad.

2.1.1 Shifting cultivation and land degradation

Shifting cultivation had been a livelihood activity of different communities once in a while or sometime in the past, and is still in practice in tropical hilly areas of Southeast Asia, the Pacific, Latin America, the Caribbean, and Africa (Cairns and Garrity, 1999; Craswell *et al.*,1997; Eastmond and Faust, 2006; Kato *et al.*, 1999; Lawrence and Schlesinger, 2001; Ramakrishnan, 1992a; Stromgaard, 1992; Thomaz, 2009). In India, it is essentially prevalent in north eastern states and to some extent, in hills of Andhra Pradesh, Bihar, Madhya Pradesh, Orissa and Karnataka (Tejwani, 1994). Agriculture in these areas mostly consists of small farms with intensive production, where varieties of crops are grown in mixtures. The average size of jhum plot varies from 1.0 to 2.0 ha and the average family consists of two adults and three to four children (Borthakur, 1992).

In India, slash and burn agriculture is regarded as one of the major factors contributing to deforestation, especially in the hilly north-eastern region and eastern ghats. Studies on vegetation dynamics associated with slash and burn agricultural practices have been intensively carried out in the north-eastern part of India (Prasad *et al.,* 2001). Due to increasing human population, the biotic pressure on the native forest is inevitable. The uncontrolled lopping and felling of trees for fuel wood, leaf fodder, burning of ground vegetation for forage are some of the factors responsible for exploitation of forests (Bargali *et al*., 1998). Rajora (1998) suggested that the indiscriminate cleaning of slopes should be prohibited and no land with more than 20 percent slope should be cleared for the cultivation.

Due to shifting cultivation and large scale deforestation, there had been a continuous degradation of the land leading to ecological imbalance including soil and water loss, which leads to problems in agricultural production (Ramakrishnan, 1992b). The annual loss of soil and crop yield due to the shifting cultivation in north eastern region of India was estimated to be 15.5 million tonnes and 52.23 thousand tonnes respectively (Chauhan, 1990). Singh and Singh (1980) also observed soil erosion at 147 tonnes/ha in the second year jhum and only 30 tonnes/ha in abandoned jhum with 50-60 percent slopes. This shows that soil losses are much higher under the shallow-rooted vegetable cultivation than in deep rooted forest cover. The studies in ICAR on shifting cultivation on steep slopes (44-53 %) have indicated the soil loss to the tune of 40.9 tonnes per ha and the corresponding nutrient losses per ha area are: 702.9 kg of organic carbon, 145.5 kg of P_2O_5, and 7.1 kg K_2O (Munna Ram and Singh, 1993). The continuous short cycle of shifting cultivation in some areas left the hill barren without soil and badly degraded field are often abandoned to infestation of grass invasion.

2.1.2 Alternative farming systems

Since the early 1970s' research have been forced to develop low input alternatives often referred to as agroforestry, to address the problem (Sanchez,1976; Kang and Spain, 1986) associated with shifting cultivation. It is often envisaged that these alternative systems will include selected woody perennials which could diversify the production base, enhance productivity and allow a sustainable cropping systems, thereby minimizing the over exploitation of land, water and forest resources (Chauhan *et al*., 1993).

However agroforestry as a new applied science is of recent origin as stated by Jha (1995). The principle underlying the aim of the present investigation therefore is reclamation of degraded land due to shifting cultivation and natural causes through agroforestry system involving systematic management of leguminous tree species or shrubs in the sloppy land in Mizoram.

Lundgrean and Raintree (1983) stated that agroforestry is a collective name of land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboo etc) are deliberately used on the same land management unit as agriculture crops and /or animals, either on the same form of spatial arrangement or temporal sequence. Torres (1983) also defined agroforestry as the deliberate combination of trees with crop plantation or pastures, or both, in an effort to optimize the use of accessible resources to satisfy the objectives of the producer in a sustainable way.

According to Nair (1989) agroforestry refers to practices, which deliberately or intentionally mix or retain trees on the crop/animal production fields. It combines elements of agriculture, whether crops or animals with elements of forestry in production system in its land piece, either simultaneously or sequentially. Rao (1989) 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.

Patel and Singh (2000) reported that tree planting improve the physical, chemical and biological characteristics of the soil by several mechanisms such as an increase in organic matter of the soil through addition of leaf litter and other parts, more efficient nutrient cycling within the system, biological nitrogen fixation or solubilization of relatively unavailable nutrients.

Advantages of agroforestry system in rain-fed agriculture are numerous (Singh and Korwar, 1986). Surface run-off in shifting cultivation areas is quite significant and introduction of the tree component in agriculture have numerous service functions, which make agroforestry a profitable enterprise (Gill, 2008). A strip of trees planted along contours serves the same purposes as terraces. In most tribal area in India, soil losses and surface run-off are now much higher on account of loss of forest cover. Thus, a strip of trees along contours and agroforestry practices would reduce both surface run-off and soil erosion. Growing of trees on degraded/wasteland, which is unproductive, is the prime step towards obtaining required biomass, which can meet the demands of both industry and individuals (Rao *et al*., 2000).

Different kinds of agroforestry systems were reported for Sikkim by Singh (1998) and Balaraman (1998). The productivity of the different agroforestry systems and their components in terms of yield and profitability especially that of agri-horticulture was low compared to the national averages. Observation on the agroforestry systems in Sikkim with special reference to large cardamom revealed that nine major agroforestry systems are in practice in the sub-tropical and mid-hill temperate zones. Only three agroforestry systems were observed in the temperate zone (Avasthe *et al.*, 2007). Silvipastoral system is highly suitable for those areas where livestock rearing is used to supplement income by small and marginal farmers (Singh, 1986; Puri, 1989; Vishwanathan *et al*., 1999). It provides firewood or fodder while grasses reduce surface soil erosion due to their high soil binding capacity and also produce much needed fodder.

Alley cropping is planting perennial trees or shrubs yielding forage in rows at some distances in association with agricultural crops. It is an agroforestry practice, which emerged as an alternative to shifting cultivation in humid tropics. It is a system in which food crops are grown in alleys formed by hedge rows of trees and shrubs. The primary purpose of alley cropping is to maintain or increase crop yields by improvement of soil fertility (through legume tree component and mulching) and microclimate (Singh, 1995). Trees in alleys form reliable fodder source in lean season, conserve the soil and moisture; and improve the soil productivity to provide sustained yield (Sekar *et al.*, 1993).

Studies on six different viable agroforestry models in Haryana and Uttaranchal revealed that Net Present Value(NPV) for different models on six years rotation varies from Rs. 26,626 to Rs. 72,705 ha^{-1} yr-^{1} whereas benefit-cost ratio and Internal Rate of Return(IRR) vary from 2.35 to 3.73 and 94 per cent to 389 per cent respectively, and Kumar *et al.* (2004) reported that agroforestry has not only uplifted socioeconomic status of the farmers but also contributed towards overall development of the region.

2.2 Role of Nitrogen-fixing trees in agroforestry

A number of workers have studied the roles of Nitrogen-fixing trees in farming system which are reviewed and discussed below:

2.2.1 Restoration of soil fertility

Jha and Tiwari (1993) have suggested to introduce intensive hedgerows or alley cropping or wide alley cropping system for solving problems attributed to jhum land like soil erosion, increase run-off, loss in nutrient status. The hedgerows must be established across the slope on the contour line. *Leucaena leucocephala* or any nitrogen fixing trees (NFTs) suitable for agroforestry system are planted at close spacing. Two rows may be considered the best. Hedge forming trees species are generally felled above 10-15 cm from the ground.

Young (1989) mentioned that trees are capable to control erosion. This is achieved in two ways with trees acting as barriers or as cover. The barrier function in the conventional approach to erosion control by checking run-off of water and the canopy reduces the raindrop impact. On sloping land, leguminous tree species when planted along the contour, minimizes soil erosion. Tree foliage can be used as mulch and fertilizer for food crops (Reynolds *et al.,* 1988). Multipurpose tree species like *Leucaena leucocephala, Calliandra calothyrsus, Sesbania aegyptica* are generally preferred because they impart flexibility to the system (Singh and Singh, 1988). They provide 50 percent of income for 20-30 per cent of the rural and tribal people in India (Theagarajan, 1994). There are many compatible species, depending upon region of the country, value, and markets.

Studies was conducted in Bangladesh on problem with soil fertility related to organic matter depletion, farmers reported that organic matter increases yield, reduces the production cost, improves crop growth and the economy, increases water-holding capacity and improves the soil structure. Some farmers are using fast-growing trees such as *Flemingia macrophylla*, Ipilipil (*Leucaena leucophala)*, *Glyricidia sepium*, BogaMedula (*Tephrosia candida*), DholKolmi*(Ipomoea fistulosa*) (Zahid Hossain, 2001).

Nutrient added to the soil through litter fall create zone of enrichment under tree and shrub crowns (Zinike and Crocker, 1962). Study was conducted on 12 multipurpose tree species to evaluate amount of litter fall and nutrients returned and their effect on fertility status of soil. The 12 species studied were effective in bringing about improvement in the soil properties. Higher available N, P_2O_5 and K_2O as well as higher organic carbon percentage were noted under canopy of *Albizia procera* followed by *Leucaena leucocephala* (Das *et al.*, 2007).

Nandeshwar *et al*. (2006) reported that *Dalbergia sissoo* and *Gmelina arborea* were among the faster growing species and appear to be promising tree species for rehabilitation of degraded land. *Leucaena leucocephala* alley cropping trial in central Malawi have shown that plots receiving leaves of *Leucaena leucocephala* had higher organic C, total N, pH, exchangeable Ca, Mg, K, and S, and lower C/N ratios in the 0-15 cm soil layer than plots where leaves had been removed (Jones *et al.*,1996).

Evaluation trial was conducted at Makdoompur in the district of Unnao in U.P to develop suitable silvipasture model for large scale planting of fodder tree-grass combination. Three species were *Leucaena leucocephala, Albizia lebbek* and *Cassia siamea* along with forage grasses like *Brachiaria mutica, Panicum maximum* and *Chlorisgayana*. The results revealed considerable improvement of the entire system with huge amount of fodder biomass production (Mishra *et al*., 2006).

A long-term alley cropping trial was undertaken in south western Nigeria. Two nitrogen fixing hedgerow species *Gliricidia sepium* and *Leucaena leucocephala* and two non-legume hedgerow species *Alchornea cordifolia* and *Dactyladeni abarteri* were used. Alley cropping with the four woody species greatly enhanced the total plot biomass yield/ha, higher soil organic carbon, phosphorus and potassium levels. NFTs showed higher nutrient yields than Non-NFTs (Kang *et al.*, 1999).

Ikpe *et al*. (2003) observed the effects of age (1 or 2 years) of *Tephrosia candida* fallow on nutrient accumulation, on weed biomass. Total biomass and litter were three times higher in plots fallowed for 2 years with *Tephrosia candida* than in those under natural fallow for the same period. Weed biomass was 205% lower in *T. candida* plots fallowed for 2 years than in the natural fallow.

2.2.2 Effect of leguminous plants on Nitrogen availability

It was reported that leguminous crops like soybeans have been described as suitable to provide nitrogen to other crops in the range of 30 and 40-80 kg/ha, respectively (Singh *et al*., 1985; Singh *et al*., 1986; Chandel *et al*., 1989). Beneficial effects for succeeding crops of legumes may be of no direct advantage for intercropped species but play an important role within crop sequences. Compared to monocrops of non-legumes, mixed systems with legumes have significant positive effects on succeeding crops: in a sugarcane-based intercropping system, pulses increased organic carbon, total nitrogen and available phosphorous content but had no effect on cane yields (Yadav *et al*., 1987). Soybeans and blackgram in mixture with maize increased yields of succeeding wheat significantly (Singh and Singh, 1984) and soybean used as green manure in mixture with maize favoured corn yields (Pandey and Pendleton, 1986).

Nitrogen fixing trees are regarded to fix atmospheric nitrogen and increase nitrogen availability in the soil. Besides fixation of atmospheric nitrogen, the possibility of direct nitrogen-transport from a legume to a non-legume crop is of special interest. Field trials conducted have shown that *Tephrosia candida* and *Cajanus cajan* increased surface soil organic carbon and total nitrogen levels over the natural bush. However, only *Tephrosia candida* plots produced improved maize grain and stover yield (Gichuru, 1991).

Nitrogen fixed by trees is transferred through fine root decay, nodule decay, excretion of nitrogen from nodules in the below ground parts or litter fall and pruning applied as mulch above the ground. Mostly nitrogen fixing trees are advocated for agroforestry since they can adopt to low nitrogen soils than the other species. About 5 per cent of the nodule weight is nitrogen. Substantial amount of nitrogen is expected to add to soil through the nodule and root decay. A proper association of annual crop benefits from such processes depend upon the proximity with the scattered trees (Pathak, 2008).

Nitrogen content increased significantly in sorghum grown intercropped with nodulated *Leucaena* over sole sorghum. In mixed culture, sorghum gains an average of 0.03 mg N day^{-1} $plant^{-1}$ (Avery and Rhodes, 1990).

The integration of trees into farmland has been suggested to combat soil nutrient depletion in tropical cropping systems (Sanchez, 1995). Trees are able to mobilise nutrients from the subsoil and then return these nutrients to the top soil making them available for an annual crop (Buresh and Tian, 1998). Trees may reduce nutrient leaching and form a 'safety-net' under the root zone of the annual crop (Van Noordwijk *et al*., 1996).

Soil analysis after seven years of experimentation revealed that tree species (up to 6 m distance) lowered soil pH by 0.3 units, improved organic carbon content by 0-15 per cent and decreased bulk density by 0.1 Mgm^{-3} (Tomar *et al*., 1994).

Lehmann *et al*. (1999) stated that combining annual and perennial crops provided a higher internal nutrient cycling than the monocultures. Result of the experiment indicated that nutrient leaching losses from the topsoil (0–30 cm) were lower in the sorghum monoculture than in the tree based systems. In the subsoil (120 cm), however, leaching was effectively reduced. In the alley cropping of *Sorghum bicolour* and *Acacia saligna* leaching losses of nitrogen under the sorghum were 53% lower than in the sorghum monoculture. This could be attributed to higher root abundance and a higher ratio of nutrient uptake-to-leaching in the agroforestry system than in the monocultures indicating a higher nutrient efficiency.

Banful *et al. (*2000) compared *Leucaena leucocephala* and *Flemingia macrophylla* (Willd.) Merr. grown as hedgerows. The results indicated the superiority of *Flemingia macrophylla* over *Leucaena leucocephala* in higher biomass yield, higher retention of soil moisture and lower soil temperatures than mulching with prunings of *L. leucocephala* and significantly greater growth performance of crop in *F. macrophylla* mulched plots. It was also reported that Flemingia *macrophylla* has qualities that suppress nematode populations.

2.2.3 Influence of Nitrogen fixing trees on crop yield

An approach to integrating calliandra (*Calliandra calothyrsus*) and *Leucaena leucocephala*, into maize (*Zea mays* L.) production system was investigated in the sub-humid highlands of central Kenya. When alley-cropped with *Leucaena* sps, maize produced significantly higher yields compared to maize monoculture. The study showed that, alley cropping with *Leucaena* sps was advantageous (Mugendi *et al*., 1999). Growing of maize as agricultural crop in agroforestry system is very common in the world agriculture.

Mafongoya *et al*. (2003) evaluated eleven *Tephrosia vogelii* and three *Tephrosia candida* provenances in Zambia. *T. candida* provenances produced two times greater amount of above ground biomass, higher yields of maize (*Zea mays* L.), lower weed growth than the *T. vogelii* provenances. Legume residues have been credited with supplying mineral nitrogen (N) to the associated cereal crop and improving soil fertility in the long term. Xu *et al*. (1993) reported a significant increase in maize production over three subsequent years after addition of *Leucaena* residues.

Khybri *et al*. (1992) reported that pure cropping of paddy and wheat was found much less economical than intercropping with *Leuceana*.

2.3 Contour hedgerow system/Alley cropping system

Tiwari and Jha (1993) have suggested different alley cropping models for the rehabilitation of jhum land, 'Intensive hedgerow (alley) cropping on the jhum land' is one of the models suggested and horizontal distance between the hedges depends upon the slope percentage.

Contour hedgerows of multipurpose tree species in the sloping lands are regarded to reduce soil erosion and also add significant amounts of plant nutrients to the soil *via* periodic prunings. Hedge rows of MPTS are periodically pruned to prevent shading and utilized for mulching/green manuring both for high as well as low rainfall zones in sloppy and plain areas (Chinnamani, 1989). These prunings which consist of leaves and immature stems are added to the soil between rows of crops. Gradual decomposition and nutrient release from added prunings could enhance the organic matter and nutrient status of the soil (Young 1989) and influence the yield of the associated agricultural crop (Wilson *et al*., 1986; Mafongoya *et al.*, 1997). Budelman (1989) also recommended that under circumstances of limited soil nutrient resources, crop and/or animal production systems involving leguminous species should be based on recycling rather than permitting the export of nutrients.

Growing tree species as contour hedgerows is an agroforestry practice recommended to achieve soil conservation in the sloping tea lands in central highlands of Sri Lanka (De Costa, 1997). It is an adaptation of Sloping Agricultural Land Technology (SALT) which was originally developed in the Philippines (Tacio, 1993). Fujisaka *et al.* (1995) also described a process of farmers adapting contour hedgerows to their specific needs in the Philippines that included developing labour-saving methods and incorporating hedgerow species that offer direct cash returns.

Reducing fertilizer inputs can be achieved by adopting integrated soil fertility management systems, which incorporate biological nutrient sources in the production system. Such systems involve among others; inclusion of nitrogen-fixing leguminous herbaceous cover crops or woody species in rotational fallow or live mulch systems (Balasubramanian and Blaise, 1993) or in agroforestry systems such as alley cropping (Kang *et al*., 1990). In peninsular India, alley cropping proved beneficial in terms of soil and water conservation with less runoff and soil loss with 3 m alleys than with 5.4 m alleys (Rao *et al.*, 1991).

Incorporation of woody species in alley cropping has the additional benefits for: continuous supply of organic material from the hedgerow prunings throughout the cropping season, needed for the maintenance of long-term soil productivity with intensive land use; higher rate of nutrient cycling (Kang, 1997); soil conservation (Kang and Ghuman, 1991; Sajjapongse and Syers, 1995); and increasing efficiency of fertilizer use by combining fertilizer application with plant residues and/or prunings. Although the management of the hedgerows increases labour requirement, however, the benefit-cost ratio of the system for maize production was higher due to savings in weeding cost and nitrogen contribution with the use of nitrogen-fixing leguminous hedgerow species (Ngambeki, 1985). Tree species used in hedgerows differ in their ability to enhance soil fertility through addition of prunings (Mafongoya *et al*., 1998). This is because of the inter-species variation in biomass of prunings produced per year (Young 1989), their nutrient contents (Palm 1995) and the rates of decomposition and nutrient release (Mugendi and Nair, 1997). The rates of decomposition and nutrient release from added prunings are determined by the climatic factors such as rainfall and temperature regimes (Meentemeyer, 1995; Mugendi and Nair, 1997) and by litter quality as determined by its lignin, polyphenol and nitrogen contents (Palm and Sanchez, 1991; Palm, 1995). Biomass decomposition and nutrient release play an important part in selection of tree species for contour hedgerows because of the need to regulate the pattern of nutrient release and synchronize it with the nutrient demand of the associated agricultural crop (Swift, 1987; Young, 1989). Chinnamani (1989) recommended that hedgerows should be planted in the direction of East and West to minimize the effect of shade.

A field trial to characterize the biomass decomposition pattern and quantify the amount of nutrients added through prunings of six tree species growing as contour hedgerows was conducted in a tea plantation in Sri Lanka. Annual biomass of prunings differed significantly between tree species. It is concluded that among the tree species tested, *Calliandra* and *Flemingia* are the most suitable species for contour hedgerows in tea plantations of this agro-climatic region because of their higher soil nutrient enrichment capacity and slower decomposition rates which would minimize leaching losses (De Costa *et al*., 2001).

2.4 Research on permanent land use system in North East India

In the last 25 years, various research institutions working in the North-east region have significantly developed and perfected a number of agroforestry practices, such as silvipastoral systems, sericulture, tree fodder production systems, aquaforestry and microwatershed approach to develop various land use systems, self-regenerative forestry, tea and rubber plantation at low hills, improvement of shifting cultivated (jhum) land through contour hedge intercropping and other agroforestry interventions.

The noteworthy feature of North-East India is that the hills are mostly inhabited by tribal populations which are also rich in forest wealth, biodiversity, traditional knowledge systems, art and culture and the hill people have a very high affinity to the forests and land. In most hills the forest-people bonds have been reinforced by way of religious beliefs, and taboos often based on principles of conservation management (Tiwari *et al.,* 1998).

In the north eastern parts of the country in general and Mizoram in particular, the practice of shifting cultivation is an age old practice and with the present population pressures, this form of agriculture is proving to be a strong deterrent to conservation efforts and a threat to the existing forest cover (Nadagouder *et al.,*2000)

Alder tree (*Alnus nepalensis*) is a common early succession and nitrogen fixing tree species, which is innovated by the Nagas for its soil fertility management and yield high biomass in this farming system since time immemorial. A case study conducted by Changkija *et al.* (2000) on agroforestry farming based on alder tree in Nagaland indicated that the system comprising of alder tree (density 200-400/ha) with plantation of various crops has intensify swidden into a two years cropping and two years fallow cycle (relatively 1:1) of cropping of fallow periods. Other than manure deposited by the livestock and the decomposition of the crop residue no external input of fertilizer is applied to the system, yet crop yields are as high now as at any time within memory.

Jha (1995) also recommended a new cropping system for Mizoram known as *Zoram Technology or Zo Tech* (TGhCFS). In *Zo Tech* trial, NFT viz. *Leucaena leucocephala*, *Cajanus cajan* and Non-NFT species *Manihot* *esculenta* were planted at closed spacing to establish hedges. The result shows that soil erosion and nutrient loss were less in TGhCFS in comparision with jhum land which indicated potential of TGhCFS in reclamation of degraded jhum land. Department of Agriculture in Mizoram has also developed its own contour trench farming for jhum areas (Anon., 1995).

Jha (1995) further opined that the biophysical causes and socio-economic problem of farmers in North-East India can be tackled by adopting alley cropping system in large scale. Agricultural crops, tree species varies in different agroclimatic zone, in each agroclimatic zones, suitable model must be tried with local species as well as exotics. He suggested that government should allot land permanently to the jhumias, individually or community basis as has been provided in the New Land Use Policy of the government of Mizoram.

Singh (2000) recommended contour hedgerow technology (bioterracing) as the technology is more economical than construction of bench terrace across the slope by cut and fill method. Further, Singh (2000) concluded that agroforestry technologies will play a major role in the synthesis of sustainable farming systems for economic prosperity of tribals living in north eastern hills, the degree of success will continue to vary due its location specificity, appropriate choices and a number of local factors.

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CHAPTER -3

MATERIALS

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METHODS

CHAPTER - 3

MATERIALS AND METHODS

3.1 Study area

3.1.1 Mizoram

Mizoram is situated in the North-East region of India which is one of the most backward and remote areas in the country. It lies between 21^{0}58' to 24^{0}35' North Latitude and 92^{0} 15' and 93^{0}29' East Longitude. It has geographical area of 21,087 km^2, and it shares 404 kms international border with Myanmar to the east and 318 kms with Bangladesh to the south and west. It shares state boundaries with Assam, Manipur and Tripura (Map 1). Unlike the great plain of central India, the general topography is mostly hilly with steep slopes to moderate slopes forming deep gorges between mountains ranges. A narrow river valley flanked by two ridges provides the general pattern, the flow of water from hills drain into the rivers which generally flow either to the north or south direction. The average height of the hills is about 900 metres, over 80 per cent of the total geographical area is hilly with steep hills. The elevation in general is higher and steeper in the eastern part of the State slowly lowering down towards the border of Tripura state, Assam and Bangladesh as such the eastern part of the State has moderate summer but severe winter and the western part has warm and humid summer and consistently shorter and moderate winter. It receives an annual rainfall of about 2400 mm, the mean temperature varies from 24^0C to 32^0C in summer and from 8^0C to 25^0C in winter, (Anon.,2010a). The rainy season normally starts from May and lasted up to October; it rains heavily during June to August.

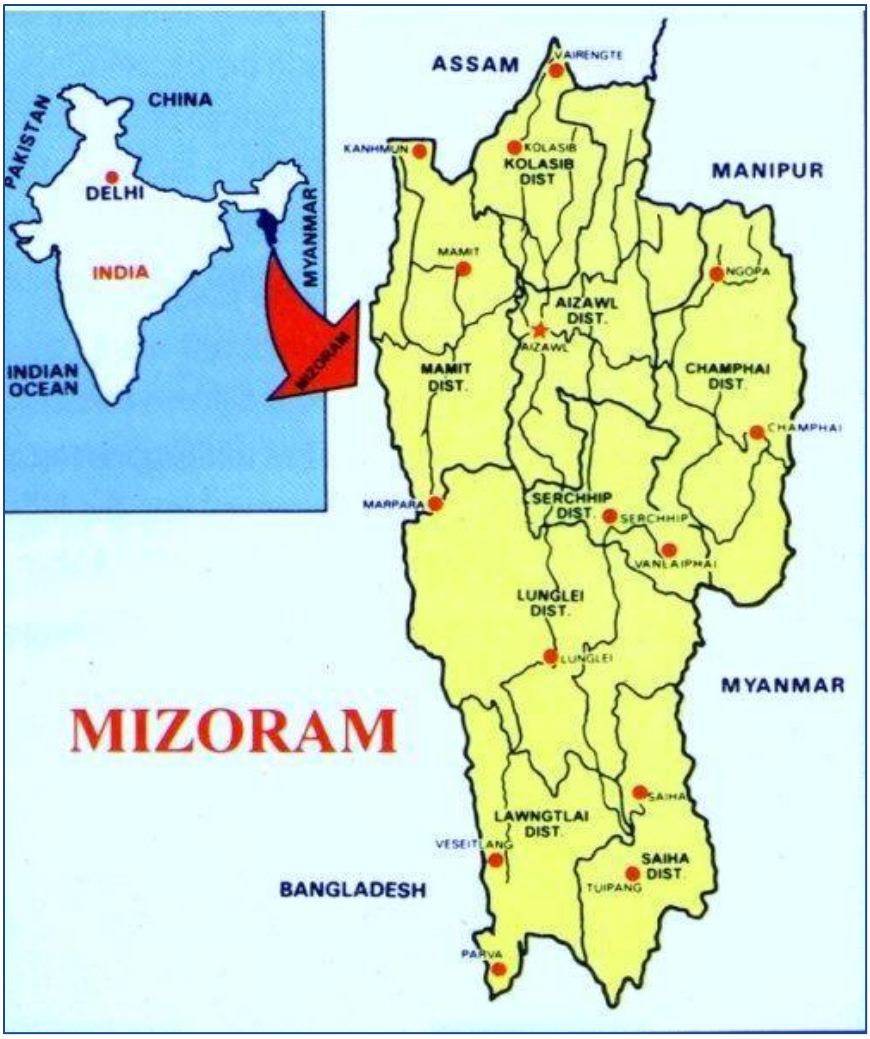
The total population of the State as per Census of India 2011 *Provisional Population Totals,* is 1,091,014*,* a little less than 50 per cent of the populations live in 830 villages. Majority of the population are scheduled tribe. Though the State falls behind other states in infrastructural development, corporate sector, economic stability and sustainable development which is perhaps due to its remote locality or inaccessibility intensified by the unique landscape, but very commendable advancement it has is high literacy percentage. Mizoram state has attained the third highest literacy percentage in India in 2011 by securing 91.58 per cent (Anon., 2011).

3.1.2 Kolasib District

Kolasib district is the northern most district among the eight districts of Mizoram, it borders Assam state to the north and west (Map 2). The neighbouring districts are Mamit district to the west, Aizawl district to the south and east. It lies between a latitude of 23^0 70' N and 24^0 50' N and 92^0 50' – 93^0 E longitude. The district is named after the name of its district capital known as Kolasib town which is located at around 85 kms from the state capital Aizawl. The total area of the district is 1,382 km^2 (Anon., 2010). It accounts for about 15.5 per cent of the total geographical area of Mizoram. The district consists of two Rural Development Blocks, namely Thingdawl R.D. Block and Bilkhawthlir R.D. Block. The total population as per 2011 census is 83,054 and the literacy percentage is 94.54 (Anon., 2011). The biggest mini hydel project as of now in the State known as Serlui B hydel project is located in Kolasib district on the river of Serlui near Bilkhawthlir town. The river Tlawng, the longest river in the State passes through the district to the west of the district capital.

The Kolasib district falls under sub-tropical climate characterizes by hot and wet summer and moderately cold and dry winter. It is by and large the warmest district in Mizoram, May and June are the hottest months in a year with maximum air temperature of 36 ± 2^{o} C. The air temperature is lowest in the month of January with minimum temperature of 7 ± 2^{o}C. It enjoys a typical monsoon type of climate. The topography in general is undulating and hilly ranges traverse in north-south direction, between the hilly ranges valley lands suitable for cultivation of field crops are found in several places. Chemphai, Tuichhuahen, Buhchangphai are WRC belt in the district. Arecanut, Red oil palm, Hatkora, etc., are largely grown in the lower elevation of the district. The altitude of the district ranges between 36 - 900 meter above mean sea level (Anon., 2008) The soil in general is acidic, soil pH ranged between 4.5 - 6, deficient in base material, medium in organic carbon, low in available phosphorus and high in potash. (Anon., 1991).

Map 1: Map of Mizoram

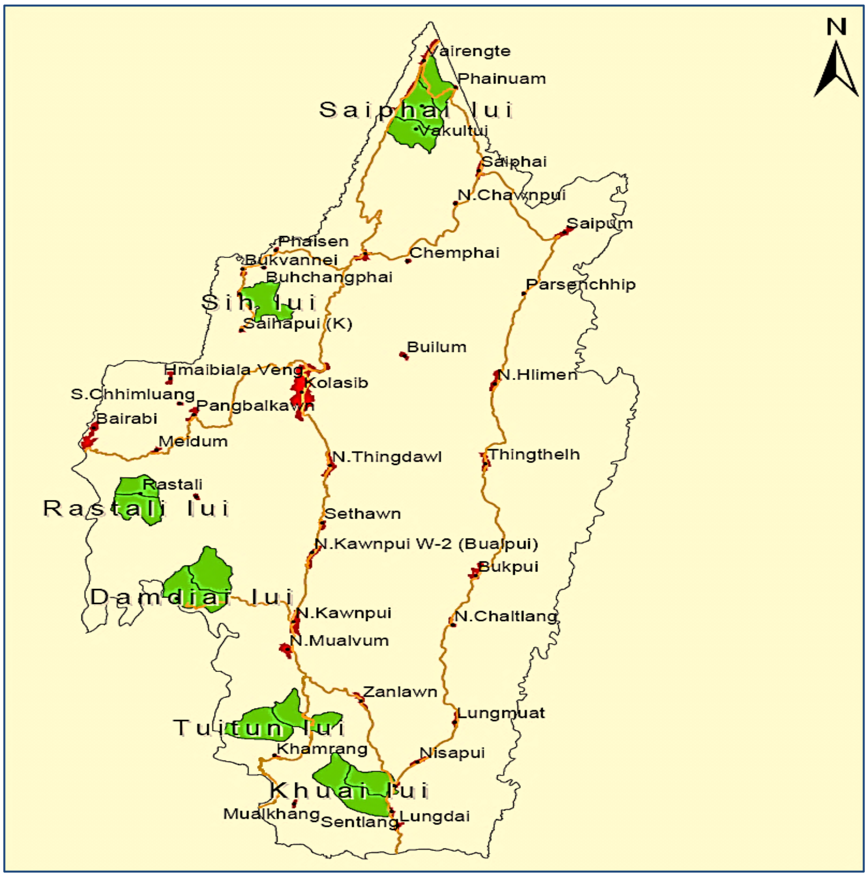


3.1.3 Location of the experimental site

The experimental site was located at the outskirt of Kolasib town; it lies adjacent to KVK complex, below the national highway 54 from Silchar to Aizawl about 700 mts. from the road. It was a private garden previously used for growing paddy and vegetables. Arecanut and banana plantation are found in the surrounding areas. It faces south east direction, moderately sloped; it has well textured soil, naturally free from stubbles, rocks, stones and debris. The elevation of the study site is about 722 metre above mean sea level. It is particularly warm during summer and moderately cold and dry during winter. The slope gradient of the experimental site is about 10 per cent; the lower portion is gentler than the upper portion of the experimental site.

The dominant herb species growing around the experimental plot are *Mimosa pudica, Mikania micrantha, Euphatorium odoratum, Saccharum spontaneum* and *Imperata cylindrical*, etc.

Map 2: Map of Kolasib District



3.2 Methodology

The investigations reported in this thesis were carried out during March to November in the year 2005 and 2006. The experiment was conducted using Randomized Block Design (RBD) with three replications. There were 18 sub plots or treatment combinations in each replications and the total sub – plots were 54 in total. The size of each sub - plot was 4m x 3m (12 m^2). The treatment consist of 6 combination of maize + leguminous tree species having 1 pruning and 2 pruning management, 3 sub-plot of maize control (sole maize) corresponding to different tree species; and 6 combination of rice + leguminous tree species with two pruning management; and 3 sub-plots of rice control (sole rice). Double rows of densely populated leguminous tree species were grown as hedges across the experimental field at a distance of 2.5 mts. Crops were grown in the alley between the hedges. Before sowing of seeds, treatment combinations were distributed randomly within the field.

3.3 Experimental design

Design of Experiment	:	Randomized Block Design
Number of Replication	:	3 (Three)
Sub-plot size	:	4m x 3m (12 m^2)
Number of Treatment combinations	:	18
Total Net plot size	:	648 m^2

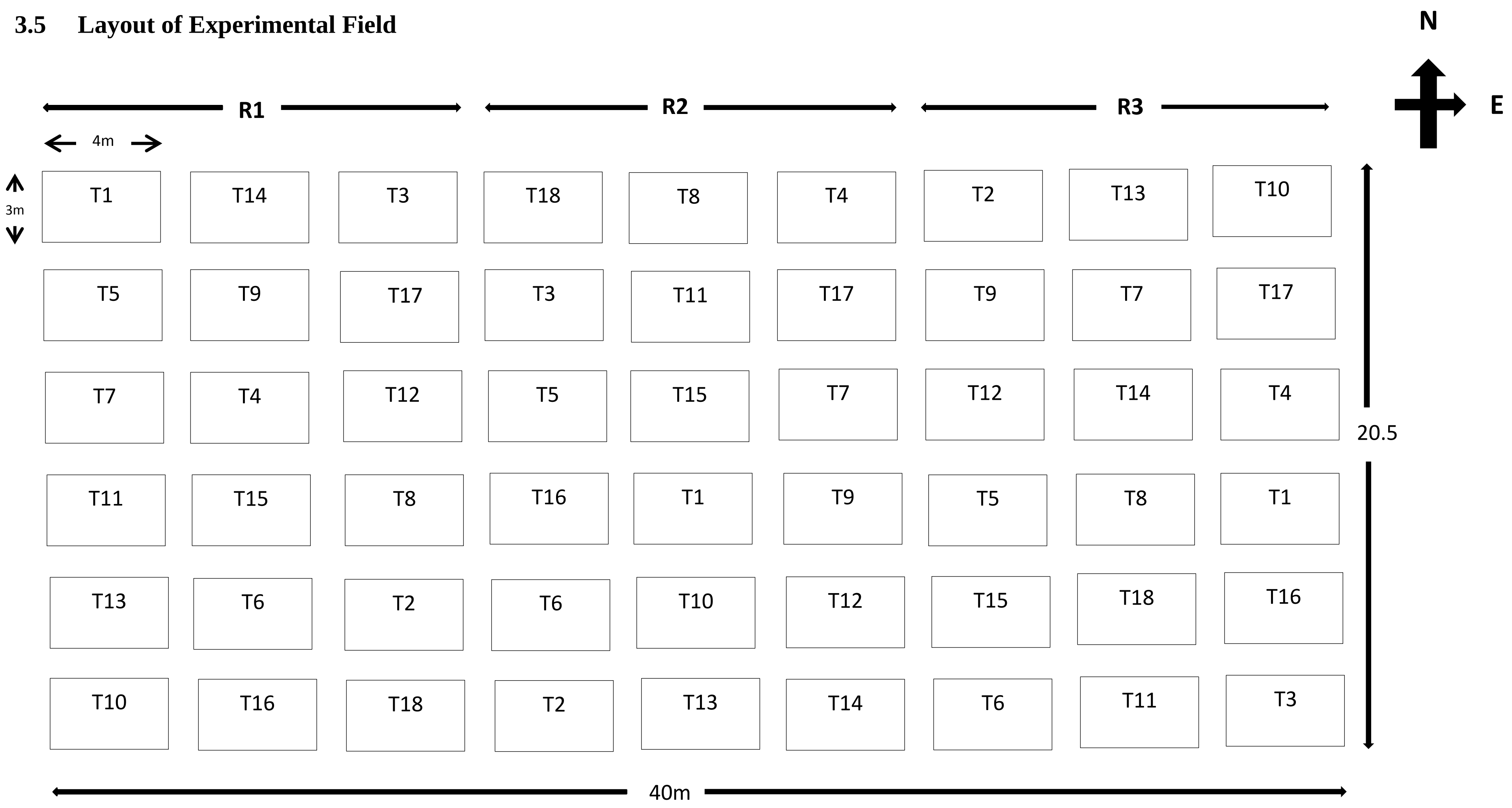
Tree Species	:	1) *Leucaena leucocephala*(Lam.) de Wit 2) *Flemingia macrophylla*(Willd.) Merr 3) *Tephrosia candida*
Spacings of tree species	:	No plan to plant spacing, Distance between hedgerow – 2.5 mt.
Pruning management	:	One pruning (P1) and two pruning(P2) management during the crop period for the leguminous tree components to study the effect of pruning management on the crop components.
Agricultural crops	:	1) Rice (*Oryza sativa)* 2) Maize (*Zea mays)*
Spacing of agricultural crops	:	1) Maize- 60cm x 25 cm row to row and plant to plant 2) Rice- 14 x14 cm plant to plant and row to row
Variety	:	Maize - Vijay Composite Rice - Ido (local variety)

3.4 Treatment Details

T – I	-	*Leucaena leucocephala*+ Maize + P 1
T – 2	-	*Leucaena leucocephala*+ Maize + P 2
T – 3	-	Control (Maize alone)
T – 4	-	*Leucaena leucocephala*+ Rice + P 1
T – 5	-	*Leucaena leucocephala*+ Rice + P 2
T – 6	-	Control (Rice alone)
T – 7	-	*Tephrosia candida* + Maize + P1
T – 8	-	*Tephrosia candida* + Maize + P2
T – 9	-	Control (Maize alone)
T – 10	-	*Tephrosia candida* + Rice + P1
T – 11	-	*Tephrosia candida* + Rice + P2
T – 12	-	Control (Rice alone)
T – 13	-	*Flemingia macrophylla*+ Maize + P1
T – 14	-	*Flemingia macrophylla*+ Maize + P2
T – 15	-	Control(Maize alone)
T – 16	-	*Flemingia macrophylla*+ Rice + P1
T – 17	-	*Flemingia macrophylla*+ Rice + P2
T – 18	-	Control (Rice alone)

P1	-	One pruning
P2	-	Two pruning

3.5 Layout of Experimental Field



Sub-plot size- 4m x3m=12sq.m

Total net plot size- 648 sq.m

3.6 Site preparation and sowing

The experimental field was cleaned in the month of March, removed stubbles, and burnt collected debris on the spot. Randomization of treatments and measurement was completed before sowing of seeds. No additional fertilizers or humus was applied in the field. Seed of *Leacaena leucocephala* was soaked in water for 48 hrs before sowing for better germination. Double contour lines across the field were marked by using 'A' frame leveller for sowing tree species. The lines were opened with hand hoe and seeds of *L.leucocephala, T. candida, F.macrophylla* were sown by hand and placed closely together so as to get rows of optimum densely populated live hedge on the double contour lines and covered with soil lightly; at least one double row of tree species run across the sub-plots except control plots. During the month of May, maize and rice were sown in the alleys between the hedgerows. Sub-plots of maize and rice were arranged alternatively to achieve complete randomization.

3.7 Description of the crops and tree species

The present investigation involved hedgerows or alley cropping system and it takes after part of Sloping Agriculture Land Technology(SALT) but complete system of SALT is not followed meanwhile three leguminous tree species namely *Flemingia macrophylla, Tephrosia candida and Leucaena leucocephala* suitable for hedges were selected as hedgerows. Rice and maize were selected as agricultural crops. Densely populated double rows of each species were grown along the contour as hedgerows.

3.7.1 ***Leucaena leucocephala*** (Lam.) de Wit.

Leucaena leucocephala is a perennial non-climbing, non-spiny shrub or tree. Native to tropical America, it is use as a fodder, wood source and reclamation species. It is considered a versatile and widely used multi-purpose tree legume in the tropics. *Leucaena leucocephala*(Lamark) de Wit 1961 is the most economically important species in the genus *Leucaena*, which is in the tribe Mimoseae of the subfamily Mimosoideae of the family Leguminosae (Fabaceae). *Leucaena* is essentially a tropical species requiring warm temperatures (25 ^{o}C to 30 ^{o}C) for optimum growth. It has poor cold tolerance and significantly reduced growth during cool winter months in subtropical areas. It can grow on a wide variety of deep, well-drained fertile soils (Hughes, 1998 ; Brewbaker,1987). Kang *et al*. (1999) reported that despite the very intensive pruning regime of 3–5 prunings/year for thirteen years, four hedgerow species including *L. leucocephala* still performed well.

3.7.2 ***Tephrosia candida***

Tephrosia is a genus of flowering plants in the pea family, Fabaceae. It is an erect shrub or small tree reaching a height of 1-3.5 m, with straggling branches from the base. It is a perennial plant, it can flower and fruit all year round. It is grown as a pasture plant, a green mulch; old stems can be used as fuel. The plant is also used as a temporary shade crop for newly planted horticultural crops such as citrus, coconut, coffee, rubber and tea, etc. It grows well in the seasonally dry tropics and does not tolerate frost or waterlogging. The species is suitable for rehabilitating degraded land. It forms root nodules with Bradyrhizobium and fixes large amounts of atmospheric nitrogen. It is known to improve soil structure, water-holding capacity and permeability, and decrease soil losses caused by water erosion. It is suitable for making hedges along contours, around fields and homegardens. It is commonly used for hedgerows, providing mulch for different upland crops. *T. candida* is widely grown in mixed cultivation, for example with pineapple, maize and other annual crops (Anon., 1986; Nguyen and Thai, 1993).

3.7.3 ***Flemingia macrophylla*** (Willd.) Merr

Flemingia macrophylla is a perennial, deep-rooted, leafy, leguminous shrub, growth habit ranges from prostrate to erect with numerous stems arising from the base. Its natural distribution is southeast Asia, southern China, Taiwan, India and Sri Lanka in the sub humid to humid. *F. macrophylla* is a multipurpose species. It is used as hedges for erosion control, mulch and green manure in alley cropping hedgerows; as a shade plant in young coffee and cocoa plantations, as a weed suppressing and soil enriching cover plant in fruit tree orchards and to provide fuel wood and stakes for climbing crop species, as a medicinal plant, and a number of other purposes. Once established, the plants require little attention (Budelman and Siregar, 1997; Shelton, 2001). Because of its excellent coppicing capacity and regrowth after cutting, *F. macrophylla* is highly suitable for alley cropping.

3.7.4 **Maize** (*Zea mays*)

Maize (*Zea mays)* belongs to family *Gramineae* and genus *Zea*. It is a tall annual plant which grows to a height of one metre to 3 metres or more in some cases (Singh, 1998). It is one of the most important cereal crops grown in Mizoram. It is generally cultivated along with rice in upland condition. Popcorn and local variety known as sticky maize are common among Mizo people. It has been cultivated more as subsidiary food than fodder purpose. In 2009-2010 area under maize cultivation in Mizoram was 8,551 ha and total production of 11,510 tonnes (Anon., 2010a). It is next to rice crop in area and production.

3.7.5. Rice (*Oryza sativa*)

Rice belongs to genus *Oryza* of *Gramineae* family (Singh, 1998). It is the staple food of Mizo people and majority of Indian. It is the most important and extensively grown food crop ranking first both in terms of area and production, occupying an area of about 42.3 million ha of cultivated land which accounts for 27 per cent of the total agricultural land in India. It is grown extensively in tropical and sub-tropical regions of the world.

Among rice growing countries India ranks second with a production of rice about 20.40 per cent of the total world's production (Anon., 2004).

3.8 Major field operations.

i) **Gap filling:** Tree species were sown in the month of March, 2005. *T.candida* and *F.macrophylla* germinated and established well. However, *L.leucocephala* required gap filling and was resown twice before sowing of agricultural crops.

ii) **Irrigation :** Irrigation was applied to tree species in the month of April before on set of monsoon rain in 2005. In case of agricultural crops, no sign of dehydration was detected and hence no irrigation was given.

iii) **Weeding:** In the first year and second year, four hand weeding each was done including pre-sowing weeding.

iv) **Pruning of tree species:** One pruning and two pruning operations during the cropping period was carried out in both the years. During the two years of investigation, pruning operations were carried out six times. In pruning operation, five number of sample plants in each plot were left standing in the field for taking observations on growth performance.

v) **Harvesting and threshing of agricultural crops:**
Maize and rice were harvested manually at dried ripen stages from each plot. Grains were cleaned and weighed from each net plot for expressing yield in quintal per hectare.

3.9 Soil analysis

3.9.1 Soil Sample Collection

Soil samples were collected from one location in each replication using spade from a depth of 0-15cm at an interval of 45 days starting from the date of sowing of tree species in the first year and 45 days after sowing of crops in the second year. In the first year, soil samples were collected four times and three times in the second year. The soil samples were sun dried, crushed, sieved through finer mesh and subjected to analysis.

3.9.2 Determination of soil pH

The pH of the soil samples was measured by digital pH meter. Soil to water ratio of 1:2.5 was maintained. Soil sample of 10 g was taken in a 100ml beaker to which 25 ml of water was added. The suspension was stirred at regular intervals for 30 minutes and the pH was recorded with the help of pH meter.

3.9.3 Estimation of Organic Carbon

The method given by Walkley and Black (1934) was adopted to estimate organic carbon; standard procedure for estimation of organic carbon was followed. 1.00 g of finely grounded soil sieved through 0.2mm was kept at a dry 500 ml. conical flask, 10 ml of 1N $K_2Cr_2O_7$ was pipetted in and swirled a little. Then 20 ml of H_2SO_4 (containing 1.25 % Ag_2SO_4) was run in and swirled again two or three times. The flask was allowed to stand for 30 minutes; after that, 200 ml of distilled water was added. 10 ml of phosphoric acid or 0.5 g Sodium Fluoride and 1ml. of diphenylamine indicator was added again and titrated with Ferrous Ammonium Sulphate solution till the colour flashes from the blue violet to green. Simultaneously, a blank titration was run without soil. The result was calculated by the following method:

$$\text{Organic Carbon (\%)} = \frac{10(B-T)}{B} \times 0.003 \times \frac{100}{S}$$

Where,

B= Volume of Ferrous Ammonium Sulphate solution for blank titration in ml.

T= Volume of Ferrous Ammonium Sulphate solution needed for soil sample titration in ml.

S= Weight of soil in gram.

3.9.4 Estimation of Nitrogen (N) content

The Total Soil Nitrogen (N) was estimated by following Kjeldahl's Digestion Method. The soil analysis for estimation of Nitrogen content of the soil consists of three important steps, viz. digestion, distillation and titration.

Digestion : 1gm of soil sample was taken in each of Kjeldahl flask for digestion tube and 10ml Conc. Sulphuric Acid was added in each flask. Also, 3gms of catalyst mixture (Kjeldahl catalyst) was added in each of digestion tube and the balance without a soil sample was maintained. Temperature was set at 420^{o}C and it was digested for approximately 1hr till the sample became green colour. Then, the digester was switched off and the flask was allowed to cool.

Distillation : Firstly, the conical flask was loaded (with 20ml of 40 % Boric acid) in the receiver side which will be pink colour as it contain 3 drops of Bromo cresol green and Methyl red solution of 5 drops. Then, the digested sample was loaded for distillation. Again, 40% of NaOH was added slowly in automode in the order of 10ml each time till the colour changes from bluish green to brown precipitation and the process time was set for 6 minutes for soil sample. After 6 minutes, the sample colour in a conical flask changed from pink to green colour which was the end point. The flask was then prepared for titration.

Titration : The distillate solution was then titrated against 0.1 N HCl. The titration was stopped when the colour changed from green to pale pink. The percentage of Nitrogen Content was calculated by the following formula:

$$\text{Total N (\%)} = \frac{14 \times \text{Normality of acid} \times \text{Titrant value}}{\text{SampleWeight} \times 1000} \times 100$$

3.9.5 Estimation of Phosphorus

The methods developed by Olsen *et al.* (1954) and Dickman & Brays (1940) was followed for estimation of Phosphorus in the soil samples. 2.5 g of the soil sample is taken in 100 ml conical flask, and a little of Dargo G 60 or equivalent grade of activated carbon (free of phosphorus) is added followed by 50ml of Olsen's reagent. A blank is run without soil. Then the flasks are shaken for 30 minutes on a platform type shaker and the contents are filtered immediately through dry filter paper (Whatman No.1) into clean and dry beakers or vials.

In the filtrate phosphorus is estimated colorimetrically by Dickman and Bray's procedure (Dickman & Brays, 1940). 5 ml of soil extract is pipette into a 25 ml volumetric flask to which 5 ml of the Dickman and Bray's reagent is poured in. The rock of the flask is washed down and the content is diluted to about 22 ml. Thereafter, 1 ml of the diluted stannous chloride solution is added and volume makes up to the mark level. The intensity of the blue colour is measured (using 600 mμ filter) just after 10 minutes and the concentration of phosphorus is determined from the standard curve. With each sample a blank is maintained. The formula used for calculation of P is:

$$\text{Olsen's Phosphorus (Kg/ha)} = \frac{R \times V/v \times 1/S \times (2.24 \times 10^6)}{10^6}$$

$$P = R \times (50 \times 5) \times (1/2.5) \times 2.24 = R \times 8.96$$

Where,

V = Total volume of extractant (50ml).

V = Volume of aliquot taken for analysis (5ml).

S = Wt. of soil (2.5g).

R = Wt. of P in the aliquot in μg (from standard curve).

3.9.6 Estimation of Potassium

Available Potassium (K) incorporates both exchangeable and water soluble forms of the nutrient present in the soil. The estimation of K of water soluble forms has been carried out with the help of Flame Photometer as suggested by Ghosh *et al.* (1983). 5gm of soil sample is mixed and shaken with 25ml of normal of Ammonium acetate (pH 7) for 5 minutes and filtered immediately through a dry filter paper (Whatman No.1). First few ml of the filtrate is rejected. Potassium concentration in the extract is determined in the flame photometer.

3.10 Growth parameters of agricultural crops.

i) **Maize - Plant height:** Five sample plants of maize were selected randomly from each plot and height was measured from the ground level, up to the tip of the longest leaf at 20, 40, 60, 80 days after sowing (DAS) and at harvest. The mean values were computed and expressed in cm.

ii) **Rice - Plant height:** Five sample of rice plants were selected randomly from each plot and height was measured at 20 days interval from the date of sowing (Days After Sowing) till harvest. The mean values were computed and expressed in cm.

3.11 Yield parameters of agricultural crops

3.11.1 Maize

i) **Number of cob per plant:** Number of cobs per plant of five sample plants was counted at harvest.

ii) **Number of kernels per cob:** The kernels or grains of sample plants were removed and counted.

iii) **Test weight (1000 grain weight):** One thousand grains were counted from each grain sample and their weights were recorded in grams.

iv) **Yield (qt/ha)**: The total grain yield per sub-plot was recorded in kg and converted to qt/ha.

3.11.2 Rice

i) **Number of grains per plant:** Number of grains per sample plants (hill) were counted and recorded.

ii) **Test weight (1000 grain weight):** One thousand filled grains were counted from each grain samples and their weights were recorded in grams.

iii) **Yield (qt/ha)**: The total grain yield per sub-plot was recorded in kg and converted to qt/ha.

3.12 Growth parameters of tree species

i) **Plant height:** Five sample plants of each tree species were selected randomly from each sub-plot and height was measured at an interval of 60 days during the cropping period, the measurement taken was expressed in centimetre (cm).

ii) **Basal thickness:** Basal thickness of the five selected sample plants of each tree species was measured at 60 days interval and expressed in centimetre (cm) during the cropping period, the average was expressed as basal thickness.

3.13 Details of cultural operations:

The details of cultural operations carried out during the course of the present investigation are given in the table below:

Table 3.1 : Details of cultural operations

Name of operations	Dates of operations	
	2005	**2006**
Site preparation, clearing of weed, rubbles, burning of dried debris.	Completed within first fortnight of March	Completed within first fortnight of April
Marking of contour lines with the help of A frame and sowing of tree species	17.3.2005	-
First pruning operation of tree species in the second year	-	12.5.2006
Sowing of crops	14. 5. 2005	12.5.2006
Thinning and gap filling; irrigation in the first year. No irrigation was given in the second year.	30. 5. 2005	26.5.2006
First pruning operation of tree species in the first year.	20.6.2005	-
1st hand weeding.	20-21. 6. 2005	16-17.6. 2006
2nd hand weeding.	23-24.7.2005	19-20.7.2006
Second pruning operation of tree species.	20.8.2005	26.7.2006
3rd hand weeding.	25-26.8.2005	23.8.2006
Harvesting of maize.	26.8.2005	24.8.2006
Harvesting of rice.	1.10.2005	29.9.2006

3.14 Statistical Analysis.

The various data recorded pertaining to each parameters during the course of study were statistically analyzed with the help of SPSS software package by using analyses of variance technique (ANOVA) for Randomized Block Design. The significance of the treatment difference was tested by “F” test (Variance ratio) at 1 and 5 per cent level. Further, mean values for different parameters are calculated and presented along with Standard Deviation (SD), Standard Error (SE) and Critical Difference (CD) at 5 %.

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CHAPTER - 4

RESULTS

CHAPTER – 4

RESULTS

4.1 Meteorological data of the study area

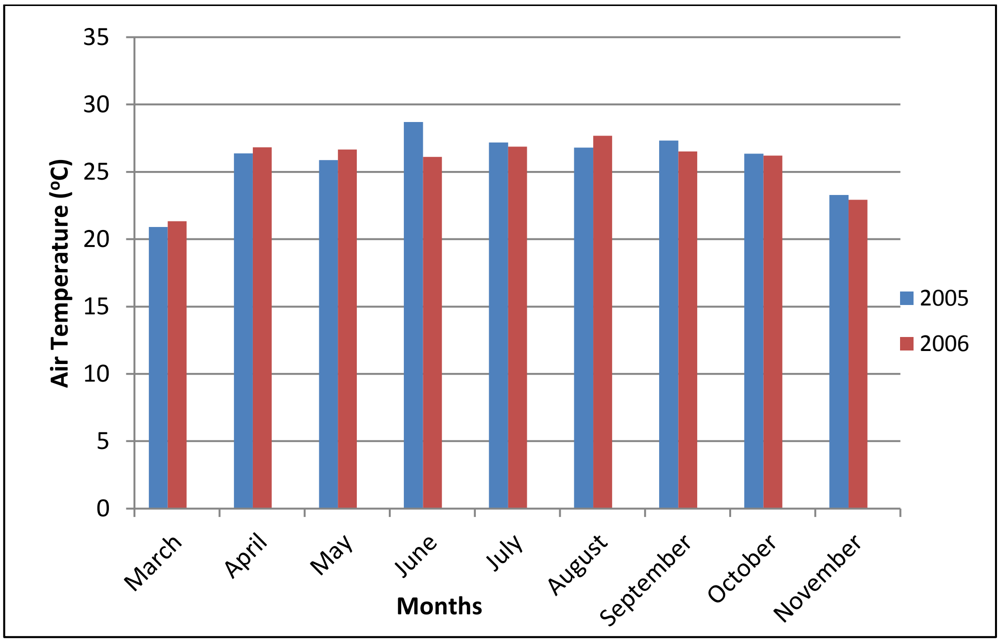
4.1.1 Temperature

During the study period the annual temperature ranges from 14.82 ^{0}C to 25.71 ^{0}C in winter and 23 ^{0}C to 32 ^{0}C in summer. The month wise maximum noon temperature recorded in 2005 was 31.66 ^{0}C in the month of June and 30.4 ^{0}C in the month of July in 2006. The data recorded and graph showing the mean monthly temperature are presented in Table 4.1 and Fig. 4.1.

Table 4.1: Air temperature of the experimental area during the study period.

Months	1st year (2005)			2nd Year (2006)		
	Min^{o}C	Max^{o}C	Mean Temp	Min^{o}C	Max^{o}C	Mean Temp
March	18.77	23.04	20.90	20.14	22.51	21.32
April	23.31	29.45	26.38	24.03	29.64	26.83
May	22.91	28.82	25.86	23.75	29.59	26.67
June	25.75	31.66	28.70	23.60	28.63	26.11
July	24.11	30.24	27.17	23.34	30.4	26.87
August	23.91	29.69	26.8	25.14	30.24	27.69
September	23.73	30.92	27.32	23.62	29.4	26.51
October	23.88	28.81	26.34	23.41	29.00	26.20
November	21.08	25.47	23.27	20.11	25.73	22.92

Fig. 4.1: Mean monthly air temperature of the study area during 2005 and 2006



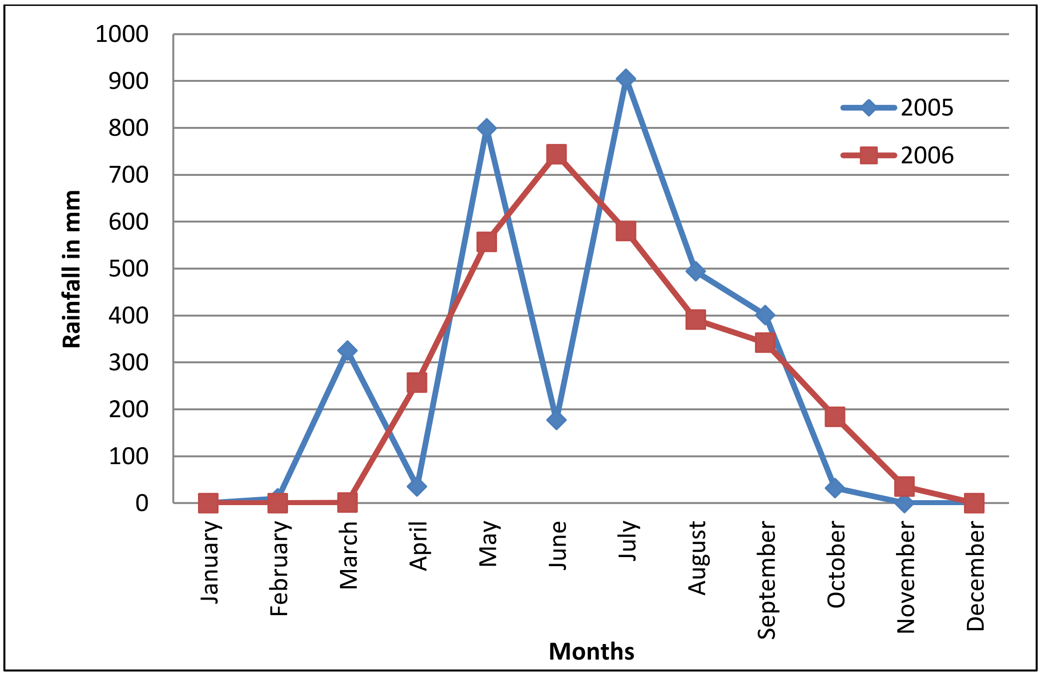
4.1.2 Rainfall

The total rainfall received by the study area during the first year of investigation in 2005 was 3506 mm. Unlike the usual cycle of precipitation, in the first year, pre-monsoon rain occurred in the month of March followed by dry and hot spell in April which entailed application of artificial irrigation to young plants. Regular rainfall started only in the month of July. The total rainfall in the second year of the study was 3091 mm. In 2006, monsoon rain followed its natural cycle; considerable amount of precipitation was received from April till October and completely ceased in December. The rainfall data recorded during the study period was presented in Table 4.2 and Figure 4.2.

Table 4.2: Rainfall data of the experimental area during the study period

Month	Rainfall (mm)	
	2005	**2006**
January	-	-
February	10	-
March	325	1
April	35	257
May	799.01	557
June	177	744
July	905	580
August	494	391
September	401	342
October	32	184
November	-	35
December	-	-
Total	**3506**	**3091**

Fig. 4.2: Annual rainfall at the experimental area during the study period.



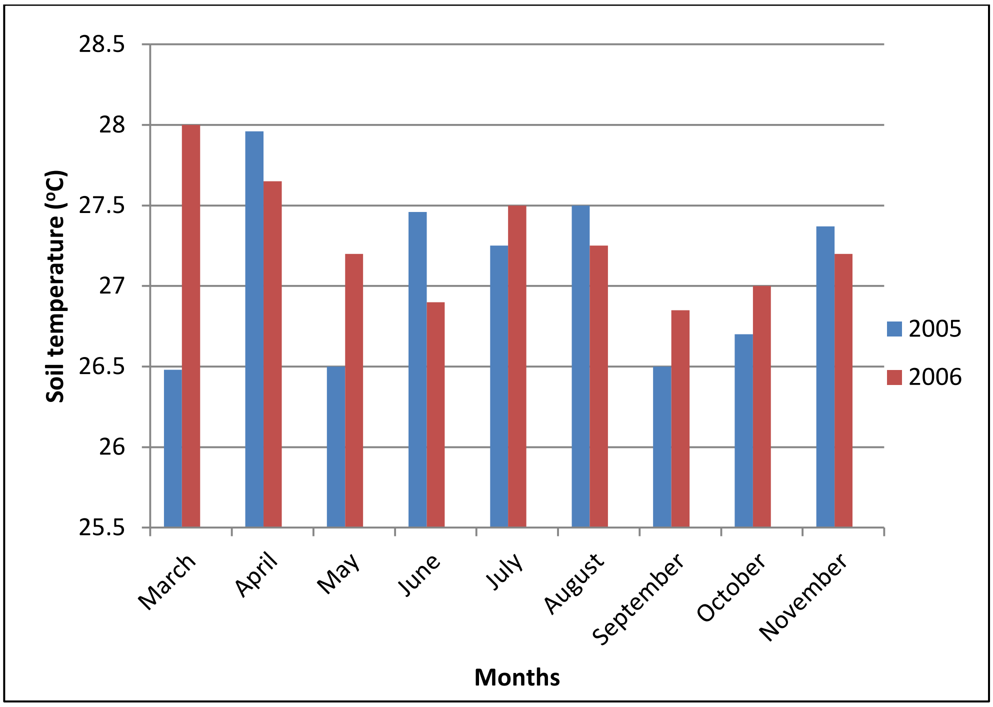
4.1.3 Soil temperature of the experimental site

The monthly soil temperature (^{0}C) at noon collected from the experimental site at a depth of 5cm for two years were presented in Table 4.3 and Fig 4.3. The soil temperature was highest in the month of April in 2005 (27.96 ^{0}C), and March in 2006 (28.0 ^{0}C) respectively during the two years of the experimentation.

Table 4.3: Soil temperature of the experimental site during the study period

Months	Soil temperature (^{o}C)	
	1st Year (2005)	2nd Year (2006)
March	26.48	28.0
April	27.96	27.65
May	26.50	27.2
June	27.46	26.9
July	27.25	27.5
August	27.50	27.25
September	26.50	26.85
October	26.70	27.00
November	27.37	27.2

Fig. 4.3: Soil temperature of the experimental site during the study period



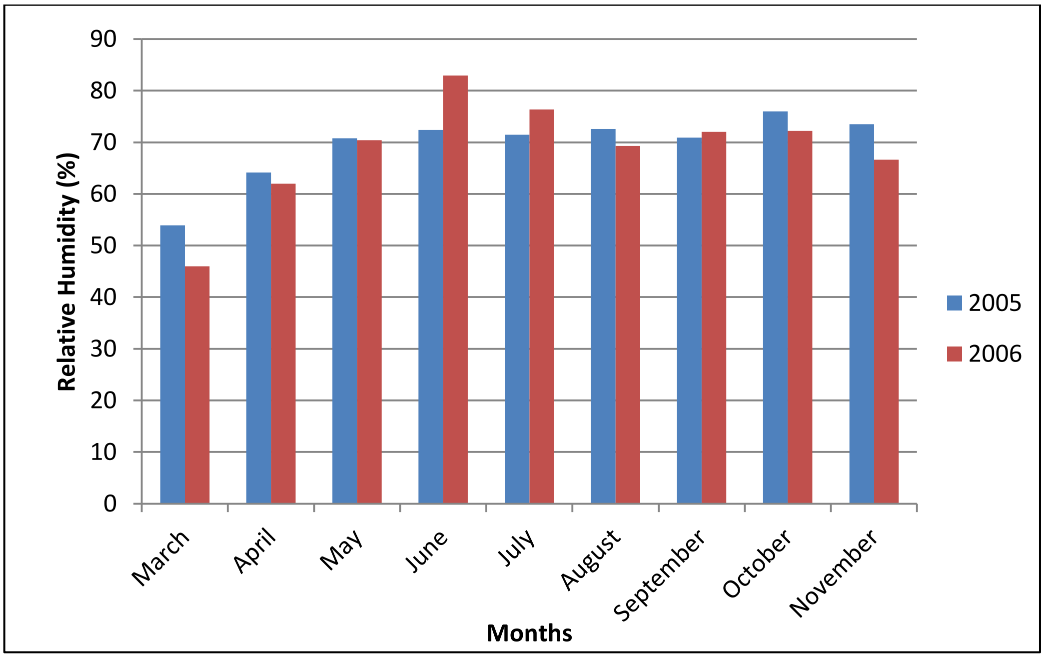
4.1.4 Relative humidity (RH %)

The maximum Relative Humidity (RH %) of the study area recorded during the first year was 83.12 % in the month of October and the minimum was 48.77 % in the month of March 2005. In 2006, the maximum RH was recorded in the month of June with RH of 89.50 % and the minimum was 37.19 % in March. The data recorded and graph are given in Table 4.4 and Fig. 4.4.

Table 4.4: Relative Humidity (RH %) of the study area during the study period.

Months	1st Year(2005)			Second Year (2006)		
	Min. RH %	Max. RH %	Mean RH %	Min. RH %	Max. RH %	Mean RH %
March	48.77	59.10	53.935	37.19	54.80	45.995
April	56.96	71.32	64.14	55.33	68.56	61.945
May	64.19	77.38	70.785	63.38	77.41	70.395
June	64.06	80.76	72.41	76.36	89.50	82.93
July	63.35	79.54	71.445	68.80	83.86	76.33
August	62.25	82.90	72.575	63.93	74.64	69.285
September	62.76	79.00	70.88	65.16	78.90	72.03
October	68.80	83.12	75.96	65.74	78.70	72.22
November	69.06	77.93	73.495	60.53	72.70	66.615

Fig 4.4: Mean monthly Relative Humidity (RH %) of the study area during the study period



4.2 Observation on growth parameters of Maize and Rice

Observations on growth parameters of maize and rice grown under different treatments were recorded at 20 days interval from the date of sowing till harvest. Average of 5 observations on plant height of crops from each sub-plots were recorded. The observations and ANOVA are tabulated in Table 4.5, 4.6, 4.7, 4.8, and 4.9, 4.10, 4.11, 4.12 and the mean values of observations are portrayed in graphs, Fig. 4.5, 4.6, 4.7 and 4.8.

The Mean values for the 9 – groups (2 crops x 3 tree species having 2 pruning management + 3 control) replicated 3 times, having five observations under each sub-plots for the two years of experimentation on growth parameters of maize and rice were analyzed. Interaction between agricultural crops and tree species were separately analyzed for maize and rice. The mean values of observations were portrayed by using graphs. The results relating to the growth patterns of maize and rice as affected by leguminous tree species are thus presented separately.

4.2.1 Plant height of Maize (in cm).

In the first year of experimentation, the ANOVA table shows that plant height was highly significant at 20 DAS and at 100 DAS respectively. Treatment combination of *F.macrophylla* + maize + P2 (T14) recorded the highest mean value at 20 DAS, 40 DAS and at 100 DAS, the highest mean plant height(130.4cm) during the crop period was obtained from this treatment combinations. The control plot (maize alone) showed improvement at 40 DAS thereby recording the third highest plant height at this particular growth stage. However, at 80 DAS, the result started showing significant patterns of mean differences between maize alone and maize under different treatment, and from this stage, plant height under different treatments were found to be higher than control plot (maize alone).

The ANOVA table for analysis of plant height of maize for the second year revealed that the effect of treatments on plant height were highly significant at all stages of growth. The mean values of observations are presented in Table 4.6 and Fig. 4.6. Treatment combination of *T.candida* + maize + P2 (T8) recorded maximum value at 20 DAS and 60 DAS. At 40 DAS, 80 DAS and 100 DAS, maize alley-cropped with *F.macrophylla* under 2 pruning management (T14) recorded the highest mean values (79.9, 158.46, 183.46). The overall mean values obtained from observations taken during the crop period till harvest manifested T14 as the best performing treatment followed by maize alley-cropped with *T.candida* (T8 and T7). The average height obtained from different growth stages showed that all the treatment combinations performed relatively better than control plot (maize alone).

4.2.2 Plant height of Rice (in cm)

The ANOVA tables for analysis of plant height of rice for two years of investigation and the mean values are presented in Table 4.10 & 4.12 and Fig. 4.7 & 4.8. The analysis of the results obtained for the first year showed significant effect of treatments at 80 DAS, 120 DAS and 140 DAS. At 20 DAS, no distinct differences in the mean values were observed between control plot and those under different treatments.

However, at 40 DAS, treatment combination of *T.candida* + rice + P2(T11) which is the best performing treatment (38.13) started gaining momentum in growth performance and continued till 140 DAS except at 60 DAS and 100 DAS. Next to T11, rice alley-cropped with *Flemingia macrophylla* + P1 (T6) showed comparatively better performance than other treatments till harvest.

The ANOVA table for the second year presented highly significant results of growth parameters during the crop period, except at 20 DAS which was significant at *p*-0.05. There were no marked tree species-wise effect on the growth performance of rice, but growth performance of rice under different treatments at different stages of growth were generally better than control plots. Rice alley cropped with *F.macrophylla* under 2 pruning management (T17) recorded maximum height at 20 DAS, 80 DAS, 100 DAS and 120 DAS. Treatment combination of *L.leucocephala* + rice+ P1(T4) which produced the highest mean value during the crop period recorded the highest plant height at 60 DAS and 120 DAS.

Table 4.5: Plant height of Maize (1st Year)

Treatments	Mean height of maize in cm					Mean height in cm
	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	
T1	29.33	65.06	112.4	159.06	189.46	111.062
T2	31.5	68.2	130	169.43	198.26	119.478
T7	31.21	70.53	140.33	178.86	192.86	122.758
T8	33.03	73.66	146.26	175.46	195.06	124.694
T13	28.96	65.2	126.46	162.4	189.6	114.524
T14	40.28	80.93	141.86	178.73	210.2	130.4
Control	20.61	73.30	124.68	151.36	170.72	108.13
SE ±	**2.208**	**2.115**	**4.476**	**4.020**	**4.485**	**2.997**
SD	**5.842**	**5.596**	**11.844**	**10.636**	**11.866**	**7.930**
$CD_{5\%}$	**4.159**	**12.343**	**24.850**	**22.446**	**15.956**	

Fig.4.5: Plant height of Maize in cm (1st year)

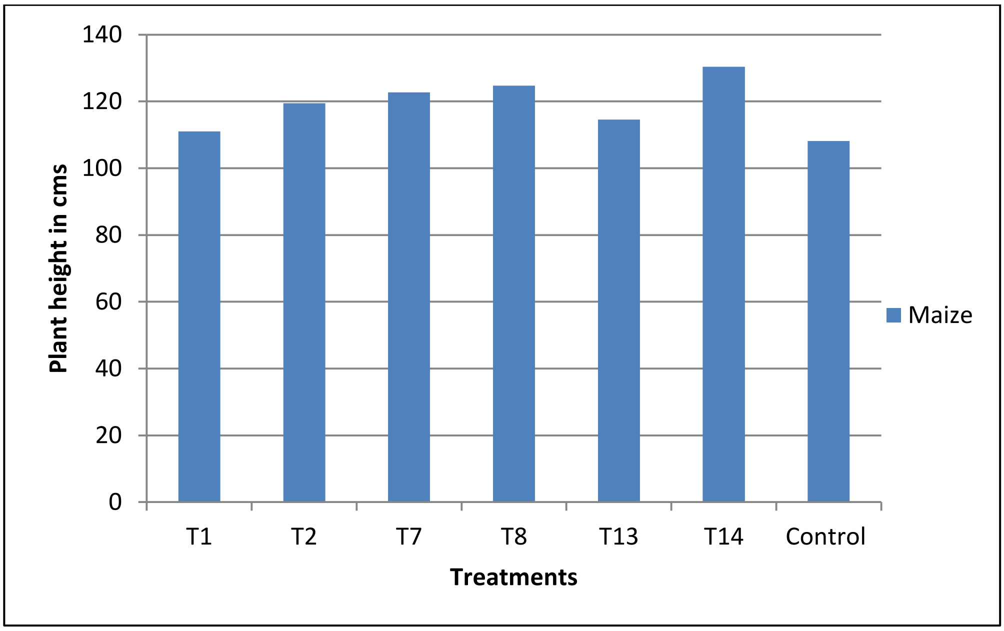


Table 4.6 : Plant height Maize (2nd Year)

Treatments	Mean height of maize in cm					Mean height in cm
	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	
T1	28.36	79.10	120.33	144.8	163.6	107.238
T2	28.94	78.63	126.5	145.93	164.76	108.952
T7	29.4	78.8	132.2	151.73	171.13	112.652
T8	29.76	79.03	135.16	154.8	175.06	114.762
T13	27.8	78.8	127	157.93	179.93	114.292
T14	28.6	79.9	128.66	158.46	183.46	115.816
Control	25.56	75.62	110.47	136.61	162.18	102.09
SE ±	**.525**	**.513**	**3.099**	**3.021**	**3.168**	**1.879**
SD	**1.389**	**1.358**	**8.201**	**7.99**	**8.382**	**4.973**
$CD_{5\%}$	**2.869**	**2.350**	**10.640**	**13.158**	**9.894**	

Fig. 4.6: Plant height of Maize in cm(2nd year)

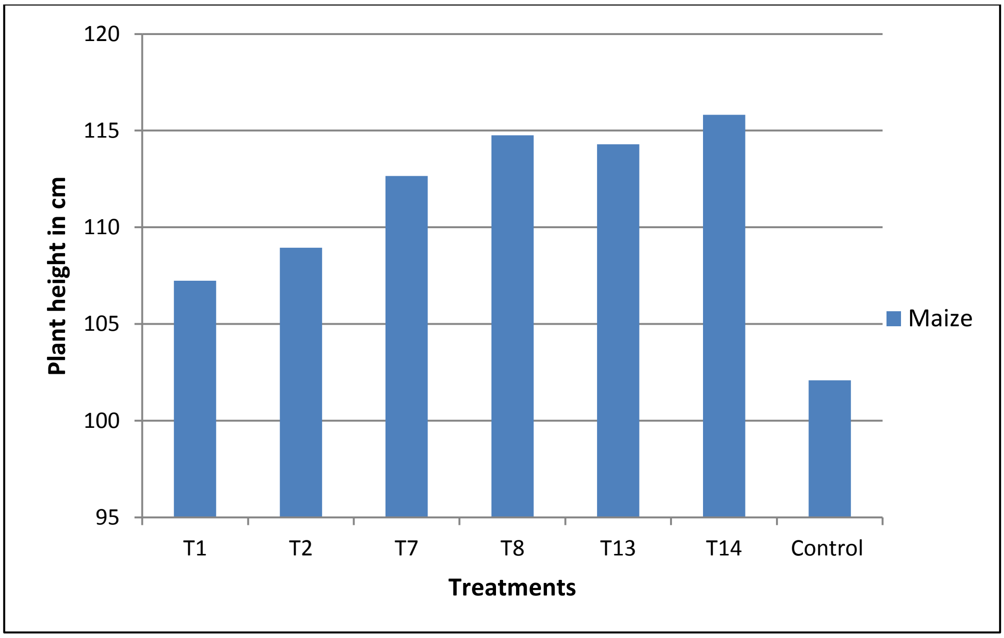


Table 4.7: Plant height of Rice (1st Year)

Treatments	Mean height of rice in cm							Mean height in cm
	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	120 DAS	140 DAS	
T4	17.5	34.49	74.4	90.53	112	117.6	120.6	81.01
T5	17.66	37.6	75.56	94.53	113.2	120.33	122.33	83.03
T10	18.1	37.06	73.03	92	112.66	117.4	120.33	81.51
T11	17.66	38.13	78.2	98.26	114.33	122.53	125.46	84.93
T16	16.47	36.2	81.73	95.93	114.6	120.93	125.06	84.41
T17	17.83	36.93	81.5	93.93	113.2	119	121.26	83.37
Control	18.68	33.01	71.85	85.56	104.93	109.42	112.93	76.62
SE ±	**.253**	**.691**	**1.496**	**1.557**	**1.247**	**1.614**	**1.572**	**1.062**
SD	**.670**	**1.828**	**3.960**	**4.121**	**3.300**	**4.271**	**4.159**	**2.810**
$CD_{5\%}$	**1.682**	**4.253**	**6.877**	**6.522**	**7.937**	**7.539**	**24.138**	

Fig. 4.7: Plant height of Rice in cm (1st year)

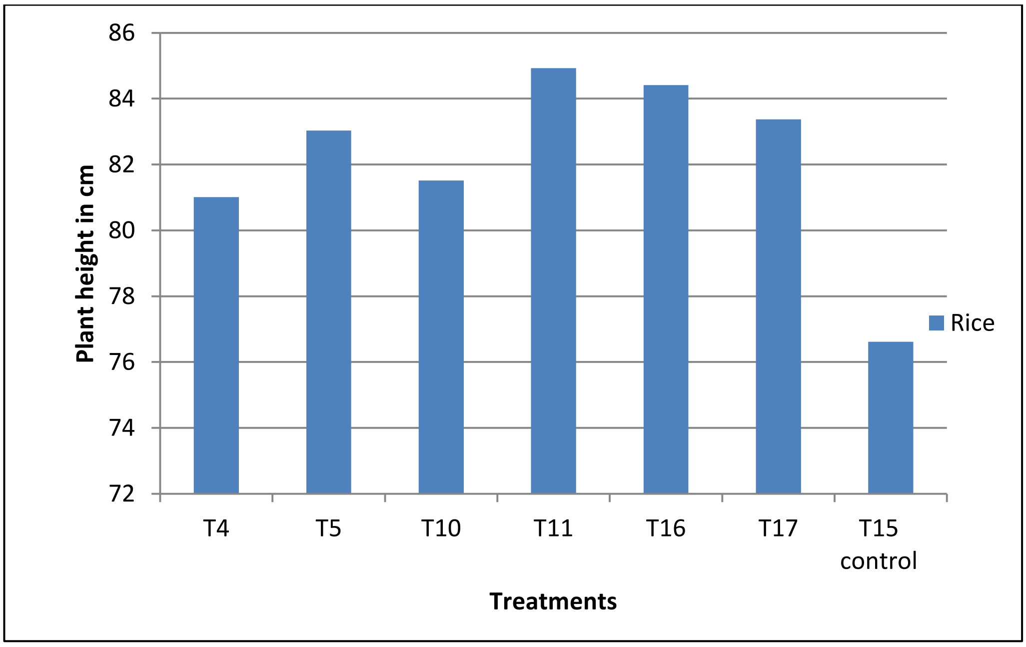


Table 4.8: Plant height of Rice (2nd Year)

Treatments	Mean height of rice in cm							Mean height in cm
	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	120 DAS	140 DAS	
T4	16.51	34.9	87.33	94.76	111.6	118.06	125.66	84.11
T5	17.04	34.76	72.38	88.63	110.2	115.86	120.66	79.93
T10	17.50	35.34	71.36	92.1	104	114.49	123.06	79.69
T11	17.66	35.3	70.10	91.94	108.02	120.13	125.26	81.20
T16	17.7	35.04	71.65	90.4	110.01	118.70	124.93	81.20
T17	18.66	35.33	74.24	95.86	114.46	121.46	125.4	83.63
Control	16.42	30.87	64.56	84.82	102.46	111.00	117.30	75.34
SE ±	**.293**	**.611**	**2.633**	**1.411**	**1.596**	**1.356**	**1.189**	**1.102**
SD	**.777**	**1.619**	**6.968**	**3.734**	**4.223**	**3.587**	**3.146**	**2.916**
$CD_{5\%}$	**1.183**	**1.250**	**3.978**	**3.409**	**3.405**	**4.254**	**4.642**	

Fig. 4.8: Plant height of Rice in cm (2nd year)

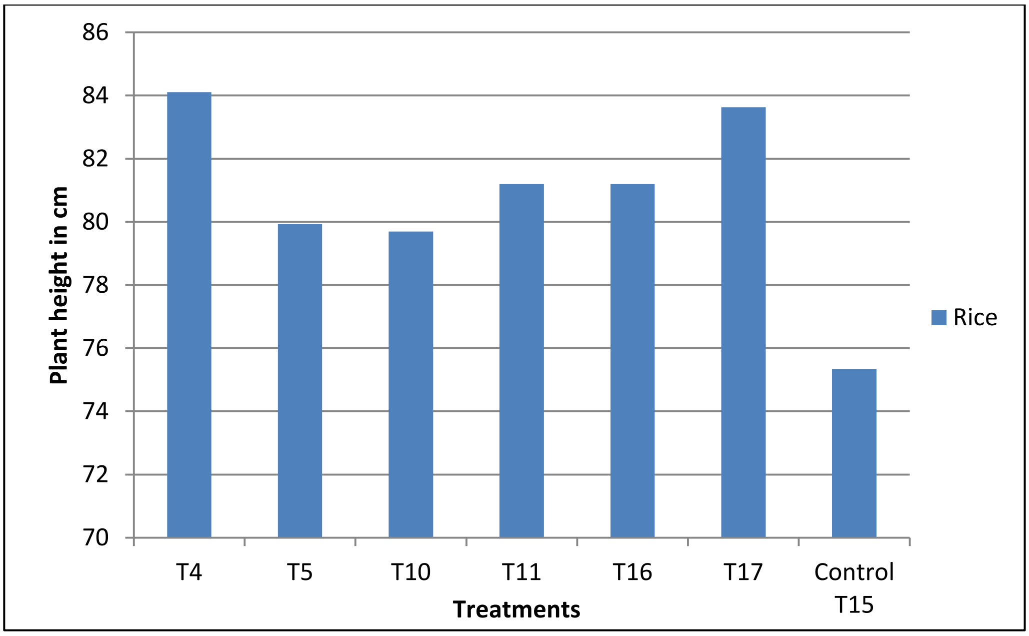


Table 4.9 : one-way ANOVA table for growth and yield parameters of maize as affected by leguminous tree species (1st Year)

Source of variation	Parameters	20 DAS		40 DAS		60 DAS		80 DAS		100 DAS	
		F-Ratio	*p-Level*	*F-Ratio*	*p-Level*	*F-Ratio*	*p-Level*	*F-Ratio*	*p-Level*	*F-Ratio*	*p-Level*
Maize control Maize x *Leucaena leucocephala,* Maize x*Tephrosia candida* Maize x *Flemingia macrophylla*	Plant height in cms	15.91*	.000	0.995 NS	.472	1.140 NS	.385	1.650 NS	.179	4.710*	.003

Yield parameters of Maize

Source of variation	No. of cob per plant at harvest		Total yield of maize per plot in kg		No. of kernels per cob at harvest		1000 grain weight of maize at harvest	
	F-Ratio	*p-Level*	*F-Ratio*	*p-Level*	*F-Ratio*	*p-Level*	*F-Ratio*	*p-Level*
Maize control Maize x *Leucaena leucocephala* Maize x *Tephrosia candida* Maize x *Flemingia macrophylla*	000 NS	000	2.642**	.041	3.192**	.019	.963 NS	.494

* Significant at P<0.01, ** Significant at P<0.05, NS = Non-significant

Table 4.10 : one-way ANOVA table for growth and yield parameters of rice as affected by leguminous tree species (1^{st} Year)

Source of variation	Para meters	20 DAS		40 DAS		60 DAS		80 DAS		100 DAS		120 DAS		140 DAS	
		F-Ratio	*p-Level*	*F-Ratio*	*p-Level*	*F-Ratio*	*p-Level*	*F-Ratio*	*p-Level*	*F-Ratio*	*p-Level*	*F-Ratio*	*p-Level*	*F-Ratio*	*p-Level*
Rice control	Plant height in cms	1.511 NS	.222	2.154 NS	.084	2.118 NS	.089	3.544 **	.012	2.137 NS	.086	3.418 **	.014	2.996 **	.025
Rice x *Leucaena leucocephala*															
Rice x *Tephrosia candida*															
Rice x *Flemingia macrophylla*															

Yield parameters of Rice

Source of variation	Average weight of rice grains per plot in kg		Average No. of grains per plant at harvest		Average 1000 grain weight of rice at harvest in gm	
	F-Ratio	*p-Level*	*F-Ratio*	*p-Level*	*F-Ratio*	*p-Level*
Rice control	5.801*	.001	5.581*	.001	1.021 NS	.455
Rice x *Leucaena leucocephala*						
Rice x *Tephrosia candida*						
Rice x *Flemingia macrophylla*						

* Significant at P<0.01, ** Significant<0.05, NS = Non-significant

Table 4.11: one-way ANOVA table for growth and yield parameters of maize as affected by leguminous tree species (2nd Year)

Source of variation	Parameters	20 DAS		40 DAS		60 DAS		80 DAS		100 DAS	
		F-Ratio	*p-Level*	*F-Ratio*	*p-Level*	*F-Ratio*	*p-Level*	*F-Ratio*	*p-Level*	*F-Ratio*	*p-Level*
Maize control Maize x *Leucaena leucocephala* Maize x *Tephrosia candida* Maize x *Flemingia macrophylla*	Plant height in cms	3.024**	.024	5.627*	.001	5.470*	.001	3.815*	.009	6.241*	.001

Yield parameters

Source of variation	No. of cobs per plant at harvest		Total Yield of maize per plot in kg		No. of kernels per cob at harvest		1000 grain weight of maize at harvest	
	F-Ratio	*p-Level*	*F-Ratio*	*p-Level*	*F-Ratio*	*p-Level*	*F-Ratio*	*p-Level*
Maize control Maize x *Leucaena leucocephala* Maize x *Tephrosia candida* Maize x *Flemingia macrophylla*	.281 NS	.964	5.326*	.002	3.130**	.021	.885 NS	.548

* Significant at P<0.01, ** Significant at P<0.05, NS = Non-significant

Table 4.12: one-way ANOVA table for growth and yield parameters of rice as affected by leguminous tree species (2nd Year)

Source of variation	Parameters	20 DAS		40 DAS		60 DAS		80 DAS		100 DAS		120 DAS		140 DAS	
		F-Ratio	*p-Level*	*F-Ratio*	*p-Level*	*F-Ratio*	*p-Level*	*F-Ratio*	*p-Level*	*F-Ratio*	*p-Level*	*F-Ratio*	*p-Level*	*F-Ratio*	*p-Level*
Rice control Rice x *Leucaena leucocephala* *Rice x Tephrosia candida* *Rice x Flemingia macrophylla*	Plant height in cms	2.72 **	.037	17.49*	.000	19.42*	.000	9.53*	.000	11.92*	.000	5.89*	.001	4.10*	.006

Yield parameters of Rice

Source of variation	Average weight of rice grains per plot in kg		Average No. of grains per plant at harvest		Average 1000 grain weight of rice at harvest in gm	
	F-Ratio	*p-Level*	*F-Ratio*	*p-Level*	*F-Ratio*	*p-Level*
Rice control Rice x *Leucaena leucocephala* Rice x *Tephrosia candida* Rice x *Flemingia macrophylla*	1.551 NS	.209	6.760*	.000	1.087 NS	.415

* Significant at P<0.01, ** Significant P<0.05, NS = Non-significant

Fig. 4.9: Opening of forest for jhumming

Fig. 4.10: Burning of jhum land

Fig. 4.11: Maize grown with *Tephrosia candida* (1^{st} year)

Fig. 4.12: Maize grown as sole crop (1st year)

Fig. 4.13: Rice grown as sole crop (1st year)

Fig. 4.14: Rice grown with *Flemingia macrophylla* (1st year)

Fig. 4.15: *Tephrosia candida* before pruning (1st year)

Fig. 4.16: *Tephrosia candida* regrowth after Pruning (1st year)

Fig. 4.17: *Leucaena leucocephala* (1st year)

4.3 Observations on yield parameters of Maize and Rice

Observations on yield parameters of maize and rice grown under different treatment were recorded at harvest. Observations on five sample plants from each sub-plot were recorded. In case of maize, number of cobs per plant, 1000 grain weight, yield per sub-plot and number of kernels per cob as affected by tree species were observed and analyzed. Number of grains per plant, yield per sub- plot and 1000 grain weight were recorded for rice. The ANOVA tables and mean values of the result thus obtained in the experimentation are presented in order.

4.3.1 Yield parameters of Maize

4.3.1.1 Number of cobs per plant

Observations on yield parameters of maize for the first year and second year are presented in Table 4.13 & 4.14 and Fig. 4.21(a-b) & Fig. 4.22(a-b), there were no significant differences in number of cobs per plant among the experimental treatments in the first year of experimentation. But in the second year, the ANOVA table (table 4.11) shows significant effect of treatments on the number of cobs per plant at 0.05 level. Significant tree species-wise effect on number of cobs per plant was not detected.

4.3.1.2 Yield of Maize per plot (qt/ha)

Statistical analysis of maize grain yield per plot showed significant result in the first year and highly significant result in the second year (table 4.9 &

4.11), the highest average yield (28qt./ha) was obtained from treatment combination of *F.macrophylla*+ maize + P2 (T14). Table 4.13 and Figure 4.21(a) showed that maize alley-cropped with tree species generally produced higher mean yields than control plots (maize alone), among tree species maize grown with *F.macrophylla* resulted the highest grain yield. Effect of pruning management on grain yield in case of maize alley-cropped with *Leucaena leucocephala* was not detected, P1 and P2 (T 1 and T2) exhibited almost similar average yield per plot.

4.3.1.3 Number of kernels per cob

The ANOVA table for the number of kernels per cob of maize for the two years of study presented in Table 4.9 and Table 4.11, the statistical analysis showed significant effect of treatments on the number of kernels per cob in both the two years of study at 0.05 level. In the first year of study, the highest average number of kernels per cob was obtained from treatment combination of *F.macrophylla* + maize + P2 (281.73). In the second year, maize alley-cropped with *L. leucocephala*+ P2 (234.4) recorded the maximum number of kernels per cob followed by T1(209.13). The patterns of mean differences are presented in Tables 4.13 & 4.14 and Fig. 4.21(b) and 4.22 (b).

4.3.1.4 1000 Grain weight (Test weight in gm)

Non-significant results were obtained from the statistical analysis of 1000 grain weight (test weight) of maize in the two years of the study (Tables

4.9 & 4.11). The mean values of the test weight are presented in Tables 4.13 & 4.14 and Fig. 4.21(b) and 4.22(b). The results revealed maximum 1000 grain weight (test weight) under *L. leucocephala* + maize + P2 (T2) in the first year (381.66) and *F.macrophylla* + maize + P2 (T14) in the second year (398.33) of the study. Though tree species-wise effect on 1000 grain weight was not detected, the mean values of 1000 grain weight obtained were lower in control plots than alley-cropped with tree species except control (T12).

4.3.2 Yield parameters of Rice.

The ANOVA table for the yield parameters of rice alley cropped with *L.leucocephala*, *T. candida* and *F.macrophylla* for the two years of study are presented in Table 4.10 and Table 4.12. Yield parameters of rice collected viz. weight of grains per plot, number of grains per plant at harvest, 1000 grain weight (test weight) of rice at harvest for the two years of experimentation are shown together in Table 4.15 & 4.16. and Fig.4.23(a),(b) and Fig. 4.24(a) & (b).

4.3.2.1 Weight of grains per plot (qt/ha)

The statistical analysis of grain yield per plot revealed highly significant effect of treatments on the grain yield of rice in the first year ($p>0.01$), and non-significant result was obtained in the second year. The pattern of mean differences shows that in the first year, treatment combination of *T.candida* + rice + P2 (T11) recorded the highest average yield per plot (25.25 qt/ha) followed by *F.macrophylla* + rice + P2 (24.58qt/ha). In the second year, the maximum grain yield of rice was recorded under *F.macrophylla* + rice + P2 (T17) treatment combinations (20.5 qt/ha) followed by T11 (19.16qt/ha), all the treatments performed better than control plots (rice alone). Though the two years of study shows little significant differences between species wise effect on the grain yield of rice, rice alley-cropped with *F.macrophylla* recorded the highest mean grain yield per plot for the two years of study among the tree species.

4.3.2.2 Number of grains per plant

The ANOVA tables showed highly significant effect of treatments on the number of grains per plant of rice as affected by three leguminous tree species in both the years. The pattern of mean differences are given in Tables 4.15 & 4.16 and portrayed in graphs, Fig 4.23(b) & 4.24(b). In the first year the results revealed the highest number of grains per plant under *L.leucocephala*+ Rice + P1 (T4) treatments (2572.73) followed by *Tephrosia candida* + rice + P2 (T11) (2343.06) and all significantly greater than rice grown as sole crop (control). A combination of *Flemingia macrophylla* + rice + P2 (T17) treatments produced the highest number of grains per plant (2693.06) in the second year of the study. Further, the two years' data shows that there are no distinct differences in the number of grains per plant as affected by different species of trees.

Fig. 4.18: *Flemingia macrophylla* (1^{st} year)

Fig. 4.19 : *Tephrosia candida* before pruning (2^{nd} year)

Fig. 4.20: Maize grown as sole crop (2^{nd} year)

4.3.2.3 1000 grain weight (Test weight in gm).

Non-significant results were obtained from the statistical analysis for the 1000 grain weight of rice as affected by the treatments for the two years of the study. The mean values of 1000 grain weight are presented in Tables 4.15 & 4.16 and portrayed in Fig.4.23 (a) & 4.24(a). The results revealed the highest 1000 grain weight (32.20) under *L.leucocephala* + rice + P2 treatment combinations (T5) followed by *T.candida* + rice + P2 (32.16) in the first year. In the second year, the highest 1000 grain weigth (33.03) was obtained from treatment combination of *Flemingia macrophylla* + rice + P2(T17) followed by *Tephrosia candida* + rice + P1 (33.02). Although, the mean values obtained in control plots were moderately low as compare to test weight under different treatments, tree species-wise effect on the mean values revealed no distinct variation in the test weight.

Table 4.13: Yield parameters of Maize (1st year)

Treatments	No. of cob per plant at harvest	Mean grain yield of maize per plot in qt./ha	Mean No. of kernels per cob at harvest	Mean 1000 grain weight of maize at harvest in gm.
T1	1	20.41	230.66	353.33
T2	1	20.5	256	381.66
T7	1	18	242.4	349
T8	1	23	260.33	368.33
T13	1	19.25	216.93	340
T14	1	28	281.73	366.66
Control	1	13.63	179.17	338.99
SE ±	**.000**	**1.672**	**12.642**	**6.016**
SD	**.000**	**4.424**	**33.448**	**15.918**
$CD_{5\%}$	**-**	**0.884**	**55.304**	**42.663**

Fig. 4.21(a): Yield parameters of Maize (1st year)

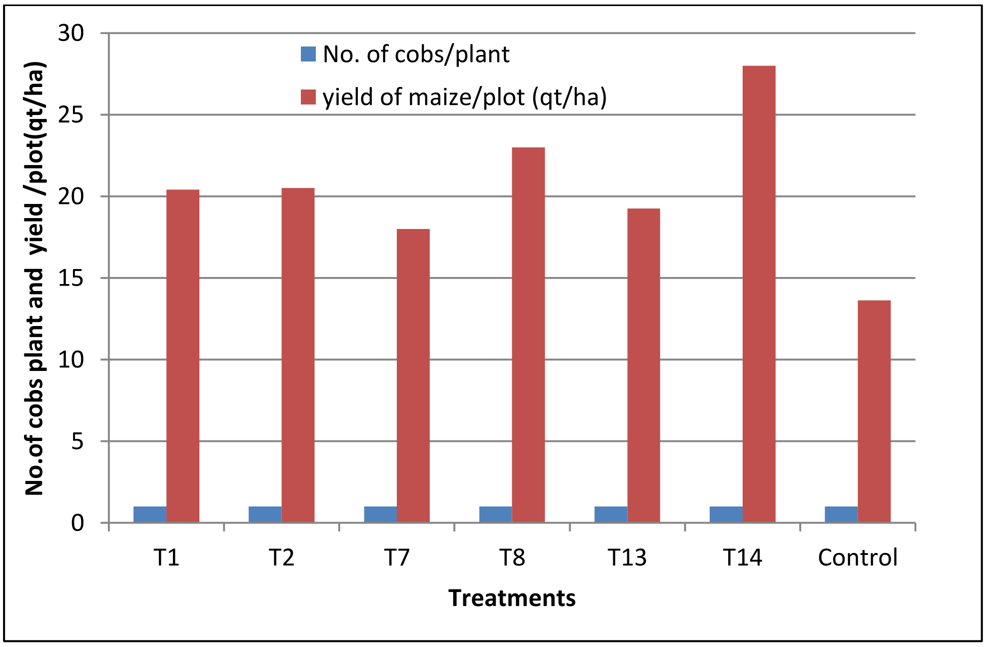


Fig. 4.21(b): Yield parameters of Maize (1st year)

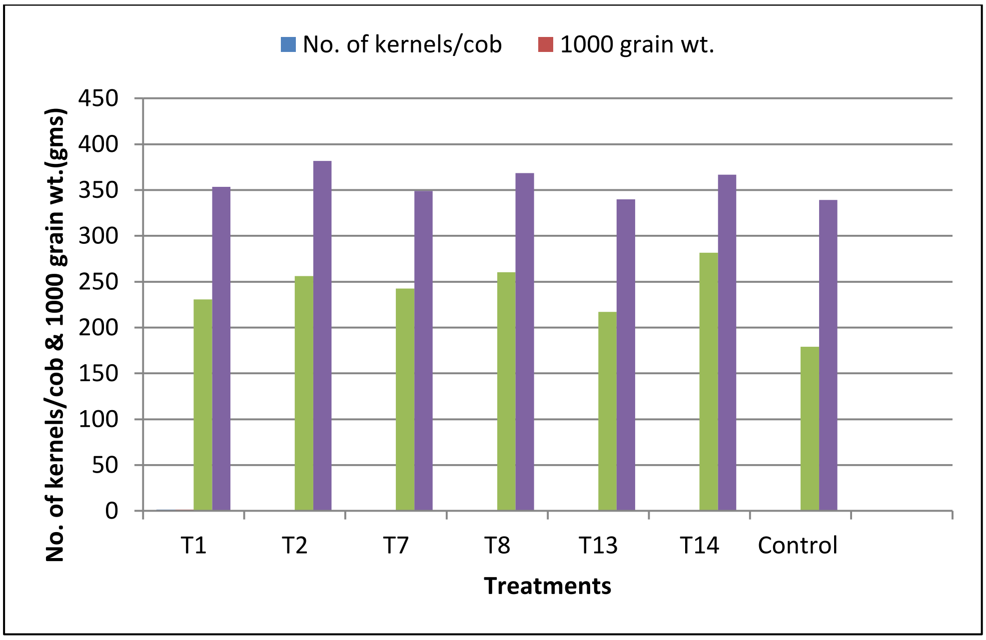


Table 4.14: Yield parameters of Maize (2nd year)

Treatments	No. of cob per plant at harvest	Mean grain yield of maize per plot in qt./ha	Mean No. of kernels per cob at harvest	Mean 1000 grain weight of maize at harvest in gm.
T1	1.06	20.25	209.13	369.33
T2	1.06	21.66	234.4	390
T7	1.06	18.33	186.73	343.33
T8	1.06	21.33	193.8	380
T13	1	16.25	203	363.33
T14	1.06	21.91	205.53	398.33
Control	1.08	15.63	180.44	360.88
SE ±	**.009**	**.989**	**6.688**	**7.086**
SD	**.025**	**2.617**	**17.697**	**18.748**
$CD_{5\%}$	**0.155**	**0.395**	**25.942**	**44.534**

Fig. 4.22(a): Yield parameters of Maize (2nd year)

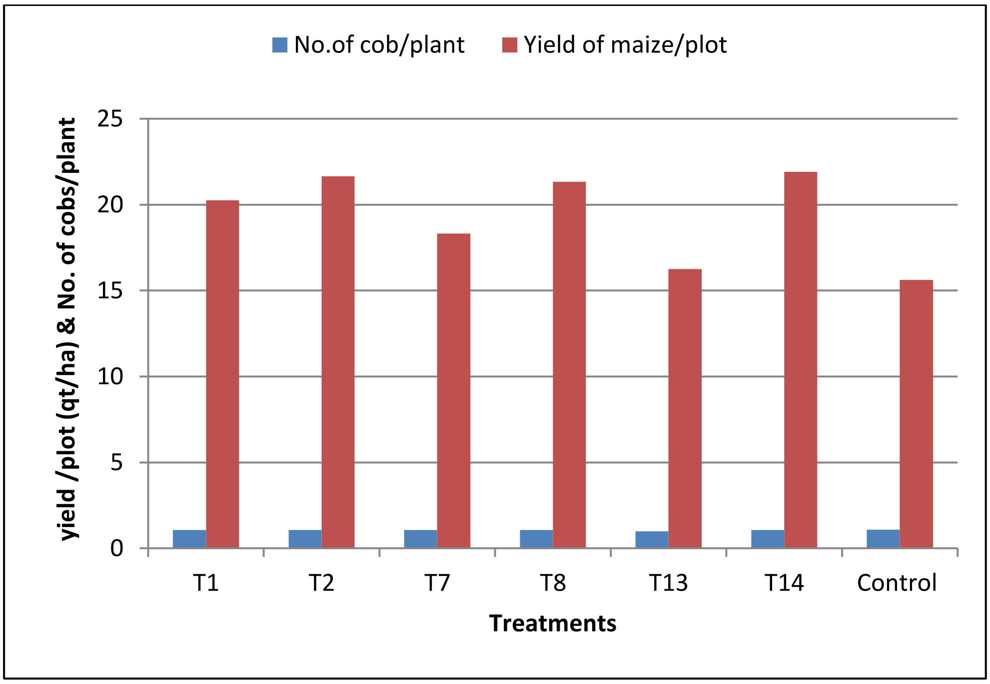


Fig. 4.22(b): Yield parameters of Maize (2nd year)

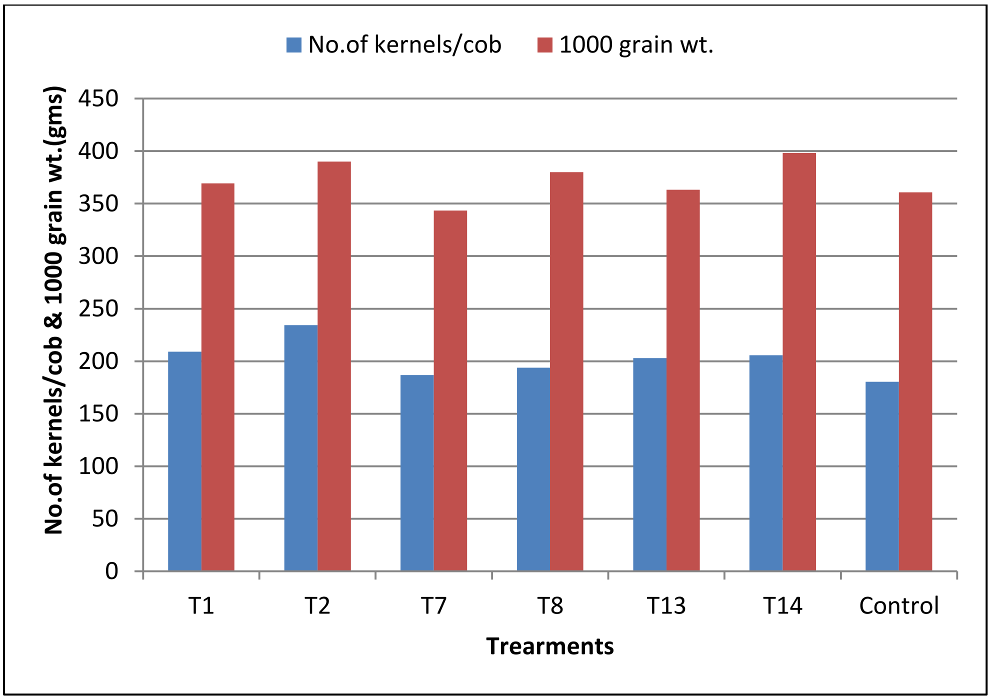


Table 4.15: Yield parameters of Rice (1st year)

Treatments	Mean grain weight of rice per plot in qt./ha	Mean No. of grains per plant at harvest	Mean 1000 grain weight of rice at harvest in gm.
T4	17.58	2572.73	31.96
T5	23.75	2046.93	32.20
T10	19.16	2119.46	32.08
T11	25.25	2343.06	32.16
T16	23.75	2132.13	32.02
T17	24.58	2293.13	31.99
Control	13.66	1269.53	31.97
SE ±	**1.653**	**155.296**	**.035**
SD	**4.375**	**410.875**	**.095**
$CD_{5\%}$	**0.629**	**535.565**	**0.369**

Fig. 4.23(a): Yield parameters of Rice (1st year)

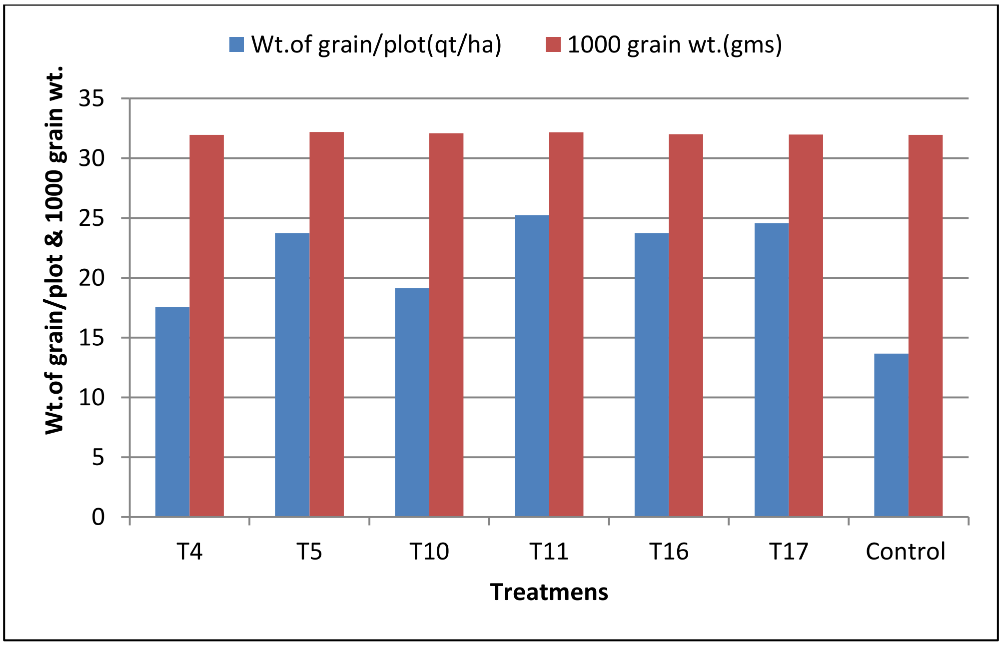


Fig. 4.23(b): Yield parameters of Rice (1st year)

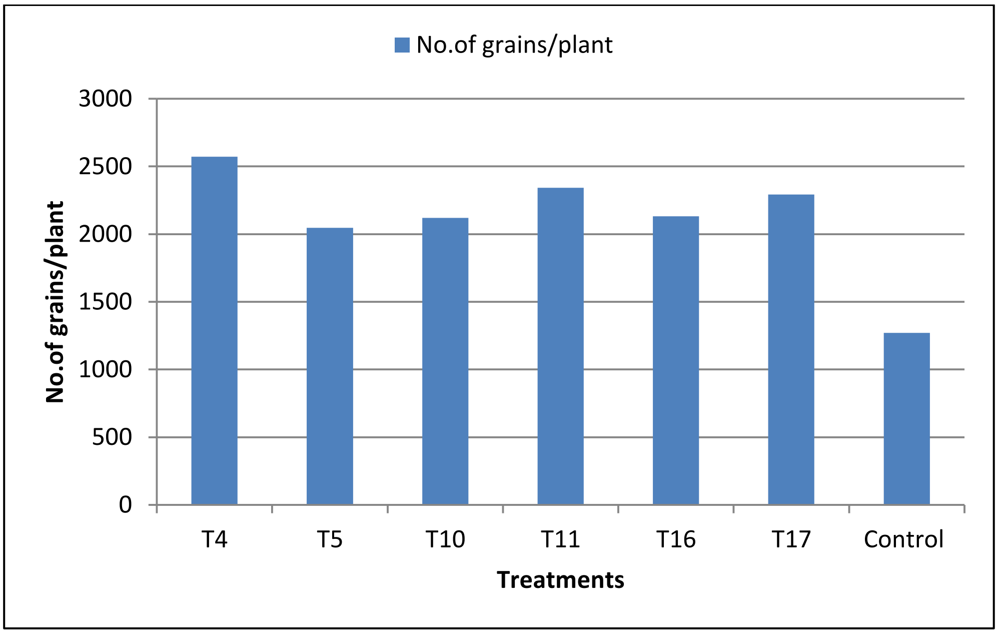


Table 4.16: Yield parameters of Rice (2nd year)

Treatments	Mean weight of rice grains per plot in qt./ha	Mean no. of grains per plant at harvest	Mean 1000 grain weight of rice at harvest in gm.
T4	17.5	2401.46	32.93
T5	17.75	2630.4	32.91
T10	17.08	2306.66	33.02
T11	19.16	2455.73	32.79
T16	17.5	2420.8	32.69
T17	20.5	2693.06	33.03
Control	16.02	1610.28	32.70
SE $\pm$	**.554**	**134.83**	**.053**
SD	**1.465**	**356.73**	**.141**
$CD_{5\%}$	**0.382**	**429.511**	**0.500**

Fig. 4.24(a): Yield parameters of Rice (2nd year)

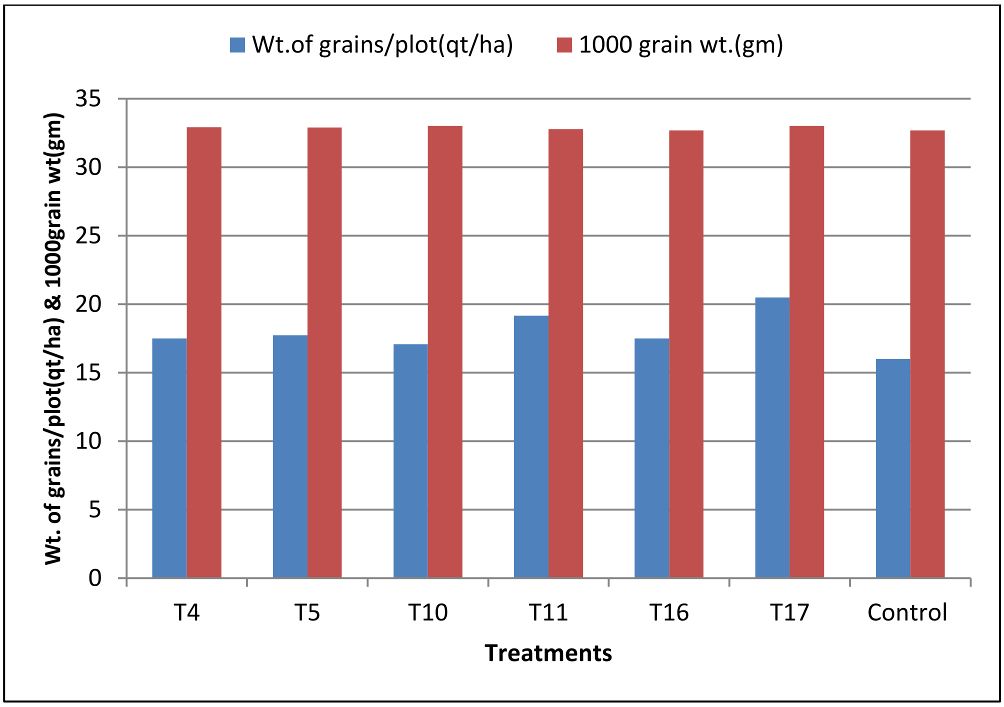
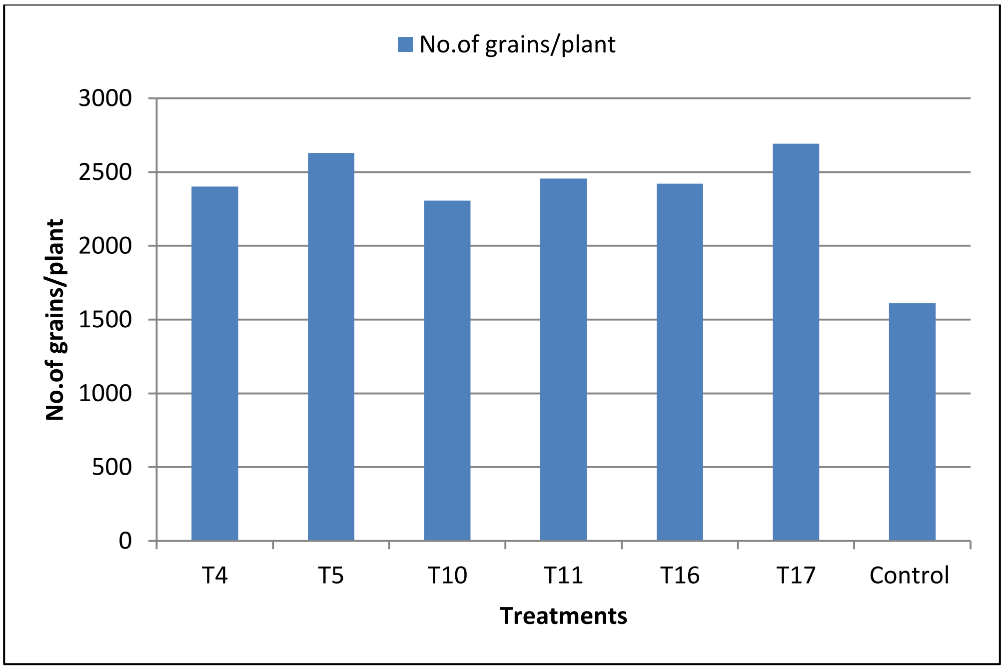


Fig.4.24(b): Yield parameters of Rice (2nd year)



4.4 Observation on growth parameters of tree species

Observations on growth parameters of tree species such as plant height and basal thickness were recorded at 60 days interval taking the date of sowing in the first year as day one. But in the second year, the day's interval for observations was counted from the date of sowing of maize and rice. Plant height and basal thickness of five sample plants from each sub-plot were recorded. The observations for the tree species namely *Leucaena leucocephala, Tephrosia candida*, *Flemingia macrophylla* are presented in order.

The experimental plot consists two double rows of each tree species which bounded sub plots of maize and rice (Fig. 4.14). Hedgerows were spaced at 2.5 m. One line of each tree species were pruned once during the cropping period (P1) and the other line of each tree species (P2) were pruned two times at a height of about 50 cm using sharp knives (Fig. 4.16). 5 sample plants were left standing in each treatment plots except *Leucaena leucocephala* as the growth rate was very slow as compare to the other two tree species. *T. candida* and *F.macrophylla* received pruning management of P1 and P2, observations in respect of *Leucaena leucocephala* was taken from 5 sample plants in each treatment. Maize and rice were grown in the same alleys but the sub-plots were arranged alternately so as to achieve complete randomization.

4.4.1 *Leucaena leucocephala*

4.4.1.1 Plant height (in cm)

Statistical analysis of plant height for the two years of investigation shows non-significant result (Table 4.21 & 4.22), it may be mentioned here that, the growth rate of *L.leucocephala* was specifically slow and pruning management was not applicable in case of *L.leucocephala* due to the fact that the desired height for hedgerows, about 50 cm from the ground level was not attained during the two years of investigation (Fig. 4.17). Therefore, two rows of *L. leucocephala* (P1 and P2) were left as such without pruning management and plant height of sample plants were measured at an interval of 60 days, starting from the date of sowing in the first year and 60 days from the date of sowing agricultural crops in the second year. The mean values of plant height are presented in Table 4.17(a & b) & 4.19. Fig.4.25 (a) showed that at 60 DAS *L. leucocephala* grown with rice + P2 (T5) recorded the highest plant height (10.00) followed by *L.leucocephala* + maize + P1(T1). At 120 DAS and 180 DAS treatment combination of *L.leucocephala* + maize + P1 (T1) shows the highest plant height. In the second year, *L.leucocephala* + maize + P1 (T1) continued to attain the maximum height till 180 DAS.

4.4.1.2 Basal thickness (in cm)

The analysis of data collected for the two years of experimentation showed that all basal thickness of tree species were statistically non-significant at all stages, the mean values of basal thickness presented in Table 4.18(a &b) & 4.20 (a & b) and Fig.4.26 (a,b,c) showed that *L.leucocephala* + maize +P2 (T2) recorded the highest basal thickness for the first year at 60 DAS and 180 DAS. However, in the second year treatment combination of *L.leucocephala* + maize +P1 (T1) recorded highest basal thickness at 60 DAS, 120 DAS and 180 DAS (Fig. 4.28 a, b & c). In general, *L.leucocephala* grown with maize at different growth stages showed higher performance than grown with rice irrespective of number of pruning.

4.4.2. *Tephrosia candida*

4.4.2.1 Plant height (in cm)

The statistical analysis of plant heights collected for the two years resulted non-significant results. The mean values of plant height are presented in Table 4.17 (a,b) & 4.19 (a,b) and Fig. 4.25(a,b,c) & 4.27(a,b,c). At 60 DAS and 120 DAS, treatment combination of *Tephrosia candida* + rice + P2 (T11) recorded the highest plant height (17.56 & 164). At 180 DAS in the first year and in the subsequent observations, *Tephrosia candida* + maize+ P1 (T7) recorded the highest plant height till180 DAS in the second year. No marked effect of pruning management on the growth performance was detected; almost identical results were obtained from P1 and P2 in all the observations.

4.4.2.2 Basal thickness (in cm)

Statistical analysis of basal thickness of *Tephrosia candida* for the two years of study revealed non-significant results. The mean values of data on the basal thickness are presented in Table 4.18 (a,b) & 4.20 (a,b) and Fig.4.26(a,b,c) & 4.28(a,b,c). *Tephrosia* alley-cropped with rice under 2 pruning management(T11) recorded the highest basal thickness at 60 DAS, 180 DAS in the first year (4.68 & 5.94) and the same treatment again marked maximum performance at 60 DAS and 120 DAS in the second year. Significant differences of basal thickness as affected by number of prunings and agricultural crops were not detected.

4.4.3 *Flemingia macrophylla*

4.4.3.1 Plant height (in cm)

The ANOVA (Table 4.21 & 4.22) for the two years of investigation on plant height in respect of *Flemingia macrophylla* showed non-significant results. The mean values of the observations are presented in Table 4.17 (a & b) & 4.19 9 (a & b) and Fig. 4.25 (a,b,c) and Fig. 4.27 (a,b,c). Significant effect of pruning management and agricultural crops on plant height was not detected. At 60 DAS in the first year, 60 DAS, 120 DAS and 180 DAS in the second year, treatment combination of *Flemingia macrophylla* + rice + P2 (T17) recorded the highest plant height, at 120 DAS in the first year, *Flemingia macrophylla* + maize + P1 (T13) recorded the maximum plant height (62.42).

4.4.3.2 Basal thickness

The ANOVA tables for the basal thickness of tree species for the two years of study are presented in Tables 4.21 & 4.22. Significant result of basal thickness in respect of *Flemingia macrophylla* was obtained at 60 DAS and highly significant result at 120 DAS in the first year. The patterns of mean differences are presented in Tables 4.18 (a, b) & 4.20 (a,b) and Fig. 4.26 (a,b,c) & 4.28 (a,b,c). The maximum basal thickness was recorded under *Flemingia macrophylla* + maize + P2 (T14) treatments in the first year (2.5) and at 60 DAS in the second year (4.48). At 120 DAS and 180 DAS in the second year, *Flemingia macrophylla* + maize + P1 (T13) and *Flemingia macrophylla* + rice+ P1 (T16) recorded the highest basal thickness. The two years' study shows no marked significant effect of pruning management on basal thickness of the tree species.

Fig. 4.25 (a): Plant height of tree species in cm (1st year)

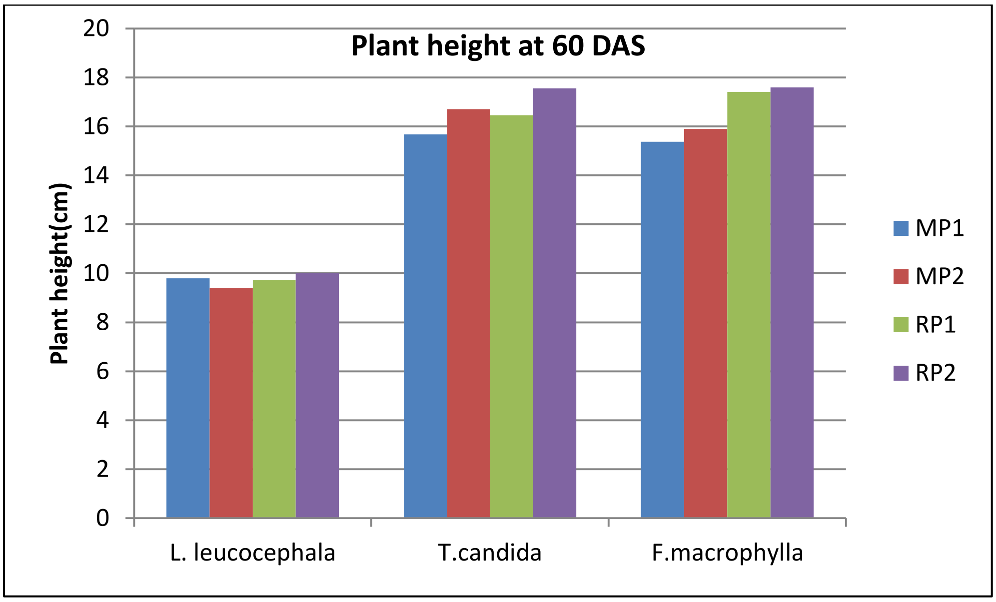


Table 4.17 (a): Height of tree species in cm (1st Year)

Days after sowing (DAS)	Mean height of tree species in cm		Pruning management & combination of trees with maize & rice			
			Maize + 1 pruning M P_1	Maize + 2 pruning MP_2	Rice + 1 pruning RP_1	Rice + 2 pruning RP_2
60 DAS	*Leucaena leucocephala*	**Mean**	9.8	9.4	9.73	10.00
		SE±	.367	.465	.462	.414
		SD	1.424	1.804	1.791	1.603
		$CD_{5\%}$	0.939			
	Tephrosia candida	**Mean**	15.68	16.7	16.46	17.56
		SE±	.847	.894	.748	.764
		SD	3.281	3.464	2.897	2.959
		$CD_{5\%}$	2.364			
	Flemingia macrophylla	**Mean**	15.37	15.90	17.41	17.6
		SE±	.849	.764	.629	.667
		SD	3.29	2.91	2.348	2.586
		$CD_{5\%}$	2.738			
120 DAS	*Leucaena leucocephala*	**Mean**	18.9	16.41	17.52	14.4
		SE±	1.272	.775	.994	1.105
		SD	4.927	3.001	3.851	4.280
		$CD_{5\%}$	2.704			
	Tephrosia candida	**Mean**	161.86	159.6	154.53	164
		SE±	5.688	5.725	5.003	6.656
		SD	22.032	22.173	19.379	25.779
		$CD_{5\%}$	16.801			
	Flemingia macrophylla	**Mean**	62.42	58.3	57.81	60.94
		SE±	3.587	2.045	3.718	4.010
		SD	13.892	7.922	14.401	15.530
		$CD_{5\%}$	13.583			

Table 4.17 (b): Height of tree species in cm (1st Year)

Days after sowing (DAS)	Mean height of tree species in cm		Pruning management & combination of trees with maize & rice			
			Maize + 1 pruning M P_1	Maize + 2 pruning MP_2	Rice + 1 pruning RP_1	Rice + 2 pruning RP_2
180 DAS	*Leucaena leucocephala*	**Mean**	25.76	20.6	20.23	18.3
		SE+	2.602	1.10	1.015	.938
		SD	10.078	4.26	3.931	3.634
		$CD_{5\%}$	6.670			
	Tephrosia candida	**Mean**	202.24	194.04	194.80	198.08
		SE+	2.916	3.270	3.619	4.405
		SD	11.297	12.66	14.019	17.061
		$CD_{5\%}$	8.685			
	Flemingia macrophylla	**Mean**	91.26	95.43	88.6	91.86
		SE+	1.350	2.00	1.632	1.233
		SD	5.229	7.747	6.322	4.778
		$CD_{5\%}$	4.250			

Fig. 4.25(b): Plant height of tree species in cm (1st year)

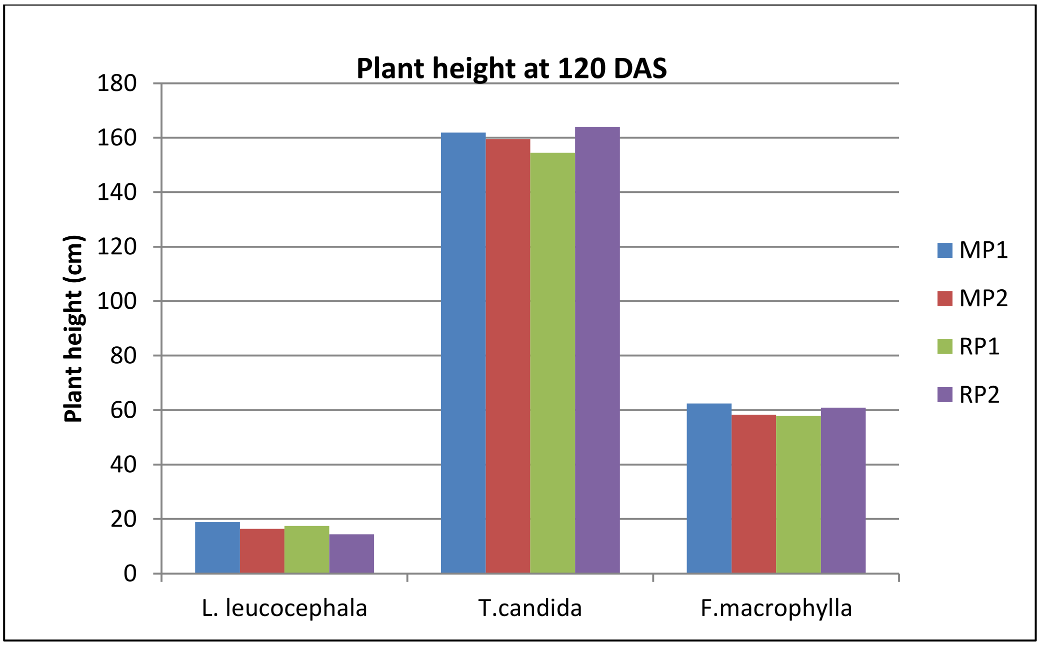


Fig. 4.25 (c): Plant height of tree species in cm (1st year)

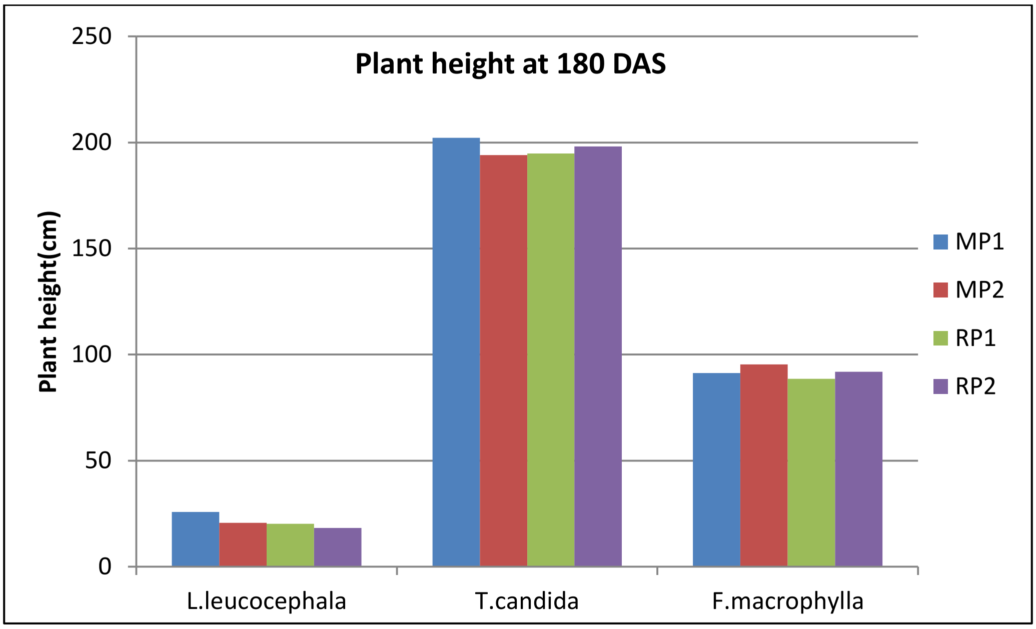


Table 4.18 (a): Basal thickness of tree species in cm (1st Year)

Days after sowing (DAS)	Mean basal thickness of tree species in cm		Pruning management & combination of trees with maize & rice			
			Maize + 1 pruning M P_1	Maize + 2 pruning MP_2	Rice + 1 pruning RP_1	Rice + 2 pruning RP_2
60 DAS	*Leucaena leucocephala*	**Mean**	1.95	2.02	1.83	1.9
		SE±	.059	.059	.045	.030
		SD	.229	.230	.175	.119
		$CD_{5\%}$	0.135			
	Tephrosia candida	**Mean**	4.4	4.59	4.52	4.68
		SE±	.076	.111	.070	.069
		SD	.296	.431	.273	.267
		$CD_{5\%}$	0.314			
	Flemingia macrophylla	**Mean**	2.34	2.47	2.24	2.5
		SE±	.041	.041	.064	.055
		SD	.159	.162	.250	.213
		$CD_{5\%}$	0.144			

Table 4.18 (b): Basal thickness of tree species in cm (1st Year)

Days after sowing (DAS)	Mean basal thickness of tree species in cm		Pruning management & combination of trees with maize & rice			
			Maize + 1 pruning M P_1	Maize + 2 pruning MP_2	Rice + 1 pruning RP_1	Rice + 2 pruning RP_2
120 DAS	*Leucaena leucocephala*	**Mean**	2.24	2.24	2.1	2.12
		SE±	.061	.052	.052	.036
		SD	.238	.203	.201	.142
		$CD_{5\%}$	0.0185			
	Tephrosia candida	**Mean**	5.17	5.2	5.5	5.42
		SE±	.093	.108	.082	.084
		SD	.361	.420	.319	.325
		$CD_{5\%}$	0.292			
	Flemingia macrophylla	**Mean**	2.87	3.01	2.68	2.96
		SE±	.056	.060	.062	.049
		SD	.218	.235	.242	.191
		$CD_{5\%}$	0.135			
180 DAS	*Leucaena leucocephala*	**Mean**	2.51	2.59	2.34	2.34
		SE±	.070	.066	.061	.046
		SD	.272	.257	.238	.180
		$CD_{5\%}$	0.254			
	Tephrosia candida	**Mean**	5.85	5.84	5.8	5.94
		SE±	.103	.116	.115	.107
		SD	.401	.451	.448	.415
		$CD_{5\%}$	0.166			
	Flemingia macrophylla	**Mean**	3.28	3.42	3.09	3.28
		SE±	.067	.100	.074	.050
		SD	.262	.388	.289	.197
		$CD_{5\%}$	0.235			

Fig. 4.26 (a): Basal thickness of tree species in cm (1st year)

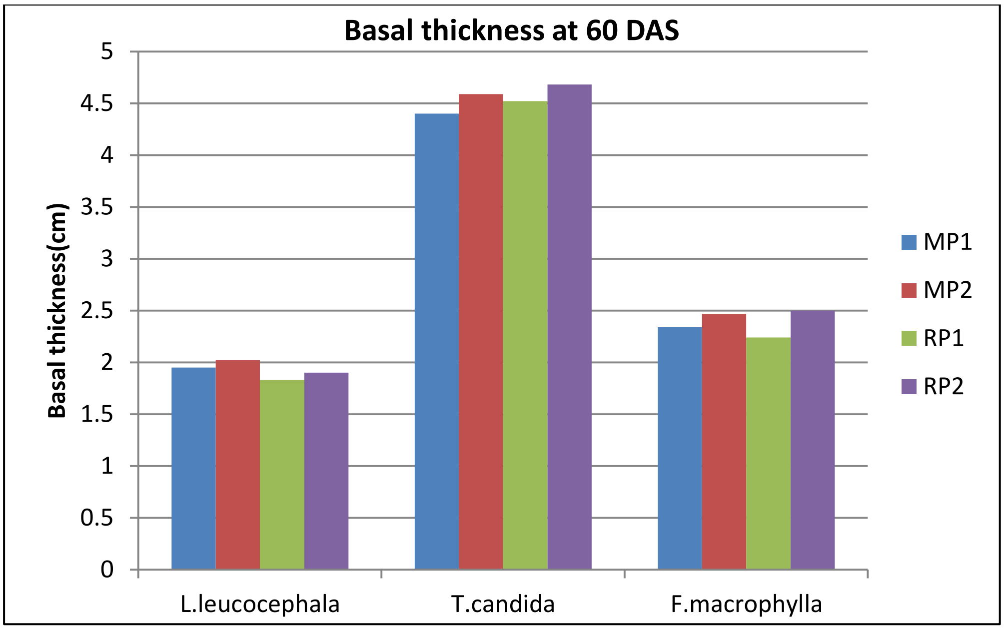


Fig. 4.26 (b): Basal thickness of tree species in cm (1st year)

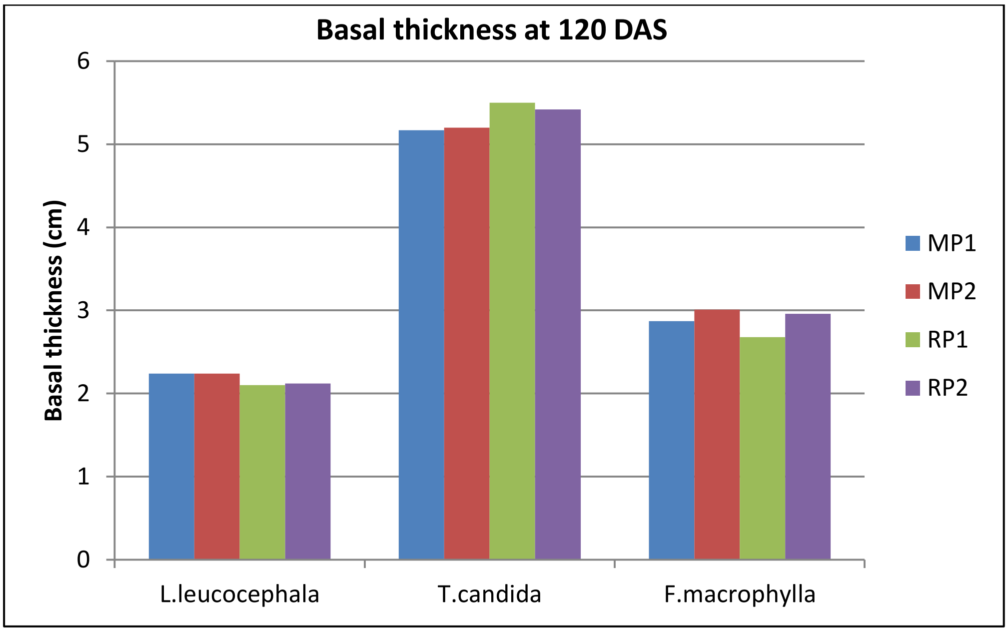


Fig. 4.26(c): Basal thickness of tree species in cm (1st year)

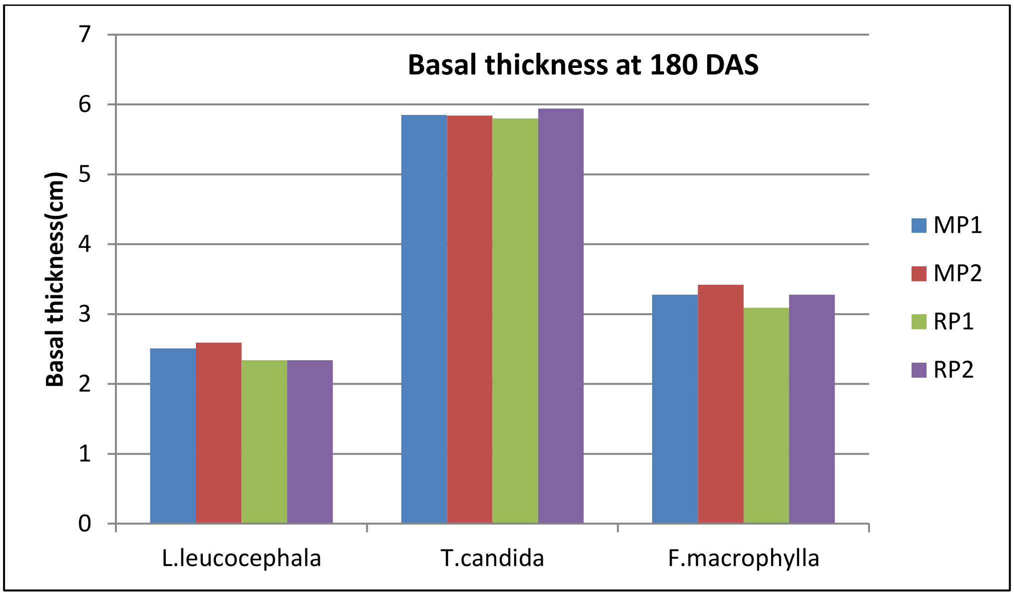


Table 4.19 (a): Height of tree species in cm (2nd Year)

Days after sowing (DAS) of maize and rice	Mean height of tree species in cm		Pruning management &combination of trees with maize & rice			
			Maize + 1 pruning **M P_1**	Maize + 2 pruning **MP_2**	Rice + 1 pruning **RP_1**	Rice + 2 pruning **RP_2**
60 DAS	*Leucaena leucocephala*	**Mean**	31.06	26.86	26.66	24.93
		SE±	2.819	1.297	.913	.907
		SD	10.918	5.026	3.538	3.514
		$CD_{5\%}$	7.906			
	Tephrosia candida	**Mean**	256.66	245.93	245.8	249.6
		SE±	3.834	5.635	4.78	5.369
		SD	14.85	21.825	18.51	20.797
		$CD_{5\%}$	16.915			
	Flemingia macrophylla	**Mean**	128.8	127.8	128.93	133.26
		SE±	2.822	2.507	2.56	1.593
		SD	10.929	9.711	9.917	6.169
		$CD_{5\%}$	9.453			

Table 4.19 (b): Height of tree species in cm (2nd Year)

Days after sowing (DAS) of maize and rice	Mean height of tree species in cm		Pruning management &combination of trees with maize & rice			
			Maize + 1 pruning M P_1	Maize + 2 pruning MP_2	Rice + 1 pruning RP_1	Rice + 2 pruning RP_2
120 DAS	*Leucaena leucocephala*	**Mean**	37.93	33.13	34.46	33.06
		SE+	3.386	1.949	1.21	.992
		SD	13.117	7.548	4.688	3.844
		$CD_{5\%}$	12.055			
	Tephrosia candida	**Mean**	304.66	291.06	298.13	302.06
		SE+	4.586	5.174	5.325	6.311
		SD	17.762	20.040	20.625	24.44
		$CD_{5\%}$	12.630			
	Flemingia macrophylla	**Mean**	178.4	174.73	180.6	182.6
		SE+	3.193	3.269	2.343	2.235
		SD	12.368	12.66	9.077	8.658
		$CD_{5\%}$	6.157			
180 DAS	*Leucaena leucocephala*	**Mean**	45.6	40.26	40.26	39.2
		SE+	3.821	1.76	1.039	.738
		SD	14.802	6.818	4.026	2.858
		$CD_{5\%}$	12.152			
	Tephrosia candida	**Mean**	313.26	307.13	307.06	309.33
		SE+	3.89	4.294	4.04	4.719
		SD	15.068	16.63	15.65	18.278
		$CD_{5\%}$	6.743			
	Flemingia macrophylla	**Mean**	201.4	194.2	200.46	203.46
		SE+	3.367	3.524	2.184	2.307
		SD	113.04	13.649	8.458	8.935
		$CD_{5\%}$	5.717			

Fig. 4.27 (a): Plant height of tree species in cm (2nd year)

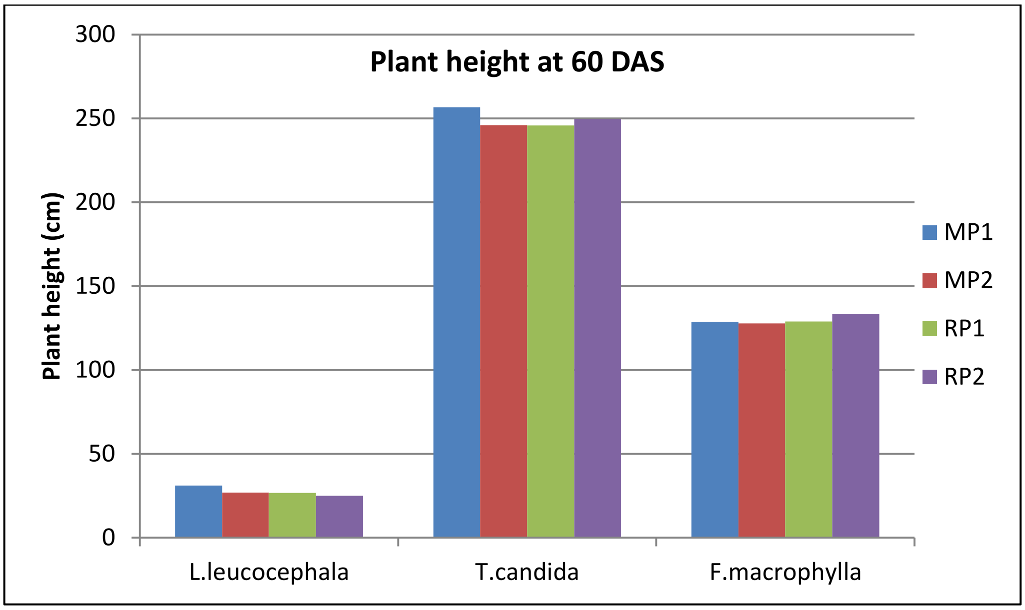


Fig. 4.27(b): Plant height of tree species in cm (2nd year)

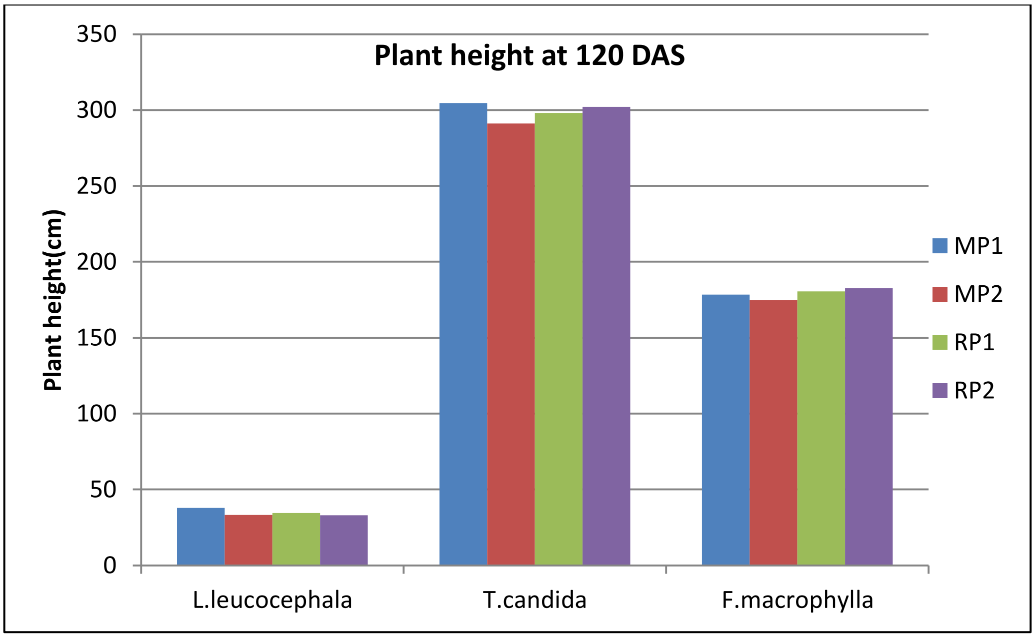


Fig. 4.27 (c): Plant height of tree species in cm (2nd year)

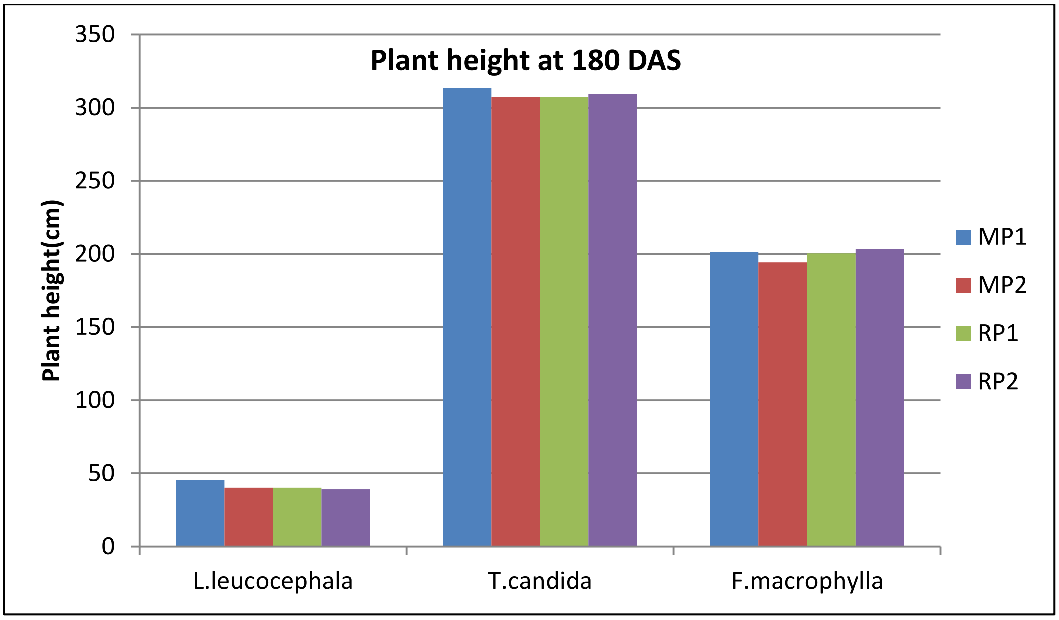


Table 4.20(a) : Basal thickness of tree species in cms (2nd Year)

Days after sowing (DAS) of maize and rice	Mean basal thickness of tree species in cm		Pruning management & combination of trees with maize & rice			
			Maize + 1 pruning M P_1	Maize + 2 pruning MP_2	Rice + 1 pruning RP_1	Rice + 2 pruning RP_2
60 DAS	*Leucaena leucocephala*	**Mean**	2.84	2.82	2.64	2.63
		SE$\pm$	.080	.072	.600	.047
		SD	.313	.280	.232	.183
		$CD_{5\%}$	0.271			
	Tephrosia candida	**Mean**	7.04	7.00	7.07	7.27
		SE$\pm$	.137	.124	.144	.150
		SD	.531	.480	.561	.582
		$CD_{5\%}$	0.203			
	Flemingia macrophylla	**Mean**	4.38	4.48	4.24	4.37
		SE$\pm$	.080	.055	.066	.052
		SD	.313	.216	.255	.205
		$CD_{5\%}$	0.197			

Table 4.20(b) : Basal thickness of tree species in cms (2nd Year)

Days after sowing (DAS) of maize and rice	Mean basal thickness of tree species in cm		Pruning management & combination of trees with maize & rice			
			Maize + 1 pruning M P_1	Maize + 2 pruning MP_2	Rice + 1 pruning RP_1	Rice + 2 pruning RP_2
120 DAS	*Leucaena leucocephala*	**Mean**	3.14	3.08	2.96	2.92
		SE±	.096	.086	.061	.045
		SD	.373	.335	.238	.175
		$CD_{5\%}$	0.336			
	Tephrosia candida	**Mean**	8.44	8.45	8.33	8.54
		SE±	.153	.167	.145	.159
		SD	.592	.649	.564	.618
		$CD_{5\%}$	0.325			
	Flemingia macrophylla	**Mean**	5.58	5.57	5.37	5.51
		SE±	.065	.057	.051	.070
		SD	.254	.221	.198	.274
		$CD_{5\%}$	0.185			
180 DAS	*Leucaena leucocephala*	**Mean**	3.40	3.37	3.29	3.24
		SE±	.102	.067	.047	.046
		SD	.397	.263	.183	.180
		$CD_{5\%}$	0.332			
	Tephrosia candida	**Mean**	9.43	9.19	9.10	9.09
		SE±	.172	.205	.172	.176
		SD	.668	.795	.669	.683
		$CD_{5\%}$	0.267			
	Flemingia macrophylla	**Mean**	6.52	6.84	6.87	6.8
		SE±	.067	.144	.124	.109
		SD	.263	.557	.483	.424
		$CD_{5\%}$	0.254			

Fig. 4.28(a): Basal thickness of tree species in cm (2nd year)

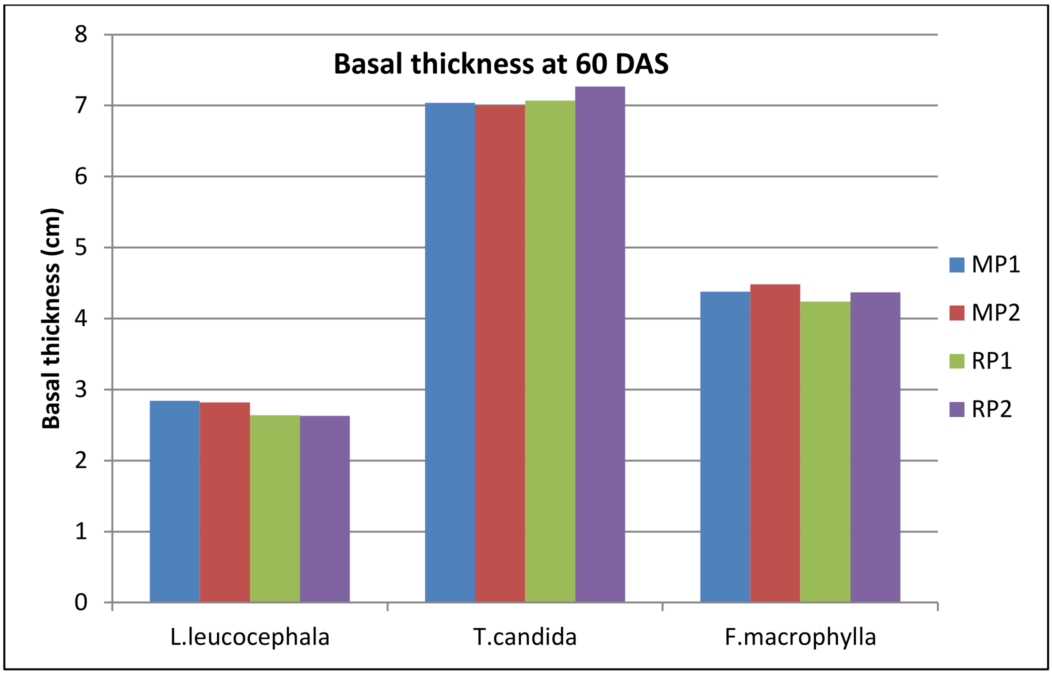


Fig. 4.28(b): Basal thickness of tree species in cm (2nd year)

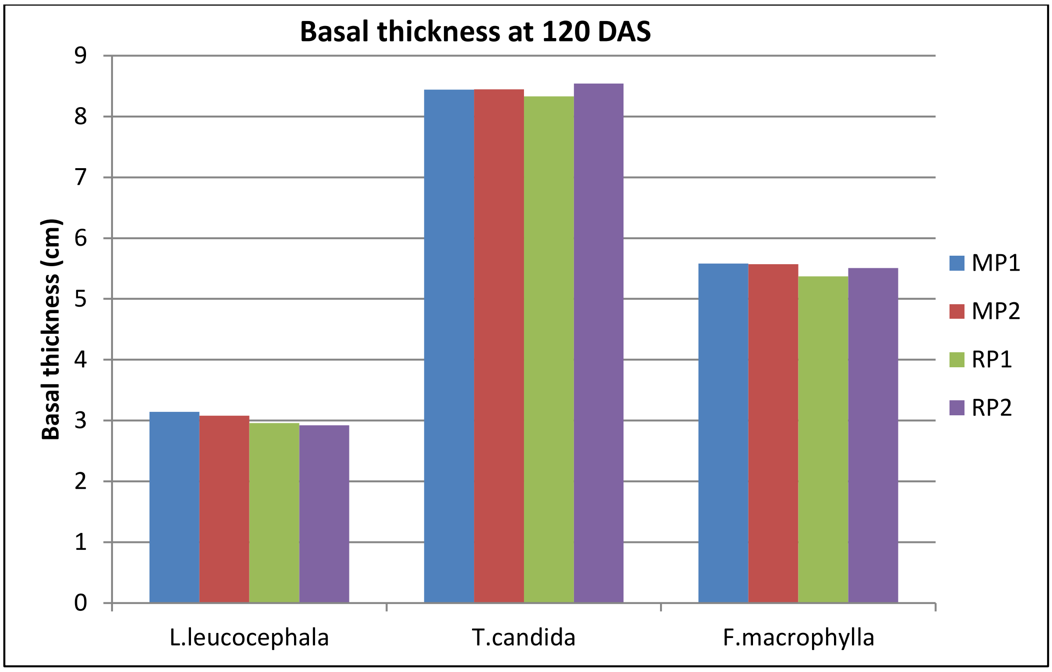


Fig. 4.28(c): Basal thickness of tree species in cm (2nd year)

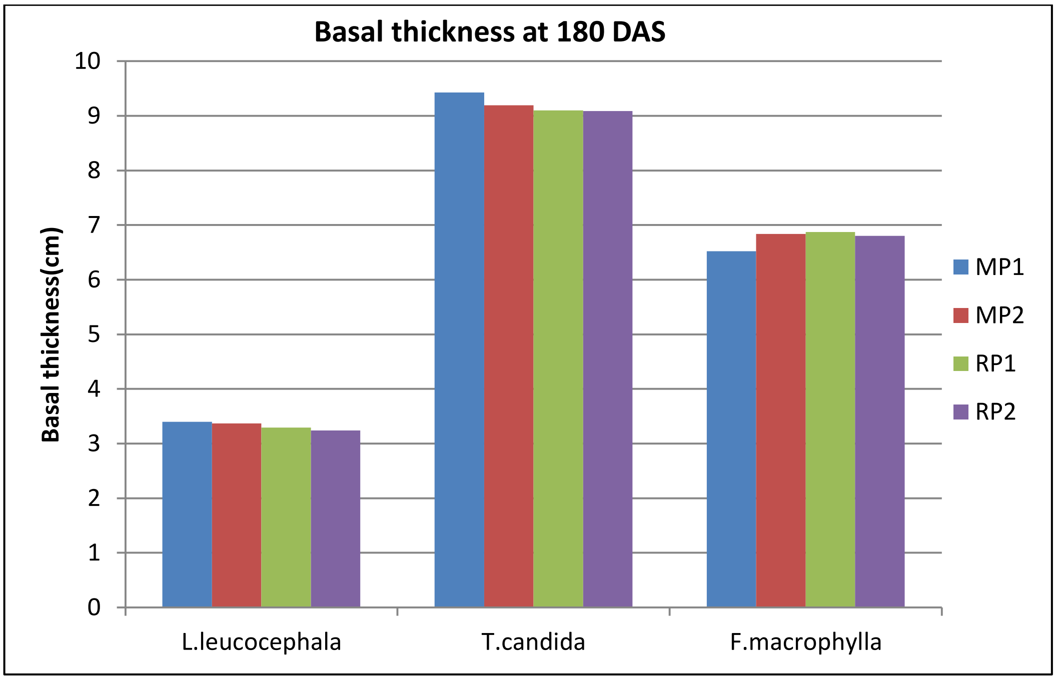


Table 4.21: one-way ANOVA table for growth parameters of leguminous tree species (1st Year)

Source of variation	Parameters	60 DAS		120 DAS		180 DAS	
		F-Ratio	*p-Level*	*F-Ratio*	*p-Level*	*F-Ratio*	*p-Level*
Leucaena leucocephala	Plant height in cms	.487 NS	.701	3.418 NS	.073	1.583 NS	.268
Tephrosia candida		.741 NS	.557	.405 NS	.754	1.279 NS	.346
Flemingia macrophylla		1.119 NS	.397	.179 NS	.907	3.028 NS	.093
Leucaena leucocephala,	Basal thickness in cms	2.458 NS	.138	1.122 NS	.396	1.729 NS	.238
Tephrosia candida		.931 NS	.468	2.188 NS	.167	.820 NS	.518
Flemingia macrophylla		4.877**	.033	7.675*	.010	2.345 NS	.149

* Significant at P<0.01, ** Significant<0.05, NS = Non-significant

Table 4.22: one-way ANOVA table for growth parameters of Leguminous tree species (2nd Year)

Source of variation	Parameters	60 DAS		120 DAS		180 DAS	
		F-Ratio	*p-Level*	*F-Ratio*	*p-Level*	*F-Ratio*	*p-Level*
Leucaena leucocephala	Plant height in cm	.751 NS	.552	.248 NS	.861	.391 NS	.763
Tephrosia candida		.627 NS	.618	1.508 NS	.285	1.287 NS	.343
Flemingia macrophylla		.457 NS	.719	2.071 NS	.183	3.370 NS	.075
Leucaena leucocephala,	Basal thickness in cm	1.124 NS	.395	.633 NS	.614	.357 NS	.785
Tephrosia candida		2.340 NS	.150	.469 NS	.712	2.397 NS	.144
Flemingia macrophylla		1.687 NS	.246	1.792 NS	.226	2.758 NS	.112

* Significant at P<0.01, ** Significant at P<0.05, NS = Non-significant

Fig.4.29 : Rice grown as sole crop (2nd year)

Fig. 4.30 : *Flemingia macrophylla* before pruning (2nd year)

Fig.4.31. *Tephrosia candida* before pruning (2nd year)

4.5 Analysis of soil nutrient status of the experimental plot

The soil nutrient status of the experimental plot (pH, OC, N, P and K) was tested before sowing of tree species and agricultural crops in the first year and the subsequent soil samples were then collected at an interval of 45 days during the cropping period of two years of study. In the second year, the soil samples were collected from 45 days after sowing of maize and rice. In general the soil is sandy loam and dark brown in colour, well-drained having deep and good texture. The results of the soil analysis for the two years are presented in Tables 4.23(i-iii).

4.5.1 Soil pH

The soil pH before sowing of crops in the first year of the experiment is very strongly acidic to strongly acidic in nature ranging from 4.96 to 5.28. After 45 days of sowing of crops, the soil analysis shows slight changes in soil pH in all the treatments. At 180 DAS, minor increase in soil pH was observed in plots having tree species as treatment combinations. At 135 DAS in the second year, the soil pH declined again to very strongly acidic and *T.candida* recorded the lowest and extremely acidic soil pH (4.21). The soil pH obtained at the end of two years of experimentation (135 DAS) were lower than the initial soil pH recorded at the beginning of the investigation (Fig.4.35).

Fig. 4.32 : Maize + *Leucaena leucocephala* (2nd year)

Fig.4.33. Rice+ *Flemingia macrophylla* (2nd year)

Fig. 4.34. Maize + *Flemingia macrophylla* (2nd year)

4.5.2 Organic carbon (%)

Results of the chemical analysis of the soil samples are high in organic carbon in the first year, all the soil samples shows declining trend till 180 DAS except *Flemingia macrophylla* and *Leucaena leucocephala* at 90 DAS which recorded slight increase in organic carbon (1.95 & 2.04). The first soil analysis for the second year highlighted increase in organic carbon this may be attributed to fallow period in between the first and the second year of experimentation. *Flemingia macrophylla* recorded the highest organic carbon at the end of the experiment (1.59). In general, decrease in organic carbon was observed in all the soil samples at the end of the experiment.(Fig.4.36)

4.5.3 Nitrogen

The initial soil analysis shows that before the start of the present study, control plot and plot under *Tephrosia candida* were medium in Nitrogen content, meanwhile plots under *Flemingia macrophylla* and *Leucaena leucocephala* were low in nitrogen content. The soil analysis after harvest of crops in the first year shows considerable declined in nitrogen content except *Leucaena leucocephala* which recorded higher nitrogen content than the initial soil analysis result (285.6). In the second year, after harvest of the crops, all the soil samples including control plot shows declined in nitrogen content, except plot under *Flemingia macrophylla* which recorded higher nitrogen content (282.06) than the initial soil analysis at the end of the experiment (Fig.4.37).

4.5.4 Phosphorous

The initial soil analysis has shown medium phosphorous content of the soil samples. Though fluctuations in Phosphorous content of the soil samples from treatments of tree species were observed at different stages of crop growth, Phosphorus content of the soil tended to gradually declined in all the plots till harvest of crops at the end of two years of investigation. A decline in Phosphorous content was lowest in control plot (7.62) at the end of two years of study (Fig.4.38).

4.5.5 Potassium (K)

The analysis of soil samples at the beginning of the experimentation have shown that all the soil samples were medium in Potassium content, plot having *Flemingia macrophylla* treatment started with the lowest Potassium content (153.44).

Potassium content of the experimental plot gradually declined with crop stages except treatment under *Flemingia macrophylla* that exhibit increasing trend of Potassium at 180 DAS in the first year (162.18) and at 45 DAS in the second year (173.15) and gradually declined again. At the end of the experiment, *Tephrosia candida* recorded the highest content of Potassium during the two years of experimentation (229.84). The results of first soil analysis for the second year demonstrated that plots under treatment of tree species recorded increased in nutrient contents after the fallow period between two years of investigation (Fig.4.39).

Table 4.23(i): Soil nutrient status of the experimental plot

Treatment Plots	Soil pH							
	Soil nutrient status of experimental plot in the first year					Soil nutrient status of experimental plot in the second year		
	Before sowing of crops	45 DAS	90 DAS	135 DAS	180 DAS	45 DAS	90 DAS	135 DAS
Control Plot	4.96	4.67	4.89	4.15	4.23	4.25	4.33	4.61
Flemingia macrophylla	5.28	4.81	4.95	4.23	5.45	4.18	4.08	4.58
Tephrosia candida	4.99	4.77	4.77	5.29	5.78	4.23	4.59	4.21
Leucaena leucocephala	5.16	4.55	4.75	5.17	5.14	4.41	4.48	4.63
Organic Carbon (%)						**Organic Carbon (%)**		
Control Plot	1.83	1.74	1.68	1.5	1.02	1.59	1.47	1.08
Flemingia macrophylla	1.89	1.95	1.32	1.2	1.23	1.59	2.25	1.59
Tephrosia candida	1.74	1.2	1.65	1.68	1.5	1.89	1.62	1.14
Leucaena leucocephala	1.59	2.04	1.62	1.92	1.44	1.98	1.23	1.17

Table 4.23(ii): Soil nutrient status of experimental plot

Treatment Plots	Nitrogen(kg/ha)							
	Soil nutrient status of experimental plot in the first year					Soil nutrient status of experimental plot in the second year		
	Before sowing of crops	**45 DAS**	**90 DAS**	**135 DAS**	**180 DAS**	**45 DAS**	**90 DAS**	**135 DAS**
Control Plot	301.06	293.04	290.95	288.51	270	280.32	263.42	254.22
Flemingia macrophylla	278.62	263.42	270.50	250.88	213.25	318.69	301.14	282.06
Tephrosia candida	303.02	313.6	238.34	200.7	238.34	345.86	326.14	258.65
Leucaena leucocephala	275.97	280.42	226.14	271.45	285.6	310.6	224.32	213.6
	Phosphorus(kg/ha)					**Phosphorus(kg/ha)**		
Control Plot	21.17	16.69	20.38	15.46	6.16	9.07	10.53	7.62
Flemingia macrophylla	24.3	20.38	18.7	20	10.55	9.63	10.86	12.99
Tephrosia candida	19.38	11.09	16.46	12.99	12.8	15.01	18.14	11.31
Leucaena leucocephala	23.63	18.26	21.84	18.7	21.17	15.12	18.78	12.77

Table 4.23(iii): Soil nutrient status of experimental plot

Treatment Plots	Potassium (kg/ha)							
	Soil nutrient status of experimental plot in the first year					Soil nutrient status of experimental plot in the second year		
	Before sowing of crops	**45 DAS**	**90 DAS**	**135 DAS**	**180 DAS**	**45 DAS**	**90 DAS**	**135 DAS**
Control Plot	204.29	173.15	168	167.78	136.64	102.37	87.14	85.57
Flemingia macrophylla	153.44	135.3	101.92	111.55	162.18	173.15	135.74	93.41
Tephrosia candida	250.88	147.39	237.44	172.7	175.26	208.22	238.13	229.84
Leucaena leucocephala	287.84	239.01	162.4	156.13	193.31	201.78	163.07	125.89

Fig. 4.35: Soil pH of the experimental plot

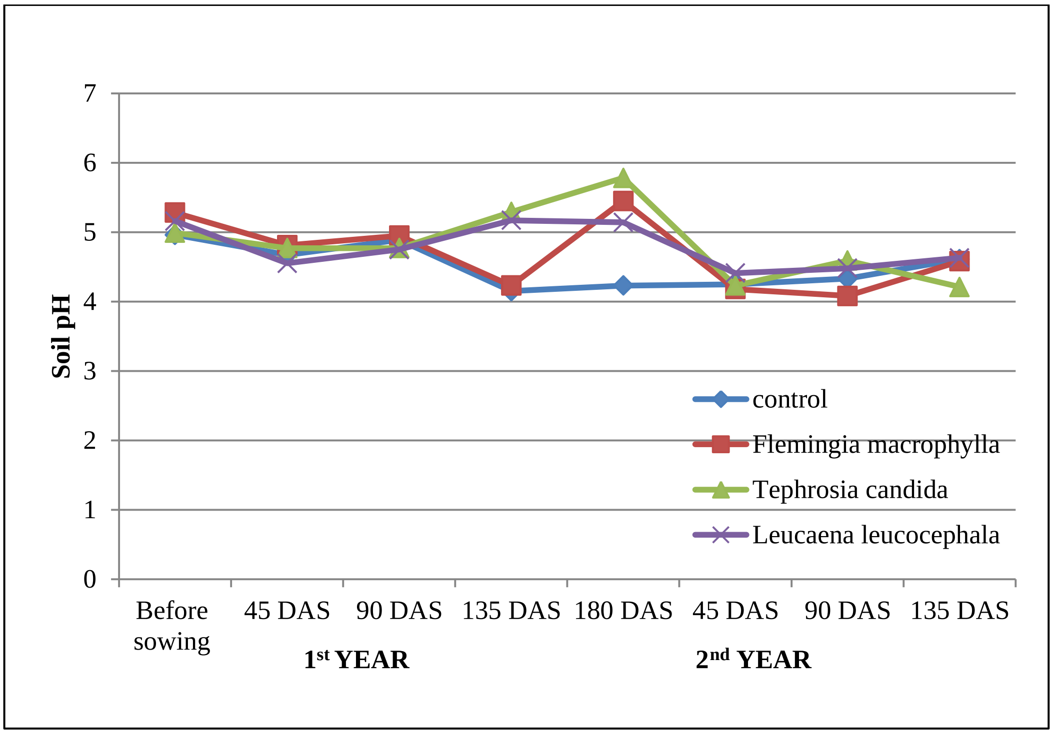


Fig. 4.36: Soil Organic carbon (%) content of the experimental plot

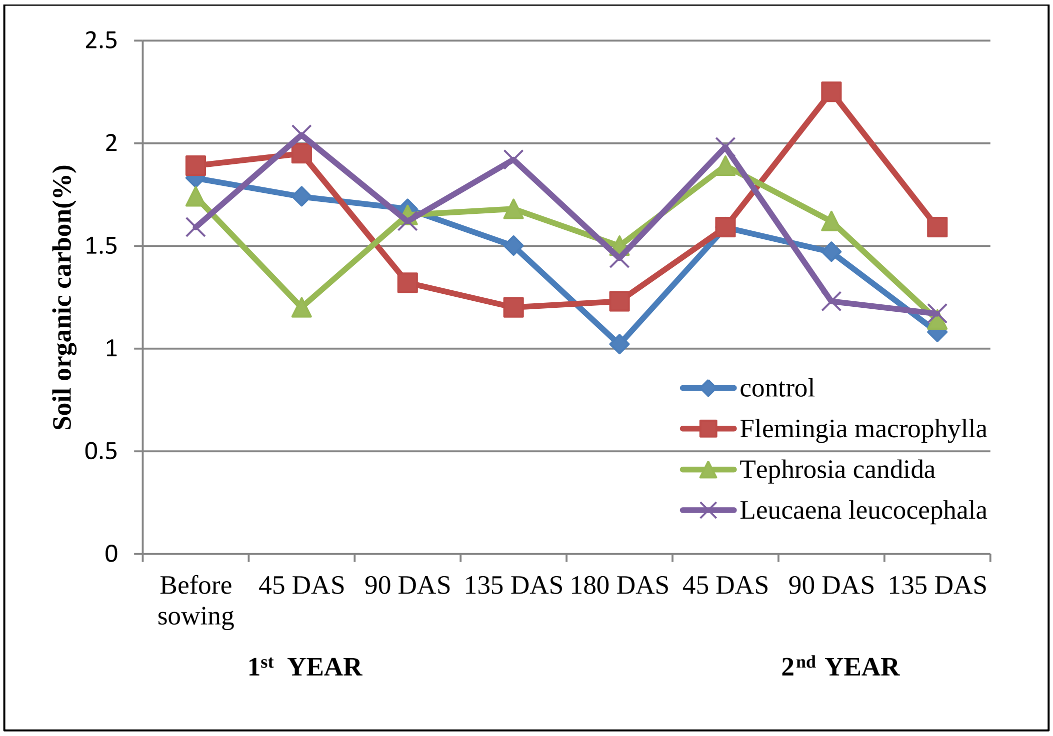


Fig. 4.37: Nitrogen content of the experimental plot (kg/ha)

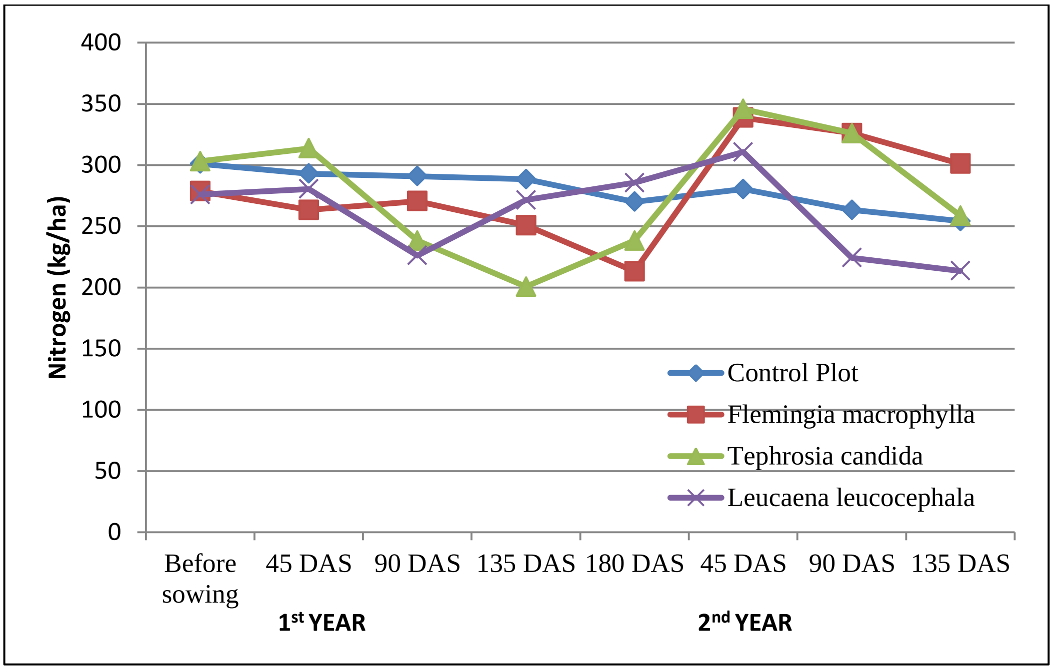


Fig. 4.38: Phosphorus content of the experimental plot (kg/ha)

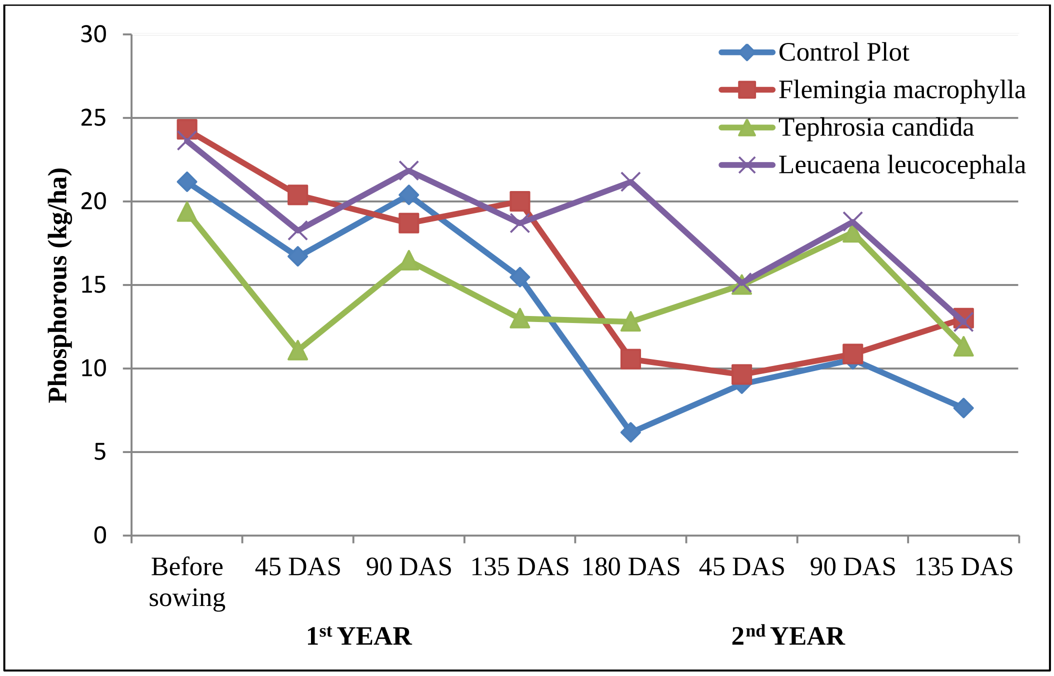
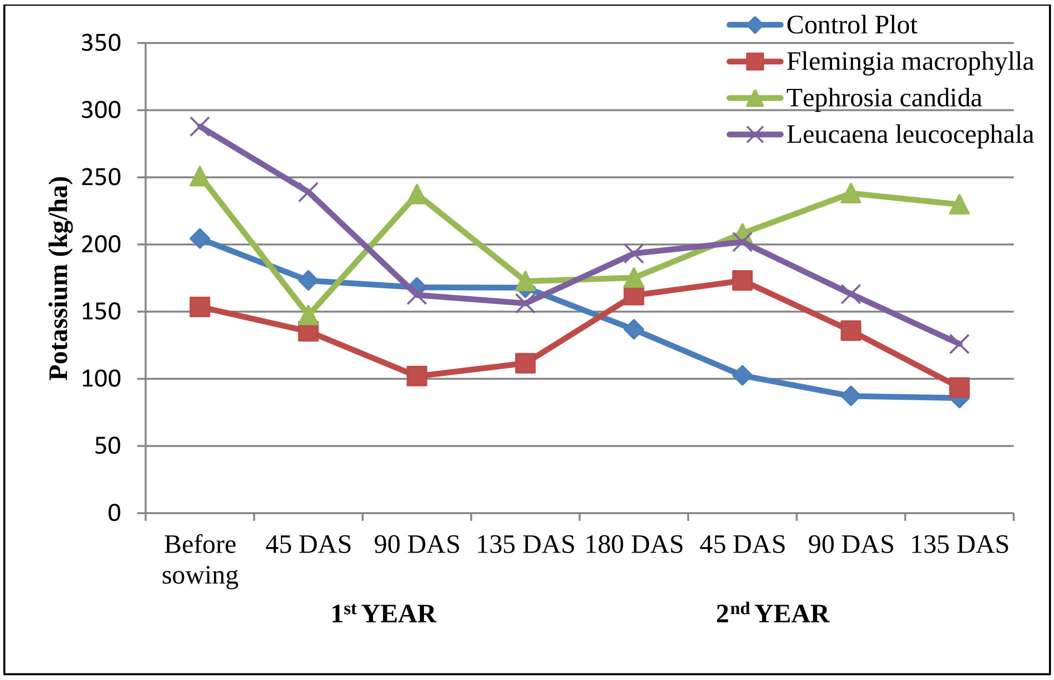


Fig. 4.39: Potassium content of the experimental plot (kg/ha)



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CHAPTER -5

DISCUSSION

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CONCLUSION

CHAPTER – 5

DISCUSSION AND CONCLUSION

5.1. DISCUSSION

The present investigation entitled, 'Performance of three newly introduced leguminous tree species in agroforestry systems of Mizoram and their effect on agricultural crops' was carried out under rain-fed upland condition of Mizoram in 2005 and repeated in 2006. The purpose of the present experimentation is to examine the effect of leguminous tree species grown as double hedgerows in a closed plant to plant spacing, on the growth and yield of maize and rice in upland condition of Mizoram. The contour live hedgerows is considered to collect detached fertile top soil later to be employed as natural or live terraces in the long run. Smucker *et al.*(1995) reported differences to the downward movement of water and nutrients due to sloping terrain benefiting the crop at the lower level immediately above the hedge.

The investigation also attempts to study pruning effect of leguminous tree species on the growth and yield performance of the companion agricultural crops, the growth performance of the tree species grown with crops and to determine the most suitable tree species for alley cropping alias contour hedgerows in the upland condition of Mizoram. Further, the soil nutrient status of the experimental field (pH, Org. C, N, P and K) was determined before sowing of crops, during and after harvest of crops at an interval of 45 days.

The experiment was conducted using Randomized Block Design (RBD) with three replications. There were 18 sub-plots or treatment combinations in each replications and the total sub – plots were 54 in total. The treatments consist of 3 different leguminous tree species viz. *Leucaena leucocephala*, *Tephrosia candida and Flemingia macrophylla* grown separately, each species having 2 rows of double densely populated hedges. Maize and rice were grown alternatively in the alleys between the hedgerows. Hedgerows were allowed to grow undisturbed during the fallow period. Each tree species has separate control plot of maize and rice grown as sole crop for comparison. Therefore, the average of growth and yield parameters of crops and growth parameters of tree species for the first and the second year (five observations under each of the treatment combinations and their replications) were taken into consideration for further analysis. The mean trends of all the observations were portrayed by using graph. The results thus obtained in this regard, presented in the previous chapter are discussed in this chapter in the light of available literature and evidence as under.

5.1.1 Growth performance of Maize and Rice

The statistical analysis of data for the first year showed that plant height of maize was highly significant at 20 DAS and 100 DAS and the results in the second year were highly significant at all growth stages except at 20 DAS which marked significant result at 0.05 level. All the control plots (maize alone) showed improvement at 20 to 40 DAS and control (T18) recorded the second highest reading at this stage but gradually declined again showing lower growth performance till harvest of the crop. The maximum growth performance was observed during 40 DAS to 60 DAS in both the years.

In the case of rice, though the analysis of plant height showed significant effect of treatments at different growth stages especially in the second year, no distinct differences in the mean values were observed between control plots and those under different treatments at 20 DAS. However, treatment combination of *T.candida* + rice + P2 (T11) which is the best performing treatment (38.13) started showing improvement in growth performance at 40 DAS. 40 DAS to 100 DAS marked the peak period for plant growth. This findings agrees with observations made by Avery and Rhodes (1990), who have reported that the enhanced growth of sorghum when intercropped with *L.leucocephala* was confined to a fairly narrow period in the growth of *L.leucocephala* (between 60 and 100 DAP) during which the rate of nitrogen gain of *L.leucocephala* was at its maximum and sorghum grown in the presence of *L.leucocephala* maintained a higher growth rate than sorghum grown alone.

The commendable growth performance of control plots (sole maize & rice) at an early stage of growth may be attributed to lesser competition with tree species for light, nutrients, water and shading effect of tree species. The improved performance of crop components from certain stages of growth as mentioned above may be attributed to availability of moisture, warm and humid temperature as the two crops are known to require hot and humid climate with assured supply of water (Singh, 1998) supplemented by the presence of nitrogen fixing trees (leguminous tree species). This result corroborates the findings of Avery and Rhodes (1990) who have reported significant increase of plant height, dry weight, and total nitrogen content in sorghum grown intercropped with nodulated *L.leucocephala* over the control, sole sorghum.

There were no marked significant tree species-wise effect on the growth performance of maize and rice, but growth performance under different treatments at different stages of growth were generally better than control plots. Nevertheless, the mean highest growth performance for the two years of study in case of maize was obtained from treatment combination of *Flemingia macrophylla* + maize + P2 (123.108) and treatment combination of *Tephrosia candida* + rice + P2 recorded the best growth performance for the two years in case of rice.

While pruning effect on *L.leucocephala* had been negligible in this study, in general crops grown under P2 treatment (two pruning management) resulted higher growth performance than one pruning management. This clearly reveals that reduced tree-crop competition due to pruning resulted better growth performance of crop components. According to Jones *et al*. (1996), hedgerows may decrease nutrient availability if they compete with the alley crop for these nutrients, or may increase nutrient availability if they cycle nutrients from depths not ordinarily accessible to the alley crops. Crops grown nearer to hedgerows usually suffer shading effect and more competition for nutrients. Mugendi *et al.*(1999) observed maize yield decline nearer the hedges which could be attributed to greater root competition due to higher densities of fine roots nearer the hedgerows as was reported by Yamoah *et al.* (1986) and Smucker *et al*. (1995). But Bunderson *et al.*(1991), Kang *et al*. (1981), and Rosecrance *et al.*(1992) found that if hedgerows were pruned in a timely fashion, little yield difference existed between maize next to hedgerows vs. maize away from hedgerows in humid environments.

5.1.2 Yield performance of Maize

Statistical analysis of yield parameters of maize for the two years revealed no significant effect of treatments on the number of cobs per plant and 1000 grain weight in both the years, but significant and highly significant effect of treatments combinations on the grain yield per plot was observed. Significant result at 0.05 level was obtained in number of kernel per cob in both the two years.

The highest mean yield per plot for the two years was obtained from treatment combination of *Flemingia macrophylla* + maize + P2 (24.91 qt/ha) followed by *Tephrosia candida* + maize + P2 combination (22.16 qt/ha). The mean highest number of kernels per cob (245.2) and 1000 grain weight (385.83 gm) for two years were obtained from treatment combination of maize alley-cropped with *L.leucocephala* + P2 (T2). The growth performance of *L.leucocephala* was exceptionally poor during the two years of the experimentation thereby resulting less tree-crop competition for nutrients, light, air and water with the agricultural crops; this may on the other hand have contributed to better yield performance of the companion crops.

The highest maize grain yield per plot (28 qt/ha) in the first year declined to 21.91 qt/ha under the same treatment combinations in the second year. This decrease in maize yield in the treatments that contained tree hedges in situ was most likely the result of below-ground competition between maize crop and tree roots (Mugendi *et al*., 1999). Absence of artificial application of plant nutrients through leaf mulches or inorganic fertilizers may have resulted in yield reduction as the experiment has been carried out in a consecutive years with a short fallow period between the two years, rather short for natural regeneration.

In general, maize alley cropped with woody legumes irrespective of its species performed better than maize grown as sole crop (control). The higher crop yields in the treatment of alley-cropped with woody legumes over control plot is reasonably due to the contribution of the biologically fixed nitrogen from these hedgerow species and from their higher decomposition rates as also reported by Tian *et al*. (1992) and Heineman *et al.* (1997). The result also agrees with the findings of Mugendi *et al.* (1999) who has reported significantly higher yields of maize alley-cropped with *Leucaena leucocephala*, than maize monoculture (both non-fertilized and fertilized) treatments. The result thus obtained shows that the overall best performing treatment combination in terms of growth and yield per plot is treatment combination of *F.macrophylla* + maize + P2. Two pruning operations during the cropping period as indicated by the results has apparently significant effect on the growth and yield of maize, except treatments under *Leucaena leucocephala* which exhibited more or less similar grain yield per plot from P1 and P2 plots.

5.1.3 Yield performance of Rice

The ANOVA table for the yield parameters of rice alley cropped with *L.leucocephala*, *T. candida* and *F.macrophylla* for the two years of the study are presented in Table 4.10 and Table 4.12. Yield parameters of rice collected are weight of grains per plot, number of grains per plant, 1000 grain weight (test weight) at harvest.

The statistical analysis of grain yield per plot revealed highly significant effect of treatments on the grain yield of rice in the first year and non-significant result in the second year. The pattern of mean differences shows that treatment combination of *T.candida* + rice + P2 and *F.macrophylla* + rice + P2 exhibited more or less similar results. Though yield declined was observed in both the treatments, the yield reduction was much higher under *Tephrosia* treatment than *F.macrophylla.* This may be due to more shading effect, more competition for light, nutrients and water, etc, as *Tephrosia* is found to grow well almost double of *Flemingia*'s growth rate during the two years of investigation as evident from the data recorded. This may have adverse effect on the yield performance of the companion crops.

The ANOVA tables showed highly significant effect of treatments on the number of grains per plant of rice in both the years. Non-significant results were obtained from the statistical analysis for 1000 grain weight of rice as affected by the treatments for the two years of the study. The mean values of observations showed that pruning management of tree species have no significant effect on 1000 grain weight. In general, the overall results for two years showed better yield performance under two pruning management than one pruning during the cropping period except number of grains per plant under *Leucaena leucocephala* + P1 treatments in the first year which recorded the highest number of grains per plant under one pruning management.

Although, the mean values obtained revealed no distinct variation in tree species-wise effect on the yield attributes of crops, the second year's results indicated that *F.macrophylla* + rice + P2 performed relatively better than other treatment combinations, this may indicate the suitability of *Flemingia* as hedgerows intercropping.

5.2 Growth performance of tree species.

5.2.1 *Leucaena leucocephala* (Lam.) de Wit

Statistical analysis of plant height for the two years of investigation revealed non-significant result (Table 4.21 & 4.22), it may be mentioned here that, the growth rate of *L.leucocephala* was specifically slow as compared to the other two tree species, two pruning management which was carried out once and twice during the cropping period was not applicable in case of *L.leucocephala* due to the fact that the desired height for hedgerows, about 50cm from the ground level was not attained by the tree during the two years of investigation. Therefore, rows of *L.leucocephala* were left as such without pruning management and measurement was taken at an interval of 60 days, starting from the date of sowing in the first year and 60 days from the date of sowing agricultural crops in the second year.

The mean values of plant height are presented in Table 4.17 & 4.19 and Fig. 4.12 & 4.14. *L.leucocephala* grown with maize showed better performance than alley-cropped with rice in terms of plant height and basal thickness at different growth stages during the two years of investigation. The reason for poor performance of *L.leucocephala* alley-cropped with rice was possibly due to the heavy nutrient uptake and shallow fibrous root system of rice and more competition for sunlight, moisture, etc., which may be detrimental to growth performance of the tree species grown with rice than grown with maize. *L.leucocephala* grows well in neutral to alkaline soil of pH 6.0 to 8.0 (Jha, 1995), as the soil analysis have shown that the experimental site is severely inclined to acidic to extremely acidic in nature, this may also have attributed to poor growth performance of *L.leucocephala.* Fine roots from *L.leucocephala* are generally concentrated below 15 cm, commonly in the 15 to 60 cm depth range (Ong *et al*., 1991; Dhyani *et al*., 1990; Jonsson *et al*., 1988). Maize roots tend to concentrate in the upper 15 cm (Jonsson *et al*., 1988), these differences in root zone may result in reduced competition between maize and *L.leucocephala*.

5.2.2 *Tephrosia candida*

In the first year, *Tephrosia candida* grown with rice performed better than *Tephrosia* grown with maize during the first 4 months, but after harvest of maize, growth performance of *Tephrosia candida* improved considerably and continued till the end of the experiment. This may indicate that reduced tree-crop competition due harvest of maize favourably affected growth performance of the tree species. Significant effect of pruning management was observed in the crop components; two pruning operations recorded higher result in terms of growth and yield parameters of agricultural crops than one pruning though effect of pruning on the tree itself was negligible. The slightly better performance of *Tephrosia candida* grown with maize than rice may be due lesser above-ground competition contributed by shorter cropping period of maize. The growth performance of *Tephrosia* is exceptionally good in comparision with the other two tree species at all the growth stages during the investigation.

5.2.3 ***Flemingia macrohylla*** (Willd.) Merr

The highest growth performance of *Flemingia macrophylla* during the two years of study was obtained from treatment combination of *Flemingia macrophylla* + rice + P2. In general growth performance of *F.macrophylla* grown with rice was better than *Flemingia* grown with maize except at certain stages. In the first year, *Flemingia* started showing improvement after harvest of maize only. This result indicated that tree-crop competition was generally lowered in alley-cropped with rice than alley-cropped with maize during the cropping period. However, basal thickness was slightly higher in *F.macrophylla* grown with maize. Though in this experiment biomass production, leaf mulching, nitrogen return of tree species were not included, available literature have shown that *Flemingia macrophylla* has qualities that suppress nematode populations. Mulching with prunings of *F. macrophylla* resulted in significantly higher retention of soil moisture and lower soil temperatures, retarding weed development than mulching with prunings of *L. leucocephala* (Banful, *et al.,* 2000; Budelman, 1988). Budelman (1989) reported that root nodulation was rare with *F.macrophylla* and he concluded that *F.macrophylla* is less demanding in terms of soil fetility and may potentially perform better under situations of lower soil nutrient status than *L.leucocephala* and *G.sepium.*

The result thus obtained and discussion above indicated that hedgerows of leguminous tree species grown with or alley-cropped with maize and rice have significant effect on the growth and yield of maize and rice as compared to control plots (sole maize and sole rice). It was also observed that two pruning management resulted better performance on the growth and yield parameters of maize and rice than one pruning management during the cropping period. Among the three different tree species tested, *Tephrosia candida* recorded the highest growth performance in terms of height and basal thickness, but their nutrient contribution through root nodules or litter fall was not specifically tested. Significant effect of pruning management on the growth performance of tree species was not detected.

5.3 Soil nutrient status

As the tree species are sown approximately one month before the crop components at the beginning of the study, the performance of *Leucaena leucocephala* was rather poor, the germination and survival of the young tree species was problematic at the initial stage of the investigation to produce significant effect on the growth and yield parameters of the crop components which was perhaps due to hot and long dry spell in the month of April, 2005. Thus the result of different treatments on the soil nutrient as evident from soil analysis at different stages of crop growth also shows no beneficial results or significant changes in the nutrient contents of the soil. All the treatments including control plot except *Flemingia macrophylla* shows lower nutrient contents at the end of the experiment. Considerable decrease in the nitrogen levels of the soil were observed after harvest of crops in all the plots except plot under *F.macrophylla* treatment; this may indicate that a large quantity of nitrogen is absorbed by the crops while the unused portion is lost from the soil most likely through leaching, runoff, denitrification. Daniel (1993) also mentioned that nitrogen fixing trees compete less with crop species than the non-NFTS for nitrogen in soil but in the nitrogen rich soils, species rely on soil nitrogen and their fixation rates are low.

At the end of two years of investigation, plots alley cropped with *Tephrosia candida* and *Flemingia macrophylla* showed lower pH than the control plot. Soil acidification of plots under *L.leucocephala* has also been reported by Heineman *et al*. (1997). Increased soil acidifications in legume based arable systems have also been reported by Coventry (1992).

Decrease in organic carbon was observed in all the soil samples at the end of the experiment but the first soil analysis for the second year of experimentation highlighted increase in organic carbon this may be attributed to fallow period in between the first and the second year of experimentation. Alley cropping with the leguminous species appeared to maintain higher soil organic carbon, phosphorus and potassium levels than the other treatments as observed by Kang *et al*. (1999). Phosphorus content was higher in the alley cropped plots than in the control treatment. Lowest potassium concentration was observed in the control plot and the highest concentration in the *T.candida* plot. A large number of screening and alley cropping trials in different climate-soil environments indicate that pruning of several tree species contain sufficient amount of nutrients to meet crop demand, with notable exception of phosphorous. A significant improvement of nitrogen status, modest in phosphorous and decline in potash status was noticed in red soil at Jhansi (Hazra, 1993).

Tree species were allowed to grow freely during the fallow period between the first year and the second year; this might have positive effect as plots under treatment of tree species demonstrated increase in nutrient contents as shown by the first soil analysis result for the second year (Table 4.23i-iii). Atta-Krah (1990) also mentioned that short period of fallowing has a positive effect on crop yield.

Since leaf mulching is not integrated in the present experiment which is regarded to contribute increased growth and yield performance of crops, the direct beneficial effect of tree species on the companion crops appeared not as effective as expected. Benefit from above ground processes are more pronounced since many studies on the use of prunings as mulch/green manure indicate increase in soil fertility (Kang *et al*, 1981, Pathak, 1987). Budelman (1989) also opined that under circumstances of limited soil nutrient resources, crop and/or animal production systems involving leguminous species should be based on recycling rather than permitting the export of nutrients and considered *L. leucocephala* as a better means to recycle nutrients than other woody legume like *Gliricidia sepium.*

The declined in crop yields were observed in both the crops. However, yield reduction though without inorganic fertilizers as evident from this experiment is not as intense as anticipated, hence it may be safe to assume that woody legumes grown as hedgerows with proper management will be able to sustain crop growth and yield for two years. While beneficial effects may be derived from trees through improved soil fertility, negative interactions between trees and crops can also occur due to above- and belowground competition for resources (Ong, 1996). In the long run, introduction of woody legumes alone as the principal source of plant nutrient although the research results presented here are highly encouraging, may result in land deprivation of essential nutrients thereby causing yield reduction. Kapkiyai *et al.* (1998) also mentioned that the major factor contributing to reduced productivity is soil impoverishment caused by continuous cropping without addition of adequate fertilizers and manures. Prasad (1999) also stated that complimentary use of organic and biological source of plant nutrient along with chemical fertilizer is of great importance for the maintenance of soil health and productivity, especially under intensive cropping system.

5.4 CONCLUSION

As evident from the review of literature and statistical data, vast majority of tribal population inhabiting N.E.India including Mizo people are still practicing shifting cultivation in spite of several government schemes for alternative farming systems. The area annually affected by shifting cultivation in

Mizoram is estimated as 1049.64 km^2 (Anon., 2008). Farmers living in remote areas by and large have no access to fertilizer inputs and other farm equipment in addition to unsuitability of adopting modern mechanized method of farming systems in hilly region like Mizoram. Government of Mizoram has recently launched New Land Use Policy (NLUP) which advocates settled cultivation and sustainable land use system mainly targeting jhum cultivators keeping in view overall development and stabilization of socio-economic condition of the poor (Anon.,2010). Thus, inclusion of nitrogen fixing woody plant in the cropping system may have a scope for sustainable and settled cultivation in hilly areas where valley land and moderate slope of land are not readily available.

The main purpose of the trial among others was to examine the effect of hedgerows of leguminous tree species on yields of maize and rice in absence of any other factors responsible for soil improvement and fertility enhancement strategies. Hence, the experiment was carried out under strict absence of artificial application of fertilizers, soil ameliorants or any other chemical.

From the present study, it has been observed that leguminous tree species grown as hedges have significant effect on the growth and yield of maize and rice which were tested under rain-fed upland condition. Crops when alley-cropped or grown with tree species resulted higher growth performance and grain yield per plot than sole crops (control) in both the years.

Two pruning management shows better result on growth and yield performance of crops than one pruning management, but substantial differences between the tree species on growth and yield performance of crops were not detected. Therefore, regular pruning is recommended to reduce shading effect on the companion crops. Kang *et al*. (1999) also reported that several hedgerow prunings per year were done to minimize shading of the associated crops, the pruning frequency was based on the rate of growth of the woody species, *Gliricidia* and *L.leucocephala* which had higher growth rates were pruned five times annually, while *Alchornea* and *Dactyladenia* were pruned 3–4 times annually. Species wise optimum pruning interval for yield optimization and long term effect on nutritional aspect of leguminous tree species may require further experiments on the upland condition of Mizoram in order to establish the most appropriate and sustainable system.

It is worth mentioning that increase in nitrogen content in plot under treatment of *Flemingia* was observed in the soil analysis at the end of the experiment though declined in nutrient status was observed in general. Other than biomass deposited by the tree species and decomposition of the crop residue no external input of fertilizer was applied to the system, the crop yields in the second year is almost as high as crop yields in the first year. Therefore, it may be inferred that decrease or changes in nutrient status without external application of fertilizers is natural occurrence when crops are grown in a continual basis due to nutrients uptake by the crops.

Thus in order to maintain soil fertility of the system inclusion of biofertilizers, organic manure, mulching with prunings and proper management of hedgerows may be suggested to retain sustainability of the system in the long run. This is supported by several workers who had stressed the beneficial role of organic manure in increasing soil fertility, improving soil physical conditions and microbiological conditions of soil as well as crop yield (Gaur *et al*., 1972; Subba Rao, 1977; De Datta and Hundal , 1984; Son and Ramaswami, 1997). Further, Jayanthi *et al.* (2003) opined that integrated farming system with different components enriches the soil fertility.

The observations and the above discussion revealed that tree species grown with rice performed better than trees grown with maize during the early period of growth stages of crops, and later after harvest of maize, tree species grown with maize shows improved growth performance apparently due to less tree-crop competition as the cropping period of maize is relatively shorter than rice and yield reduction was lower in case of rice than maize in the second year. So it may be concluded that rice may be a better option than maize as a companion crop in hedgerow intercropping with tree species in the present condition.

Finally it was further opined that, in general, the leguminous tree species under trial were beneficial to crop growth and yield, but performance of *Leucaena leucocephala* was not as good as the other two species which may perhaps be due to soil acidity and unfavourable climatic condition of the experimental site for its growth and development. Germination of seed and plant population of this species is lower than the other two species as evident from the experiment. The growth rate at the initial period of growth stages is exceptionally slow, no shading effect on the agricultural crops was observed during the two years of trial period. It is, therefore, recommended that *Leucaena leucocephala* as hedgerows may be grown well in advance or 2-3 years in advance before sowing of short duration agricultural crops to obtain maximum benefit from the tree species in a climatic condition like this.

Germination of seed and growth performance of *Tephrosia candida* is highest among the three species tested. The plant reached full growth within one year, leaf can also be utilized for mulching as reported by Nguyen and Thai (1993). Though the soil test result except nitrogen content do not exhibit increase in nutrient contents but the overall effect obtained from two years study revealed that effect of *Flemingia macrophylla* on the growth and yield performance of crop components was highest and soil test result on increase in nitrogen under *Flemingia* shows a promising trend. Therefore, from the study of two years it may be concluded that out of the three species tested *Flemingia macrophylla* may be the most suitable species for grown as hedgerows in upland rainfed condition of Mizoram as evident from observations obtained. The overall effect of *Flemingia macrophylla* and *Tephrosia candida* are by far not very distinctly different from one another, this also shows that the effect of *T.candida* on performance of crops is reasonably commendable.

In conclusion, results from this study indicate that alley cropping with hedgerows of leguminous tree species is advantageous in the sub-humid upland of Mizoram. Assuming that a farmer is willing to invest in tree establishment and has sufficient labour for hedgerow management, the tree species offer potential advantages over control treatment which is reasonably similar with jhum cultivation.

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