Effect of *Leucaena Leucocephala* on the yield of *Zea Mays* in the humid subtropics of Mizoram.

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I certify that the dissertation entitled "Effect of *Leucaena leucocephala* spacings on the yield of *Zea mays* in the humid subtropics of Mizoram" submitted by Mr. Maxborn M. Sangma for the partial fulfillment of Master of Science in Forestry of the North-Eastern Hill University, Shillong embodies the record of original investigation by him under my supervision. He has been duly registered and the dissertation presented is worthy of being considered as partial fulfillment for the award of M.Sc. Degree. The work has not been submitted for any degree of any other university.

Aizawl
The 17th December 1999

(U.K. Sahoo)
Supervisor

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(MAXBORN M. SANGMA)

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CHAPTER I

INTRODUCTION

Mizoram being basically a hilly state and dominated by Mizo tribes, 'jhum' (local name for shifting cultivation) has been the major occupation of the people of the state (Venkata *et al.*, 1987). According to the report given by the Department of Agriculture, Government of Mizoram, about 70% of total population of the state depends mainly on jhum cultivation for their livelihood and even the government servants are more or less involved in jhum cultivation (Anon., 1996). The land for this practice is distributed by the village chief depending on the availability of land and the number of families residing within his jurisdiction (Prasad and Aggarwal, 1995). Under this cultivation, maize paddy jowar, mustard, chilli, ginger, turmeric, potato, gourd species, radish, various types of lemon etc. are grown (Jha and Lilramnghinglova, 1996). Most of these crops are grown on rainfed conditions (Lianzala, 1998). The Jhum cycle in the past was about 15 years, however due to pressure on land by human as well as livestock population, it has been drastically reduced to a mere 2-3 years or even less than that (Nanda, 1994). The practice of jhum is carried out on moderate to steep slope which accounts for about 24% of the total geographical area of the state (Kumar, 1997).

Jhum cultivation has been the fulcrum of people's normal lives, the sole source of their survival. It is this activity that were into their customs, culture, measures of time, quantities and distances and thus, keep the people occupied for most of the year determining their well being and quality of life. However, the ongoing practice of jhum cultivation is unscientific and ecologically disastrous. The various evil consequences of jhum cultivation has been well documented in the whole North Eastern States of India (Shukla and Aggarwal, 1986). Since the practice involves cutting of jungle followed by slashing, it results in excessive deforestation, soil erosion, nutrient loss and loss in both soil flora and fauna causing land degradation and consequently decline in food production. Though the practice has been condemned by various governmental bodies because of its ill environmental effects, the people have not been made wean away from this practice (Mukherjee, 1974).

Many ecologist and agriculturist have proposed alternative farming systems to jhum cultivation for North Eastern Region and have suggested remedial measures for the deteriorating soil conditions. However none of these farming systems or remedial measures could be well adapted and accepted by the farmers. The failure can be attributed to a number of factor. One notable factor could be the shortage of funds or due to non implementation of the different resource projects (Tewari,1991).Similarly, Mizoram state government had adopted strategic measures through implementation of various projects to wean away the farmers from this cultivation. The various projects had given through Agricultural department, Soil and water conservation department, etc. to construct terraces and infrastructure developments such as roads, houses and drinking water facilities (Borah, 1993). However, as yet, no remedy has been foundalternative to jhum cultivation. Possibly one alternative to jhum cultivation could be the adoption of agroforestry system, which combines agricultural crops and forestry crops on the same unit of land simultaneously or sequentially (Borthakur, *et al.*, 1979). This repeatedly promotes socio-economic upliftment of the people, preserves or improves bio-physical attributes of the land, and ultimately promote general environmental protection (Singh and Tewari, 1990).

The concept of agroforestry is also not very new to the state of Mizoram. The people had been planting the trees in their gardens and orchard without knowing any scientific value of the system like that of the age old system that is slush and burnt agriculture. However, the recent discouragement at all spheres towards jhum cultivation has brought the people the instance of this indigenous from of cultivation (so called homestead forestry). There are several reasons why agroforestry use practiced by the farmers of this region, has re-emerged, about in new forms, as an appropriate form of land use in recent years. One of them is the highly adverse land-man ratio, which is progressively deteriorating in most part of the region. This system is expected to play a very important role to check the adverse effect of land-man ratio (Mahendra *et al.*, 1998).

In the broadest sense, the term 'agroforestry' encompasses all, techniques that attempt to establish or maintain both forest / tree and agricultural production on the same piece of land. According to more strictly definition, agroforsetry systems are characterised by (a) the deliberate growing of woody perennials on the same unit of land as spatial mixture or temporal sequence. (b) There must be a significant interaction (positive and /or negative) between the woody and non woody components and aimed at systematically developing land use systems where the positive interaction between trees and crops is maximized. This seeks to achieve a more productive, sustainable and diversified output from the land than is possible with conventional mono cropping systems (Rao, 1990). The major objective of agroforestry is to optimise production and economic returns per unit area, while respecting the principle of sustainable development (Westly, 1990). In order to obtain this objective, certain agroforestry moddels have been evolved and standarised combining optimum land use system with tree – agricultural – livestock production system to give maximum economic returns, simultaneously or sequentially (Jha and Sarma, 1993). However, there is an utmost need that the models so designed should be technologically feasible, ecologically sustainable, economically viable, and socially acceptable (Rastogi and Srinivas, 1996). The model may not necessarily be perceived as having all the values important to the people, however, it must be able to meet the immediate needs of the people and enhance their economic stability, so that these would be acceptable. Since the psyche of the tribe do not accept a very new technology, the innovative design/technology should be the result of creative transformation emerging from advanced technology combined with empirical methods of tribes (Friere, 1973).In the context of Mizoram where the problem of jhum cultivation and associated problems are acute, there is a need for acute, there is a need for immediate adoption of suitable agroforestry models being the trees and crops, their compatibility should be the foremost aspect in the system. Introduction of non-nitrogen fixing multipurpose tree species do not add much to the system unless they have other utilities or advantages, Similarly, nitrogen fixing tree species are not always good for agroforestry system. The combination of nitrogen fixing tree species with non-nitrogen fixing crop or vice-versa is often advantageous for sustainable crop production (Pathak and Gupta,1994).

Leucaena leucocephala commonly known as subabul is widely practiced elsewhere due to its fast growth, drought, drought resistant and nitrogen fixation (Gogate and Sharma,1981). The leaves pods, and seeds of this species are nutritious, palatable and digestable forage containing 20% crude protein, relished by cattle, sheep and goats (1990). Its roots and bark are used as medicine to relieve internal pain in Assam (Parkash and Hocking, 1985). This species is suitable for afforestation of denuded water sheds and hill slopes, agroforestry and farm forestry (Grewal *et al.*, 1992). Besides, it has tremendous potentiality to increase the yield of intercrops due to its nitrogen fixation ability (Krishnan and Toky, 1993). This species is also useful for plantation where there is a problem of soil erosion and water scarcity (Pathak, 1988). Among other utilities, it also supplements to the fuel and fodder needs of the rural masses (Kaushal and Dhanda, 1988).

Zea mays L.(maize), on the other hand, is one of the important cereal crop of the state (Chatterjee and Das, 1989). It belongs to the family gramineae and sub family Mydeae (Bor, 1991). This species can be well adapted as intercrop along with different tree species and can be grown either as a sole crop or can be mixed with other species (Hazarika and Munda, 1997). Rapid use of chemical fertilizers has been reported to decrease the yield of maize, but growing of maize with different nitrogen fixing tree may increase its yield (Mathew *et al.*, 1992). Maize yield can also be affected when intercropped with Leucaena at different spacings (Lulandala *et al.*, 1995). Legume plants with maize as intercrops generate yield advantage (Khola *et al.*, 1997).

Considering the growing demand of maize by the people of Mizoram because of its palatability, good nutrient value coupled with cheap price and ease availability in the market, there is a need to find out means of increasing maize yields in the state. One such mean is intercropping of maize with Leucaena, hypothesizing that the latter build up nutrients in the system helping increase maize productivity. Besides, the planting spacing of the former is expected to affect the latter's crop yield. Therefore, the present investigation has been undertaken to find out the effect of Leucaena leucocephala spacing on the yield of maize in the humid subtropics of Mizoram.

CHAPTER - II
REVIEW OF LITERATURE

GENETICS OF LEUCAENA :

Leucaena leucocephala (Lam) de Wit. Commonly known as Subabul has about 10 species and is a native of central America. This genus has over 100 varieties, which differ enormously in their size and form often confusing their taxonomy. They can be classified broadly into three types. Viz. (I) Hawaiian type (Short, bushy varieties which grows upto 5 m (15ft) in height that flower between 4-6 months old), (ii) Salvador type (Tall, tree like plants attaining 20 m(65 ft) in height, having large leaves, pods and seeds and thick branches trunks. Originating from inland forest of central America, they are also known as arboreal or Guatemala types. This type now being planted as sources of timber, wood products and industrial fuel, are known as 'Hawaiian Giants' or by the designatoes k8, k28 or k67) and (iii) Peru type (The plant attains upto 15 m (45 ft) height, like the Salvador type but with extensive branching even low down on the trunk (Anon., 1977).

The genus leucaena has tiny flowers formed in white, fluffy balls, which are usually self pollinated. The flower heads produced thin and flat drooping clusters having almost straight pods. The pods are translucent when young are ejecting 15-30 seeds contained in the pod. The seeds are shiny brown in colour and flattened in structure, and they have an impervious wary seed coat. Therefore, the seeds are given different pretreatment to ensure quick and uniform germination. Seed viability is generally high in freshly shed seeds. As compared to Hawaiian Leucaena types, Salvador and Peru types mature more slowly and flower less frequently. The regeneration of the species is possible through, seeds, cuttings and coppicings. The plants raised in the latter method are more vigorous than those raised from seeds (Kapoor, 1981).

LEUCAENA AS A MULTIPURPOSE TREE

Leucaena leucacephala as a multipurpose tree (MPT) has been on the forefront in many social forestry and agroforestry land management systems in recent years. This species is identified as a suitable MPT because it is capable of producing a range of products and has an active supporting role to strengthen sustainability besides improving the intercrops (Huxley, 1985). It is also used as a fertilizer, food and fuelwood. Besides it can be used for pulp, paper and small timber. Due to its drought tolerant and remarkable regenerative characteristic, it is useful for undertaking reforestation on steep slopes in hilly areas (Anon., 1980 b).

The species grows very fast and yield large quantities of fodder and fuelwood in areas having a rainfall upto 300 mm. Recent studies carried out in Madhya Pradesh on this species indicate that it can also grow well even in the areas where average annual rainfall touches 1500 mm. Showing its wide ecological amplitude (Roy *et al.*, 1980). The species also withstands large differences in rainfall, sunlight, salinity and land terrain, as well periodic inundation, fire, windstorm, slight frost and drought, etc. (Hill, 1971).

Leucaena varies extensively between varieties from bushy (5 m) to tall and slender (20 m), with deep root system, upto 2.5 m(Djikman, 1950). Due to its fast growth characteristics, the species is cultivated for fuelwood yield. The harvesting of the species is done on a 5 year rotation basis and the expected yield of fuelwood has been worked out to be 60 tonnes of wood per hectare per annum in good soils. However, when it is grown only for forage, it is estimated to yield about 50 tonnes/ha/year of green forage equivalent to 5 tonnes/ha/year of dry matter (Relwani, 1981). It is reported that, one hectare of Leucaena plantation at close spacing of 15 x 150 cm would suffice to maintain 10 heads of cattle. However, harvesting of forage should be done at an interval of 6-8 weeks, starting from the first cut, after 4 months of planting (Rangnekar, 1980). Subabul makes excellent firewood and charcoal, calorific value of the wood is 4200 to 4600 K cal/Kg and of charcoal about 7000 K cal. Its leaves, pods and seeds are fed by the animals (Parkash and Hocking, 1985). Fodder tree legumes, like leucaena, because of their deep root systems, large carbohydrate reserves in the roots, numerous latent buds, and nitrogen fixing capability can be valuable sources of high quality feed for the animals (Cobbina, 1994).

The species has a very good copping ability and thus it allows repeated harvest of plant parts for firewood, timber and foliage (Brewbaker, 1984). Stumps from plants of almost any age, variety, quickly resprout new shoots. Coppice i.e. growth is much more vigorous than seedling growth because the new shoots are served by a well developed root system.

IMPROVEMENT OF SOIL BY LEUCAENA :

According to Hocking (1990), Leucaena has rich nitrogen fixing capability making it one of the most useful MPT in agroforestry systems. As a perennial species in alley cropping it serves for soil conservation and wind break. Leucaena improves soil condition due to its nitrogen fixing ability. The small lateral roots of the plant positioned near the soil surface carry the nitrogen – fixing rhizobium nodules, which are usually 2.5 – 15 mm (0.1 – 0.5 in) in diameter and are frequently multilobed. These functioning nodules are bright pink inside. The nitrogen fixing is possible due to leucaena rhizobium partnership, annually fixing more than 500 Kg Nitrogen (N)/ha/year (Anon., 1977). Besides, this species has the ability to conserve moisture and protects the soil from nutrient erosion due to the binding capacity of its roots in the soil (Kaushal and Dhanda, 1988).

Grewal *et al* (1992) also support the above statement. Keeping in view the problems of soil and water, in north India comprising parts of Punjab, Haryana and Himachal Pradesh; They conducted an experiment to assess the performance of three MPTS (viz. *Leucaena Leucocephala,Eucalyptus teriticornis* and *Acacia* species) on rainfed agricultural lands. At the end of the experiment they found that the performance of *Leucaena leucocephala* is much better than the other two Species.

According to Krishnan and Toky (1993), most woody legume trees are capable of nitrogen fixation, thus increasing crop yield in the deficient soils. Such Species are very efficient in phosphorous uptake and other mineral nutrients. In addition to Rhizohium, the fine roots and rood hairs are usually infected with beneficial mycorrhizal fungus whose vast network of hyphae aids the plant in obtaining and making more efficient use of mineral nutrients. This helps leucaena to grow in soils low in minerals such as phosphorous (Anon. 1984 d). Mycorrhize has been found helpful in increasing the uptake of phosphorous, particularly in soils with low P-levels. Phosphorous helps improve root nodulation and increased plants height and dry matter yield (Hedge, 1982).

Studies carried out in Philippines (Anon 1977) indicate that a well grown Leucaena plot can yield around 87.3 Kg. Of phosphorous and 375 kg/ha/year of potassium (k) besides a significant amounts of calcium and other minerals, and nitrogen at the rate of 500-600 kg. N/ha/year (Escalda, 1980). Some other studies carried out in Philippines have also revealed that *Leucaena leucocephala* can improve the soil conditions by yielding 20-30 kg of N/ton, 1.5-5.0 kg p/ton and about a 13-24 kg K/ton of dry matter (Fori, 1976). Brewbaker (1975) observed that the fertilizer equivalent of years harvest per hectare of "Hawaiiant Giant" leucaena is estimated to be more than 550 kg. N, 225 kg P_2O_5 and 550 Kg K_2O.

Leucaena grows on a wide range of soil conditions, and prefer neutral and calcareous soil (Bachkheti, 1981). This Species has a deep tap root system enabling the plant not offer much competition with lower storey crops (Singh, 1982). The Species also acts as good Source of biofertilizer or green manure for lower storey crops through shedding their leaves which are high in protein content (20-25%) and mineralize quickly. Further, nitrogen return in soil from leucaena is reported equivalent to one ton of ammonium sulphate fertilizer per hectare per year assuming the plantation of this species at the rate of 1000 trees/ha. (Gizachew, 1992) Among various tropical legumes *Leucaena leucocephala* provides for different user ranging from nutritious forage, firewood, timber and rich organic fertilizer. Its diverse uses also include revegetating tropical hill slopes and providing wind breaks, finebreaks, shade and ornamentation (Rowan and Wilson, 1984).

ZEAMAYS INTERCROPPED WITH LEUCAENA LEUCOCEPHALA

Lulandala *et al.* (1995), performed an experiment of maize by growing it in between different Spacing of Leucaena without changing the spacing for maize. They reported that at narrow spacing, the yield of maize was higher and the yield significantly reduced with the increase in Leucaena spacing. The reason attributed was due to excess nitrogen supply by these legume plants at narrow spacing. Mathew *et al.* (1992), have also observed similar result when they intercropped maize with legume and non legume plants.

The yield of maize was significantly higher when intercropped with legumes than the non legumes (Khola *et al*, 1997). Similarly, the quality of maize cob was far better when intercropped with legumes than with non legumes. According to Guevarra (1976), Lulandala is a very good source of nitrogen to maize when the latter intercropped with the former. However maize utility of nitrogen from leucaena is comparatively lower (38% only). Green leaf manure (GLM) obtained from a well established Leucaena plantation can add organic manure to sustain maize yields at about 3.8 t / ha for the first two consecutive years without the supply of any nitrogen fertilizer to the system maize grain yield can also be enhanced by supplementing the yields with low nitrogen at rates of 20-80 kg N / ha depending on nature of soil condition and variety of crops (Kang *et al*, 1981).

The study conducted at Centro International de Agriculture Tropica (CIAT), Cali, Colombia, have shown that maize yields differ slightly under different spacing treatments and this decrease in maize yields grown in association with relatively fertile and uniform (Rachie, 1983). In another study, Meghemba *et al.* (1980) conducted trials of Leucaena intercropped with maize and beans in separate plots and their aim was to evaluate leucaena potentiality in increasing food and fodder production under various regimes of lopping and weeding. They observed that yield of maize and bean crop were substantially improved. The mean yield of maize was 1645 kg/ ha which was more than twice the national average yield of maize in Tanzania (Acland, 1981). Similarly, the tree growth was enhanced because of the rusting effect of the crop against weed competition, protection from browsing by both domestic and wild animals and the creation of favourable microclimate for the trees (Red head *et al*, 1983).

The impact of intercropping Leucaena hedgerows with maize upon the physical productivity of grain and fuelwood in the lowland tropics can be formulated from quantitative hypothesis basis (Torres, 1983). According to him, the production of organic nitrogen (N) by Leucaena hedgerows cut approximately every 8 weeks at a height of 15-30 cm and planted at a distance between rows wider than 150 cm is 45 gm yr-1 per line on meter hedgerow. The impact of hedgerow intercropping on maize productivity, although has been found substantial, would be limited to spacing systems where existing production levels of maize are lower than 1500 kg/ ha, so expected, production per hectare would decrease as spacing of Leucaena hedgerows increase as spacing of Leucaena hedgerows increase. The above hypothesis was further supported by Alvarez *et al.* (1983), who observed that single hedgerows of Leucaena improves the grain yield of maize than these with triple hedgerows, which was spaced five meters apart in the former. The higher grain yield of maize in single of green leaf manure as organic fertilizer. Rosecrance and Brewbaker (1992), carried out the experiment of maize by intercropping with *Leucaena leucocephala* in Randomised Block Design (RBD). The maize was grown in between the interspaces of Leucaena at narrow spacings as compared to wider spacing and this may be due to effect of nitrogen supply by Leucaena plants.

The Potential of leucaena as a source of organic nitrogen to alley cropped Maize (*zea mazs* L), and fuelwood production was studied on a mollisol at the Agricultural Research and Training Institute, Ilonga, Kilosa district, Tanzania. In this trial, maize was intercropped between single hedgerows of Leucaena tree spaced at 3, 4 or 6m frequently pruned and the pruning broadcast as mulch within the alleys. This study also included a control with no Leucaena hedgerow. In three years of continuous intercropping with maize, an average yield of 69 and 79% of the maximum yield obtained from 4m and 6m respectively (Kang *et al.*, 1983).

Leucaena intercropping with maize conducted at Malawi on the effect of *Leucaena leucocephala* (Lam) de wit, spacing on biomass partitioning and grain yield relative to photosynthetically active radiation (PAR) planted at 3.6m, revealed that interception of PAR resulted in greater biomass production both in Leucaena as well as maize and resulted in higher maize yields (Yanira and John, 1991).

Gill and Patil (1984), reported that Leucaena leaves used as a source of manure, besides supplying nitrogen recorded the highest plant height, number of leaves / tiller and fresh weight of fodder maize as compared to controls. It was also observed that maized crop manured with herbage from intercropped Leucaena produced as much grain (3.0 t/ha) as pure stand of maize (without Leucaena intercrop) fertilized with 60-30-30 kg/ha NPK. Good yield maize from land fertilized with Leucaena cuttings were also reported by Granert (1980). He obtained maize grain yields of 2090 kg/ha compared to the Philippines national average of 840 kg/ha. In another studies, chamsama (1998) conducted the trial of *Leucaena leucocephala* and *Faidherbia albida* by intercropping with maize at Morogoro, Tanzania, to assess the wood biomass, maize grain yield and soil nitrogen status. In this case, the tree were planted alone at 1x5m spacing; tree intercropped with maize and a sole maize crop. They observed that foliar N concentration in maize was higher under F. *Albida* and lowest under L. *leucocephala* Maize grain yield was little affected by the tree intercrop as competition for resources were reduced through periodic and clean weeding.

The potential of alley cropping of *Leucaena leucocephala* with maize was explored on calcareous alluvial soils of the mid-Indo-Gangetic plains of Bihar (Jha and Chaturvedi, 1995). The study involved two alley widths (2m and 3m) and two inter-row spacings (25 and 50cm) of Leucaena. Maize, wheat and green gram were cultivated in alleys, 12 months after their establishment. The study revealed a decline in grain yield, which was highest for green gram and the lowest for maize.

Various attempts have been made to evaluate the economics of various agroforestry systems by introducing subabul (*Leucaena leucocephala*) in the existing cropping systems of lower hills of Himachal Pradesh (Gogate *et al.*, 1981). Their study revealed that the integration of Leucaena trees with crops/ pastures or vice versa is more economical than cultivation of agricultural and horticultural crops alone. Thus, they recommend the adoption of agri-silvicultural system taking Leucaena as base component ever traditional cropping systems.

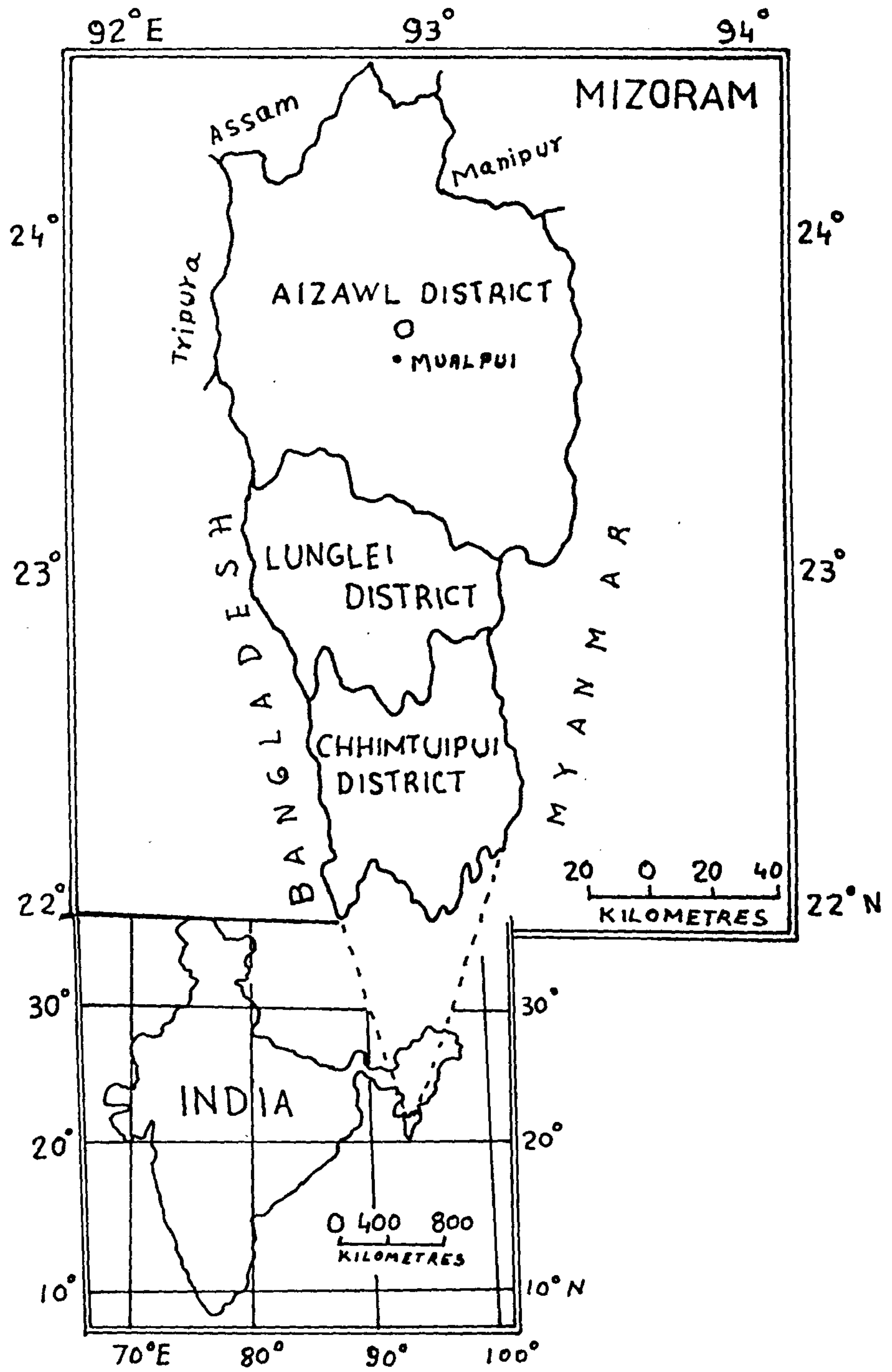
From the above review of literature, it can be depicted that although a voluminous amount of work has been carried out on Leucaena as MPT, maize yield as affected by Leucaena hedges elsewhere, no work has been carried out in Mizoram. The only available work on Leucaena is made by Lalmunpuia (unpublished) in Mizoram in which he has made an attempt to evaluate the soil conservation ability of the species. Thus, the present investigation was made to assess.

1) The effect of spacing of Leucaena on the yield of maize.

2) The effect of specing of Leucaena on the various growth attributes of maize and vice versa.

The study is expected to seek our understanding to the variability of maize- Leucaena agroforestry system which is hitherto grossly neglected in the state.

Fig. 1 Map of Mizoram, showing the experimental site at Mualpui, Aizawl.



CHAPTER III
MATERIALS AND METHODS

DESCRIPTION OF EXPERIMENTAL SITE :

The experiment was conducted at Mualpui (Fig. i), which is about 3Km away from the capital city of Mizoram, Aizawl (23° 56' and 24° 31' N latitudes, 92° 16' and 93° 26' E Longitude and about 1000 multitude and lies at the western side (Savant and Patnaik, 1998). The experimental field has a moderate slope on the upside and the slope gradually decreases towards downside. The average slope of the site is about 25% and the site is own by a local farmer. According to the owner of the land, three years before, paddy was grown there, however, due to drought conditions and low fertility of soil; yield was very poor, therefore, he abandoned that field. Thus, before conducting the experiment, the area was dominated mostly by shrubs and weeds. The common weeds present were *Eupactorium* spp *Ageratum* spp., *Galinsoga* spp. and grasses were the dominant component on the site. The soil of the site is sandy loam, red brown in colour and acidic in nature.

CLIMATE :

The South-West monsoon and North-East winter wind influence the climate of the study site. The mean monthly rainfall and temperature data for the site is given in figure ii. The months from May to October experience heavy rainfall although occasional showers are received during November to March as well. June and July are the wettest month of the year. Based on the temperature and rainfall data, the year can be divided into four seasons.

(i) Spring or mild summer (March to April)

(ii) Rainy or wet summer (May to September)

(iii) Autumn (October)

(iv) Winter (November to February).

The spring season is characterised by a gradual increase in temperature over that in the preceding winter months. With the further increase in temperature, the spring gives way to 'summer' which is characterised by somewhat gusty wind (Upto May) and abundant rainfall, with the retreat of monsoon, the season changes at the fall of temperature heralds the advent of autumn. Autumn is cool and pleasant and represents a transition period between 'rainy' and 'winter' seasons. Autumn is followed by winter seasons lasting from November to February and is characterised by low temperature, negligible rains and short photo period.

EXPERIMENTAL DESIGN TREATMENTS :

Leucaena leucocephala (Lam) de wit, Salvadorian variety, otherwise called 'Hawaiian Giant' or K 28 seedlings were raised in polythene during July 1998. When the seedlings attained about 16 – 18 cm tall, they were transplanted into the experimental field on 5th September 1998. Before planting Leucaena, the area had been cleaned and burnt; and later, the whole area was fenced by bamboo stakes in order to protect it from grazing by livestock.

The experiment was laid down according to split plot design. The total area was divided into three main blocks or replications and under each block, the treatments (spacings) were assigned randomly according to Ditlevson 1985). In this experiment, the treatments were considered as three different spacings such as (I) 2.0 x 1.5m, (ii) 2.0 x 2.0m and (iii) 2.0 x 3.0m. Control plots were also taken both for Leucaena (without maize) and maize (without Leucaena). Leucaena planting was done on 30 cm cube pits (plate No. i). In each sub plot, Four Leucaena tree were planted, one each in every corner of the plot. The total experimental area were found to 139.5 sqm. The distance between each plot was kept one meter apart but in order to check border effect, about 0.5m distance was kept in all the surrounding areas of the whole plot. In order to enhanced the growth performance of both tree and intercrops, weeding was carried out during the month of June. The plan and layout of experimental design is given in figure ii.

Zea Mays (L) was planted on 8th April 1999, in between the interspaces of Leucaena. The planting of maize was done in the same spacings in every plot, considering the spacings of 60 x 25 cm. However, the spacing taken for maize planting from main Leucaena trees are different due to three different spacing of the species. In narrow spacing (2.0 x 1.5m) plot size, the distance taken from main Leucaena trees are 45 cm. In case of plot size of medium spacing (2.0 x 2.0m) and wider spacing (2.0 x 3.0m), maize were planted at about 70 cm and 120 cm from Leucaena trees. In every plot, about 16 number of maize crops were accommodates in two rows, each row containing eight plants. Control plots i.e. maize without Leucaena was also planted within each block and the number of rows and number of maize plant was same as in case of other treatments.

STUDY ON GROWTH AND YIELD PARAMETERS:

Various growth parameters of Leucaena(Such as plant height and stem circumference) and maize (Such as plant height, stem circumference and number of green leaves) were recorded at a monthly interval from September 1998 to September 1999, following standard methods. However, the grain yield of maize was made at the time of harvest/end of cropping season. The various yield parameters on maize cobs such as mean length and diameter of cobs, number of rows per cob , number of kernels/cob/row and average kernels weight (from 1000 kernels) were recorded. All these above parameters were recorded separately for each treatment (spacing).

SOIL ANALYSIS :

Soil analysis was done twice during the study period, i.e. once before introducing intercrop and the other just after the harvest of crops and Leucaena i.e. at the end of the study period. This was done to assessed the change in nutrient contents in the soil of the system due to the introduction of Leucaena maize cropping. For this purpose, 22 soil cores were taken randomly from each treatment and control plot from a depth of 0-15 cm. Samples for each treatment were bulked and from the bulked sample, three sub samples were made for analysis of each soil parameter. Various soil parameters were analysis of each soil parameter. Various soil parameters were analysed at the Directorate of Agriculture Department, Government of Mizoram, Aizawl. Soil texture was analysed by emerging a hydrometer in soil solution. Soil pH was measured using a pH meter from 1:1 soil water (w/v) solution, organic carbon using Walkey and Black method (Anon., 1980). Total nitrogen (N), Potassium (K) and Phosphorous (P) was estimated by Tandon method (Tandon, 1993).

STATISTICAL ANALYSIS :

All the recorded data both for Leucaena and maize were analysed using two – way Analysis of variance (ANOVA) following Chaddha (1989), to see the effect of month and spacing on them. The various yield attributes of maize were tested using ANOVA if they varied significantly between different spacing.

Plate No. 1. Soil pit preparation of 30 cm^3 for Leucaena Plantation.

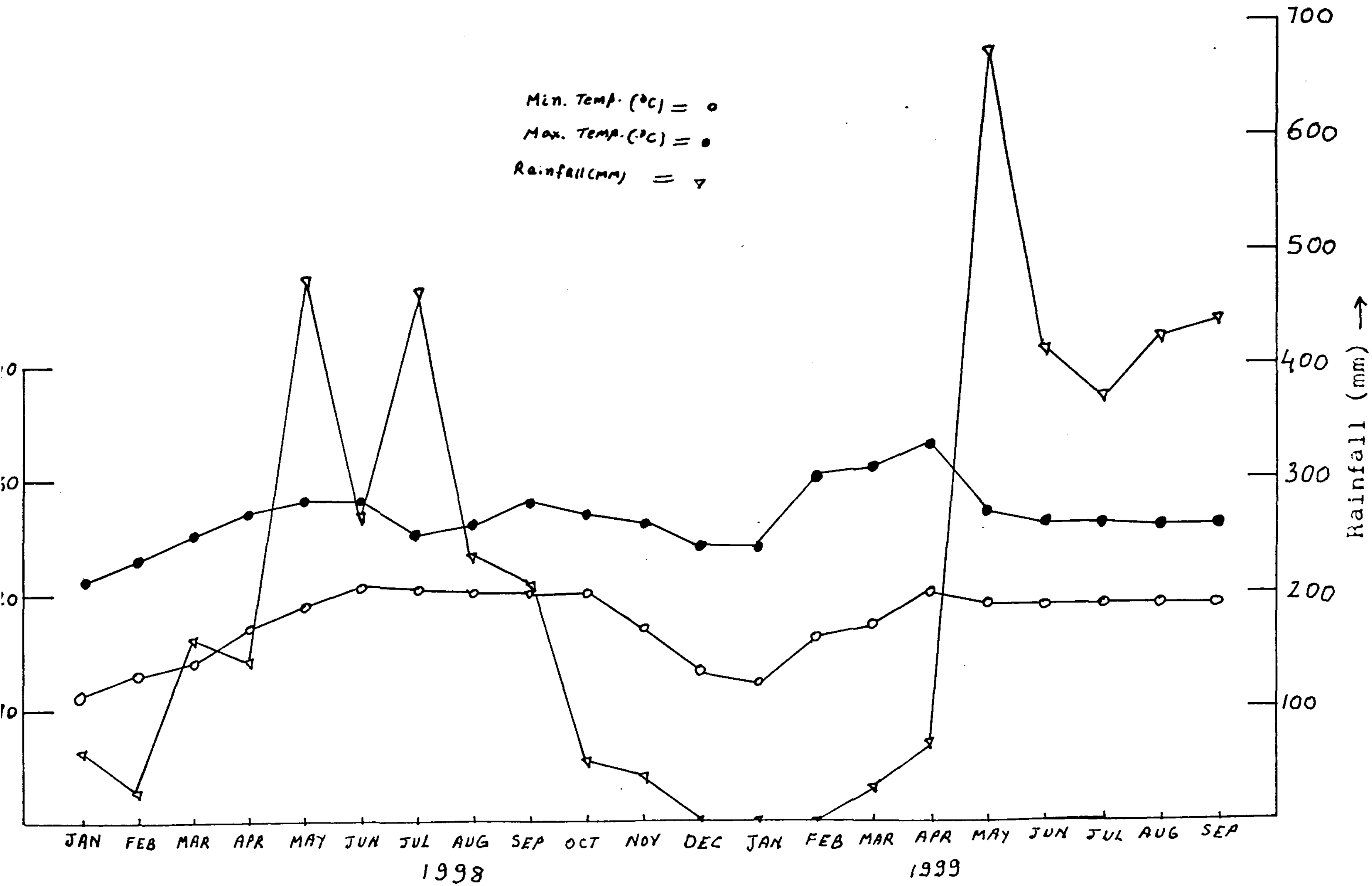
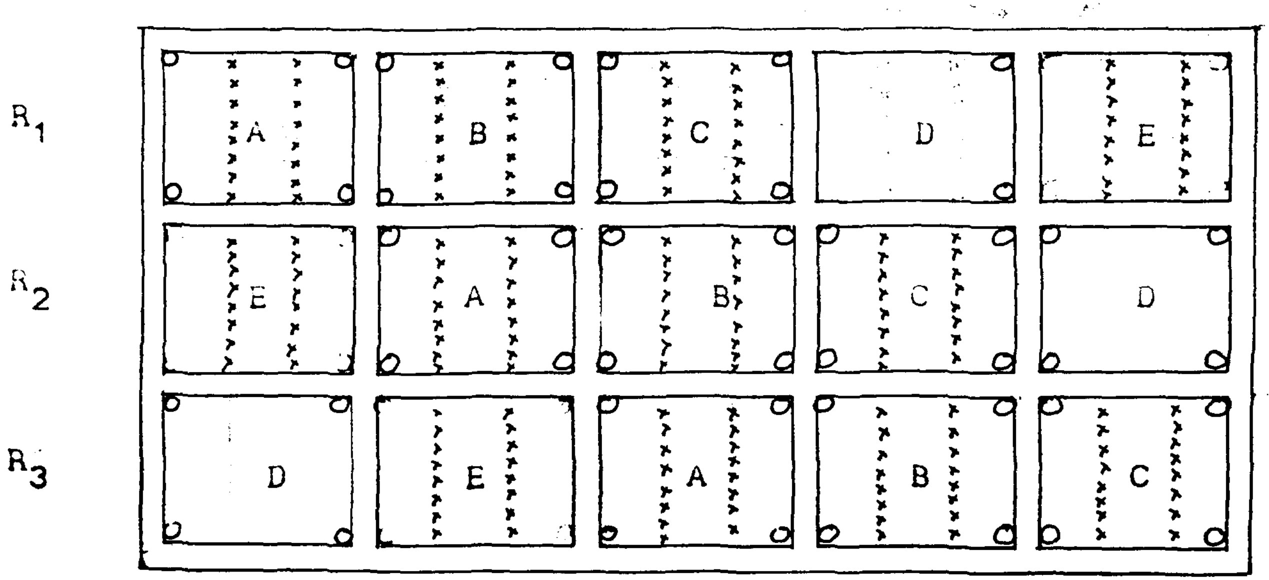


Fig.2 Monthly variation in mean maximum and mean minimum temperature(C) and monthly mean rainfall(mm) from January 1998 to September 1999 of Aizawl (Mizoram)

Fig.3 Plan and layout of experimental design.



A= 2.0 x 1.5 m   B= 2.0 x 2.0 m   C= 2.0 x 3.0 m

D= Leucaena control (Without maize)

E= Maize control (Without leucaena)

o = Leucaena Plant

x = Maize Plant

Table 1 : Mean height of *Leucaena leucocephala* at various spacing by intercropping with *zea Mays* in Mizoram at Mualpui. (cm).

Month / Year	Spacing (M) 2.0 x 1.5	2.0 x 2.0	2.0 x 3.0	Control (Leucaena)
OCTOBER 1998	25.03	24.07	22.2	22.43
NOVEMBER	32.40	30.73	28.5	29.03
DECEMBER	38.07	36.77	34.07	35.03
JANUARY 1999	44.77	43.47	41.10	41.87
FEBRUARY	47.73	46.43	43.73	45.40
MARCH	49.47	48.77	46.07	48.17
APRIL	54.00	53.73	51.43	53.2
MAY	60.03	60.73	58.13	59.73
JUNE	74.73	75.77	72.73	73.77
JULY	89.43	91.93	87.8	88.93
AUGUST	101.47	103.77	100.73	102.0
SEPTEMBER	107.37	112.83	112.0	111.67

CD at P<0.1 For (i) Months = 2.44 (ii) Spacing = 3.63
CD at P<0.5 For (i) Interaction = 2.74

Table 2 : Analysis of various (ANOVA) between month and spacing for plant height of *Leucaena leucocephala* in Maize based agroforestry system in Mizoram at Mualpui. (cm)

SOURCES OF VARIATION	df	SS	MS	F(ratio)	F(table value) 5%	1%
Replication	2	12.05	6.02			
Month(M)	11	79575.74	7234.15	6401.9**	2.3	3.26
Error(a)	22	24.91	1.13			
Spacings(s)	2	135.54	67.74	22.74**	3.19	5.08
Interaction(Mxs)	22	120.07	5.45	1.83 *	1.79	2.28
Error(b)	48	143.06	2.98			
TOTAL	107	80011.37				

** Significant at 1% level
* Significant at 5 % level

CHAPTER - IV
RESULTS

GROWTH PARAMETERS

Leucaena Plant Height :

Plant height of *Leucaena leucocephala* varied significantly ($P<0.01$) with time and space. Mean height of leucaena at three different spacing including the control have been given in Table 1. In general, the plant height of the species showed a gradual decline with the increase in spacing and a gradual increase with the increase in time. The gradual decline height with increasing in spacing was observed in the month of October. Similar was the trend in all other months, and also between the spacings. The rate of growth in plant height of leucaena varied between months and spacings. At the beginning of study, the height of the species at narrow spacing was 25.03cm, ad there was about 5-6 cm monthly increase in height in the first three months. However, the rate of growth in plant height declined subsequently till April and suddenly showed a substantial increase in height till August after which it again decreased. Similar trend in the rate of growth in the species was also observed in both medium and wider spacing (Table1). During July-September, the trend in the plant height with spacing was reversed having higher plant height at wider spacing and lower height at narrow spacing (Table 1).

The plant height varied significantly ($P<0.01$) between months and space (Table 2). The height was also affected significantly ($P<0.05$) by the interaction between month and spacing. The height of leucaena in the control plot also varied significantly between the months and the values were mostly smaller than those under different spacing conditions. However, the rate of growth in height was more or less similar with those under different spacings.

Table 3 : Mean collar diameter to Leucaena leucocephala in association with Maize under agroforestry system in Mizoram at Mualpui. (cm)

Month / Year	Spacing (M) 2.0 x 1.5	2.0 x 2.0	2.0 x 3.0	Control (Leucaena alone)
OCTOBER 1998	1.10	1.23	1.17	1.07
NOVEMBER	1.53	1.57	1.53	1.50
DECEMBER	1.93	1.97	1.93	1.90
JANUARY 1999	2.33	2.33	2.27	2.30
FEBRUARY	2.63	2.70	2.63	2.60
MARCH	2.87	2.93	2.90	2.87
APRIL	2.07	3.20	3.10	3.07
MAY	3.40	3.50	3.47	3.40
JUNE	3.83	3.87	3.93	3.93
JULY	4.27	4.33	4.47	4.43
AUGUST	4.93	5.0	5.13	5.10
SEPTEMBER	5.63	5.70	5.87	5.83

CD at P<0.1 For (i) Months = 0.19
(ii) Spacing = 0.18

Table 4 : ANOVA between month and spacing in collar diameter of *Leucaena leucocephala* in Maize based agroforestry system in Mizoram.

SOURCES OF VARIATION	df	SS	MS	F(ratio)	F(table value) 5%	1%
Replication	2	.08	.04			
Month(M)	11	191.42	17.40	2392.5**	2.30	3.26
Error(a)	22	0.16	0.007			
Spacings(s)	2	0.11	0.055	3.88*	3.19	5.08
Interaction(Mxs)	22	0.20	0.009	0.64 NS	1.79	2.28
Error(b)	48	0.68	0.014			
TOTAL	107	192.65				

** Significant at 1% level
* Significant at 5 % level
NS Non significant.

Plate No. 2. One Month old of Maize Plant by intercropping with Leucaena Plant.

Collor diameter of leucaena:

Initially, the mean collar diameter of leucaena was higher in medium and wider spacing, than narrow spacing (Table –3). Under medium spacing, mean collar diameter increased steadily from October till May (1999), and the values under narrow and wider spacing were lower than the medium spacing, the growth of collar diameter of the species slightly varied between months and spacings. The growth variation between months, during the first three months is about 0.04 cm under narrow spacing, while about 34-40 cm under the other two spacings were observed. The rate of growth in collar diameter being to decline from January to April in all the three spacings and afterwards it gradually increased till September. The overall growth performance was considerably higher, in which mean maximum of 5.87 cm are recorded highest from wider specieng. Through medium spacing are observed positive growth, reversed was observed after May, in which case, wider spacing showed a higher growth than the other spacings.

The growth performance in collar diameter of the species under control plot were more or less similar with other three spacings. In this case, the diameter considerably increased from June (3.93 cm) and a further increase in growth occurred. As compared to the values of the collar diameter under control, the corresponding values under narrow and medium spacing were lower from June to September (Table 3). The mean collar diameter of leucaena were found to be highly significant ($P < 0.01$) between months and spacings, but their interaction between months and spacings was not significant.

Maize plant height :

Maize plant height varied significantly ($P < 0.01$) with time and space under all the spacings. The height variation between spacing during the first month observation was higher under narrow spacing (39.13 cm) than the other two spacings .

Table 5 : Plant height of Maize as affected by Leucaena spacing under agroforestry system in Mizoram at Mualpui. (cm)

Month / Year	Spacing (M) 2.0 x 1.5	2.0 x 2.0	2.0 x 3.0	Control (Sole Maize)
MAY	39.13	37.2	34.43	33.43
JUNE	89.93	87.30	83.27	81.27
JULY	152.23	147.33	142.27	139.97
AUGUST	196.07	192.23	189.30	187.3

CD at P< 0.01 for (I) Months = 4.38

(ii) Spacings = 4.78

Table 6 : ANOVA between month and spacing for plant height of Maize under various spacings of Leucaena tree.

SOURCES OF VARIATION	df	SS	MS	F(ratio)	F(table value) 5%	1%
Replication	2	80.18	40.09			
Month(M)	3	125456.33	41818.77	19913.7**	4.76	9.78
Error(a)	6	12.6	2.1			
Spacings(s)	2	296.38	148.19	36.86**	3.63	6.23
Interaction(Mxs)	6	22.85	3.80	0.94 NS	2.74	4.20
Error(b)	16	64.32	5.02			
TOTAL	35	125932.66				

** Significant at 1% level

* Significant at 5 % Level

N S Non Significant

(Table 5). The growth height of maize plants decreased with the increase in leucaena spacing (Fig. 6). The rate of growth in maize height was more or less similar between the spacings during the entire study period.

Through maize plant height was significantly ($P<0.01$) affected by time and space, the interaction between months and spacings did not effect its height (Table 6). Maize plant height under control plots also increased with increase in time and a more or less similar trend in height was observed under all the spacings. The growth of maize was found to be inferior under control plots than under various spacings.

Stem circumference of maize :

Stem circumference of maize varied significantly ($P<0.01$) between spacing. Except for the month of May, the values of stem circumference declined with the increase in spacing. A gradual increase in the values were observed over time under all the spacings (Table 7). During the first month (May), the variation in values of stem circumference was negligible between spacing, however, clear differences were observed subsequently. During a 30 days period, the rate of growth in stem circumference attained was maximum under the narrow spacing than that under medium and wide spacing (Fig.7).

Both months and spacings were found significantly ($P<0.01$) affecting the stem circumference of maize plants, however, their interaction did not affect the growth in stem circumference (Table 8.) The growth behaviour of stem circumference under control plots showed more or less similar trend across months with those under various spacings, however, the value in the former were lower than the latter (Table 7).

Plate –3 : One Year old Leucaena plant after the end of the study period.

Table 7 : Mean stem circumference (cm) of Maize grown along with Leucaena under agroforestry systems in Mizoram at Mualpui.

Month / Year	Spacing (M) 2.0 x 1.5	Spacing (M) 2.0 x 2.0	Control 2.0 x 3.0	Control (Sole Maize)
MAY 1999	2.83	2.43	2.13	2.10
JUNE 1999	4.20	3.86	3.23	3.16
JULY 1999	5.16	4.93	4.40	4.20
AUGUST 1999	5.97	5.76	5.43	4.30
CD at PL < 0.01	For (i)	Months = 0.27		
	(ii)	Spacings = 0.40		

Table 8 : ANOVA for Maize stem circumference (cm) under intercropping in Agroforestry systems of Mizoram at Mualpui.

SOURCES OF VARIATION	df	SS	MS	F(ratio)	F(table value) 5%	F(table value) 1%
Replication	2	0.20	0.10			
Month(M)	3	53.19	17.73	2216.25**	4.76	9.78
Error(a)	6	0.05	0.008			
Spacings(s)	2	3.35	1.675	57.02	3.63	6.23
Interaction(Mxs)	6	0.20	0.033	1.13	2.74	4.20
Error(b)	16	0.47	0.029			
TOTAL	35	57.46				

** Significant at 1% level

N S Non Significant

Table 9. Mean effect of spacing on nuimber of Maize green leaves under Leucaena intercropping at Mualpui in Mizoram.

MONTHS	SPACING (M)			CONTROL (sole maize)
	2.0x1.5	2.0x2.0	2.0x3.0	
MAY	4.67	4.33	3.67	4.33
JUNE	8.0	7.33	7.0	6.67
JULY	11.0	10.33	9.67	9.67
AUGUST	12.0	11.67	11.33	11.33

CD at P< 0.01 For (i) Month = 3.67
(ii) Spacing = 1.63

Table 10 ANOVA for number of Maize green leaves as affected by Leucaena spacing under agroforestry system in Mizoram at Mualpui.

Sources of variation	df	SS	MS	Fratio	F (table values)	
					5%	1%
Replication	2	11.16	5.58			
Months (M)	2	296.97	98.32	75.05**	4.76	9.78
Error (a)	6	2.62	1.31			
Spacing (s)	2	6.0	3.0	6.38**	3.63	6.23
Interaction (MxS)	6	0.44	0.73	1.55^{NS}	2.74	4.20
Error (b)	16	7.56	0.47			
TOTAL	35	322.75				

* * Significant at 1% level
NS Non Significant.

Number of maize green leaves :

The number of Maize green leaves varied with time and space. The number of green leaves of maize decreased with increase in space. This was true during the entire study period (Table 9). Both monthly as well as spacing significantly (P< 0.01) influenced on the bearing of green leaves in maize (Table 10). The number of green leaves under control plots were always lower than those under various spacings. Among the spacings, maximum mean number of maize green leaves were recorded under narrow spacing (12 No.) at the time of harvest, followed by medium wan wider spacing in order.

YIELD PARAMETERS

Maize grain yield :

Maize grain yield was affected significantly (P<0.05) by leucaena spacing. The grain yield decreased gradually with the increase in spacing, and the total maize grain yield from all the plots are showed in plate 4. At harvest best grain yield was observed under narrow spacing, which produced maize grain yield about 1.57 kg /plot (5.2 t/ha), followed by medium (1.32 kg/plot or 3.3 t/ha) and wider spacing (1.17 kg/plot or 1.9 t/ha) (Table 11). The grain yield was lowest under control condition. The variation in yield between the replicates was negligible (Table 12).

Maize cob length :

Maize cob length did not vary much between the spacings (Table 13), however, mean length of maize cob was highest under narrow spacing (16.8 cm) than that under medium (16.27 cm) and wider spacing (15.97 cm). The mean length in maize cob under control plot was almost same as that under wider spacing. Maize cob length as affected by leucaena spacing are found to be non significant (Table 14).

Plate No. 4. Maize cob yield after the end of harvest .

Table 11. Effect of Leucaena spacings on Maize grain yield under agroforesty system in Mizoram at Mualpui.

TREATMENTS (SPACING mm)	Mean maize grain yield (kg / plot)
2.0 x 1.5	1.57
2.1 x 2.0	1.32
2.0 x 3.0	1.17
Control (sole maize)	0.78
CD at P< 0.05 for spacing = 0.22	

Table 12. ANOVA for maize grain yield (kg / plot) under various spacing of Leucaena plant

Sources of variation	df	SS	MS	Fratio	F (table values) 5%	1%
Replication	2	0.09	0.04			
Spacing	2	0.23	0.11	11.0 *	6.94	18.00
Error	4	0.06	0.01			
TOTAL	8	0.38				

* Significant at 1% level

Table 13. Effect of Leucaena spacings on Maize cob length (cm) under Leucaena intercropping in Mizoram at Mualpui.

TREATMENTS (SPACINGS mm)	Mean maize cob length (cm)
2.0 x 1.5	16.8
2.0 x 2.0	16.27
2.0 x 3.0	15.97
Control (sole maize)	15.70

Table 14. ANOVA for Maize cob length due to effect of Leucaena spacings.

Sources of variation	df	SS	MS	Fratio	F (table values)	
					5%	1%
Replication	2	0.46	0.23			
Spacing	2	1.06	0.53	4.81^{NS}	6.94	18.00
Error	4	0.46	0.11			
TOTAL	8	1.98				

NS Non Significant.

Maize cob diameter:

tendency of

A gradual increase in mean maize cob diameter was observed with the decrease in spacing (Table 15) or in other words, with the increase in spacing. 'he highest mean cob diameter was observed under narrow spacing (12.43 m). The growth variation in mean maize cob diameter was negligible ıetween the different spacings. Similarly no significant variation in the liameter was observed between the replicates under a particular spacing Table 16).

kernel

Jumber of maize rows / cob:

Number of maize rows / cob were more or less same between the eplicates under a particular spacing. A more number (14. 67) of maize rows / :ob were observed under narrow spacing . A decreased in the number of naize rows / cob was observed with an increased in spacing (Table 17). The :orresponding number of rows / cob under medium and wider spacing were airly good.

The number of maize rows / cob was significantly ($P<0.01$) affected by he leucaena spacing (Table 18). The difference in the number of rows / cob vas more between control and narrow spacing than that of control plots and he other two spacings.

Number of kernels / row / cob :

The number of maize kernels / row / cob gradually declined with the increase n spacing (Table 19) and the difference between the spacings were more or ess uniform. The maximum mean number of kernels / row / cob under narrow spacing was 40.33, followed by medium (39.33) and wider spacing (38.67) and control plot (38.33). Through the number of kernels / row / cob did not vary much between the replication under a given spacing, it varied significantly ($P<0.05$) between the spacing (Table 20).

Table 15. Mean effect of Leucaena spacings on Maize cob diameter (cm) in Mizoram at Mualpui.

TREATMENTS (SPACINGS in M)	Mean maize cob diameter (cm)
2.0 x 1.5	12.97
2.0 x 2.0	12.87
2.0 x 3.0	12.43
Control (sole maize)	12.17

Table 16. ANOVA for Maize cob diameter (cm) under Leucaena intercropping in Mizoram at Mualpui.

Sources of variation	df	SS	MS	Fratio	F (table values)	
					5%	1%
Replication	2	0.01	0.005			
Spacing	2	0.48	0.24	5.64[NS]	6.94	18.00
Error	4	0.17	0.04			
TOTAL	8	0.66				

NS Non Significant.

Table 17. Number of Maize rows / cob as affected by Leucaena spacings under *agroforestry system in Mizoram at Mualpui.*

TREATMENTS (SPACINGS in M)	Number of Maize raws / cob
2.0 x 1.5	14.67
2.0 x 2.0	13.67
2.0 x 3.0	13.0
Control (sole maize)	12.67
CD at P< 0.01 for spacing = 1.24	

Table 18. ANOVA for Number of Maize rows / cob under Leucaena intercropping in agroforestry system of Mizoram at Mualpui.

Sources of variation	df	SS	MS	Fratio	F (table values)	
					5%	1%
Replication	2	2.88	1.44			
Spacing	2	4.22	2.11	18*.75*	6.94	18.00
Error	4	0.45	0.11			
TOTAL	8	7.55				

* * Significant at 1% level.

Table 19. Mean number of Maize kernels / row / cob due to effect of Leucaena Spacings in Maize based agroforestry system in Mizoram at Mualpui.

TREATMENTS (SPACINGS in M)	Number of Maize kernels / row / cob
2.0 x 1.5	40.33
2.0 x 2.0	39.33
2.0 x 3.0	38.33
Control (sole maize)	37.67
CD at P< 0.01 for spacing = 1.16	

Table 20 ANOVA for number of Maize kernels / row / cob under Leucaena spacings in Maize based agroforestry system in Mizoram at Mualpui.

Sources of variation	df	SS	MS	Fratio	F (table values)	
					5%	1%
Replication	2	6.89	3.44			
Spacing	2	4.23	2.11	7.62*	6.94	18.00
Error	4	1.11	0.27			
TOTAL	8	12.23				

* Significant at 5% level.

Weight of maize kernels per 1000 number:

The weight of 1000 kernels did not vary significantly between the spacings. The weight of maize kernels per 1000 number, however, declined with the increase in spacing. Under narrow spacing 1000 kernels weighed about 298.67 gm and the corresponding values under medium and narrow spacing were 289.33 gm and 283.33 gm respectively (Table 21), and the values for control was 280.0 gm per thousand kernels. The kernels weight was altered significantly due to spacing and replication (Table 22).

Soil parameters :

The soil of the site was sandy loam and its particle fractionation did not vary much between the spacings, thus they were reported separately, but mentioned only under the textural class. Similarly, no variation was marked in the soil texture before and after intercropping. The soil pH was relatively higher at the end of intercropping. The values for nitrogen, phosphorous and potassium declined after intercropping compared to their corresponding values before intercropping (Table 23).

Table 21. Mean weight of Maize kernels per 1000 number due to effect of Leucaena Spacings.

TREATMENTS (SPACINGS in M)	Mean weight of 1000 kernels (gm)
2.0 x 1.5	298.67
2.0 x 2.0	289.33
2.0 x 3.0	283.33
Control (sole maize)	280.0

Table 22 ANOVA for 1000 kernels weight (gm) under Leucaena intercropping.

Sources of variation	df	SS	MS	Fratio	F (table values)	
					5%	1%
Replication	2	166.89	83.44			
Spacing	2	358.23	179.11	5.46^{NS}	6.94	18.00
Error	4	131.11	32.77			
TOTAL	8	656.23				

NS Non Significant.

Table 23 Soil analysis before and after intercropping of Maize with Leucaena under agroforestry system in Mizoram at Mualpui.

Parameters	pH	Organic Carbon (%) N	P_2O_5 (kg/ha)	K_2O (kg/ha)	Texture
Before Inter-cropping 2.0x1.5m	5.3	0.66md	16md	150md	Sandy Loam
2.0x2.0m	5.4	0.69md	17md	159md	
2.0x3.0m	5.2	0.65md	13md	148md	
Control (a)	5.3	0.70md	15md	151md	
Control (b)	5.4	0.67md	14md	156md	
After Inter-cropping 2.0x1.5m	5.5	0.53md	14md	127md	
2.0x2.0m	5.6	0.50md	14md	125md	
2.0x3.0m	5.3	0.52md	10d	114md	
Control (a)	5.5	0.48md	12d	111d	
Control (b)	5.5	0.43md	11d	110d	

NB : md = medium
d = deficient

CHAPTER–V

DISCUSSION

Growth parameters of Leucaena

Plant height of leucaena :

The gradual decline in the plant height of *leucaena leucocephala* with the increase in space could be due to specific growth requirement of the species. At narrow spacing of leucaena, the plants were able to release more amount of nitrogen to the soil, helping themselves to grow better, however at medium and wider spacing, since the plants were spaced widely, the amount of nitrogen released by the plants were probably not sufficient enough to enrich their growth. Our assumption also finds support from the works of Lulandala *et al.*, (1995), who have also reported that the growth of leucaena at their early stages decreases under wide spacing. The increase in plant height over time was due to the growth characteristics of the species. At the beginning of the study, the growth of the plant was fairly good, because those were raised in polypots and were about 2 months old. During the first 3 months, about 5-6 cm monthly increase followed by slight decrease and then vigorous growth can be related to the prevailing climatic condition of the site. The rainfall during January to April was scanty, and temperature during this period was also relatively lower, thus reduced the growth of the plant. However, the growth was again accelerated from May till August due to heavy downpour and suitable temperature prevalence on the site. Since the plots were adjacent to each other, the variation in climatic features were negligible, resulting in the similar height pattern between the plots i.e. under different spacings.

In the months of June, all the plots under different spacing treatments were weeded, thus all the plots became weed free, resulting the availability of nutrients only to the intercrop and tree species in the plots. Since at narrow spacing, the maize were closely planted (45 cm away from Leucaena plant), and had attained a good height, the nutrient requirement of the crop were very vigorous, making less available for the tree. Thus, the height of the tree i.e. leucaena was affected, however at medium and wider spacing, reverse was the trend, obviously due to similar nutrient uptake between the intercrop and tree spacing. Similar report have been reported by Alvarez and Arturo (1984) on maize intercropping with leucaena.

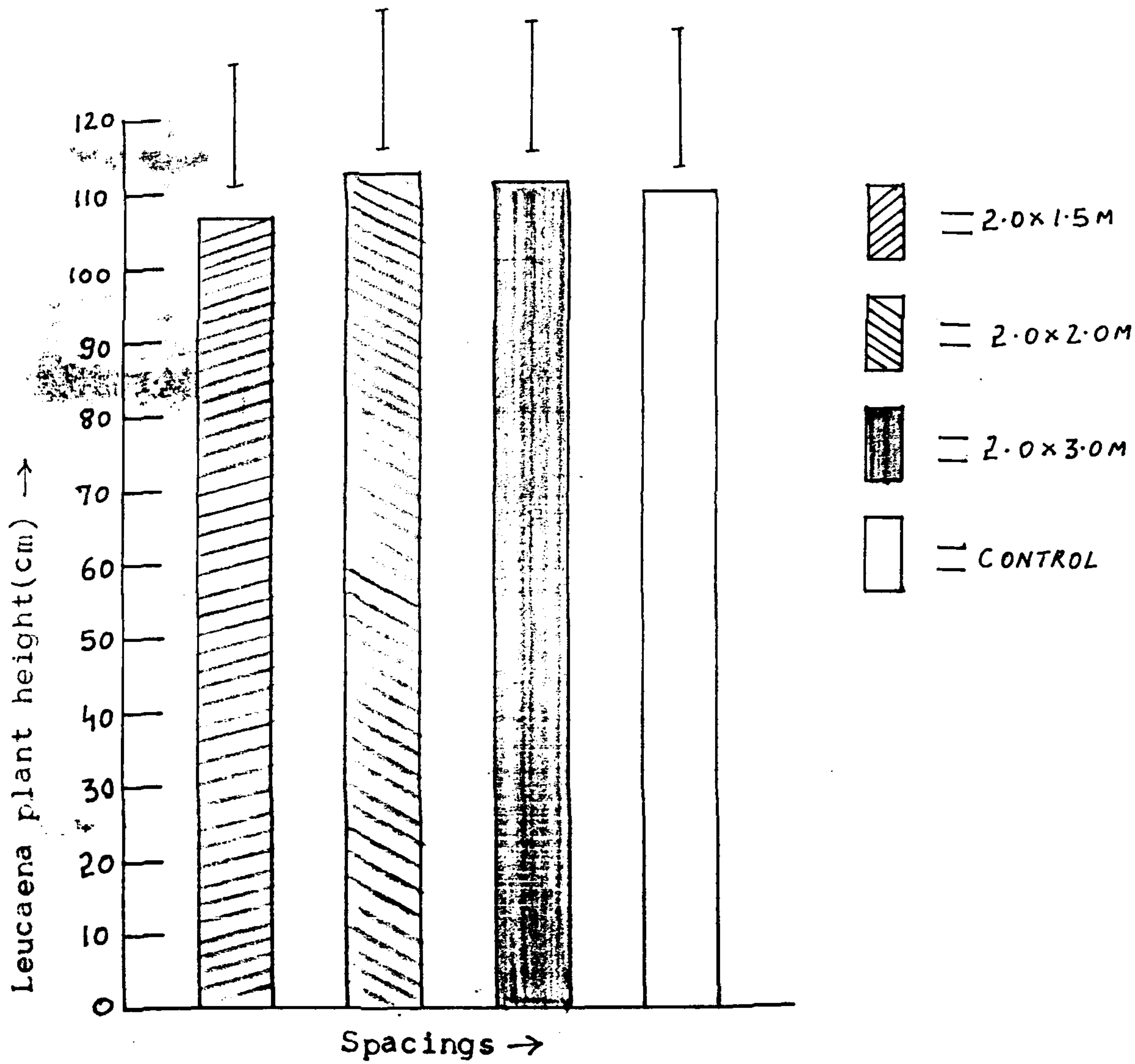
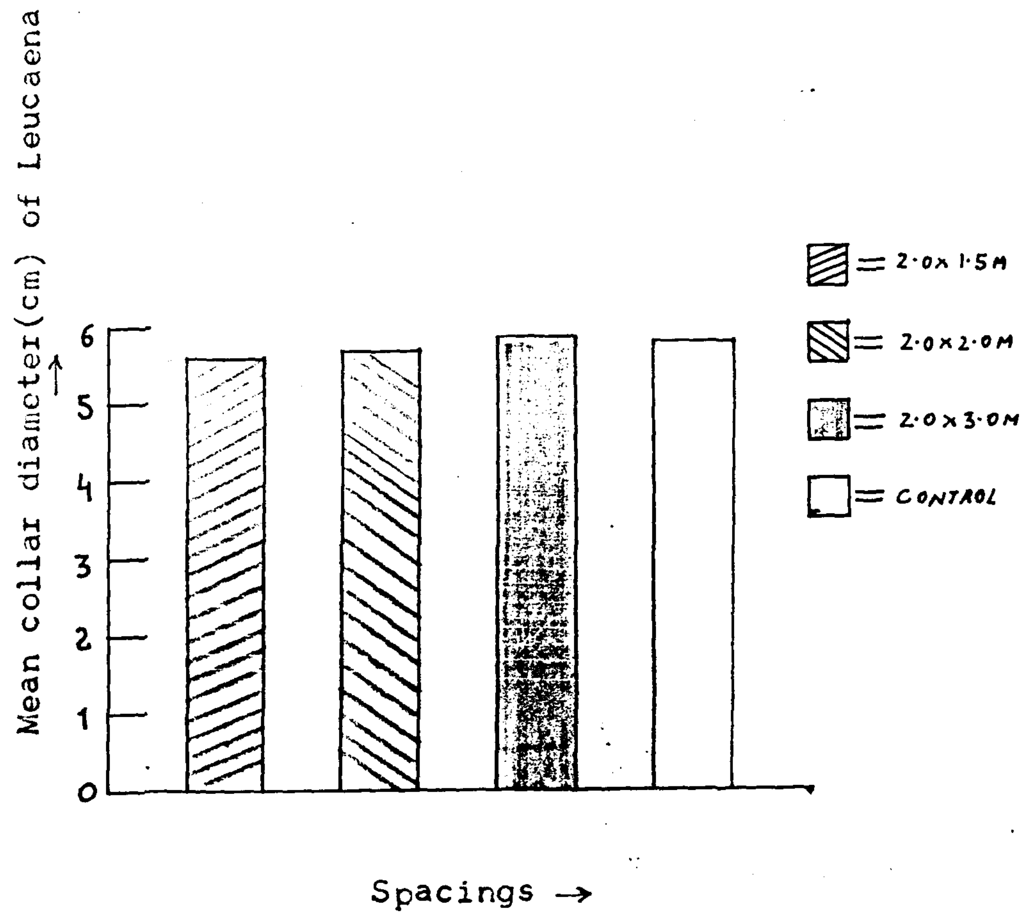


Fig.4 Mean plant height(cm) of leucaena leucocephala at different spacings by intercropping with maize plant.

Collar diameter of leucaena:

Better growth performance of collar diameter under medium and wider spacing than the narrow spacing could be due to specific space requirement of the species. Least variation between replicated under a particular spacing in the present investigation could to be attributed more or less uniformity in soil conditions and same micro-environmental conditions which affects its growth. The growth at the first record i.e. in the month of May was an accumulation of growth right from the seedling that is for about a 2-2/1/2 period, thus the plants were able to attain a diameter of about 1.0 cm by this time. However the decline in the rate of growth subsequently till March was related to the prevailing low temperature and relatively poor rainfall on the site. Our results are in accordance with Maghembe and Redhead (1980), who reported that rainfall pattern and soil moisture condition play important role on the growth of leucaena seedlings. The increase in leucaena length followed its decrease in collar diameter under different spacing could be due to increase in initial longitudinal growth in the plants than the horizontal growth. Guevarra (1976) have attributed this type of behaviour in the growth of leucaena to the intensive division of optical meristem at the shoot apices of the plant influencing the longitudinal growth over the lateral or horizontal growth.

Fig.5 Mean collar diameter(cm) of Leucaena leucocephala at different spacings by intercropping with maize crop.



Growth Parameters of Maize Plants

Maize plant height:

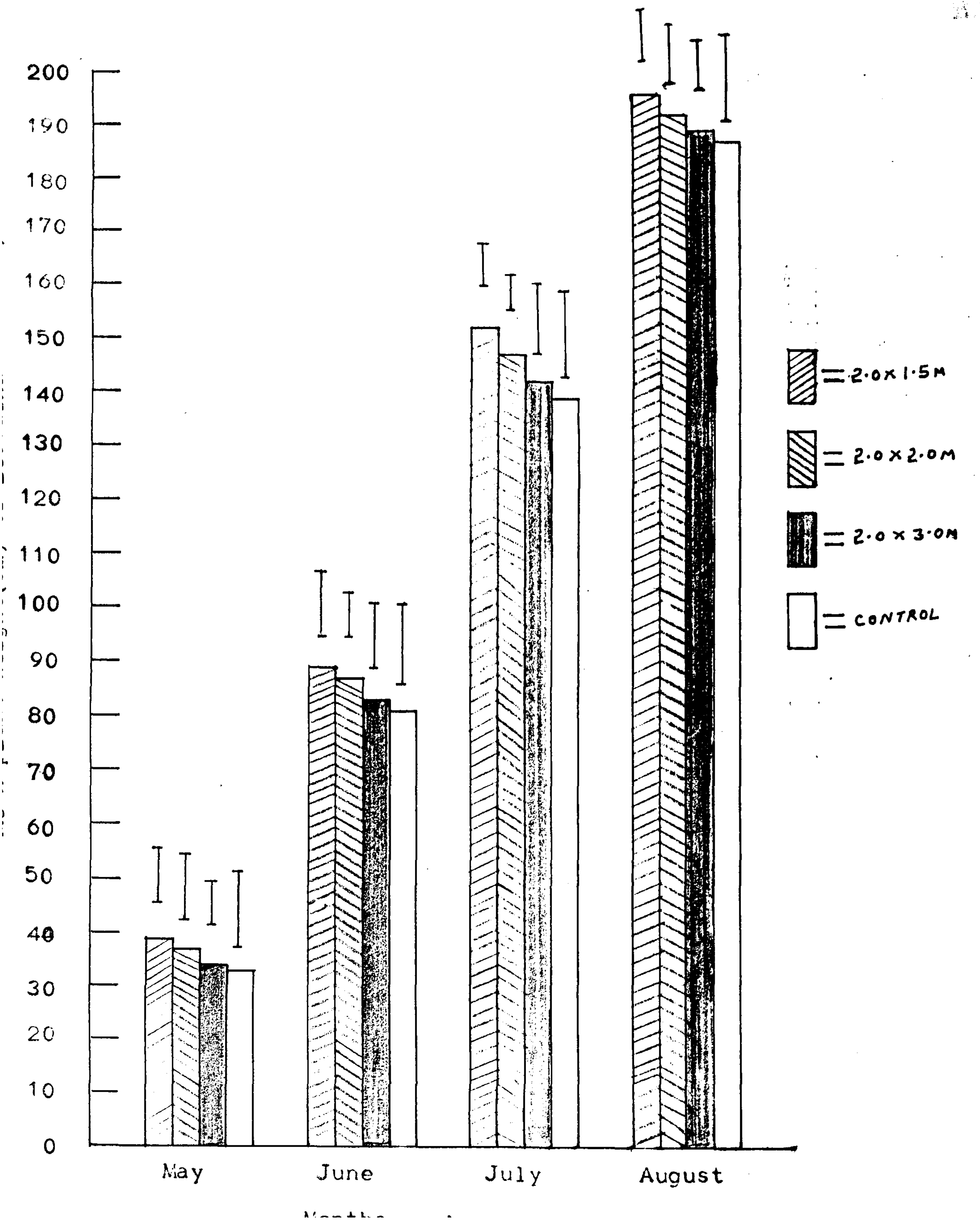
Best height growth of maize under narrow spacing was due to the fact that leucaena supplied more of its nitrogen to the closely planted maize. Since the maize planted were relatively distant from the leucaena plants under medium and wide spacing, their height was lower than that under narrow spacing, As the rainfall was higher during wet summer (June-July), the growth was accelerated during this period. Adequate supply of nitrogen by leucaena during this period followed by favourable temperature during this period could be another reason for such a trend. This assumption found support from the work of Brewbaker (1979) who reported that 'Salvadorian' type of leucaena, can released more than 550 kg N, 225 kg P_2O_5 and 550 kg K_2O, which helps the maize plants to attain highest growth under narrow spacing. Maize height was considerably reduced after July under all spacing conditions, which may be due to a higher rate of growth of maize in nature.

The uptake of nutrients by maize as well as leucaena plants was vigorous during the growth period of both the plants . ~~Compared to leucaena~~, Maize plants faster than leucaena (Rachie, 1983), therefore, their nutrient uptake value is comparatively higher than the later. This higher nutrient uptake by maize could have been the result of a lower height under medium and wide spacing than the narrow spacing. According to chin et al (1992), this variation could be due to their competition at both above and below ground level affecting this overall growth performance of maize and can also be due to this varying maize plant distance from the main leucaena plants.

Stem circumference of maize:

The declined trend in stem circumference of maize with the increase in spacing was also related to the distance of leucaena plants from the maize plants, which in turn is related to the nitrogen releasing ability of the former. A positive growth was in the stem circumference over time, and their rate of growth was due to the growth pattern of the species itself without the interference of any climatic variables. The growth, in general, was slower

Fig.6. Mean *Zea Mays* height(cm) in different months under *Leucaena leucocephala* intercropping.



during the initial stage or 'lag phase'. However , the differential growth behavior through spacing was certainly due to the position of the maize plant in relation to the position of leucaena. This view finds support from the works by Forri(1976) and Haggar and Beer(1989). According to Forri (1976), leucaena can contribute about 20 – 36 kg N/ton, 1.5 – 5.0 kg P_2O_5/ ton and 13 – 24 kg K_2O/ton to the maize plants, thus resulting better growth performance of maize under narrow spacing.

Number of maize green leaves:

Similar to the height and stem circumference, the mean number of green leaves in maize declined with the increase in spacing, Which can be again related to the effect of leucaena plants. Since the availability of nitrogen in the soil was more under narrow spacing of leucaena as compared to the other two spacing. Escalda(1980) has attributed this variation in the number of leaves to the availability of leucaena plants to yield nitrogen approximately 500 – 600 kg N/ha/year.

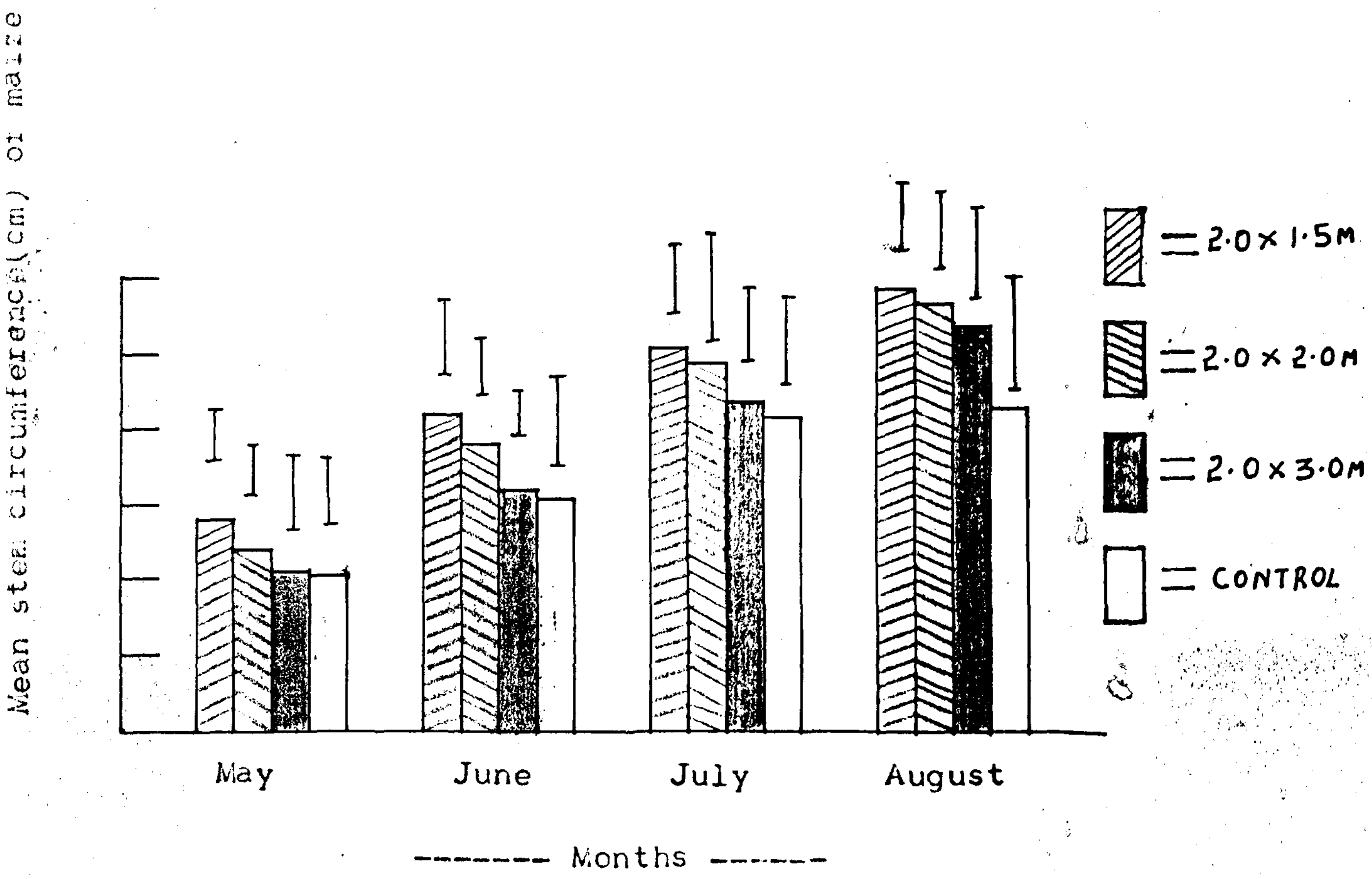
After July, the retardation in the number of leaves observed was possibly due to a higher nutrient translocation to the other parts of the plants owing to vigorous vegetative growth resulting less allocation to the leave position. The interior leaves count under control plot was due to the absence of leucaena component and thus the plots were deficient in phosphorous, potassium and nitrogen content in the soil. On the contrary, better green leaves count under narrow spacing was due to the effect of leucaena spacing as also supported by Rosecrance and Brewbacker (1992) .

Yield parameters of maize plant

Maize grain yield :

The variation in maize grain yield under different leucaena spacings was due to the effect of leucaena spacing. A reasonably good grain yield under narrow spacing (1.57 kg/ plot) was because of more nitrogen availability in the soil found similar results under two spacings of leucaena intercropped with maize. According to them, maize grain yield was 4.4 t/ha

Fig. 7 Mean stem circumference (cm) of Zea Mays in different months under Leucaena leucocephala intercropping.



under narrow spacing (2 x 2m), where as only 3.7 t/ha was found under wider spacing (4 x 4m). The decline in yield under medium and wider spacing through space, as discussed earlier was due to the effect of leucaena spacing as also argued by Mathew *et al.*, (1992) and Jha and Chaturvedi (1995). According to Jha and Chaturvedi (1995), under 3 x 0.25m leucaena spacing, the Maize grain yield was 1938 kg / ha, whereas 1869 kg / ha yield under 3x0.50m leucaena spacing.

Maize cob length:

The little growth difference in mean maize cob length under various spacing was related to the over all growth behaviour of the species. The relatively higher cob length under narrow spacing (16.8 cm) was obviously due to the availability of more nutrients in the soil, because of closer leucaena planting. Rachie (1984) depicted legumes enriched the soil considerably and hence improve the quality of intercrops. Potentiality of leucaena to increase the nitrogen content in the soil was also reported by Torres (1983), who stressed that both grain yield and the quality of maize cob is improved under narrow spacing, when it is grown along with leucaena in lowland tropics.

Maize cob diameter:

The less difference in growth of maize cob diameter between spacing was due to the more or less same maize cob length. The slight increase in maize cob diameter with the decrease in spacings. The maximum cob diameter was observed under narrow spacing (12.97 cm) was due to the better quality of cobs under this spacing than those two other spacings. Maghembe and Redhead (1980), reported that better quality of cob (both size and weight) are observed in nearby leucaena plants, in which the latter supply more nitrogen requirement to the former.

Number of maize rows/cob:

A significant (P<0.01) decline of the number of maize rows/cob between the spacing was again related to the legumes distance form the maize plants. The decreased in number of rows/cob through spacing was because of nitrogen released by leucaena were less in order under wider spacings. Good performance of intercropped maize yield and its other components was observed best in nearby leucaena plant than the distantly placed leucaena and no leucaena plots (Guevarra, 1976). Brewbaker (1975) also reveled that, leucaena improves the quality of cob by releasing 550 kg, N, 225 kg P_2O_5 and 550 kg K_2O to the intercrops.

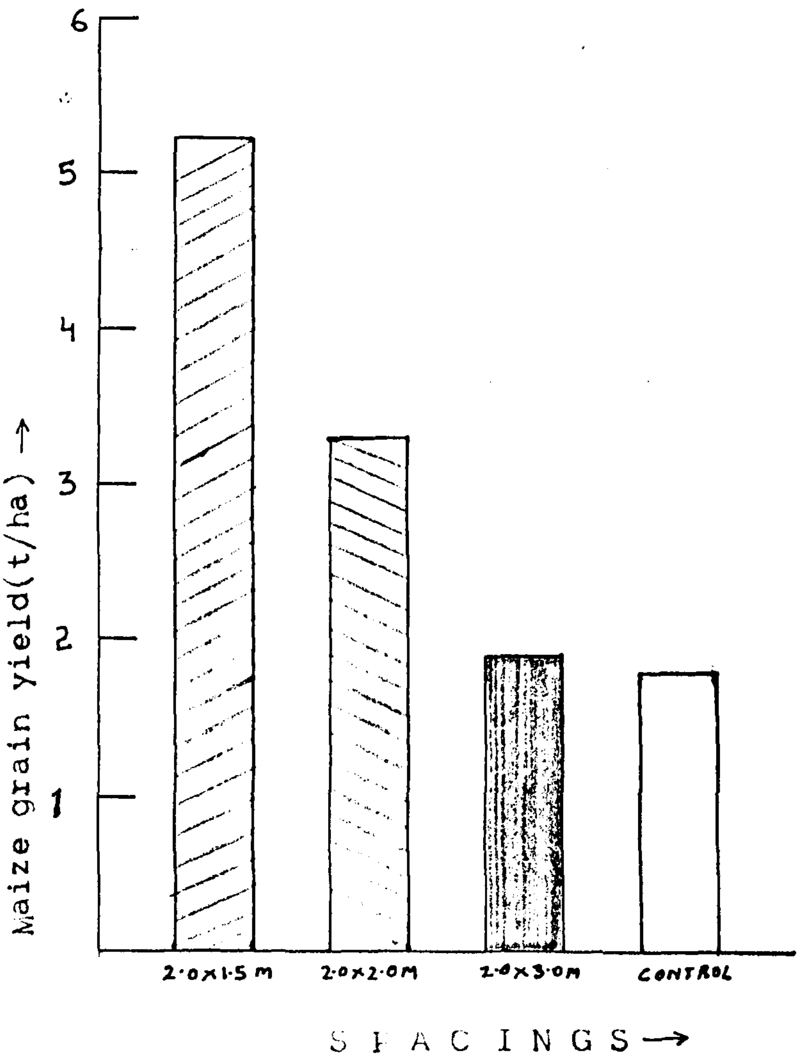
Number of Maize kernels/row/cob :

The maximum number of maize kernels/low/cob observed under narrow spacing than the other two spacings of leucaena was due to the overall better growth of maize plant under narrow spacing than the wider spacings. Leucaena being a nitrogen fixing tree has proved beneficial of the intercrops, besides yielding foliage and fuelwood (Anon.,1984). Other workers like Alvarez and Arturo (1984), reported that, leucaena, when well established as hedges, they improve the soil conditions by releasing ,more nitrogen, which acts as organic fertilizer on the growth and yield of intercrops. Dense planting of leucaena was able to release more nitrogen which in turn was able to produce more reproductive output of the species under this spacing. The effect of leucaena spacings were found to be significant ($P<0.01$), but after comparing critical difference value from control plot, no significant differences are found except for narrow spacing. A small critical difference between the spacing and a larger critical difference between control and narrow spacing indicate the narrow spacing as the right spacing for better production of maize in the system.

Weight of maize kernels per 100 number:

The little differences in the weight of maize kernels per 1000 number as observed under different spacings was due to quality of maize cobs. The quality of maize cobs were far better under narrow spacing than those under both medium and wide spacings. That is the reason why the mean weight of kernels declined with the increase in spacing (Table 21). As it has already been discussed, the production good quality of maize cob under narrow spacing was due to better supply of nitrogen by leucaena plant. The function

Fig.8 Mean yield(t/ha) of maize grain under different spacings of leucaena.



of nitrogen helps the plant to grow better, increasing n the height, stem circumference, number of leaves, and good yield components (Tandon, 1993). The presence of Potassium helps in good cob yield, which too was a case in the present investigation (Table 23). Significance of nitrogen fixing trees for improving the overall growth performance of intercrops have been stressed by Krishnan and Toky (1993) and Mahajan *et al.*, (1996).

Intercropping of maize with leucaena over a one year period, though it did not significantly alter the nutrient content or chemical constituents of the soil at the study site, certainly the cropping had a tendency in influencing these parameters. As for example, pH showed a slight increase at the end of the study period, which may be due to the leaching of base ions from the system even through leucaena was made to check loss of these base nutrients from the system. It was difficult to reach any conclusion as because the present investigation was only for a very short duration and moreover, due to limitation in our data collection on the nutrient dynamics. The depletion in soil organic carbon, soil phosphorous and soil potassium contents at the end of cropping season (Table 23) could have been due to their utilization by the intercrop. Although leucaena plants were responsibility for adding much of their nitrogen to the system at a closer planting, improving both the quality and the quantity of maize production, however, it was not possible to know how leucaena affected to other nutrients like phosphorous and potassium contents of the soil.

CHAPTER-VI

CONLUSION

From our findings, it can be depicted that Leucaena plays a positive role on maize growth and its yield components. Its nitrogen fixing ability helps in increasing the good yield of maize grain at narrow spacing, although wider spacing were also found affecting in increasing yield of maize compared to the control plots. Leucaena being a very fast growing species, it attained mean height as high as 112.83 cm during a one year period in the present study, which is reported elsewhere to result its poor growth in acidic soils (Anon., 1977). Maize height and stem circumference were observed best under 2.0 x 1.5 m spacing, in which case, maize was planted only 45 cm distance from main Leucaena plant. Best performance in closer spacing was due to the fact that the well established leucaena plants compensated the nitrogen to the intercrops. Good yield of maize components like cob length and diameter, number of maize rows/cob, etc. was not only because of nitrogen supply by the leucaena plants, but also due to soil binding capacity of the species owing to their well developed root systems in hilly slopes (Kaushal and Dhanda, 1988).

Maize is the second important cereal crop in the state, therefore, it is essential to increase its productivity without deteriorating the soil conditions. According to the statistical report of Agriculture department, the maize grown area covers in the state is approximately 8,260 hectare (Anon., 1998), and maize is cultivated in the jhum lands which often has a poor nutrient status and where soil erosion is a major problem. The study conducted by the Agro-Economic Research Center For North-East India, Jorhat, indicated that in addition to the evil effects of jhum cultivation or the ecological setting, in certain areas the economy of the people dependent on this cultivation, has already reached a critical point because of the shortening of jhum cycle due to land pressure of human population (Shukla and Aggarwal, 1986). In order to compensate the nutrient erosion in Jhum land, farmers can use fertilizers, but most of the farmers cannot afford to by such fertilizers, and hence jhum cultivation has become economically non-viable (Szott and Kass, 1993). The government of Mizoram has launched different programmes to wean away the

Jhum cultivators but the success was only nominal. The main reason for this was due to improper monitoring and poor extension of these programmes. There was no single suitable, sustainable, economically-viable and socially acceptable land use systems for the region in general, and the state in particular (Sharma, 1998). If the old age practice (Jhum) is allowed to continue in the state, then not only the maize but also the other agricultural crops production in the state may decline beyond their expectation (Garbyal,1999). As has already discussed, the production of maize can be improved by introducing Leucaena by the farmers in their cultivated jhum lands which would improve the soil conditions besides providing food, fodder and fuel wood supply for the rural masses (Rangnekar, 1980)

Considering all the beneficial aspects of Leucaena under the present investigation it is suggested to grow maize crop along with Leucaena under agroforestry systems. This will satisfy to a greater extent in various conditions of judicious land management, soil conservation and production function for the hill slopes. Besides, it is suggested that the maize crops be planted widely at a closer Leucaena spacing (2.0 x 1.5 m) to improve both the quality and quantity of maize yield.

The effect of Leucaena spacings on maize yield components had major limitations in the present study. Since, the study was only for a period of one year, therefore, a long term research be carried out on the above subject to draw some concrete results. Similarly, the study on production of biomass and fuelwood yield, which where not included in the present study should be undertaken for a better understanding on the growth performance of the intercrops and Leucaena and their interaction. Besides, research should be intensified on the above aspects to provide appropriate guidance to improve the practices and enable the farmers to attain optimal productivity on a sustained basis. Factors such as nutrient requirements, contribution of nutrients to the soil by Leucaena and its utilization efficiency which influence the optical production of the traditional system as a whole, should be studied in a greater detail. Moreover more data are necessary on spacing effects to draw both temporal and spatial variability in growth attributes.

SUMMARY

A study on the effect of Leucaena spacings on the yield of maize was carried out from October 1998 to September 1999 at Mualpui, located 3 Km west of Aizawl, the capital city of Mizoram. The experiment was based on a split plot design in which the three spacings were considered, and were allocated randomly in the field. A set of two controls plot were taken, one for leucaena (without maize) and the other for maize (without leucaena), to asses the variation in growth parameter and yield attributes are compared to the control plots. The results were subjected to Analysis of Variance (ANOVA) to find the effect of leucaena spacings on both growth and yield components. The growth parameters were recorded at a monthly interval while yield components were recorded only once that is on their harvest.

The major findings of the present investigation were as follows:

(i) The plant height and collar diameter in leucaena varied significantly ($P<0.01$) with time and space. The height of maize was significantly ($P<0.05$) affected by maize-leucaena interaction where as the collar diameter was not significant due their interaction.

(ii) Though the growth in both height and collar diameter increased significantly with the increase in time, however, after April, the rate in growth was substantially increased till August after which again it decreased.

(iii) Both maize plant height and stem circumference varied significantly ($P<0.01$) with time and space under all the spacings. However, the interaction between months and spacings as affected by leucaena spacing were non significant.

(iv) The growth of maize height and stem circumference decreased with the increase in leucaena spacing, and their rate of growth was more or less similar between the spacings.

(v) The effect of leucaena spacing on maize green leaves was significant ($P<0.01$), however their interaction between months and spacings were found to be non significant.

(vi) Maize grain yield was affected significantly ($P<0.05$) by leucaena spacing and the grain yield decreased gradually with the increase in spacing. The best grain yield was observed under narrow spacing (5.2 t/ha), which were followed by medium (3.3 t/ha) and wider spacing (1.9 t/ha).

(vii) Maize cob length and diameter did not vary much between the spacings. A gradual increase in both maize cob length and diameter was observed with the decrease in spacing. However, in both the cases of both maize cob length and diameter, as affected by leucaena spacing were found to be non significant.

(viii) The number of maize rows / cob varied significantly ($P<0.01$) between the spacings, With the decreased in spacing the number of maize of maize rows / cob was observed more, in which under narrow spacing recorded more in number of maize rows / cob.

(ix) Though the number of maize kernels / row / cob did not vary much between the spacings, however, the effect of leucaena spacing on the number of kernels / row / cob are found to be significant ($P<0.05$).

(x) The weight of maize kernels per 1000 number as affected by leucaena spacing was found non significant. In this case also, the weight of maize kernels per 1000 number declined with the increase in leucaena spacing.

From our present investigation, it can be depicted that spacing (Plant distance from each other) has an important role to the production of maize in the humid sub-tropics of Mizoram. Furthermore, plant distance of 45 cm of maize from leucaena plant was found significantly increasing maize production and other yield attributes. Therefore, since maize is the second important cereal crop in the state, intercropping of maize along with leucaena can be taken up for improving the quality as well as increasing the quantity of maize cobs under agroforestry systems in Mizoram.

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