

**SPATIAL EFFECT ON THE GROWTH BEHAVIOUR
OF *LEUCAENA LEUCOCEPHALA* (LAM) DE WIT
ALONG WITH *ZEA MAYS* L. ON A HILL
AGROFORESTRY SYSTEM OF MIZORAM**

BY

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C E R T I F I C A T E

I certify that the thesis entitled " Spatial effect on the growth behaviour of *Leucaena leucocephala* (Lam.) de Wit along with *Zea mays* L. on a hill agroforestry system of Mizoram " submitted by Mr. Ngurrinsanga Sailo, for the partial fulfilment 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 thesis presented is worthy of being considered as partial fulfilment for the award of M.Sc Degree. The work has not been submitted for any degree of any other university.

Aizawl

The ^{28th} December 1999.

(RAKESH MOHAN) 28/12/99

Supervisor

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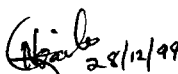
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ABSTRACT

Crops yield in Mizoram are low because of faulty cultivation practice. Shifting cultivation is the traditional way of farming practice in which majority of the farmers are still practising. This results into poor soil fertility, more erosion of soil, runoff water and ultimately poor production. An alternative method of farming technology is highly required in order to boost up the productivity of the land in this hilly region of Mizoram. In view of these problem, agroforestry system of cultivation has been tried in this experiment.

An agroforestry field experiment was conducted at Zemabawk, about 5kms away from Aizawl town, during September 1998 to September 1999 to study the growth of *Leucaena leucocephala* along with the intercropped maize, and to find out the best spacing of *Leucaena* such as 3m x 3m, 4m x 4m and 6m x 6m of its growth and to boost up the intercropped maize production by improving soil fertility as compared to control (maize alone) in hilly terrain of Mizoram. The experiment was laid out in Randomised Block Design with 3 replications.

Assessment of maize grain yields and monitoring of soil fertility trends was carried out. It was observed that the closer spacing of *Leucaena* adds more nutrients and as a result 3m x 3m spacing gives highest maize grain yield (30.75 Q/ha); the second highest was observed in 4m x 4m spacing (27.22 Q/ha), followed by 6m x 6m spacing (23.99 Q/ha) and the lowest maize grain yield was observed in control plot (20.01 Q/ha). The other maize yield components like plant height, basal diameter, number of leaves, cob length, cob diameter, grains per cob, 1000 grains weight showed the similar observation as grain yield that, the best has been recorded in closer spacing having more tree density.

Leucaena growth components like survival percent, plant height, basal diameter, biomass production after 1 year of transplanting was found to be best in 3m x 3m, followed by 4m x 4m and 6m x 6m respectively though statistically non-significant.

Soil tests also showed an increase in % organic carbon, phosphorus, potassium and pH of the intercropped plots over the control plot. This was due to the nutrient released from the tree root. In this experiment, it was found that, the closer the tree spacing or higher tree density/ha, the higher the concentration of soil nutrients including an increase in soil pH.

Hence, it was concluded that among the different spacings tested under Leucaena intercropping with maize, 3m x 3m spacing was considered the best spacing in terms of growth and yield of both Leucaena and maize in hill agroforestry system of Mizoram.

CHAPTER - I

INTRODUCTION

1. INTRODUCTION

The physiography of the state of Mizoram falls under hilly terrain with an area of about 21,087 square kilometres and lies between 21° 56' to 24° 31' north latitudes and 92° 16' to 93° 26' east longitude in the North-Eastern corner of the Indian Union. It is bounded by Cachar District of Assam and the state of Manipur in the North. Chin Hills of Myanmar in the East and South, and the Chittagong Hill Tracts of Bangladesh and the state of Tripura in the West. Having an international boundary of about 710 kilometres, the state is strategically very important. Moreover, with a population of about 690,000 (1991) distributed in 671 villages and 22 urban conglomerates, the state of Mizoram has to cope with ever expanding demands on its limited physical and natural resources. Despite a very large concentration of population in urban conglomerates (46.33%) the economy of the state is essentially agriculture based. It is obvious from the fact that about 71.15% of the working population finds engagements in agricultural activities (Statistical Abstract, Department of Agriculture & Minor Irrigation, Mizoram, 1997-98). About 35% of the workers are provided employment directly or indirectly by the state government whereas less than 2% people are engaged in secondary industrial activities and transformation. Agricultural land, thus, appears to be the only productive resource in the state. Agricultural lands including pastures, cultivable wastes, fallows and net sown area, however, account for only about 24% of the geographical area of the state.

In the State, the most destructive traditional way of cultivation (shifting cultivation) which had been practised from times immemorial is still in vogue. Shifting cultivation (slash and burn agriculture, or jhum agriculture) which is till today common in Mizoram is becoming less sustainable as cultivation cycles are shortened due to population pressures. Once this cycles goes below 10-12 years it seems that it is no longer an economic

form of agriculture compared to possible types of settled agriculture. A reduction in the length of jhum cycles has a number of adverse environmental consequences. It reduces the biodiversity and increases the rate of erosion, apart from its unfavourable economic consequences for the cultivator. One-tenth of its area is at present affected by shifting cultivation even as the annual harvested area is 57,000 ha. As shifting cultivation is the major mode of farming the land has become moderately productive and cause enormous social cost in the form of loss of nutrients, soil and forest cover. Even with little portion of settled farming (about 21,500 ha.) it produces less than a third of the food requirement of the state (Upadhyaya and Jha, 1997). Jhuming system of farming on hill slopes without any soil and water conservation measures fails even to meet the minimum food requirement of the people who practice it (Singh and Prasad, 1980). Since the major constraints to agricultural production in jhum lands are related to soil and water, productivity, the development and management of land and water resources should become the primary objective towards the improvement of farming system.

In addition, firewood (the major sources of energy for the area) is increasingly becoming deficient, especially in and close urban settings. The demand for wood as fuel and uncontrolled grazing are another factor that lead to depletion of forest cover. According to Progress Report of Forestry in Mizoram, 1990, the firewood actually cut far exceeds new growth and it is possible to stop this cutting in the face of growing demand for firewood since approximately 8000 families along are gas consumers out of the estimated one lakh families in 1990. According to Department of Agriculture and Minor Irrigation, Statistical Abstract 1997-98, the percentage of cultivator families is 71.15 %, they also depend on firewood as a sources of energy. It was against this background of crop production problems and projected fuelwood shortage that intercropping leguminous multi-

purpose tree such as *Leucaena leucocephala* (Lam.) de Wit hereafter simply referred to as Leucaena, was identified as an important topic. During the 1970's and early 1980's Leucaena was known as the " miracle tree " because of its worldwide success as a long-lived and highly nutritious tree, and its great variety of other uses. In addition to forage, Leucaena provides fuelwood, timber, green manure, shade and reduce soil erosion. Leucaena is a nitrogen fixing tree (NFTs) and NFTs often considered to be critical components of sustainable agroforestry system. It is widely accepted that the N fixed by NFTs can be used to improve production of crops and soil fertility.

Maize (*Zea mays* L.) is an important cereals and forage crop of Mizoram. In Mizoram maize covers an area of 8260 hectares with the annual production of 16499 MT with an average production of 1997.45 Kg/ha. for the year 1997-98 (Statistical Abstract, Department of Agriculture and Minor Irrigation, Mizoram, 1997-98) which is still very low in order to satisfy the needs and demand of the people . Some of the factors that leads to low yield of maize in Mizoram are the loss of fertile soil in hilly slopes due to runoff water, high erratic rainfall, faulty cultivation practice i.e. shifting cultivation leading to poor soil fertility levels (with high leaching rates) and weed problems. The soils of Mizoram are dominated mainly by loose sedimentary formations. They are generally young, immature, sandy and leached owing to high rainfall (Annual precipitation varies from 1700mm-3900mm). Deprived soils with red, loamy texture is also found with high level of laterite. The soil is highly acidic in nature and low in potash and phosphorus contents. But in an uneroded soil, the content of nitrogen is quite high fostered by accumulation of organic matters (Progress Report, Department of Environment & Forests, Mizoram, 1990). The organic matter of the soil was high in view of luxuriant vegetation and low temperature prevalent in the area, but

due to repeated Jhuming and with high rainfall soils are now degraded. Moreover, due to the slopy landscape the soils in the valleys are heavier as they were brought down by rain water from high altitude (Rintluanga Pachuau, 1994). Therefore, fertilizer application is sometimes critical for high maize yields. However, fertilizer costs and the poor facilities (supply of fertilizers and access roads problems) existing in many area, at times prevent efficient distribution and use of fertilizers. Farm Yard Manure could potentially be used to improve soils, but since the amounts required, about 20-25 tons/ha to suppliment fertilizers are quite high for poor farmers, it is not an easy alternative.

To solve these problems and replace them with a better and improved method of cultivation, a need was felt to find out a suitable agroforestry system that can offer an alternative means of cultivation with a positive impact on the environment and enhancing the basic natural resources leading to higher and sustainable production. Keeping these in view an experiment was conducted with MPT's such as *Leucaena* intercropped with maize with the objective of amelioration of basic food production problem (soil fertility decline, soil erosion, weed control) and supply of useful products such as food, fodder, fuelwood in Mizoram.

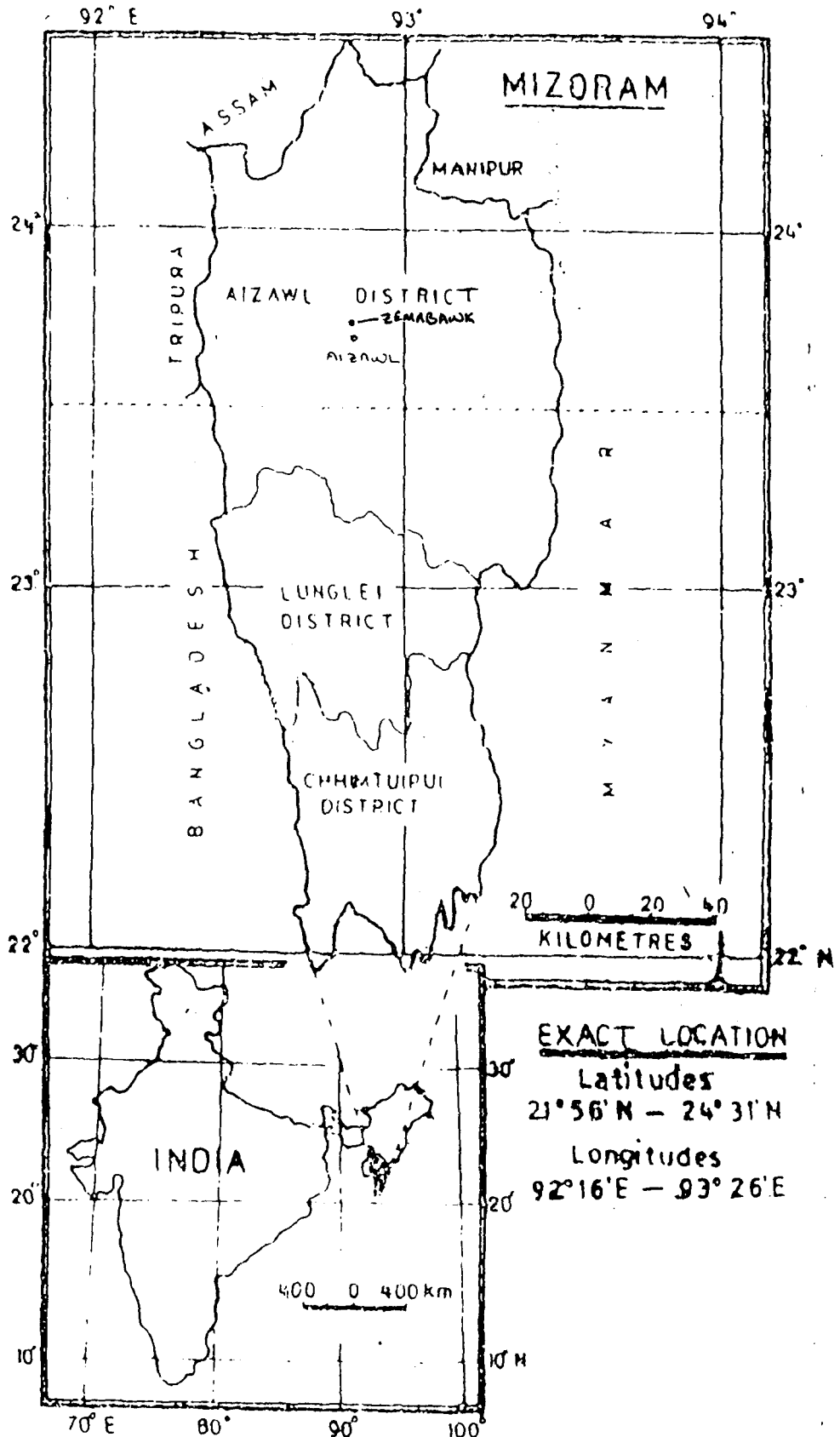
1.1. SPECIFIC OBJECTIVES :

The specific objectives of the experiment were two-fold :-

- (i) To identify the appropriate spacing of *Leucaena leucocephala* on the basis of its dynamics of growth in a combination with intercropped maize.
- (ii) To determine the effect of different spacings of *Leucaena leucocephala* on growth, yield and yield attributes of intercropped maize.

FIG. 1

Map of Mizoram showing the location of Zemabawk (Experimental site).



CHAPTER - II

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Agroforestry, a form of planned fallow lands had been suggested as a substitute for the fallow lands of shifting cultivation in modern sedentary agriculture due to increasing human population pressure. According to Bene *et al.*, (1977), agroforestry is a sustainable management system for land that increased overall production, combines agricultural crops, tree crops and forest plants and/or animals simultaneously or sequently applies management practices that are compatible with cultural patterns of local population. Torres (1983) has stated that agroforestry can be defined as the deliberate combination of trees with crop plantation or pastures or both, in an effort to optimise the use of accessible resources to satisfy the objectives of the producer in a sustainable way. Lungdread and Raintree (1983) have opined that agroforestry is a collective name for land use systems and technology 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 on ecological and economical interactions between the different components.

The positive role of multipurpose trees (MPTs) in mixed farming systems that have been infrequently studied may prove themselves to be very valuable for agroforestry. This arises out of the experience with traditional shifting cultivation and the subsequent fallow period and lands thereafter created environmental resources, both in spatial and temporal terms, and both above and below ground, can usually be better shared between a mixture of species than by sole cropping. This is one of the advantages of mixed cropping (Huxley, 1985). Yadav (1982) investigating the nitrate-N profile of soil in sole and parallel multi-cropping system of maize and beans observed that there was nitrate-N in the deeper horizons due to

leaching from inter-row spaces of single crop system, whereas the nitrate-N content beyond 30 cm depth was drastically reduced in multi-parallel cropping because it was better utilised by the crops.

Legume intercropping in cereals has also been reported to reduce N-leaching (Singh *et al.*, 1978), and its positive effect in the conservation of soil N has also been demonstrated by Yadav (1981) and further stated that the practice of intercropping, particularly with MPTs, besides reducing nutrient leaching, could also reduce the long fallow cycle of traditional agriculture to one-year period, which could mean an increase in arable crop land and therefore crop(s) produced.

Scattered examples of the preservation and use of naturally occurring leguminous trees for fertility maintenance in indigeneous farming systems (Okigbo and Lal, 1978) and the results of early research on planted fallows and intercropping systems for cereal and root crop production between rows of leguminous trees (Pareira, 1978, Bengue, 1979, Wilson, 1979) have demonstrated the potential of such systems to maintain high soil nitrogen levels (Raintree, 1980).

Intercropping in agroforestry, is a system in which crops are grown in between rows of woody shrubs, which are pruned periodically during the cropping season to prevent shading and to provide green manure and/or mulch to the arable crops (Getahun, 1980, Kang *et al.*, 1981, Anon., 1982a, Balasubramanian, 1983, Nair, 1984). The larger branches are used for poles or fuelwood. In the dry season, the trees are allowed to re-grow and draw nutrients from deep soil levels (Kang *et al.*, 1984), aiding in the recycling of leached nutrients from the subsoil back to the surface, by means of leaf drops and/or foliage pruning, where they can be used by shallow rooting arable crops such as maize (Raintree, 1980).

Agroforestry intercropping system is an adaptation and refinement of the bush fallow system commonly practised by small scale farmers in Africa (Wilson and Kang, 1981). Encouraging results have been obtained from agroforestry intercropping studies conducted at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria (Hartman, 1981,

Wilson and Kang, 1981) where the practice originally acquired its name. The choice of deep rooting leguminous trees such as *Leucaena* not only lends a measure of the much needed drought resistance to the system, but also the canopy developed during the dry season could also control weeds (Kang *et al.*, 1984).

According to Aiyer (1949), intercultivation of trees species with agricultural crops benefits the farmer by way of the following :-

- (i) Additional income.
- (ii) The undercrop and its by-products are extra yield.
- (iii) Maximum land used.
- (iv) Greater stability of yield over different seasons.
- (v) Better control over weeds, pests and diseases.
- (vi) Better use of growth resources.
- (vii) One crop provides physical support to the other crop.
- (viii) One crop provides physical support to the other crop.
- (ix) Erosion control through providing continuous leaf cover over the ground surface.
- (x) It is the small farmers of limited means who is most likely to benefited.

Species select for agroforestry intercropping must however be easy to establish, fast growing, deep rooted, coppicious, have the ability to withstand frequent prunings and be able to produce heavy and easily degradable foliage (Wilson and Kang, 1981). These properties as well as biological nitrogen fixation (BNF) are possessed by *Leucaena* (Guevarra, 1976).

2.1. PROPERTIES OF *LEUCAENA LEUCOCEPHALA* :

Leucaena leucocephala (Subabul) is one of the most common species for agroforestry practices such as agrosilviculture, silvipastoral, alley cropping, farm boundary, farm bunds, energy plantation and degraded and

wastelands because of its fast growth, nitrogen fixing ability, high nutritive fodder and runoff and soil erosion control capacity. In addition, *Leucaena* provides fuelwood, timber and green manure. The experimental evidences showed that *Leucaena leucocephala* intercropped with agricultural crops and fodder grasses increases total yield of food grain fodder, fuelwood and enrich the soil (Solanki and Ram Newaj, 1997).

Leucaena is a multipurpose plant with large number of uses, e.g., fodder (mainly for ruminants), fuelwood (24-100 m³/ha.) (Anon., 1980) and wood (pulp, paper, construction). It also provides service roles such as soil conservation and fertility improvement through Biological Nitrogen Fixation (BNF) and green leaf manure. Besides, it helps break impervious subsoil layer, improve water percolation and prevent surface runoff (Anon., 1980, Nair, 1984). *Leucaena* is a deep rooted plant, with an aggressive tap root that can penetrate deep into the soil and thus enable the plant to withstand drought (Jiang, 1982). Solanki and Newaj, NRCAF (1997) also stated that *Leucaena* is drought tolerant and, therefore, in areas where rainfall is erratic, the risk of total crop failure is reduced.

Leucaena is a fast growing species and has a range varieties from tall and slender (to 20m tall) to bushy types (to 5m), with deep roots of upto 2.5m (Djikman, 1950). Its high growth and wood production potential is the shortest rotation in many part of the country. When planned as an energy plantation of different duration of the dry areas in the semi-arid regions, it produced wood upto 60 tonnes/ha/yr. Even on dry habitats production upto 32.1 tonnes/ha/yr. in 2m x 1m spacing was noticed (Pathak, 1997).

Leucaena coppices well. Its coppicing ability allows repeated harvests for firewood, timber and foliage (Brewbaker, 1984). Stumps from plants of almost any age, variety, quickly resprout new shoots. Coppice regrowth is much more vigorous than seedling growth because the new shoots are

served by a well developed root system. *Leucaena* can grow in a wide range of environments ranging from semi-arid low rainfall (250mm) to areas of high rainfall (600-1700mm), with heavy clay and alkaline soil. Once *Leucaena* is established, it has several advantages such as :-

- (a) Leached plant nutrients are recycled from sub-soil,
- (b) Provide biologically fixed nitrogen to the companion crop,
- (c) Provide favourable conditions for soil macro- and micro-organisms,
- (d) Provide prunings, applied as mulch, and shade during the fallow period to suppress weeds,
- (e) Protect soil against erosion,
- (f) Provide fuelwood, fodder and its seeds are often used as human food (Ngambeki and Wilson, 1983).

2.2. LEUCAENA IN AGROSILVICULTURE :

High density plantations (10,000 tree/ha) and short rotation intensive cultivation of 3 to 5 years were found to be economically sound practice for deep soils of Nellor and Prakasam district of Andhra Pradesh. In these districts, 50% of rainfed area is occupied by *Casuarina* and *Leucaena* tree species (Singh, 1995).

The experimental evidences showed that *Leucaena leucocephala* intercropped with agricultural crops and fodder grasses increases the total yield of food grain, fodder and fuel (Tiwari, 1970; Anon., 1984a; Pathak, 1989).

In agroforestry trial Chauhan (1995) studied the effect of mulberry (*Morus alba*), Poplar (*Populus deltoides*), Safed siris (*Albizia procera*) and Subabul (*Leucaena leucocephala*) on the yield of rainfed wheat. The grain yield of wheat was higher at 10 and 8m distances from the tree and lower grain yield was recorded at 6, 4 and 2m distance from tree. The overall grain yield of wheat was highest under subabul.

A field experiment on competition studies on tree-crop association with *Leucaena* under farm forestry indicated that *Leucaena* tree line had an adverse effect on yield of crops (Prasad, 1993).

2.3. IMPROVEMENT OF SOIL FERTILITY BY LEUCAENA :

The *Leucaena* have potential to improve the soil fertility by improving in physical and nutrients parameter of the soil. *Leucaena* plantation on calcareous wasted lands with pH 9.5, after 4 years reduced the soil pH upto 8.0, besides increasing soil organic matter and enrichment of major nutrients (Pathak, 1997).

An experiment on soil nutrient changes under *Leucaena leucocephala* in different planting durations- Immediate (1yr.), Short term (3yrs.), Mid term (9yrs.), Long term (45yrs.) plantings, showed that available N, P and K levels increased with time by 50%, 192% and 179% within 45yr, 11%, 8% and 24% under short term and 33%, 42% and 27% under mid-term duration respectively (Jha *et al.*, 1991).

An experiment on recycling of *Leucaena* leaves for nutrient supplementing and moisture conservation of rainfed wheat revealed that at the time of wheat sowing, the plot receiving 6 tonnes/ha of *Leucaena* mulch contained 14.87% moisture in 0-15cm soil layer as compared to no mulch plots (10%) whereas, marginal increase was observed within the mulch doses. However incorporation of mulch at different timings could not influence moisture content of the soil. The highest water use efficiency was observed under 6 tonnes/ha mulch treatment for all the years but less variation was noted with other mulch doses. Three years (1990-93) average data indicated that maximum grain yield (3.6 tonnes/ha, 39% higher than control) were recorded in plots which received 6 tonnes/ha mulch dose whereas, marginal increase was seen within the mulch doses (Sharma *et al.*, 1993).

2.4. EFFECT OF LEUCAENA AS ORGANIC FERTILISER IN MAIZE PRODUCTION :

Scientists have investigated the use of *Leucaena* with maize as an alternative low nitrogen input system, in which maize yield can be sustained at a relatively low level without nitrogen inputs (Guevarra, 1976, Kang *et al.*, 1981, Ngambeki *et al.*, 1983). Such a system would not only be sustainable in terms of nitrogen requirements, but it could also contribute to reduction of both soil erosion in the uplands (hedges are planted along contour lines) and help to reduce the ever increasing fuelwood shortage (Torres, 1983).

Kang *et al.*, (1981) investigated the effectiveness of *Leucaena* prunings, what they referred to as Green Leaf Manure (GLM) as nitrogen source of maize, using both field and pot trials, in sandy Apomu soil (Psemmentic Usthorthent) at Ibadan, Southern Nigeria. The GLM significantly increased N-uptake of seedlings and N-percentage in ear and leaves of maize. High maize grain yield was obtained with application of 10 tons fresh GLM and N at 50 Kg/ha. With no N-application or removal of *Leucaena* tops after each prunings, maize grain yield were significantly lowered by a total of about 46% compared to those in which the prunings were retained.

The prunings (GLM) as N-source appeared most effective when incorporated than when applied as surface mulch. This can be explained in terms of faster rate of mineralisation of the incorporated GLM, within 1-3 weeks (Weeraratna, 1982) and possibly reduced loss of N due to volatilization than with surface mulch (Evensen, 1982). Likewise, the lower efficiency of broadcast prunings, could partially be attributed to ammonia-N volatilization loss during decomposition under high temperature conditions in the field (Messan, 1980). Largely because of these losses, only about 65%

of nitrogen in *Leucaena* is available for the crop growth (Brewbaker and Evensen, 1984).

Evensen (1982), further showed that *Leucaena* GLM surface mulching to be only 41.2% as efficient in supplying N to maize as in urea. These efficiencies were however higher than Guevarra's (1976) 38% value because Guevarra used chopped whole *Leucaena* foliage including the woody fraction. Woody materials would release N slowly during their decomposition and therefore decreases total available-N.

Crop yields and growth of *Leucaena* from two years-old study plots showed no serious disadvantages from the establishment of *Leucaena* through intercropping (Kang *et al.*, 1981). The use of *Leucaena* tops maintained maize yields at a reasonable level; even with no additional nitrogen input on low fertility sandy inceptisols. An increase of 40% in maize yields from two-year intercropping with *Leucaena* over control plot of maize alone at IITA which had the same basal fertilizer rate and maize population density has also been reported (Anon., 1982a). The effect of nitrogen contributed by the *Leucaena* mulch on maize grain yield was about 100 kg N/ha for every 10 tons/ha of fresh prunings, other studies at IITA showed higher N-yields of 189-250 kg N/ha from 5,000-8,000 kg/ha dry leaves with 3.2-3.5% N-content (Kang *et al.*, 1981).

The use of *Leucaena* as green manure for maize applied on the soil surface has also been studied by Guevarra (1976), and showed that plots receiving *Leucaena* leaves yielded 4.2 t/ha compared to check plots, which gave 1.8 t/ha only. The former even yielded more than those plants treated with organic fertilizer at the rate of 75 kg N/ha.

Besides GLM, biological nitrogen fixation (BNF) is yet another important attribute of *Leucaena*. Under favourable year-around growing conditions, nitrogen fixation rates as high as 500-600 kg/ha/yr. have been measured (Guevarra, 1976) in Hawaii. However, lower yields of 100-200 kg N/

ha/year (equivalent to 50-100 kg Ammonium phosphate/ha/year) have similarly been measured (Halliday, 1984) in Hawaii.

The stimulation of regrowth in *Leucaena* and other legumes following pruning has recently been shown to activate nitrogen fixation (Rachie, 1983). *Leucaena* is therefore, more efficient both in growth and nitrogen fixing ability following topping as compared with normal growth (Evensen, 1982). *Leucaena* pruned of one metre high as three months intervals can yield 50-600 kg N/ha per year (Escalada, 1980).

Leucaena provides more than just nitrogen; mineral elements such as phosphorus and potassium, absorbed by the roots from deep soil become incorporated into the foliage. This helps *Leucaena* grow in soils low in minerals such as phosphorus (Brewbaker, 1984). In Hawaii, *Leucaena* foliage harvested from one hectare after one year growth contained 44 kg of phosphorus and 187 kg of potassium, as well as calcium and micronutrients (Anon., 1984c). Similar studies in the Philippines (Anon., 1977) have demonstrated that a well grown *Leucaena* plot can yield around 87.3 kg of phosphorus and 375 kg/ha/year of potassium. Significant amounts of calcium and other minerals will also be included.

Though the efficiency of N-utilization by maize from *Leucaena* leaf mulch is low- 38%, perhaps due to fast rate of decomposition to humus, (after only 2 weeks), the maize-*Leucaena* intercropping can still be utilised as a low-input system (Guevarra, 1976). Addition to *Leucaena* GLM from full grown plant rows was able to sustain maize grain yield at about 3.8 t/ha/year for two consecutive years with no N-addition, while with no addition of prunings, maize grain yields declined. Higher maize grain yields were obtained by supplementation with low N-rates of 20-80 kg N/ha depending on variety and soil (Kang *et al.*, 1981). However, Evensen (1982) reported yields of maize grain of almost 5.0 t/ha was obtained by incorporation of 150 kg GLM N/ha and with no supplemental fertilizers.

Other studies (Rachie, 1983) of intercropping in comparatively fertile soils at Centro Internacional de Agricultura Tropica (CIAT), Cali, Colombia, have shown that maize yields varied only slightly under various treatments of *Leucaena* population and spacings. These studies indicated very little competition by the *Leucaena* with maize, when cut-topped to 10-20cm, and GLM and branches used as organic manure.

The slight decrease in maize yields grown in association with *Leucaena* is understandable since CIAT soils are relatively high fertile, and therefore little response from nutrients re-cycled by *Leucaena* foliage was expected at the outset (Rachie, 1983). However, some reduction in plant height occurred in maize intercropped with *leucaena*, although this effect was not reflected in the final yields. From these studies, *Leucaena* population of 10,000 to 20,000 plants/ha at CIAT appeared adequate to provide sufficient foliage to cover soil and supply sufficient quantities of nutrients without competing with maize. The effects however depend on site conditions (soils fertility and climatic conditions prevailing) and cannot therefore be generalised.

In the CIAT experiment, mulch from dry season *Leucaena* pruning and toppings, and tree management practice such as pruning 4-6 weeks after crop is sown was instituted as a measure to support the maize crop.

In Morogoro, Tanzania, trials were laid out in 1980-1981 with *Leucaena* (intercropped with maize and beans in separate plots) to evaluate its potential in food and fodder production under various regimes of lopping, and a variety of weeding regimes (Maghembe *et al.*, 1980). The yield of maize and bean crops was improved. The mean yield of maize was 1645 kg/ha and was greater than twice the national average yield of maize in Tanzania (i.e., 670 kg/ha) (Acland, 1981). The mean yield of bean was 401 kg/ha, an average yield by farmers' standards (Acland, 1981). Tree growth was similarly enhanced because of the nursing effect of the crop

against weed competition, protection from browsing by both domestic and wild animals and the creation of favourable micro-climate for the trees (Redhead *et al.*, 1983). The fact that the food crops are weeded has a beneficial effect on the young trees, even more than the 'spot' weeding carried out as Tanzanian forest practice (Redhead *et al.*, 1983).

In some parts of Asia, *Leucaena* and *Sesbania grandiflora* are among legumes recognized as efficient soil fertility restorers (Guevarra, 1976, Anon., 1977). Gill *et al.*, (1982) investigated the effect of *Leucaena* foliage compared to *Sesbania* foliage as source of green manure. The results demonstrated the usefulness of *Leucaena* foliage as a green manure. The results demonstrated the usefulness of *Leucaena* foliage as a source of green manure (though actual yields were not given by the author) and subsequently an important source of manuring the crops for tropical and sub-tropical climatic conditions. Besides increasing crop production, *Leucaena* provided organic matter that improved the soil's properties - increasing aeration, water retention, and cation exchange capacity.

Intercropping studies of *Leucaena* in India showed that the production potential of *Leucaena* appears to be much higher when associated with a crop (sorghum) than when sown alone (Gill, 1985) - perhaps because of complementary effects rather than competition.

In Brazil, *Leucaena* used as green manure at the rate of 5 t/ha increased bean yields (*Phaseolus vulgaris*) from 1.4 t/ha for the unfertilized control to 2.2 t/ha (Kluthcouski, 1980).

Torres (1983) for example, used information available to formulate quantitative hypothesis on the impact of *Leucaena* hedgerows with maize upon the physical productivity of grain and fuelwood in the lowland tropics. Torres observed that data available would indicate that the production of organic nitrogen (N) by *Leucaena* hedgerows cut approximately every 8 weeks at a height of 15-30cm and planted at a distance between rows

wider than 150 cm is 45 gm/yr per line or metre hedgerows. In addition, Torres deduced from the published data that "the impact of hedgerow intercropping on maize productivity, although substantial, would be limited to systems where existing production levels of maize are lower than 1500 kg/ha. As expected, production per hectare decreases as spacing of *Leucaena* hedgerows increases".

This later hypothesis of Torres is supported by Alvarez *et al.*, (1984) studies in the Philippines. They observed that a higher grain yield of maize was obtained in plots where *Leucaena* intercrop was established in single hedgerows spaced 5 m apart. The maize yield were higher in the single as compared to tripple because the fresh herbage yield from subsequent growth over four cutting periods and applied to the maize crop as organic fertilizer were consistently higher in plants established in single hedgerows as compared to those of the tripple hedgerows. Soil organic matter content, pH and exchangeable K were not significantly effected by *Leucaena* herbage nor by inorganic fertilization.

Torres (1983) further noted from the information collected that " at the close spacing, hedgerows would produce enough fuelwood per hectare to satisfy the yearly needs of approximately four people, assuming a specific gravity for *Leucaena* wood of 0.46 and per capita consumption of 0.85 cubic metres". Torres' deduction, however are for a given ecological condition, *Leucaena* variety used and above all management practices instituted (e.g. pruning height at 15-30 cm) and cannot be generalized.

Brewbaker (1975) observed that the fertiliser equivalent of a years harvest per ha. of "Hawaiian Giant" *Leucaena* is estimated to be more than 550 kg N, 225 kg P₂O₅ and 550 kg K₂O.

In Torres' analysis, shading effect on the crop by the tree was discarded because of the low cutting height (15-30 cm) used. But production of intercropped maize could also be effected by the competition arising

from the adjacent *Leucaena* hedgerows. Kang *et al.*, (1981) studied this competitive effect and concluded that shading from *Leucaena* hedges was main factor affecting yield of the adjacent maize rows (in their experiment, hedges were cut at 1-1.5 m high).

In assessing the quantity of dry matter and nitrogen that can be produced from *Leucaena*, Pallad *et al.*, (1983) reported that the highest total dry matter production and nitrogen per hectare was obtained from high tree/crop ratio. If such green manures can be produced during the course of normal cropping season without effecting crop yields, it may be possible to supply atleast partially the nitrogen requirement of subsequent crops. Other experiments in Hawaii and the Phillipines have also shown that *Leucaena* foliage placed around maize can boost maize yield with increases similar to those achieved with manure or inorganic fertilizers (Guevarra, 1976). A yield increase of 1.0 ton of maize required only 1.0 ton (dry weight basis) of GLM, the equivalent of 4.0 tons of freshly harvested foliage with 4% nitrogen (Guevarra, 1976). Similarly, it was observed in India that *Leucaena* used as a source of manure recorded the highest plant height, number of leaves/tiller and fresh weight of fodder oats as compared to controls of urea, *Sesbania sesban* and *Desmanthus virgatus* (Gill and Patil, 1984). It was also observed that maize 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.

Mendoza *et al.*, (1981) also recorded good responses of maize to *Leucaena* fertilization in Taiwan, where yield of green maize increase from 1.48 t/ha in unfertilized check plots to 4.06 t/ha from plots with incorporated foliage. Good maize yields from land fertilized with *Leucaena* cuttings were also reported by Granert (1980). He obtained maize grain yields of 2090 kg/ha compared to the Phillipines national average of 840 kg/ha.

Other researchers such as Pathak and Patil (1982) studied the value of *Leucaena* as green manure on red, gravely murram soils at Jhansi, India. *Leucaena* planting (40,000 plants/ha) of different durations were established and were followed by a cereal fodder crop. They found that, compared with control plots, 30 kg/N/ha gave a 36% increase in the yield of the first crop but no increase in the successive crop of grass. However, with increasing periods under *Leucaena* plantings, there were increasing levels of improvements in the first cereal fodder crop and also in the second crop. The *Leucaena* GLM improved yields by as much as 150% for the first crop and 84% for the second crop when soil fertility was allowed to generate under *Leucaena* plantings for two years.

2.5. TREE MANAGEMENT : SIMULTANEOUS FODDER AND FUELWOOD PRODUCTION :

Leucaena leucocephala has excellent coppicing ability, which allows rapid and repeated harvest for firewood production. However, very few studies have been done in India determining the firewood production under coppiced management of systems. In a trial to compare shoot production in common *Leucaena* varieties at Jhansi during different seasons and at different heights, Pathak *et al.*, (1982) observed that trees felled in March produced more shoots than those felled in January. They also noted that shoot production was twice as high when trees were cut at 15 cm above ground compared to trees cut at ground level, although not appreciably different from that cut at 30 cm cutting height. They recommended that for good shoot production trees be felled at 10 cm or slightly higher.

Dutt *et al.*, (1984) reported that more firewood production at 50 cm cutting height than at 100 cm. But neither of these studies indicated the quantity of firewood produced in different years at various coppicing heights. This paper reports results from a field trial that determined the

volume of firewood produced at different coppicing heights in the first 3 years.

The giant *Leucaena* varieties are known to produce substantial biomass (fodder and fuelwood) (Brewbaker and Hutton, 1979). At Ibadan, a well established rows of *Leucaena leucocephala* variety K-28 grown on a sandy Entisol at 4 m inter-row spacing produced between 15 and 20 tons of fresh prunings (5.0 to 6.5 tons dry matter) per hectare with 5 prunings per year (Kang *et al.*, 1984). When allowed to grow uninhibited for one year in the Ibadan trials, the *Leucaena* rows easily reached a height of over 7.5 m and produced more than 88 tons of wood per hectare.

For the Salvadorian varieties, eg. K-28, harvesting should be done leaving a taller stump than other varieties so that several auxiliary buds are retained (Hedge, 1982). The higher cutting requirements of the Salvadorian types are apparent from a study in which a uniform height (5 cm) was maintained for both Hawaiian and Salvadorian types ; the former markedly out-yielded the later (Guevarra, 1976).

Takahashi and Ripperton (1949), studying the Hawaiian type, obtained the highest yield (50.9 t/ha) of green forage when *Leucaena* was cut at 5 cm above ground. At 38 cm and 78 cm, yields were 43.40 t/ha and 40.28 t/ha respectively. However, Parera (1982) observed that periodic pruning at higher points, 75-80 cm, prevents *Leucaena* from becoming weeds, which they do at lower heights, a practice making them unacceptable to farmers.

In a trial conducted in the Phillipines (Mendoza *et al.*, 1975), highest annual dry-matter yields (23.6 t/ha) were obtained when plants were maintained at 3 m high and the leaves were plucked. Also yields were maximised when 25% of the foliage were left on the plants (Mendoza *et al.*, 1975). A cutting height of 30-50 cm has been recommended in Hawaii

(Kinch and Ripperton, 1962) while in India, harvesting at 90-100 cm th produced good yields as well as minimising ^{ed} the labour cost for weeding and manual harvesting (Hedge, 1982).

Other studies suggest that plants can frequently be coppiced but will have a longer and more productive life if stems are allowed to reach 3 cm thick in diameter before the first cutting and are cut at 0.3-1.0 m height, and allowed to regrow for 3 months in the rainy season and 4 months in the dry season. In many cases, poor performance of hedgerow can be cut back and kept pruned during the cropping period and leaves and twigs applied to the soil both as mulch and as nutrient source with the bigger branches used as stakes or firewood (Parera, 1980).

Guevarra (1976) and Ferraris (1979) in Hawaii and Australia respectively found out that harvesting at monthly intervals brought down the yield of fodder as well as the nutritive value. Sampet and Pattaro (1979) also reported that frequent harvests (every 4-6 weeks) in Thailand reduced the woody yield. In Papua New Guinea, under adequate moisture conditions, the crop was ready for fuelwood harvest in 6 weeks during the summer months (Hill, 1971).

Leucaena, however, can only serve one main purpose at a time. For example, the most leaves are produced when the tree is frequently coppiced and, hence does not continuously produce seeds or wood. If both seeds and leaves are desired from one plant the production of both will be lower than if only one product (i.e. seeds or leaves) is regularly harvested.

The supply of fuelwood from the system therefore depends on the effect of interval and intensity of cutting of the tree. Das (1981) reported from a drought prone area of India that cutting at one metre height above ground and at interval of 60 days yielded more foliage compared to those cut at other intervals, while cutting at one metre height under 90 days

interval yielded more fuelwood. Osman (1981) in Mauritius investigating the effects of cutting interval on relative dry matter production of 4 cultivars of *Leucaena* reported that a cutting height of between 45 and 90 cm is recommended for maximum yields of dry matter. Therefore, it seems that the choice of cutting height and interval will be determined by the users' priority needs from that system (food, fodder and fuelwood considerations), and the coppicing ability of the variety under the given set of environment (rainfall, temperature and soil) and management conditions.

2.6. WEED CONTROL BY LEUCAENA INTERCROPPING :

Leucaena intercropping has the potential to reduce weed infestation through shading during the dry season (Anon., 1984b, unpublished data, Kang *et al.*, 1984). The early ground cover of *Leucaena* achieves good weed control through shading (Hedge, 1982).

The understorey of *Leucaena* plantations often carries very few weeds, although a substantial number of *Leucaena* seedlings may be present (Wildin, 1980). Although an allelopathic mechanism has been proposed to explain mature *Leucaena*'s ability to suppress other plants, and although mimosine has been shown to be allelopathic *in vitro*, shading is a more plausible explanation, as weeds thrive in stands with mature, but partially opened canopies (Anon., 1982b).

Caution however is needed in the use of *Leucaena* for erosion control. Plantation solid stands of *Leucaena* at high populations on steep slopes is not recommended because ground cover will usually be shaded out, more so when the foliage is cut for forage or green manure. The result is exacerbated erosion, as water flows freely down the slopes between the trees (Anon., 1982b). The tap-root system of *Leucaena* makes it unsuitable for binding surface soil, a situation leading to excessive soil erosion especially under dense pure *Leucaena* stands (Pound *et al.*, 1983). It has

therefore been suggested that interplanting or strip planting of a second species or planting a shade tolerant "live mulch" grown under *Leucaena* crop (Tergas *et al.*, 1978) could be a solution. Low profile legumes such as *Centrosema pubescens* or *Psophocarpus palustris* would seem possible candidates (Pound *et al.*, 1983). Nevertheless, the aggressive and deep rooting system break up and aerate impervious soils (Djikman, 1950), allowing greater water infiltration and surface runoff and soil erosion are thus decreased (Anon., 1980). Moreover, the litter and the humic layers on the soil surface act as a cushion against erosion (Nair, 1984). Loppings and prunings could also provide mulch to aid in preventing sheet erosion between trees.

CHAPTER - III

MATERIALS AND METHODS

3. MATERIALS AND METHODS :

During 1998-1999 one field experiment was conducted at Zemabawk, Aizawl, Mizoram. The experiment was an agroforestry based intercropping system of cultivation with a view to find an alternative to shifting cultivation which is a major mode of cultivation and is unproductive and very harmful way of cultivation as far as environment is concerned in Mizoram. The aim of this experiment was to study " spatial effect on the growth behaviour of *Leucaena leucocephala* (Lam.) de Wit along with *Zea mays* L. on a hill agroforestry system of Mizoram ".

3.1. EXPERIMENTAL SITE AND SOIL :

The field experiment site was located in the upland area of Zemabawk which is situated at north part of Aizawl town and is about 3 km north of Aizawl, the capital of Mizoram. Zemabawk lies in between 92°15' to 93°29' E Longitude and 21°58' to 24° 35' N Latitude with an altitude of 1132 metres i.e. 3715 feet, with an average rainfall of 235 cm. Summer temperature varies from 21° to 30°C where as the winter temperature varies from 11° to 23°C.

The texture of the soil in the experimental area, before planting was analysed in Soil Testing Laboratory, Department of Agriculture and Minor Irrigation, Govt. of Mizoram, and was found to be Sandy clay having 61.96% sand, 7.20% silt and 30.84% clay with an average pH value of 5.3.

3.2. EXPERIMENTAL DESIGN AND TREATMENTS :

In the field the experiment was laid out in Randomised Block Design (RBD) with three replications. Four treatments were allocated in each replication. As such there were 12 treatments in the field experiment i.e. 12 plots including control. The size of each plot measured 12 m X 12 m.

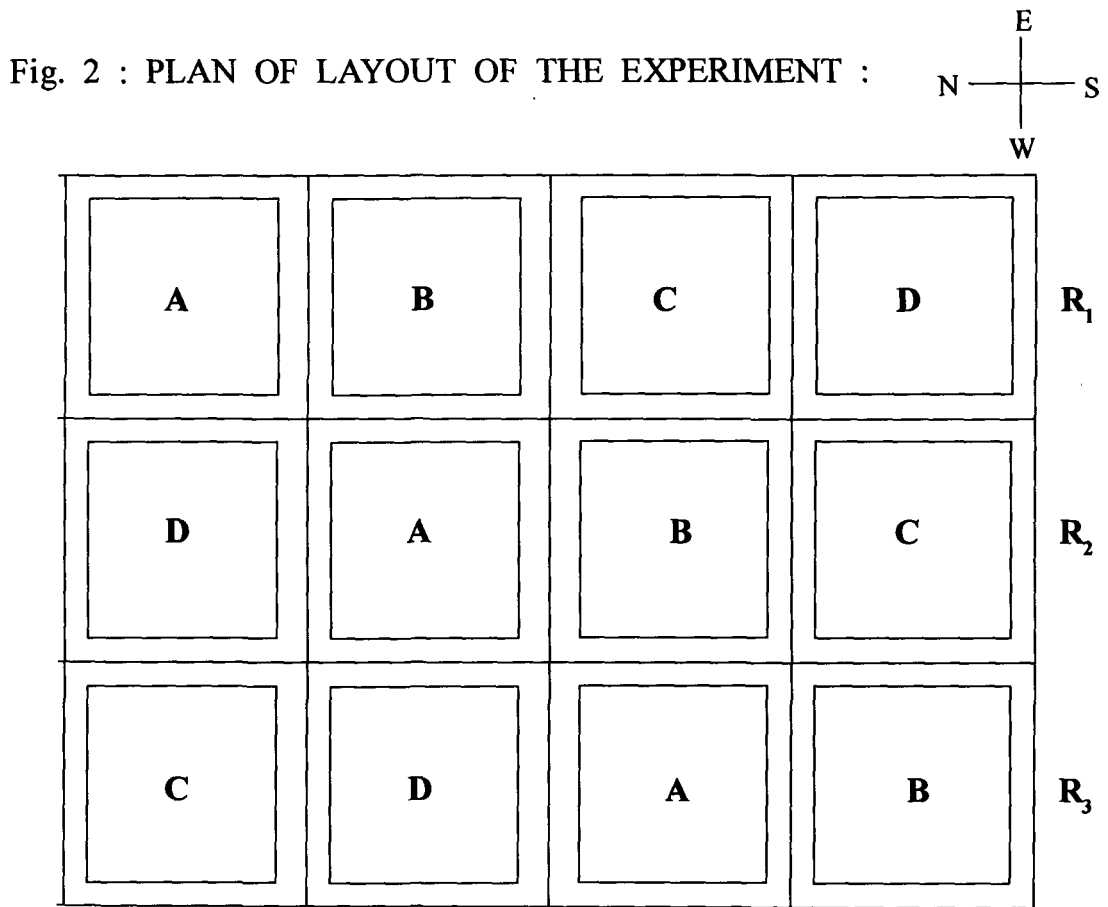
The vegetation of the whole experimental field was cleared with the help of dao, hand hoe, etc., after clearing the land, *Leucaena leucocephala* (Lam.) de Wit, variety Salvadorian, also called Hawaiiin Giant or K-28, seedlings 15-20 cm tall, raised in polypot in the month of August 1998, from nursery were collected and transplanted in a pit of 1 cubic feet which was filled with a mixture of top soil and Farm Yard Manure (FYM) @3-4 kg/pit in the end of September 1998. The planting was done with three different spacings (3m x 3m, 4m x 4m and 6m x 6m) which were replicated three times. Altogether there were 87 number of plants. These were intercropped with maize (*Zea mays* L.) and there were three 12m x 12m control plots of sole crop maize (60cm x 50cm) randomised within overall layout. However, no management was given to *Leucaena* except watering in the initial transplanting time with an objective to get good tree survival which form a baseline for intercropping of maize crop.

Maize (variety - Ganga 11) taken as intercrop was sown at 60cm x 50cm, (2-3 seeds per hill and then thinned, always to leave virtually complete stand, having approximately 33333 plants/ha) in late April covering the long rainy season (April-August).



Plate - 1 : One cubic feet pit prepared for transplanting of Leucaena.

3.3. FIELD LAYOUT :



DESIGN - RANDOMISED BLOCK DESIGN

TOTAL EXPERIMENTAL AREA - 48m x 36m.

PLOT SIZE - 12m x 12m

TREATMENTS :

A = Leucaena (6m x 6m) + Maize (60cm x 50cm)

B = Leucaena (3m x 3m) + Maize (60cm x 50cm)

C = Leucaena (4m x 4m) + Maize (60cm x 50cm)

D = Control (Maize alone - 60cm x 50cm).

3.4. PARAMETERS COLLECTED :

3.4.1. Parameters collected on growth components of Leucaena :

As the tree was in an establishment phase, management of tree was not so necessary except weeding which was done three times (January, April, July 1999). The data however collected from the tree was :-

- (a) Survival percentage of Leucaena.
- (b) Tree heights and diameters as a measure of growth.

Tree heights were taken from the bottom to the tip of the tallest branch using a metre scale at monthly interval. The diameter was taken from the best of the tree just above the ground level with the help of a thread which was again measured with a metre scale.

- (c) Leucaena biomass production :

This includes measurement on dry weight of shoot, root and total plant, root length and root spreading one month after transplanting of Leucaena to the experimental field (October 1998) and after one year of transplanting (September 1999).

3.4.2. Parameters collected on maize crop :

Maize was sown on 26th April 1999 and no fertilizer was applied in the field. The crop parameters monitored were :-

- (a) Maize plant height (cm) and basal diameter (cm) at regular intervals (42, 62 DAS and at harvest).
- (b) Number of leaves at regular intervals (42, 62 DAS and at harvest).
- (c) Maize cod length (cm) and diameter (cm) at harvest.
- (d) Maize grain rows per ear/cob at harvest.
- (e) Maize grain per ear per row at harvest.
- (f) Total number of grains per cob at harvest.

- (g) Number of maize cob yield per plot.
- (h) 1000 grains weight (gm) of maize.
- (i) Maize grain yield Q/ha.

3.4.3. Soil Parameters :

In order to assess soil (chemical) fertility changes overtime, soil sample from each plot was taken at a depth of 0-15 cm twice during the study period, once before planting of Leucaena (i.e. just after clearing the experimental area) and after harvesting of maize crop, and was analysed at Soil Testing Laboratory, Agriculture and Minor Irrigation, Govt. of Mizoram. Soil parameters analysed and specific methods used were as follows :-

- (i) Texture : Hydrometer method.
- (ii) Organic carbon : Walkley-Black method.
- (iii) Phosphorus : Olsen method by using calorimeter.
- (iv) Potassium : Mongan's method (Sodium Actate extraction) by using flame photometer.
- (v) pH : pH meter method (Glass electrode pH meter, 50 ml polythene beakers, glass rod).

CHAPTER - IV

RESULTS

4. RESULTS :

In this section, results are presented in chronological order based on the cropping sequence used in the experimental period. Thus, the data studied for tree species were presented first right from the initial phase of establishment (1998) which were followed by maize crop in sequence of cropping (1999).

4.1. ESTABLISHMENT AND GROWTH PARAMETERS OF *LEUCAENA LEUCOCEPHALA* :

The interesting factors studied on tree species for the experiment were the effect of different spacings of *Leucaena* on :-

- (i) Survival per cent.
- (ii) Plant height.
- (iii) Basal diameter.
- (iv) Biomass production including-
 - (a) Dry weight of shoot, root and total plant.
 - (b) Root length.
 - (c) Root spreading.

These are presented in sections as follows :-

4.1.1. TREE SURVIVAL PER CENT :

Survival count of all plants in its spacing was done in the end of the month after transplanting i.e. October 1998 and actual mean survival per cent of the number initially planted is shown in Table 1 and Fig. 3. It can be seen from the table that the effect of treatments on *Leucaena* survival percentage ranged from 83.34 to 93.75 %. The maximum survival percentage of *Leucaena* was found in 3m x 3m spacing which was followed by 4m x 4m spacing (92.58%), and 6m x 6m (83.34) which shows the least survival percent. However, the effect of treatments on *Leucaena* survival percent after 1 month of transplanting was found to be non-significant.

Table 1 : Effect of spacings on survival % of *Leucaena leucocephala*, 1 month after transplanting. October 1998.

Treatments. Tree spacings (m)	Survival %
6 x 6	83.34
3 x 3	93.75
4 x 4	92.58
S.Em ±	8.28
C.D (P= 0.05)	N.S

N.S = Non-significant at.

4.1.2. PLANT HEIGHT OF LEUCAENA :

The result pertaining to the height of Leucaena plants as influenced by different spacings at monthly interval are presented in Table 2, Fig. 5. It can be seen from the results that the variation in Leucaena plant height as affected by different spacings under agroforestry system was found to be significant in the month of February, March, April and May 1999, whereas in the rest months the effect of treatments was found to be non-significant.

In February 1999, Leucaena height (cm) ranged from 42-57.3 cm which showed significant difference as affected by treatments. The maximum height being found in 3m x 3m and 4m x 4m plot (both 57.3 cm) and the least being 6m x 6m plot (42 cm).

The plant height in March 1999 ranged from 51.3 to 78.6 cm. The height of the plant as recorded in 3m x 3m spacing (76.6cm) was significantly higher which was followed by 4m x 4m (71cm). However, the height of the plant at 3m x 3m and 4m x 4m was statistically at par. But both the treatments proved their superiority over 6m x 6m spacing (51.3cm).

Similar trends were noticed in April and May 1999. In general, the trees planted at a closer spacing grew taller than wider spacing. Maximum height was recorded in 3m x 3m (96.6cm and 115cm respectively), followed by 4m x 4m (88cm and 104cm) in April and May respectively. The least height was observed in 6m x 6m (78.3cm and 90.6cm respectively).

After 1 year of transplanting of Leucaena (September 1999) the cumulative plant height ranged from 135.6 to 190cm. But effect of treatments on cumulative plant height was found to be non-significant. However, the maximum plant height was recorded in 3m x 3m (190cm), followed by 4m x 4m (173.6cm) and minimum height was observed in 6m x 6m (135.6cm).

Table 2 : Height (cm) of *Leucaena leucocephala* as affected by different spacings at monthly intervals. Sept. 1998 to Sept. 1999.

Treatments.	Height of <i>Leucaena</i> (cm) at monthly interval.												
	1998				1999								
Tree spacings (m)	Sept	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug	Sept
6 x 6	17.3	21.3	27	32.3	37	42	51.3	63	78.3	90.6	106.3	121.3	135.6
3 x 3	18.3	27.6	37.3	46.67	56.3	57.3	78.6	96.6	115	134	152.3	170.6	190
4 x 4	18.3	27.3	36	42	50.3	57.3	71	88	104	121.3	139	156	173.6
S.Em±	1.63	1.93	3.36	4.42	5.54	5.88	6.34	8.43	9.83	12.42	13.49	14.68	16.48
C.D (P= 0.05)	N.S	N.S	N.S	N.S	N.S	16.33	17.6	23.42	27.3	N.S	N.S	N.S	N.S

N.S = Non-significant.



Plate - 2 : One year old Leucaena plant after harvesting of intercropped maize.

4.1.3. BASAL DIAMETER OF LEUCAENA :

Leucaena basal diameter was measured at monthly interval after transplanting in the experimental field, the effect of spacing on basal diameter of *Leucaena leucocephala* by different spacings at monthly interval after transplanting under agroforestry system, from September 1998 to September 1999 has been presented in Table 3. A perusal of the results indicated that the basal diameter of plants vary significantly due to spacing, barring in April and June, 1999, whereas in the other months the effect of treatments on basal diameter was found to be non-significant.

In April 1999, Leucaena basal diameter ranged from 3.16 to 4.2cm which was found to be significant. Maximum basal diameter was observed in 3m x 3m spacing (4.2cm) which was significantly different in comparison to basal diameter of 6m x 6m spacing. However, there was no marked variation in basal diameter of plant between 4m x 4m and 6m x 6m spacing.

Another significant difference due to treatments on Leucaena basal diameter was observed in the month of June where the basal diameter of Leucaena plant ranged from 3.96 to 5.76cm and maximum basal diameter was recorded in 3m x 3m spacing (5.76cm) which proved its superiority over 6m x 6m spacing (3.96cm). However, there was no marked variation in basal diameter of plant between 4m x 4m (5.16cm) and 3m x 3m.

After 1 year of transplanting of Leucaena (September 1999) the basal diameter ranged from 5.4 to 7.43cm. There was no conspicuous difference in the cumulative increase in radical growth of the trunk. In general, the maximum basal diameter was recorded in 3m x 3m spacing (7.43cm), followed by 4m x 4m (6.83cm) and the least basal diameter

Table 3 : Basal diameter (cm) of *Leucaena leucocephala* as affected by different spacings at monthly intervals. Sept 1998 to Sept 1999.

Treatments. Tree spacings (m)	Basal diameter of <i>Leucaena</i> (cm) at monthly interval.												
	1998				1999								
	Sept	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug	Sept
6 x 6	1	1.2	1.3	1.46	1.7	2.06	2.56	3.16	3.6	3.96	4.43	4.96	5.4
3 x 3	1.1	1.23	1.36	1.63	2.03	2.7	3.4	4.2	5.16	5.76	6.23	6.83	7.43
4 x 4	1.03	1.2	1.36	1.66	2.1	2.73	3.26	3.9	4.53	5.16	5.7	6.3	6.83
S.Em ±	0.07	0.09	0.09	0.13	0.2	0.32	0.31	0.27	0.42	0.48	0.5	0.56	0.6
C.D (P= 0.05)	N.S	N.S	N.S	N.S	N.S	N.S	N.S	0.76	N.S	1.34	N.S	N.S	N.S

N.S = Non-significant.

was recorded in 6m x 6m spacing of *Leucaena* (5.4cm).

4.1.4. LEUCAENA BIOMASS PRODUCTION :

4.1.4.1. Dry weight of shoot, root and total plant of *Leucaena* at 1 month and 1 year after transplanting :

The data on the effect of spacings on biomass accumulation in *Leucaena leucocephala* at one month (October 1998) and one year after transplanting (September 1999) are presented in Table 4 and Fig. 6. It can be seen from the table that the accumulation of dry matter in shoot under different treatments at 1 month after transplanting ranged from 0.36 to 0.41g which showed significant variation due to spacing. The maximum shoot dry weight of *Leucaena* was recorded in 3m x 3m spacing (0.41g), followed by 4m x 4m (0.39g) and the least being 6m x 6m spacing (0.36g). It is also evident from the same table and Fig. that the effect on shoot dry weight by different treatments at 1 year after transplanting (Sept. 1999) ranged from 65 to 103g. But there was no conspicuous difference increase in shoot dry weight. Maximum shoot dry weight was observed in 3m x 3m spacings (103g), followed by 4m x 4m (90g) and minimum shoot dry weight was found in 6m x 6m spacings of *Leucaena*.

The accumulation of dry matter in roots at 1 month after transplanting i.e. October, 1998 did not exhibit any marked variation due to spacing. It would be evident from the table that the mean root dry weight of different treatments ranged from 0.26 to 0.3g. In general, maximum root dry weight was recorded in 3m x 3m spacing (0.3g) followed by 4m x 4m (0.28g) and the least being 6m x 6m spacing (0.26g).

Similarly, it can be seen from the same table and Fig. that the root dry weight as affected by different treatments at 1 year after transplanting ranged from 33 to 68g. But did not exhibit any marked variation

Table 4 : Increase in biomass production of *Leucaena leucocephala* as affected by different spacings. Oct. 1998 to Sept. 1999.

Treatments. Tree spacings. (m)	Shoot dry weight. (g)		Root dry weight. (g)		Total plant dry weight. (g)	
	Oct.'98	Sept.'99	Oct.'98	Sept.'99	Oct.'98	Sept.'99
6 x 6	0.36	65	0.26	33	0.62	98
3 x 3	0.41	103	0.3	68	0.71	171
4 x 4	0.39	90	0.28	55	0.67	145
S.Em ±	0.012	12.82	0.014	10.48	0.022	23.09
C.D (P= 0.05)	0.03	N.S	N.S	N.S	0.06	N.S

N.S = Non-significant.

due to spacing. In general, maximum mean root dry weight was observed in 3m x 3m plot (68g), followed by 4m x 4m plot (55g) and the minimum being 6m x 6m plot (33g).

A perusal of the results also indicated that the total plant dry weight of different treatments at 1 month after transplanting (Oct.1998) ranged from 0.62 to 0.71g. There was conspicuous variation in dry matter accumulation in plant due to spacing at the initial stage. Maximum plant dry weight was observed in 3m x 3m spacing (0.71g), which was significantly higher than 6m x 6m spacing and followed by 4m x 4m (0.67g). The influence of 4m x 4m and 6m x 6m spacings on total plant dry weight was significantly at par. However, a perusal of the results at 1 year after transplanting (Sept. 1999) indicated that the total plant dry weight ranged from 98 to 171g. But there was no conspicuous difference increase in total plant dry weight. In general, maximum mean plant dry weight was recorded in 3m x 3m spacing (171g) followed by 4m x 4m (145g) and the least being 6m x 6m (98g).

4.1.4.2. Root length and root spreading of Leucaena at 1 month and 1 year after transplanting. (October 1998 to September 1999) :

The results pertaining to effect of spacing on Leucaena root length and root spreading at 1 month and 1 year after transplanting are depicted in Table 5 and Fig. 7. The various spacing failed to exert any strong influence on the initial root length of plants. In general, the root length as observed at 3m x 3m spacing was marginally higher than the subsequently wider spacing at 1 month after transplanting (Oct. 1998). However, it may be seen from the table that the root length after 1 year of transplanting (Sept.1999) ranged from 30 to 45cm which did not exhibit any marked variation due to spacing. In general, maximum root

Table 5 : Effect of *Leucaena leucocephala* on root length and root spreading by different spacings at one month and one year after transplanting. Oct 1998 & Sept 1999.

Treatments. Tree spacings. (m)	Root length. (cm)		Root spreading. (cm)	
	Oct.'98	Sept.'99	Oct.'98	Sept.'99
	6 x 6	13	30	9.1
3 x 3	13.3	45	9.8	40
4 x 4	13.2	38	9.6	30
S.Em ±	0.5	4.88	0.09	6.62
C.D (P= 0.05)	N.S	N.S	0.24	N.S

N.S = Not-significant.

length was recorded in 3m x 3m spacing (45cm), followed by 4m x 4m (38cm) and the least being 6m x 6m spacing (30cm).

It would be interesting to note that the root spreading of Leucaena plant differed significantly due to different spacings at one month after transplanting (October 1998) The mean root spreading ranged from 9.1 to 9.6cm in Oct. 1998. Maximum root spreading was noted in 3m x 3m spacing plot (9.8cm) which was significantly different in comparison to 6m x 6m spacing and closely followed by 4m x 4m (9.6cm) while the minimum mean root spreading was found in 6m x 6m spacing (9.1cm). No significant difference was found between 3m x 3m and 4m x 4m spacing. However, no significant difference was observed on mean root spreading at 1 year after transplanting (Sept.1999) as affected by different treatments. In general, maximum root spreading was recorded in 3m x 3m spacing (40cm), followed by 4m x 4m (30cm) and the least root spreading was recorded in 6m x 6m (18cm).

4.2. GROWTH PARAMETERS OF MAIZE :

4.2.1. Plant height of maize :

The pattern of growth in height of maize plant in a Leucaena and maize combination is reflected in Table 6 and Fig. 8. It is evident from the table that there was significant difference in maize plant height (cm) at 42 days after sowing under different spacings of Leucaena. Maximum height of maize plants was recorded (90cm) in 3m x 3m Leucaena spacing, with a 5.88% increase over control and showed significant difference over the height of maize plant at 6m x 6m Leucaena spacing and control. However, there was no significant difference between the height of 3m x 3m and 4m x 4m Leucaena spacings. The effect of 6m x 6m spacing of Leucaena plants though caused 2.35% increase over control but failed to reach the level of significance.

Table 6 : Maize plant height (cm), at 42, 62 days after sowing (DAS) and at harvest, as affected by different spacings of *Leucaena leucocephala*.

Treatments. Tree spacings. (m)	Plant height (cm)					
	42 DAS		62 DAS		At harvest	
	Actual height (cm).	% increase over control.	Actual height (cm).	% increase over control.	Actual height (cm).	% increase over control.
6 x 6	87	2.35	173	1.16	176	1.73
3 x 3	90	5.88	181	5.84	185	6.93
4 x 4	88	3.53	175	2.33	181	4.62
Control	85	-	171	-	173	-
S.Em ±	1.08	-	1.17	-	0.91	-
C.D (P= 0.05)	2.64	-	2.88	-	2.23	-

It can be seen from the same table that maize plant height at 62 days after sowing ranged from 171 to 181cm. The effect of different treatments on plant height differed significantly over control at 62 days after sowing. It would be seen from the data that maximum height was recorded at 3m x 3m spacing of Leucaena (181cm) with an increase of 5.84% over control and closely followed by 4m x 4m spacing (2.33% increase over control). The effect of 4m x 4m Leucaena spacing also caused significant increase in maize plant height as compared to control. However, control and 6m x 6m spacing did not show any significant differences in respect of the height of maize plant.

It would also be seen from the table that the mean effect on maize plant height by different Leucaena spacings ranged from 173 to 185cm. The effect of different treatments on plant height differed significantly over control at harvest. The percentage increased in maize plant height at harvest over control was also calculated and presented in the same table. It would be evident from the table that mean maximum height of maize at harvest was observed in 3m x 3m Leucaena spacing plot (185cm) with an increase of 6.93% over control, which was followed by 4m x 4m (181cm) with an increase of 4.62% over control, and 6m x 6m (176cm) with an increase of 1.73% over control. However, control plot shows minimum height among the treatments at harvest (173cm).

4.2.2. Basal diameter of maize plant :

The effect of different Leucaena spacings on maize plant basal diameter at various stages of crop growth are presented in Table 7. It is evident from the table that the maize plant basal diameter at 42 days after sowing ranged from 3.7cm to 4.0cm. There was significant variation in basal diameter of maize plant due to different spacing of Leucaena plants at 42 days after sowing. Maximum basal diameter of maize plant was



Plate - 3 : Close view of maize plant before harvesting as an intercrop with Leucaena.

Table 7 : Maize plant basal diameter (cm), at 42, 62 days after sowing (DAS) and at harvest, as affected by different spacings of *Leucaena leucocephala*.

Treatments. Tree spacings. (m)	Plant basal diameter (cm).					
	42 DAS		62 DAS		At harvest	
	Actual basal diameter. (cm)	% increase over control.	Actual basal diameter. (cm)	% increase over control.	Actual basal diameter. (cm)	% increase over control.
6 x 6	3.7	0	5.1	2	5.4	1.88
3 x 3	4.0	8.1	5.5	10	5.8	9.43
4 x 4	3.8	2.7	5.4	8	5.7	7.54
Control	3.7	-	5.0	-	5.3	-
S.Em ±	0.08	-	0.11	-	0.07	-
C.D (P= 0.05)	0.19	-	0.27	-	0.17	-

found in 3m x 3m Leucaena spacing (4.0cm) with an increase of 8.1% over control which was followed by 4m x 4m, 6m x 6m. The influences of 4m x 4m and 6m x 6m spacing failed to evoke any perceptible difference when compared with control at 42 days after sowing.

It would be clear from the table that mean maize plant basal diameter at 62 days after sowing ranged from 5.0cm to 5.5cm, and was observed that there was significant influence of Leucaena spacings on basal diameter of maize plant. The maximum maize plant basal diameter was found at 3m x 3m Leucaena spacing (5.5cm) with an increase of 10% over control which was statistically at par with 4m x 4m spacing (8% increase over control). No significant variation could be discernible between the effect of 6m x 6m spacing and control in respect of basal diameter of maize plant.

The effect of different Leucaena spacings on maize plant basal diameter at harvest has also been presented in Table 7. It was observed that there was significant influence of Leucaena spacing on basal diameter of maize plant at harvest. It is evident from the table that the diameter of maize plant ranged from 5.3cm to 5.8cm. The maximum basal diameter was found at 3m x 3m Leucaena spacing (5.8cm) with an increase of 9.43% over control which was statistically at par with 4m x 4m spacing (7.54% increase over control). No significant variation could be discernible between the effect of 6m x 6m spacing and control in respect of basal diameter of maize plant.

4.2.3. Number of leaves per maize plant :

The results on number of leaves affected by different Leucaena spacings are presented in Table 8. It was observed that there were no significant difference in the number of leaves of maize throughout the stages of crop growth.

Table 8 : Number of leaves of maize/plant at different intervals as affected by different spacings of *Leucaena leucocephala*.

Treatments. Tree spacings. (m)	No. of leaves/plant at different intervals.					
	42 DAS.		62 DAS.		At harvest.	
	Actual no. per plant.	% increase over control.	Actual no. per plant.	% increase over control.	Actual no. per plant.	% increase over control.
6 x 6	7	16.67	10	11.12	11	0
3 x 3	8	33.34	11	22.23	13	18.18
4 x 4	8	33.34	10	11.12	12	9.09
Control	6	-	9	-	11	-
S.Em ±	0.7		0.7		0.96	
C.D (P= 0.05)	N.S		N.S		N.S	

DAS = Days after sowing.

N.S = Non-significant.

The mean number of leaves per plant at 42 days after sowing ranged from 6 to 8. Maximum leaves per plant (8 nos.) was found in 3m x 3m and 4m x 4m Leucaena spacing, followed by 7 number of leaves in 6m x 6m Leucaena spacing plot and 6 number of leaves in control plot.

At 62 days after sowing, the mean number of leaves per plant ranged from 9 to 11 leaves, in which maximum leaves per plant (11 nos.) was found in 3m x 3m Leucaena spacing, followed by 4m x 4m (10 nos.), 6m x 6m (10 nos.) and control (9 nos.).

At harvest the mean number of leaves per plant ranged from 11 to 13 leaves in which maximum number of leaves (13 nos.) was found in 3m x 3m Leucaena spacing, followed by 4m x 4m (12 nos.), 6m x 6m (11 nos.) and control (11nos.). In general, the 3m x 3m spacing had slight edge over others in respect of number of leaves per plant throughout the crop growth period.

4.2.4. Maize cob length at harvest :

Maize cob length at harvest was assessed and the effect of Leucaena spacings on length (cm) of maize cob at harvest (August 1999) has been presented in Table 9. The percentage increase in maize cob length over control has also been calculated and presented in the same table. It may be seen from the table that the mean length of maize cob under different treatments ranges from 14cm to 16cm, in which the maximum maize cob length was found in 3m x 3m Leucaena spacing (16cm) with an increase of 14.28% over control, followed by 4m x 4m (15.6cm) with 11.42% increase over control, 6m x 6m plot (15cm) with 7.14% increase over control. The smallest cob was obtained in control plot (14cm). But, the maize cob length (cm) at harvest, however, ^{did} not differ significantly.

Table 9. Length (cm) of maize cob at harvest as affected by different spacings of *Leucaena leucocephala*.

Treatments. Tree spacings. (m)	Maize cob length. (cm)	% increase over control.
6 x 6	15	7.14
3 x 3	16	14.28
4 x 4	15.6	11.42
Control	14	-
S.Em \pm	0.84	
C.D (P= 0.05)	N.S	

N.S = Non-significant.



Plate - 4 : Maize cob at harvest.

4.2.5. Maize cob diameters at harvest :

Maize cob diameter at harvest was evaluated, and the effect of Leucaena spacings on maize cob diameters at harvest has been represented in Table 10. The percentage increased in maize cob diameter over control has also been calculated and presented in the same table. It would be evident from the table that the mean maize cob (cm) at harvest under different treatments ranged from 11cm to 12.4cm. The cob diameter differed significantly due to spacing of Leucaena plants and all the spacing treatment caused significant increase of cob diameter as compared to control. The data revealed that maximum maize cob diameter (cm) was found in 3m x 3m Leucaena spacing (12.4cm) with an increase of 12.72% over control, followed by 4m x 4m plot (12cm) with an increase of 9.09% over control, and 6m x 6m (11.5cm) with an increase of 4.54% over control. The least maize cob diameter was found in control (11cm) at harvest.

4.2.6. Maize grain rows per ear at harvest :

The data pertaining to the effect of different Leucaena spacings on number of maize grain rows per ear at harvest and percentage increase over control have been presented in Table 11. It would be seen from the table that the mean number of maize grain rows per ear ranged from 11 to 13.3 though the variation was not significant. In general, maximum number of maize grain rows per ear was found in 3m x 3m Leucaena spacing (13.3 nos.) with an increase of 20.9% over control, followed by 4m x 4m (12.3 nos.), 6m x 6m (12 nos.) and control (11 nos.). The least number of maize grain rows per ear was found in control plot.

4.2.7. Maize grain per row per ear at harvest :

The results on the effect of Leucaena spacings on number of maize grain per row per ear at harvest have been presented in Table 12. It would be seen from the table that the number of maize grain per row per ear at harvest ranged from 27 to 32. There was conspicuous effect of

Table 10 : Diameter (cm) of maize cob at harvest as affected by different spacings of *Leucaena leucocephala*.

Treatments. Tree spacings. (m)	Diameter of maize cob. (cm)	% Increase over control.
6 x 6	11.5	4.54
3 x 3	12.4	12.72
4 x 4	12	9.09
Control	11	-
S.Em ±	0.14	
C.D (P= 0.05)	0.34	

Table 11 : Number of maize grain rows per ear at harvest as affected by different spacings of *Leucaena leucocephala*.

Treatments. Tree spacings. (m)	Maize grain rows per ear. (nos.)	% Increase over control.
6 x 6	12	9.09
3 x 3	13.3	20.9
4 x 4	12.3	11.81
Control	11	-
S.Em ±	0.75	
C.D (P= 0.05)	N.S	

N.S = Non-significant.

Table 12 : Number of maize grains per row per ear at harvest as affected by different spacings of *Leucaena leucocephala*.

Treatments. Tree spacings. (m)	Maize grains per row per ear. (nos.)	% Increase over control.
6 x 6	29	7.4
3 x 3	32	18.51
4 x 4	31	14.81
Control	27	-
S.Em ±	1.05	
C.D (P= 0.05)	2.58	

Leucaena spacings on number of grains per row per ear. The maximum number of maize grain per row per ear at harvest was obtained in 3m x 3m Leucaena spacing (32 nos.) with an increase of 18.51% over control (27 nos.) which was significantly different when compared with 6m x 6m and control. However, 3m x 3m and 4m x 4m spacings showed no significant difference. Also, 6m x 6m and control plots shows no significant difference on the number of maize grain per row per ear at harvest.

4.2.8. Number of maize grains per cob at harvest :

The results on the effect of Leucaena spacings on number of maize grain per cob at harvest has been presented in Table 13. It was observed from the table that the mean number of grains per maize cob at harvest ranged from 297 to 427. There was conspicuous effect of Leucaena spacing on number of maize grain per cob. The percentage increase in number of grains per maize cob at harvest over control has also been calculated and presented in the same table. Maximum mean number of grains per maize cob at harvest was recorded in 3m x 3m Leucaena spacing (427 nos.) with an increase of 43.77% over control. The least mean number of grains per maize cob was found in control plot (297 nos.). 3m x 3m Leucaena spacing shows significant difference on 6m x 6m and control plots. No significant variation could be discernible between the effect of 6m x 6m spacing and control in respect of maize grain per cob.

4.2.9. 1000 grains weight of maize at harvest :

The mean 1000 grains weight (g) of maize at harvest as affected by Leucaena spacings has been presented in Table 14. It may be seen from the table that the mean 1000 grains weight of maize at harvest under different treatments ranged from 285 to 300g which did not exhibit

Table 13 : Number of maize grains per cob at harvest as affected by different spacings of *Leucaena leucocephala*.

Treatments. Tree spacings. (m)	Maize grains per cob. (nos.)	% Increase over control.
6 x 6	347	16.83
3 x 3	427	43.77
4 x 4	381	28.28
Control	297	-
S.Em ±	28.23	
C.D (P= 0.05)	69.09	

Table 14 : 1000 grains weight (g) of maize as affected by different spacings of *Leucaena leucocephala*.

Treatments. Tree spacings. (m)	1000 grains weight. (g)	% Increase over control.
6 x 6	290	1.75
3 x 3	300	5.26
4 x 4	300	5.26
Control	285	-
S.Em ±	7.36	
C.D (P= 0.05)	N.S	

N.S = Non-significant.

any marked variation due to spacing. The percentage increase of 1000 grains weight of maize at harvest over control has also been calculated and presented in the same table. In general, maximum 1000 grains weight of maize at harvest was recorded in 3m x 3m and 4m x 4m spacings (300g each), followed by 6m x 6m (290g). The least 1000 grains weight of maize was found in control (285g).

4.2.10. Number of maize cob yield per plot :

The result on effect of different Leucaena spacings on number of maize cob yield per plot (144sq. m) have been presented in Table 15. It is evident from the table that the mean number of maize cob yield per plot ranges from 330 to 360 cobs. There was significant influence of Leucaena spacing on number of maize cob yield per plot. The percentage increased number of maize cobs per plot over control has also been calculated and presented in the same table. It can be seen from the table that maximum number of maize cob yield per plot was recorded at 3m x 3m Leucaena spacing (360 cobs) with an increase of 9.09% over control, which was followed by 4m x 4m (350 cobs) with an increase of 6.06% over control, and 6m x 6m (339 cobs) with an increase of 2.72% over control. The least number of maize cob yield per plot was recorded in control plot (330 cobs).

4.2.11. Maize grain yield :

Maize sown on 26th April 1999 as an intercrop between different spacings of Leucaena was harvested on 30th August 1999, and the grain yield Q/ha are shown in Table 16 and Fig. 9. It may be seen from the table that there was significant influence of Leucaena spacing on maize grain yield. There has been 20.01 to 30.75 Q/ha increased in grain yield in different treatments. The percentage increase in grain yield over

Table 15 : Number of maize cob yield per plot (i.e.144 sq. m) as affected by different spacings of *Leucaena leucocephala*.

Treatments. Tree spacings. (m)	Maize cob per plot. (nos.)	% Increase over control.
6 x 6	339	2.72
3 x 3	360	9.09
4 x 4	350	6.06
Control	330	-
S.Em ±	0.81	
C.D (P= 0.05)	1.99	

Table 16 : Grain yield of Maize (Q/ha) as affected by different spacings of *Leucaena leucocephala*.

Treatments. Tree spacings. (m)	Maize grain yield. (Q/ha)	% increase over control.
6 x 6	23.99	19.89
3 x 3	30.75	53.67
4 x 4	27.22	36.03
Control	20.01	-
S.Em ±	1.95	
C.D (P= 0.05)	4.78	

control has been calculated and presented in the same table. It would be seen from the data that maximum grain yield Q/ha (30.75) has been observed in 3m x 3m which was statistically at par with 4m x 4m spacing which showed an increase of 36.03% in grain yield. No significant variation could be discernible between the effect of 6m x 6m spacing and control in respect of grain yield. This clearly suggest that closer spacing of Leucaena have certain significant effect on grain yield when intercropped with maize.

4.3. SOIL FERTILITY CHANGES :

Changes in soil chemical properties under different treatments before planting of Leucaena (September 1998) and after harvesting of maize crop (September 1999) was studied by testing soil sample at these two times and are presented in Table 17. In general, the concentration of mean % organic carbon (O.C), phosphorus (P), and potassium (K) in the intercropped plots showed substantial increments as compared to their respective control plots, even though no fertilizers were applied to the experimental field. Soil pH also increased in the intercropped plots as compared to the control. Besides, these increases in nutrients tended to increase with increase in tree density, 3m x 3m Leucaena spacing generally having the highest nutrient levels as compared to 4m x 4m and 6m x 6m spacing plots.

Table 17 : Fertility of top soil (0-15cm) as affected by different spacings of *Leucaena leucocephala*.

Treatments.	Time of soil sample collection.	pH	O.C %	P	K
6m x 6 m Leucaena + Maize (60cm x 50cm)	Before planting Leucaena (just after clearing land). September 1998.	5.29	1.23	19.25	101.92
	After harvesting of maize. September 1999.	5.34	1.33	18.06	125.15
3m x 3 m Leucaena + Maize (60cm x 50cm)	Before planting Leucaena (just after clearing land). September 1998.	5.43	1.01	19.36	124.44
	After harvesting of maize. September 1999.	5.54	1.26	25.58	135.08
4m x 4 m Leucaena + Maize (60cm x 50cm)	Before planting Leucaena (just after clearing land). September 1998.	5.72	0.97	19.36	113.12
	After harvesting of maize. September 1999.	5.77	1.16	19.68	127.24
Control. Maize alone (60cm x 50cm)	Before planting Leucaena.(September 1998)	5.14	1.07	17.33	99.2
	After harvesring of maize.(September 1999)	5.46	0.91	16	96.33

CHAPTER - V

DISCUSSION

5. DISCUSSION :

This section is presented according to the biological stages of experimental period separately for *Leucaena* and maize. Data collected from *Leucaena* and maize intercropping under agroforestry system is then presented respectively for discussion.

5.1. SURVIVAL PER CENT OF LEUCAENA :

The critical factor monitored in the initial phase of experiment was the effect of three different spacings on *Leucaena* survival percent. Though no significant difference between treatments on survival percent was noticed, generally the percentage of survival at wider spacings (6m x 6m) was lower than that of closer spacings (4m x 4m and 3m x 3m) as shown in Fig. 3. Similar observation have been reported by Gray (1968). This survival per cent may be influenced by the genotype, hardiness of the individual plant to various environmental stresses, soil condition and the suitability of the environment for a particular species. Farinas (1952) also emphasized on the importance of environmental condition for the better survival of *Leucaena*. NAS (1977) stated that, in order to get *Leucaena* established efficiently and for good survival, the site must be carefully prepared and weeds should be controlled. The non-significant effect of spacing on plant survival might be due to uniform soil and environmental factors. The slight mortality in wider spacing may be due to more weed growth, scorching sun and some other abiotic factors.

5.2. PLANT HEIGHT OF LEUCAENA :

Leucaena plant height was measured at monthly interval after transplanting during the experimental period (Sept 1998 to Sept 1999). During the initial 6 months (Sept 1998 to Feb 1999) the plant grew at an average rate of 5.7cm/month which received very less rainfall of 305mm in 6 months as shown in Fig. 4, (Rainfall Report, Directorate of Agriculture,

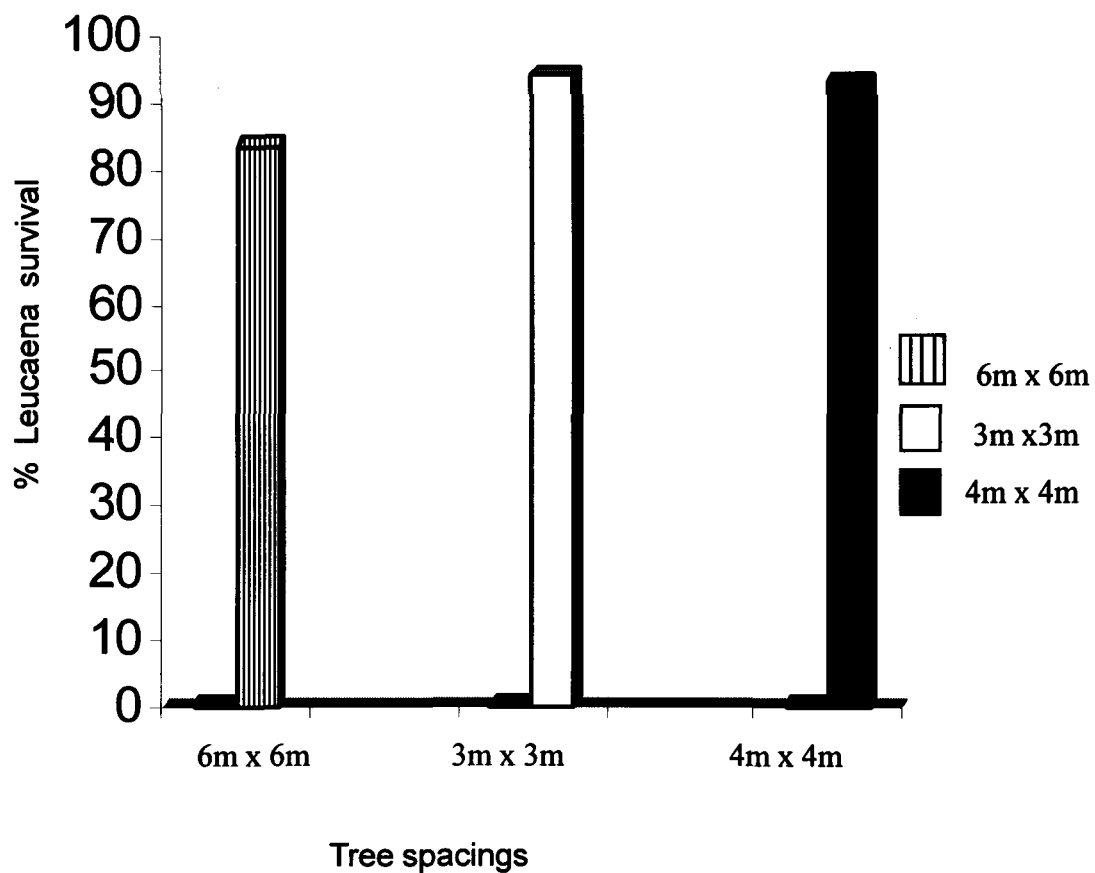


Fig. 3 : Effect of different spacings on survival % of Leucaena 1 month after transplanting. October 1998.

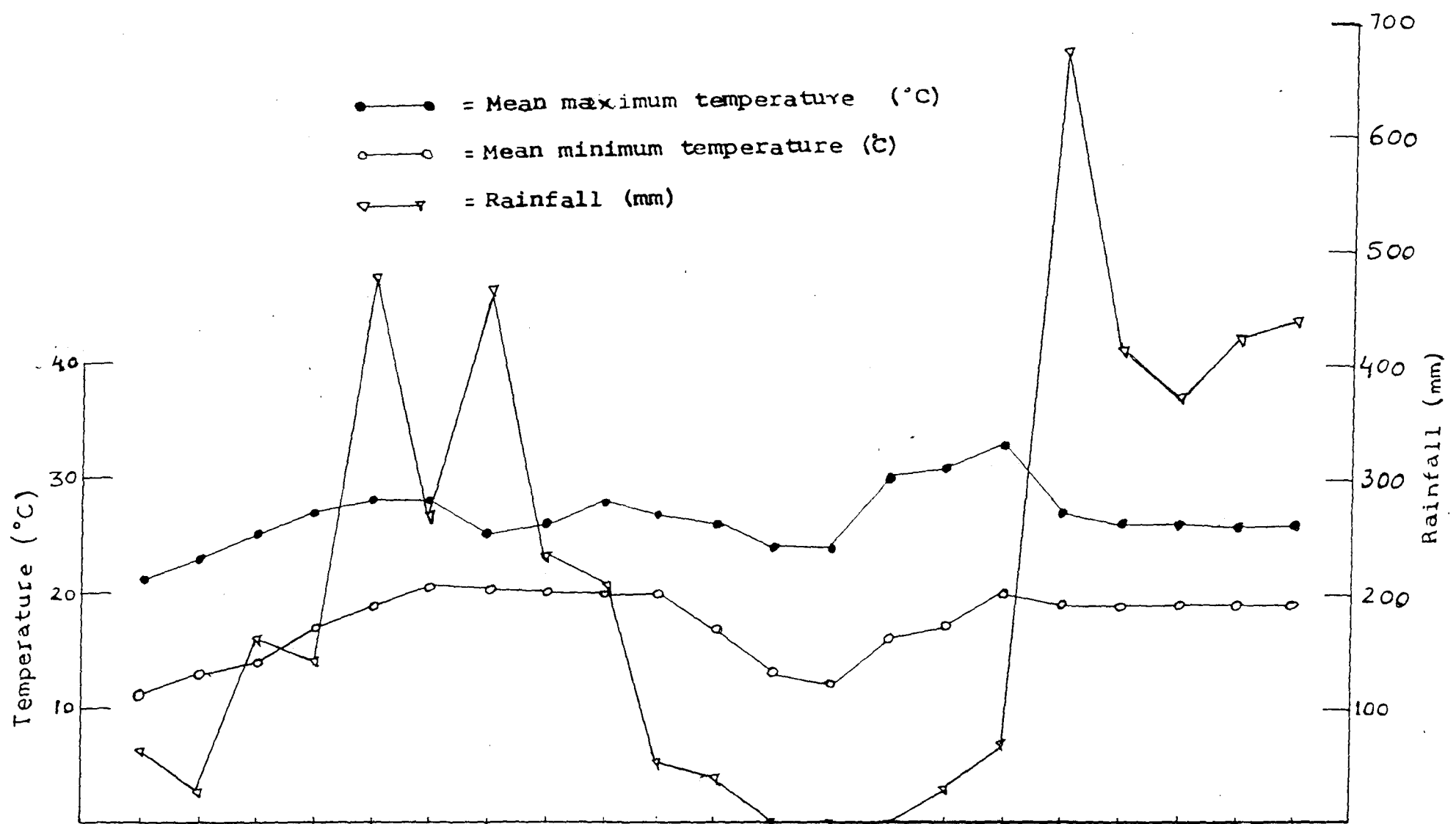


Fig.4 Monthly variation in mean maximum and mean minimum temperature(°C) and monthly mean rainfall(mm) from January 1998 to September 1999 of Aizawl, Mizoram.

Mizoram), rather there was no rainfall during Dec - Feb. But from March to Sept 1999, the plant height boosted up as more rainfall was received, the plant grew at a faster rate with an average of 16.31cm/month. During these time more rainfall of 2361mm in 7 months was received. Since the Leucaena seedlings were planted under rainfed condition it was observed that rainfall plays an important role in boosting up the growth of Leucaena plant especially during the initial stage of growth.

No significant differences in plant height was observed on Leucaena as affected by treatments during the initial 5 months (Sept 1998 to Jan 1999). But in the next 4 months (Feb to May 1999) there was significant differences on Leucaena height as affected by treatments. Maize was intercropped on late April. Then after one month (from June to Sept), again, no significant difference was observed on Leucaena height as affected by treatments. Though no significant difference was observed after one year of transplanting (September 1999). It was found that the mean height of Leucaena at 3m x 3m showed maximum height (190cm) followed by 4m x 4m (173.6) and the minimum plant height was observed in wider spacing of 6m x 6m (135.6), (Fig. 5). This showed that plant height of Leucaena increased with increase in plant population. Similar observation have also been reported by Mohatkar *et al.*, (1985) in Madurai, Tamil Nadu. Djikman (1950) reported that the rate of growth of Leucaena is optimum under closer spacing receiving full sun, more so under high temperature once it has become established (Savory, 1979). The linear increase in plant height at closer spacing in quick growing plants might be ascribed to competition for light as there is a tendency in plants to grow taller so as to enable it to harvest maximum sunlight for photosynthesis.

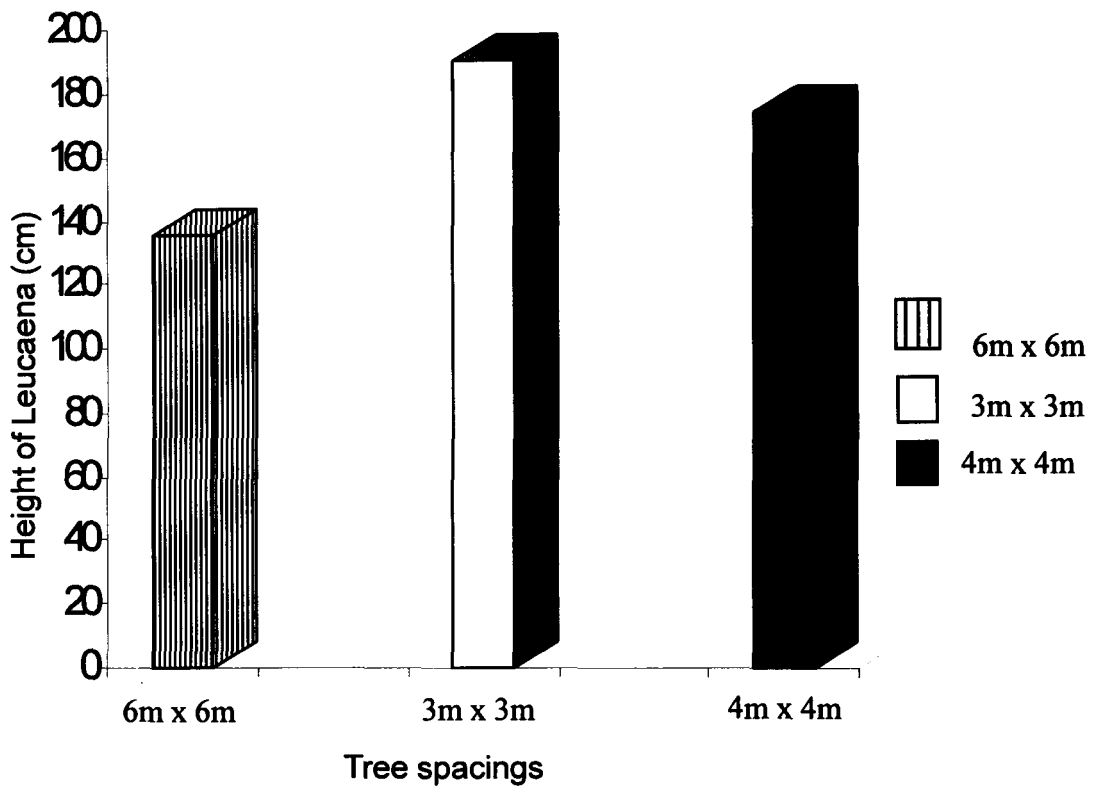


Fig. 5 : Effect of different spacings on height (cm) of *Leucaena leucocephala* after 1 year of transplanting.

5.3. BASAL DIAMETER OF LEUCAENA :

Leucaena basal diameter was also measured at the time when the plant height was measured at monthly interval. Since Leucaena were only in a seedling stage the effect of three different spacings on basal diameter was found to be non-significant in almost all the month. However, significant difference in basal diameter as affected by treatments was noticed in the month of April and May 1999. The radical growth of the stem is due to accumulation of stored food material. The non-significant effect of spacing on basal diameter at initial stage might be due to the fact that initially the net photosynthesis were utilised for producing more leaves and roots and there was minimum translocation towards radical growth. Towards the end of the rapid increase phase of linear growth, the excess assimilates might have been translocated to the storage tissue and caused significant increase in basal diameter in April and May, 1999.

Although no significant difference was observed in the basal diameter of Leucaena after one year of transplanting (Sept 1999) the mean basal diameter of Leucaena was found to be maximum in closer spacing of 3m x 3m plot (7.43cm) followed by 4m x 4m (6.83cm) and the least basal diameter was observed in 6m x 6m spacing of Leucaena. This shows that the closer spacing has still influences the increase in basal diameter of Leucaena. This vigour of growth and increase in basal diameter have also been reported by Wilson and Kang (1980), and Kang *et al.*, (1981).

5.4. LEUCAENA BIOMASS PRODUCTION :

The biomass production (Dry weight of shoot, root, total plant, and root length and root spreading) was observed two times. First, 1 month after transplanting and, second, 1 year after transplanting (Sept 1999). The total plant dry weight and root spreading shows significant difference over treatments at one month after transplanting, whereas no significant differ-

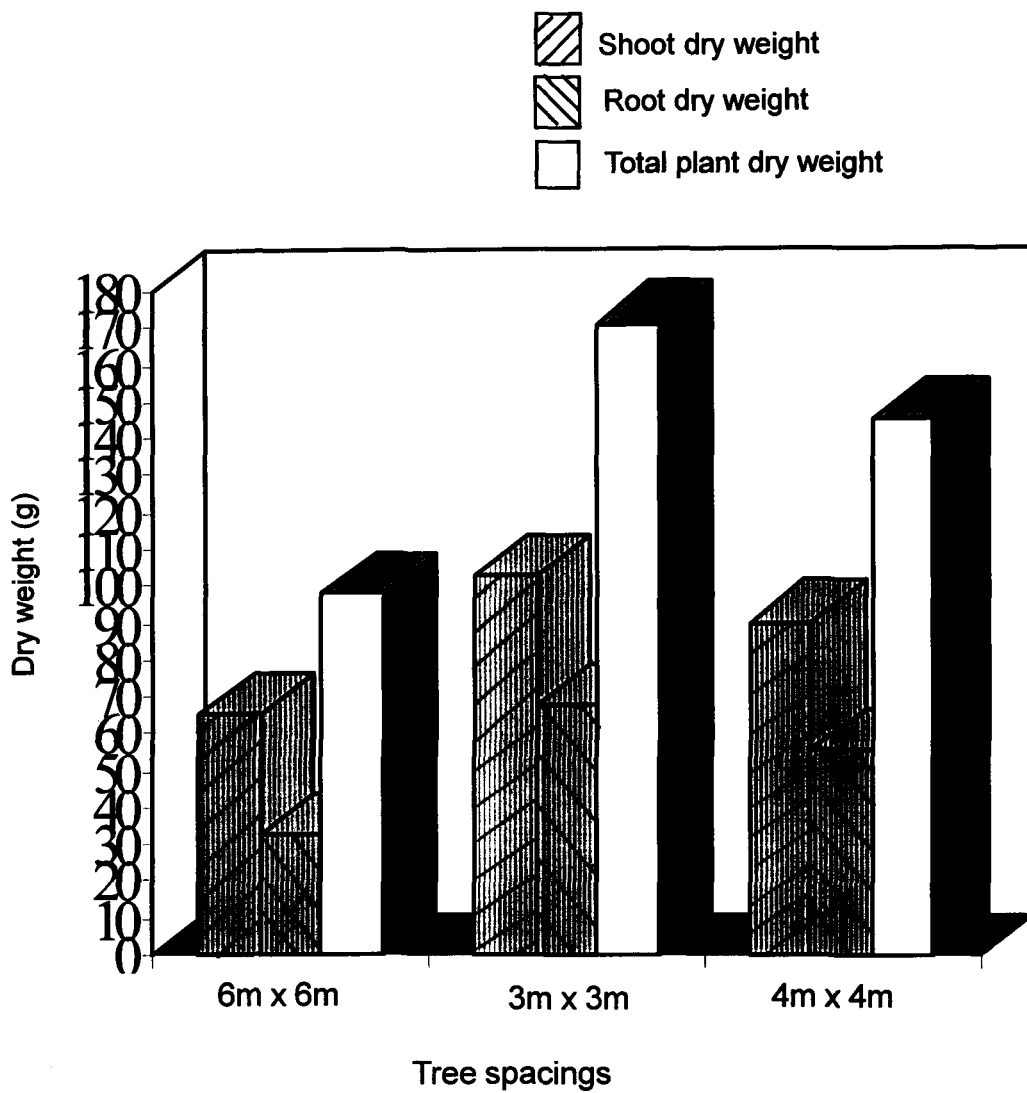


Fig. 6 : Increase in biomass production of *Leucaena leucocephala*, as affected by different spacings 1 year after transplanting. Sept. 1999.

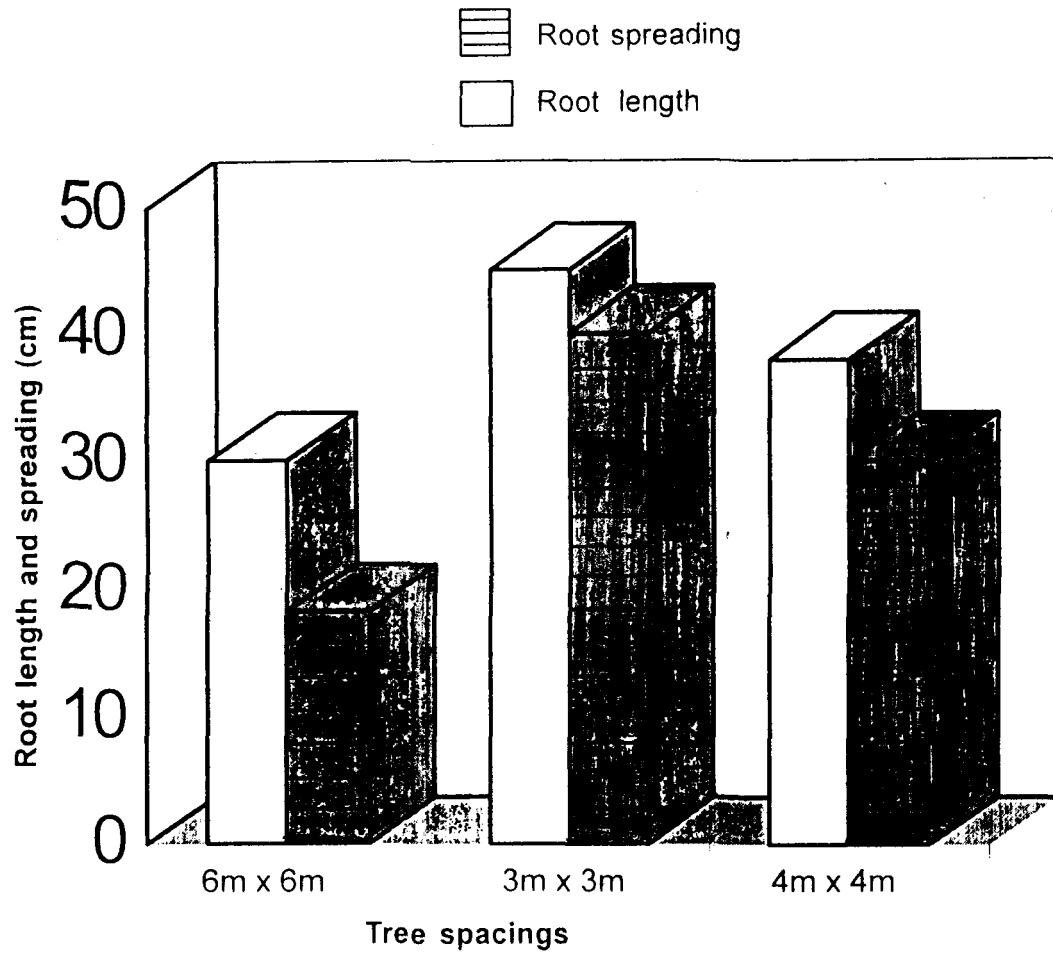


Fig. 7 : Effect of *Leucaena leucocephala* on root length and root spreading (cm) by different spacings after 1 year of transplanting. Sept. 1999.

ences was recorded in root length and root dry weight. However, highest yield occurred with closer tree spacing i.e. 3m x 3m plot and the lowest yield in biomass were constantly observed in 6m x 6m spacing plot (Fig. 6).

After one year of transplanting, though the mean biomass production shows highest yield in closer spacing, no significant difference was observed between different treatments. However, highest *Leucaena* total plant dry weight was observed in closer spacing (Kang *et al.*, 1981). Maximum plant dry weight, root length and root spreading was observed in 3m x 3m plot (171g, 45cm and 40cm respectively) followed by 4m x 4m plot (145g, 38cm and 30cm respectively) and the lowest was observed in 6m x 6m plot (98g, 30cm and 18cm respectively). Though *Leucaena* plant was only 1 year old, lots of variation in growth component occurs within the same treatment. But still the treatment means shows higher yield of *Leucaena* biomass in closer spacing. This increased production of *Leucaena* biomass under closer spacing plantation have also been reported by Mbekeam and Bassman (1991).

5.5. MAIZE YIELD COMPONENTS :

The significant increase in maize plant heights (Fig. 8) and basal diameters over the control plots only 42 days after sowing and at later stages and harvesting in the absence of shade in the intercropped plots suggested the beneficial effects of *Leucaena* on the intercropped maize. The height and basal diameter of maize shows significant difference on different treatments at harvest. Maximum height and basal diameter was observed in 3m x 3m plot (185cm and 5.8cm respectively), followed by 4m x 4m plot (175cm and 5.7cm respectively) in which both the treatments shows significant difference in their height and diameter as compared to control plot.

In addition to maize plant height and diameter, other growth components such as maize cob diameters, maize grain per row per ear, number of

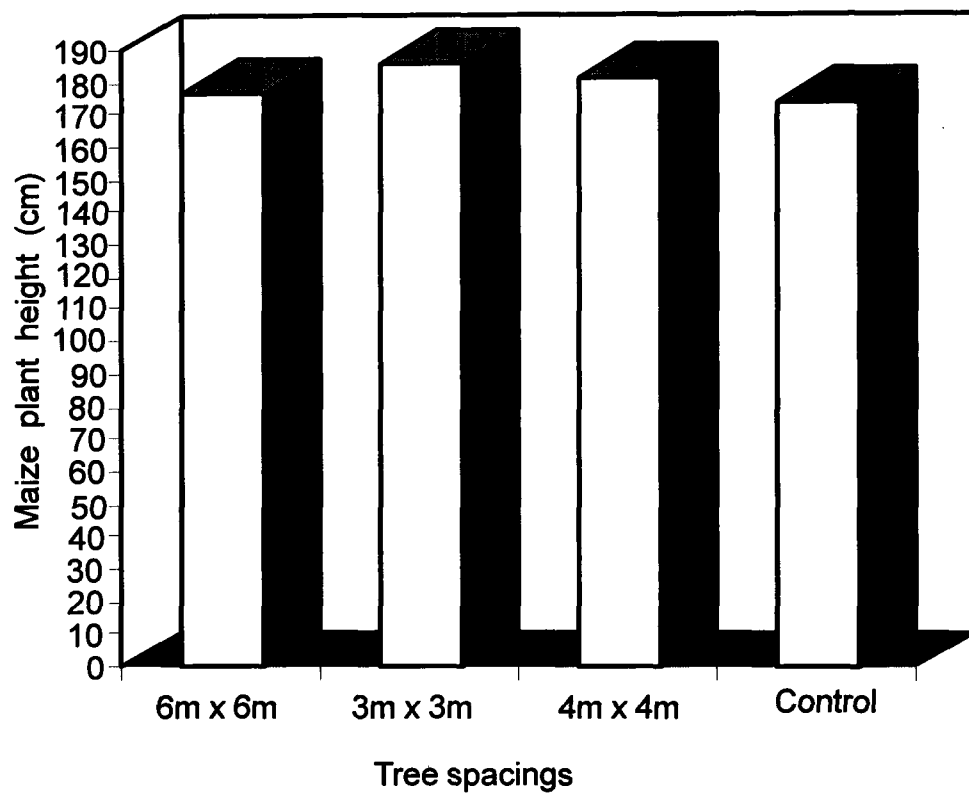


Fig. 8 : Effect of different spacings of *Leucaena leucocephala* on plant height of Maize at harvest.

maize grain per cob, number of maize cob yield per plot (i.e. 144 sq. m) were also significantly higher than those of the control plots. However, treatment effects on number of leaves, cob length, grain rows per ear, 1000 grains weight were not significant. In comparing the effect of treatments on all the growth components it was observed that the all best result was obtained in a closer spacing of Leucaena 3m x 3m spacing, followed by 4m x 4m and 6m x 6m plot, and the least results was obtained in a control plot. This clearly showed that the closer spacing of Leucaena when intercropped with maize gives better condition for the growth of maize which might be the improvement of soil by nitrogen fixation through root nodules. Leucaena has been observed to nodulate profusely in the soil and N-fixation by these nodules and or subsequent release of nutrients by the roots upon death and decomposition to humus could also have led to the superior performance of maize plants when Leucaena has been planted at closer spacing (Ssekabembe, 1984). Nevertheless, other studies by de la Rosa (1979) showed that both cob length and diameter as well as cob weights were significantly increased by Leucaena as compared to control (maize alone), an improvement which attributed to the better performance of maize under Leucaena intercropping. However, he reported that plant height, ear height, number of cobs per plant under Leucaena were not significantly increased as compared to control.

Other studies by Ssekabembe (1984) at Machakos, Kenya on effect of multipurpose trees on maize yield components and grain yield also showed number of leaves per plant and maize plant heights were consistently higher than the control plot of maize, though the differences were not statistically significant.

5.6. MAIZE YIELD :

The significant higher maize grain yield (Table 16 & Fig. 9) of the intercropped plots as compared to the control suggested the beneficial effect of *Leucaena* trees on the crop. An increase of 10.74 Q/ha in maize grain yield was obtained by the highest mean yielding intercropped plot (3m x 3m *Leucaena* spacing) as compared to the control. Kang (1981) however reported an increase of 46% in maize yield at Ibadan, Nigeria. Flores (1975) and Leviste (1976) citing the work of Brewbaker also reported that maize yield was increased by 133% when fertilized with *Leucaena* GLM as compared to control plots.

In general, maize yields were higher when intercropped with high density *Leucaena* plants than low density. The findings of de la Rosa (1980) is also in conformity with the results of this experiment. He reported that the intercropping of maize under high *Leucaena* population/ha increased the grain yield of maize per plant. Similar findings have also been reported by Rachie (1983) who observed that higher maize yield was obtained under high density *Leucaena* plantation.

The most possible reason for the higher yield of maize obtained when planted under high density *Leucaena* than low density and the control was due to improved soil fertility as a result of the fixation of nitrogen through root nodules, and in later stages on growth, through GLM leaf dropping and root decomposition. Brewbaker (1984) observed that *Leucaena* provides more than just nitrogen; mineral elements such as phosphorus and potassium absorbed by the roots from deep soil also become incorporated into the foliage. This foliage upon falling or incorporation into the soil lead to an increase in soil nutrient levels and therefore enhanced crop performance. Besides, the improved crop performance could be due to reduced N-leaching under legume intercropping as opposed to single crop system (Singh *et al.*, 1981; Yadav, 1981).

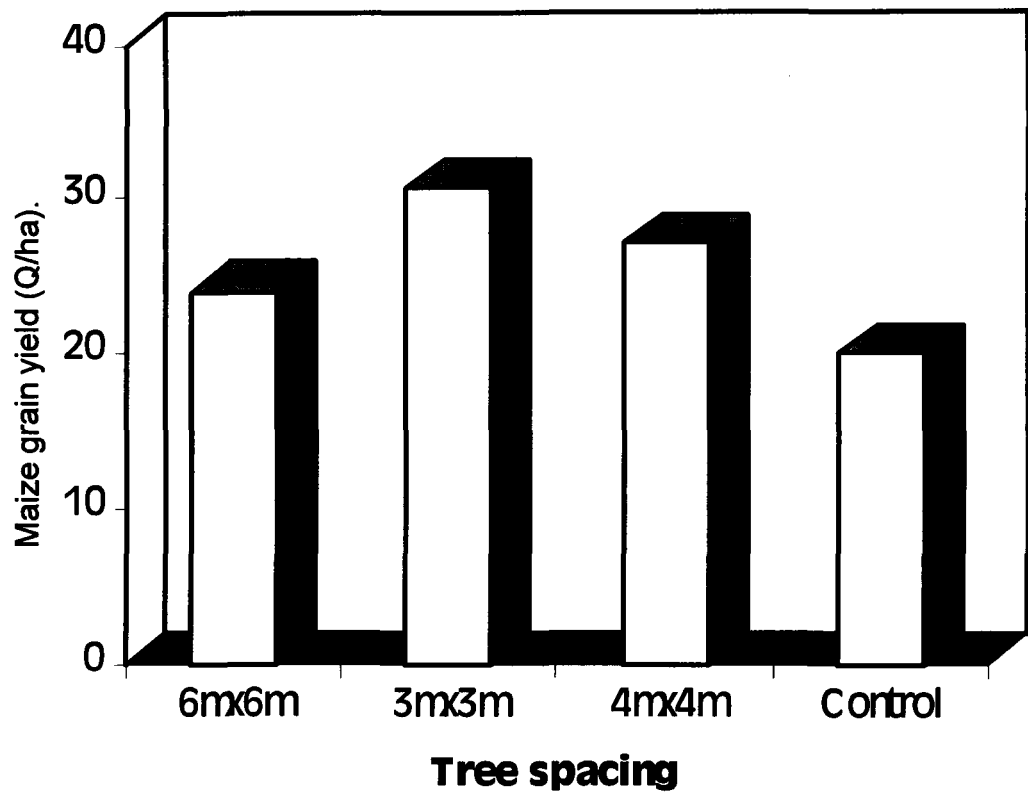


Fig. 9 : Effect of different spacings of *Leucaena leucocephala* on grain yield of maize (Q/ha).

5.7. SOIL FERTILITY IMPROVEMENT :

The concentration of % organic carbon, phosphorus and potassium in the intercropped plot showed substantial increases in the top soil (0-15cm depth) after harvesting of maize as compared to their respective control plots, even though no fertilizer was applied to the experimental field. Soil pH also increased in the intercropped plots as compared to the control. This phenomenon suggested the beneficial effect of *Leucaena* in increasing soil fertility.

The closer the tree spacing or higher tree density/ha, the higher the concentration of soil nutrients (Table 17) generally, with soil reaction (pH) becoming less acidic. These trends will perhaps be more conspicuous in the long run because processes of soil nutrients build up are generally of long term duration. Hu Tai-Wei *et al.*, (1984) in China reported that soil nutrient reserve (0-30cm) content under *Leucaena* increased in available nitrogen phosphorus, potassium at a rate of 5.52, 1.67, 13.94 kg/ha/year on an average respectively after 4.5 years of growth.

The increased levels of soil nutrients indicated have undoubtedly contributed to increased maize yields in different treatments. This studies, however, indicated the increases in nutrients with increase in tree density in closer spacing, 3m x 3m spacing generally having highest nutrient levels as compared to 4m x 4m, 6m x 6m and control plot.

CHAPTER - VI

SUMMARY AND CONCLUSION

6. SUMMARY AND CONCLUSION :

Field Experiment was conducted to study the spatial effect on the growth behaviour of *Leucaena leucocephala* (Lam.) de Wit along with *Zea mays* in hill agroforestry system of Mizoram at Zemabawk about 5 kms from Aizawl town. In this experiment, Three different spacings of *Leucaena* was taken as treatments (3m x 3m, 4m x 4m and 6m x 6m) in which maize ^{was} ~~been~~ taken as intercropped ^{being} was sown at a spacing of 60cm x 50cm covering the whole experimental field. Control plot was also made where maize alone was sown. The experiment was laid out in Randomised Block Design having three replications. The whole experimental area was 1728 sq. m in which the size of one plot was 144sq. m. Different growth component of *Leucaena* and maize were studied.

1. *Leucaena* growth components :

In *Leucaena* the following growth component studied were :-

- (i) Survival percent.
- (ii) Plant height.
- (iii) Basal diameter.
- (iv) Biomass production including -
 - (a) Dry weight of shoot, root and total plant.
 - (b) Root length.
 - (c) Root spreading.
- (v) Soil assessment before planting of *Leucaena* and after harvesting of maize.

2. Maize growth components :

The growth components studied on maize plant were :-

- (i) Plant height at 42, 62 days after sowing and at harvest.
- (ii) Plant basal diameter at 42, 62 days after sowing and at harvest.

- (iii) Number of leaves per plant at 42, 62 days after sowing and at harvest.
- (iv) Cob length at harvest.
- (v) Cob diameter at harvest.
- (vi) Grain rows per year at harvest.
- (vii) Grain per row per ear at harvest.
- (viii) Total grains per cob at harvest.
- (ix) Number of maize cob yield per plot.
- (x) 1000 grains weight at harvest.
- (xi) Grain yield Q/ha.

The salient features of the results were as indicated below :

- (1) Though the survival percentage of *Leucaena* was not statistically significant, it was consistently higher in closer spacing of 3m x 3m as compared with 4m x 4m and 6m x 6m.
- (2) The growth of *Leucaena* regarding height and basal diameter as affected by three different spacings after one year of transplanting were statistically non-significant but it was observed that the highest growth was found in 3m x 3m spacing, followed by 4m x 4m and the least been found in 6m x 6m.
- (3) The biomass production regarding dry weight of shoot, root, total plant, and root length and root spreading were found to be maximum in 3m x 3m spacing as compared to wider spacing of 4m x 4m and 6m x 6m, though statistically non-significant.
- (4) Soil fertility levels such as % organic carbon, phosphorus, potassium and pH was improved after 1 year which was found to be due to the ability of soil improvement by *Leucaena*. The soil under closer spacing (3m x 3m)

of *Leucaena* was found to be more fertile at the end of the experimental period as compared to wider spacings and control plot.

(5) The improved maize crop performance on height and basal diameter was observed in the intercropped plots as compared to control. There was significant increase in maize plant height and diameter as affected by treatments. Maximum height and basal diameter was observed at 3m x 3m spacing, followed by 4m x 4m, 6m x 6m and the least being in control plot.

(6) The maize grain yield was recorded highest at 3m x 3m spacing of *Leucaena* (30.75 Q/ha), followed by 4m x 4m (27.22 Q/ha), 6m x 6m (23.99 Q/ha) and the lowest being control (20.01 Q/ha). Other growth components like number of leaves, cob length, cob diameter, grains per cob, 1000 grains weight, number of maize cob yield per plot was maximum in closer spacing of *Leucaena* i.e. 3m x 3m.

This experiment has therefore elucidated the beneficial effects of intercropping maize with *Leucaena leucocephala*, leading to improved crop yield due to improved soil fertility status. It was, thus concluded that, among the different spacings of *Leucaena leucocephala* intercropping with *Zea mays* such as 3m x 3m, 4m x 4m, 6m x 6m and control (maize alone), 3m x 3m spacing was considered the best spacing in terms of the growth components and yield of both *Leucaena* and maize in hill agroforestry system in Mizoram.

CHAPTER - VII

RECOMMENDATIONS FOR FUTURE RESEARCH

7. RECOMMENDATIONS FOR FUTURE RESEARCH :

This study has shown the levels of production of maize in between different spacings of Leucaena, but this experiment was based on one year data only. In order to have more accurate results, further research has to be conducted. Since the trees are only one year old there was complicity in studying the interaction with crops. There is a good scope for future studies and the recommendation for future research are as follows :

- (i) As no fertilizer effect was studied, there is a need for testing the fertilizer effect on yield of the intercrop.
- (ii) There is also a need to study the coppicing ability of Leucaena and also pruning effect on the intercrop by incorporating the GLM in the soil when tree matures.
- (iii) The ability of Leucaena to control soil erosion has also need to be studied.
- (iv) The interaction of tree spacings on the analysis of weed types and biomass yields of weeds need to be studied for future research.

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