EFFECT OF DIFFERENT SPACINGS ON THE GROWTH PERFORMANCE OF SUBABUL (*Leucaena leucocephala*) LAM DE WIT AND PRODUCTIVITY OF MAIZE (*Zea mays* L.) ON A HILL AGROFORESTRY SYSTEM IN MIZORAM.

THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE DEGREE OF MASTER OF SCIENCE IN FORESTRY (AGROFORESTRY)

BY
K . ZOHMINGLIANI

DEPARTMENT OF FORESTRY
SCHOOL OF LIFE SCIENCES
NORTH-EASTERN HILL UNIVERSITY
MIZORAM CAMPUS,AIZAWL,INDIA
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The 21st....... December, 2001.

(K. ZOHMINGLIANI)

NORTH EASTERN HILL UNIVERSITY
DEPARTMENT OF FORESTRY
MIZORAM CAMPUS, AIZAWL - 796012

Dr. Rakesh Mohan
Reader, NEHU, Mizoram Campus

CERTIFICATE

I certify that the thesis entitled " Effect of different spacings on the growth performance of Subabul (*Leucaena leucocephala* Lam. de Wit) and productivity of maize (*Zea mays* L.) in a hill agroforestry system in Mizoram" submitted by K.Zohmingliani, for the partial fulfillment of Master of Science in Forestry of the North Eastern Hill University, Shillong, embodies the record of original investigation by her under my supervision. She has been duly registered and the thesis presented is worthy of being considered as partial fulfillment for the award of M.Sc Degree. The work has not been submitted for any degree of any other university.

(Dr. RAKESH MOHAN)

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Supervisor

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CHAPTER-I
INTRODUCTION

1.1 GENERAL INFORMATION

Mizoram, one of the North Eastern Hill States of India, lies within 20^0 58'20" and 22^0 59'35"N latitude and 92^0 30'15" and 93^0 15' 20"E longitude (Anon.1996). It has the total geographical area of 21,087 Sq.kms with the length (North to South) of 277 kms and breadth (East to West) of 121 kms, giving the state a rather rectangular form (Statistical Abstract of the State Agriculture Department, 2000-2001). The state is bounded by Cachar district of Assam and Manipur in the north, and a small portion of the north-western side by Tripura state. It also has International Boundaries with Myanmar in the south and eastern sides, and the Chittagong Hill Range of Bangladesh along the western side of the state.

Being one of the hill states of NE India, it has the general land feature of hilly terrain and deep, rugged valleys. A large number of small hill ranges are found in the state which are mostly running in north-south direction. The average height of hill ranges in Mizoram is 920m from the Mean sea level.

By and large, the state has a typical sub-tropical type of climatic condition. However, hot and moist, tropical and sub-temperate climates also prevail in some parts having lower and higher altitudes respectively. Before the commencement of the periodical monsoon rains, spring is generally hot and dry. But this period is short and usually followed by summer season with the North-West monsoon rain, which starts right from May-June and continues till October. Pre-Monsoon rain may also start from April-May with a heavy downpour. Contrary to this, winter is cool and dry. The average annual rainfall is recorded as 2541mm; out of which, most of the rainfall occur during the summer season of 6-7months. The mean annual temperature during summer is 24^0C-33^0C, as against 11^0C-23^0C during winter. It may as well be worth mentioning that the sufficient rainfall received in the state is not efficiently utilised due to the scanty forest cover along the hill slopes. The coarse texture of the soil also accelerates the rate of water entry beyond the sub-soil level which may be unavailable for the plants.

Various soil types are found in the state. Due to the porous nature of the soil combined with heavy rainfall, the soils are highly leached and are generally deficient in Nitrogen, Phosphorus; and Potash. The typical soil type is sandy loam or clayey loam with a low water holding capacity. The pH of the soils shows acidicity when no soil amendment is provided.

According to 2001 census, the state has the total population 8,91,058 with the density of 42 persons per Sq.km. Out of the total of 1,43,578 households, 74,516 are engaged in agricultural activities, i.e. 51.89%. (Statistical Abstract of the State Agriculture Department, 2000-2001). It has also been observed that most of the cultivator families still practise shifting cultivation on the hill slopes. The rest of the population find themselves engaged in government jobs, or in other semi-government/corporations, or as daily labourers.

The forests of Mizoram can be broadly classified into three main categories following the system of Champion & Seth (1968) -

1) Tropical Wet Evergreen Forests
2) Tropical Semi-evergreen Forests
3) Montane Sub-tropical Pine Forests

According to the State Forest Report, 1997, the forest cover of the state is 18,775 Sq.kms which is about 89.1% of the total geographical area. It is reported to have an increase of 199 Sq.kms from that of 18,576 Sq.kms in 1995 (SFR,1997). But legally, the area of forest cover including National Parks and Wildlife Sanctuaries in the District Councils and State-Owned area totals to 8,012 Sq.kms.

Basically, the whole forest cover consists of reserved forests and unclassed state forests. About 58% of the forests is unclassified state forest and is controlled by the District Councils. Most of the unclassed state forests are managed and maintained by the Village Councils. Being a tribal community, the people are given priviledge to collect fuelwood and small timber either freely or at nominal costs as per the Mizo District (Forest) Act, 1955, which has been enforced since the District Council period.

With deforestation still going on mainly for shifting cultivation and for fuelwood purposes, plantations being raised by the State Forest Department does not seem to increase the extent of forest cover. But a form of farm forestry has recently been practised by some farmers in the state by growing Teak and Gamar, which, altogether accounts for about 8,000 hectares of land. Nevertheless, this also contributes towards the development of more forest in the state.

1.2 SHIFTING CULTIVATION IN MIZORAM

Broadly speaking, shifting cultivation refers to any temporally and spatially cyclical agricultural system that involves clearing of land - usually with the assistance of fire followed by phases of cultivation and fallow periods. However, the length of the cycle and components may vary depending on the area, time and system of a particular locality.

Though globally, shifting cultivation or slash-and-burn agriculture results in the cutting and burning of over 10 million hectares of tropical moist forest every year (ICRAF, 1996), and that till today, it is estimated to support the livelihoods of some 300-500 million people worldwide (Brady, 1996). In Mizoram, shifting cultivation has been extensively practised by the farmers since time immemorial as in any other tropical part of the world, and is still the main source of earning livelihood especially among the farmers of the Mizos. This is evident from the fact that there is no available flat land for development of Wet Rice Cultivation (WRC), and settled agriculture on the slopes has not yet been popularised. Diversion of forest lands into agricultural land and felling of trees for firewood and construction proposes are the main causes of deforestation in the state. But more specifically, in the state, about 40,000 hectares of land has been used for shifting cultivation annually and about 71.15% of the working population are still involved in it (Statistical Abstract of Agriculture & Minor Irrigation, 1997-1998). According to the latest report by Agriculture & Minor Department, 5,147 hectares of land has been affected by shifting cultivation during 2000-2001 (Statistical Abstract of the State Agriculture Department, 2000-2001).

The different steps involved in shifting cultivation is more or less similar with those of the other tribal communities of the North Eastern Hill States. In this system, all the farm works are carried out by manual labours of the Jhumia families. The first step involved here is selection of a piece of land and clearfelling of this selected virgin forest during January-February. This is followed by allowing the felled logs and branches to dry in the sun, after which, the dried materials are collected to form heaps and then burnt. After burning of all the felled logs and undergrowths, sowing of a mixture of seeds, usually kharif crops, is done usually by dibbling or broadcasting. After these operations, no hard work is needed except for a few weedings during the growing season. Harvesting can be done from July-August for vegetables and short-duration crops. For cereals and other cash crops, products can be obtained from September-November and may last till December.

This system of farming may be very productive in the beginning and may last for about 2-3 years and thereafter, start declining. The reduction in production may be attributed to the fact that top fertile soil is being used up for the vegetative growth of the crops, and that torrential rains on the slopes wash them away when the land is without proper vegetative cover.

Due to this reduction in production, the land is left fallow for natural regeneration to build up the soil fertility. After a certain period of time, the Jhumias move back to the same plot to repeat the same farming process.

Due to increase in the population resulting in higher demand for food doubled by the limitation of available land for cultivation, the fallow period is being reduced from 10-15 years in the past decades to about 3-4 years. Though various attempts had been made to replace shifting cultivation in the state, the results achieved so far were not up to the expectations and the traditional method of farming still prevails only with a little reduction in the area affected.

1.3 AGROFORESTRY- AN ALTERNATIVE TO SHIFTING CULTIVATION

With the increase in the population of human and livestock, there is an increasing demand for food, fodder and other life-sustaining needs. In Mizoram, this problem is also being faced when available culturable land becomes less and less unproductive with the practice of shifting cultivation. The loss of top fertile soil is now beyond control due to reduction in forest cover combined with the erosive action of heavy rains on the natural hill slopes. A management system, therefore, needs to be devised which is capable of producing food from marginal agricultural land and also capable of maintaining and improving the quality of the producing environment.

To put simply, agroforestry is using trees on farms. Using trees on farms is an ancient art. For millennia, farmers have nurtured trees on their farms and pasture lands and around their homes. Neither the concept nor the practice of agroforestry is new. But modern world is developing that ancient art into a science.

Growing trees with agricultural crops on the same plot of land can provide many products, such as -

* timber
* food
* fruits,nuts
* fuelwood
* poles
* improve micro- climates
* provide living fences for crops and fruit trees
* demarcate boundaries
* sequester carbon
* stabilise watersheds
* protect biodiversity

Agroforestry sytems, thus, become the right enterprises for meeting multiple requirements of the people in the sense that they provide more outputs per unit area, and are more sustainable. Moreover, agroforestry is a landuse system that seems well-adapted to tropical, hilly lands.

Keeping in view the mentioned problems, the present experiment was conducted with the main objectives of working out the production potential of degraded jhum land. The research experiment had the components of *Leucaena leucocephala* intercropped with maize in the sub-tropical, hills slope of Zemabawk, Aizawl. The experiment was also aimed to show the suitability of an agroforestry system with MPTs in the state by proving itself as a new land use option which positively combines the ecological and socio-economic aspects of the local conditions, and might as well replace shifting cultivation which is still practised by most farmers of the Mizos.

Leucaena leucocephala, a fast growing evergreen tree was chosen for the research study as the tree component. Leucaena is known to improve soil nutrient status by adding humus through the biomass yields besides that of Nitrogen fixation by the roots. This property is greatly beneficial to the field crops when sown in proximity, particularly the cereals. It also has the morphological feature of smaller sizes of leaves and crown suitable for use in agroforestry practices with least competition effect between the crop components. It serves multiple uses such as feed for anmals and human beings, fuel sources and construction purposes. Moreover, productivity is quickly achieved owing to a relatively higher growth rate. Like most of the tree species, Leucaena also helps in reducing surface runoff and erosion, maintaining soil moisture and temperature which are one of the important aspects considered as far as hill farming is concerned.

Annual crops such as cereals, on the other hand, are being reported to produce more yields when grown with Nitrogen - fixing tree species like Leucaena. Additional Nitrogen supply through rhizobial activity in the root zones is the main reason for higher productivity. Thus, adoption of this tree-crop combination seems to be suitable for use in hilly areas.

SPECIFIC OBJECTIVES OF THE EXPERIMENT

The research was conducted mainly to meet the following specific objectives -

* To investigate the effect of 2-year old *Leucaena leucocephala* spacings on the growth and productivity of *Zea mays.*
* To determine the improvement in fertility status of the soil.
* To help in popularising agroforestry systems in Mizoram.

CHAPTER-2
REVIEW OF LITERATURE

Agroforestry system, with the essence of combining trees and agricultural crops, is one of those integrated land use system. This system of associating food and fuel sources had been practised either in the form of shifting cultivation or Taungya system by people of different regions all over the world for the past years. King (1968) has reviewed about 79 tree species and 42 agricultural crops in Taungya cultivation. In recent years, different agroforestry systems have attracted a great deal of interest, particularly from the forestry and agricultural communities and from others with an interest in natural resource management and environmental conservation.

Agroforestry is the first concrete concept that was built on a synthesis of much of the practical experience and scientific knowledge acquired over the past decades (Jha,1996). The system has been defined as a sustainable land management system which increases the yield of the land, combines the crops (including tree crops) and forest plants and, or animals simultaneously or subsequently on the same unit of land and applies management practices that are compatible with the cultural practices of the local population (King & Chandler,1978).

Torres (1983) has stated that agroforestry can be defined as the deliberate combination of trees with crop plantations 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. This indicates that agroforestry systems are more or less flexible depending on the needs of the farmers.

Recently, ICRAF defines agroforestry as a dynamic, ecologically based, natural resources management system that, through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels.

ICAR (Annual Report, 1999-2000) has stated that agroforestry is the science of designing and developing integrated self -sustainable land management system which involves introduction or retention of woody components including trees, shrubs, bamboos, canes, palms, along with agricultural crops including pastures/animals simultaneously or consequentially on the same unit of land and at the same time, meet the ecological as well as socio-economic needs of the people.

Agroforestry, in a strict sense, thus means the technique of intercropping agricultural crops with woody perennials. Intercropping basically aims to produce green manure, mulch, fodder and timber requirements during the cropping period. In most of the models, it is aimed to increase the total productivity of the land, where a part of the main agricultural yield is sacrificed to produce proportionately higher output from the woody perennials.

In agroforestry systems, intercropping provides stability of yield over different seasons, better use of growth resources, better control over weeds, pests and diseases and surplus income to farmers (Aiyer,1949). Young (1989) also pointed out that appropriate agroforestry system has the potential to control soil erosion, maintain soil organic matter and physical properties, augment Nitrogen fixation and promote efficient nutrient cycling.

Agroforestry systems are sustainable in drought prone areas also. This is attributed to the fact that most of the tree species have tap root systems which help in tapping water from the deeper layers of the soil profile. A substantial evidence through research suggests that growing trees with agricultural crops provides benefits which results in higher production. According to an investigation done by Peter Poschen (1986) in eastern Ethiopia on farmers field indicated a statistically significant increase in crop yields (Maize and Sorghum) under the tree canopies as compared to open areas. Sheikh et al., (1983) also reported that irrigated plantation of hybrid Poplars did not depressed grain or straw yields within the rows. The latest report by IITA indicates that alley cropping is most suitable for food production on Alfisols and other high-base soils in the humid and sub-humid tropics with regard to salt affected areas(Kang, 1993).

The use of MPTs in agroforestry can improve production per unit area and increase the quantity of benefits. Tangible benefits promote more people's participation which improves the ecological environment and consequently restores nutrients for sustained productivity. Puri (1989) stated that integration of rapidly growing nitrogen-fixing trees has the potential to enhance the rehabilitation process and increase production. Singh (1999) also aided the benefits of cereal-legume mixture due to an efficient fixation of atmospheric Nitrogen into the soil. Leaves of most of the legumes are small in size, decompose fast and add large quantities of humus and nutrients to the soil.

The experiments carried out by the Forest Department, West Bengal since 1965 in the forest areas of North Bengal to find out the feasibility of growing intercrops in between lines of forest plantations has given ample evidence about the efficacy of the system (Lahiri, 1980,1989).

However, in an ideal agroforestry system, the most important consideration is to see how the mixtures of different kinds of plant components can be made to interact optimally so as to fulfill their individual yield potentials. According to Bapat (1995), integrated management of mutually complimentary productive components, namely, the tree species, agricultural crops and cottage-level economic activity based on raw materials from agroforestry products, could be achieved through manoeuvring the vertical and horizontal competitions of tree and crop communities. The correct blending of such elements is crucial in agroforestry.

Intercropping provides the following advantages -

- A cereal-legume mixture is beneficial because of an efficient fixation of atmospheric Nitrogen into the soil.
- Total biomass production/unit area/ unit of time is increased because of fullest use of land as the inter-row space will be utilised which otherwise would have been used for weed growth .
- The fodder value in terms of quantity and quality becomes higher when a non-legume is intercropped with legume, viz. Napier + Cowpea.
- It provides crop yields in instalments which reduces the marketing risks.
- It offers best employment and utilisation of labour, machine and power throughout the year.

2.1 PROPERTIES OF LEUCAENA

Leucaena leucocephala, also known as Subabul, Kubabul or Ipil-Ipil, is a native of Central America (Singh, 1985). More than hundred varieties of it are known which are broadly classified into three types-the Hawaiin type, Salvador type and Peru type (National Academy of Sciences, 1977). The Hawaiin type is a bushy plant and grows upto 5m in height. The Salvador type is about 20m in height whereas the Peru type can attain about 15m height. Besides its native region, it has been naturalised throughout the tropics and sub-tropics. In India, all the varieties have been introduced and are grown mainly in the states of Andra Pradesh, Tamil Nadu, Karnataka, Himachal Pradesh and Uttar Pradesh (Lohani,1979).

The plant withstands a wide range of rainfall, temperature, wind, drought and altitude though growth rate decreases with an increase in elevation. It is a tropical and sub-tropical tree and grows upto an elevation of 800m. Best growth is obtained with 600-1700mm annual rainfall. However, it can grow in areas with as little as 250mm annual rainfall (National Academy of Sciences, 1977). Optimum range of temperature for growth is between 25^{0}C and 30^{0}C. Below 10^{0}C, there is little or no growth at all.

Leucaena is known to inhabit a wide range of soil types. It is characterised by a well developed and deep tap root system which is capable of even breaking seemingly impervious layers of the soil in sub-horizons (Gray, 1968). Farinas (1951) reported that it can grow on any terrain and type of soil provided the annual rainfall does not exceed 1650mm. Light-textured soil is better than clayey soil for root development and growth (Singh, 1985). Neutral to slightly alkaline soils are considered best for its growth (National Academy of Sciences, 1977), with a pH range of 5.5 and 9.0 (Bapat, 1995). It is reported to have low tolerance for acidic soils (Hills,1971), and in soils with high aluminium content or which are waterlogged for any period of time (Bapat, 1995).

Leuceana is a light-demanding, evergreen plant which coppices well. Its coppicing ability allows repeated harvests for firewood, timber or foliage (Brewbaker, 1989). It produces seeds in large quantities and therefore, vegetative propagation is usually not practised on a large scale. However, it can be reproduced by cutting or grafting but with difficulty (National Academy of Sciences, 1977). Because of the hard waxy seed coat, pre-sowing treatment is required to obtain high and uniform germination (Ramdeo,1971).

It has been reported to be one of the highest biomass yielding tree species (Anderson *et al.*,1983). It forms symbiotic relationship with *Rhizobium loti*, the Nitrogen-fixing bacteria (Halliday & Somasegaran,1983). Being a legume, it is capable of fixing atmospheric Nitrogen and as such, becomes suitable for various agroforestry programmes.

Leucaena wood can be used for construction poles, pit props, furniture, flooring and fuelwood. The wood has a specific gravity of 0.45 - 0.55

and a higher heating value of 4600 Kcal/kg (RAPA,1988).

As a forage, Leucaena has a high protein and carotene contents and pellets or cubes are internationally marketed as animal feed. Its foliage is also known to provide vitamin K and Riboflavin. Raharjo *et al.,*(1986) observed that woody legumes appeared to be the most promising among forages tested by them for rabbit production. They also observed fibre digestibility of more than 50% for Albizzia, Leuceana and Sesbania. However, the leaves contain a non-nutritive toxic amino acid - mimosine. The leaves are used as mulch/cover to check runoff in hill areas. This reduces soil loss and maintains soil productivity on sustained basis. The plant has been used as a green manure crop in shifting cultivation as well as a number of other utilisations including human food.

2.2 PROPERTIES OF MAIZE (*Zea mays.* L)

Maize (*Zea mays.*L), also known as 'corn' in the USA, is one of the most important cerial crops in the world. It is an annual plant belonging to the grassy family Gramineae, and the genus Zea. It is also regarded as one of the tribes of Maydae (also called Tripsaceae). Today, there are hundreds of varieties of maize produced out of natural synchronisation of flowering times amongst different populations (Stebbins, 1950); as well as due to hybridisation process for special purposes.

According to many authors, maize is considered to be originated from Central America and Mexico, because no trace of maize was found in the world until Columbus found it in Haiti where the local inhabitants referred to it as 'Mahiz' (Jotshi, 1993). Spain is the first country in Europe where maize was cultivated. Later on, it spread from Spain to France, Italy and other parts of the world. In India, it is presumed that it was introduced during the Sixteenth Century through the trade links by the Portuguese.

However, the historical records regarding the cultivation of maize in India date back only to the Maratha Empire. Soon after its introduction, it gained popularity throughout the whole country.

Botanically, maize is a tall (0.43m-6.0m) annual grass having a stout, erect stem and large, narrow leaves (30cm - 125cm long and 2.2cm -12.0cm broad). The leaves are spaced alternately on opposite sides of the stem. Unlike those of most grasses, it possesses both male and female inflorescences. Staminate (male) flowers are borne on the tassel while pistillate (female) flowers are spikes with thickened axes, which, on maturity, become the ears. The pod corns are characterised by having each kernel enclosed within a pot or husk. It is the most primitive type of cultivated maize.

1) *Zea mays indurata* or 'Flint corn' :-

This type is most commonly grown in India. The kernels are usually rounded, but are sometimes short and flat. Colour may be white or yellow.

2) *Zea mays indentata* or 'Dent corn':-

The kernels have both hard and soft starches. After drying and shrinking of the soft starch, various forms and degrees of indentation result. This is the most common type in USA.

3) *Zea mays everta* or 'Pop corn' :-

This type posseses the unique characteristic of popping quality. Size of the kernels is small but with a hard endosperm. Kernels of this type contains high amount of sugar giving a sweeter taste than any other type. On drying, the water in the kernels collapse giving a wrinkled appearance.

4) *Zea mays amylacea* or 'Soft corn' :-

This type of maize posseses a soft kernels. The colour of the grains is usually blue and white or any other colour.

5) *Zea mays tunicata* or 'Pod corn' :-

The pod corns are characterised by having each kernel enclosed within a pot or husk. It is the most primitive type of cultivated maize.

6) *Zea mays ceratina kulesh* or 'Waxy corn' :-

The kernel, when cut or broken, gives a waxy appearance. The starch produced has adhesive quality.

Maize varieties differ from each other to a large extent. In general, it can be grown in all types of soil and can withstand a wide range of climatic condition. It can be grown as rabi crop as well as kharif crop. But since it is a light-demanding crop, it is grown mainly during kharif season as the main crop or as intercrop with legumes or non-legumes. It is known to be grown in the tropics, sub-tropics, temperate and even in the Arctic region.

It is grown in almost all types of soil even in the swampy areas of Eastern Bengal and on the sandy desert tracts of Central India (Jotshi, 1993). However, it grows best on well drained, sandy loam or fertile loam soil having a good water retention capacity. It thrives well in neutral soils (pH 7.0).

The products of maize can be widely diversified by way of grading, boiling, fermenting and processing them for human and livestock. The grain is generally consumed as human food as it is an excellent source of energy and contains about 65 - 70 % starch having a high metabolisable property. The crude protein content in the grain varies from 8 % - 12 %. The protein is a good source of amino acids, such as Triptophan and Lysine. DCP (Digestible Crude Protein) varies from 6 - 8 % ; TDN (Total Digestible Nutrients) from 78 - 80 %. It has about 3 - 6 % oil and contains high proportions of unsaturated fatty acids ideal for reducing blood cholesterol.

It finds itself many uses in the preparation of beverages, confectioneries, bakeries and dairy products. Dextrose, cornstarch, lactose and sucrose are the by-products of carbohydrates used in antibiotic products such as Tetracycline, Penicillin, Neomycine, Streptomycine etc. Sorbitol, a modified form of dextrose is used in the production of synthetic vitamin C. Products in other forms such as cornbread, corn muffins, cornflakes, popcorns, etc. are favoured as snacks. Baby corn is a new product which is valued for infant and gaeriatric nutrition.

The cobs are also used as blast polishes, as absorbent carriers for pesticides, fertilizers, vitamins etc. More finely divided fractions are used in cosmetics, hand soaps (Murugkar and Verma, 2000).

As a feed for animals, it can be given as cereal fodder and as concentrate feed. It is a good crop for making silage and hay. Maize bran, maize meal cakes and gluten meal are also the by-products as concentrates (Goswami & Saikia, 2001).

2.3 NITROGEN FIXATION BY LEGUMES

Tropical soils vary so much in texture and nutrient status that generalisations are difficult. This is due to the impact of the heavy rains which causes subsequent erosion resulting in leaching or washing away of the available soil nutrients through surface runoff. Since most of the Nitrogen is accumulated in the top layers of the tropical soils, it is easily washed out in steep, denuded slopes.

It was estimated from survey reports that during a five year period in Rubber Plantation (*Hevea braziliensis* Meul Arg.) in Malaysia, Nitrogen fixation by grass legume, viz. *Stylosanthes*, *Calopogenium* and *Centrosema*, was nearly 880 Kg/ha. Despite the fact that the legumes died out after the sixth year, increase in rubber yield persisted for about 20 years.

Many of the leguminous trees and shrubs have the ability to develop deep root system and fix atmospheric Nitrogen, they can withstand water and salinity stresses. These characteristics, which favour survival and high productivity, have increased the interest in the cultivation and management of woody leguminous stands for fuel and forage and for stabilisation and improvement of soil.

Legumes are cosmopolitan with a wide range of adaptability and are well-represented in tropical, sub-tropical, temperate and in arid and semi-arid regions. The ecological success of this legumes is due to their ability to form tubercles or nodules in the root system in association with the soil-borne bacteria (*Rhizobium* species or *Bradyrhizobium* species) or with Actinomycete *Frankia.* The effective nodules are pinkish and fix atmospheric Nitrogen. Under favourable condition, they can fix up to 194 Kg/ha/year of elemental Nitrogen from the atmosphere (Sacheti, 1985).

Though rhizobia for most leguminous trees occur almost everywhere, Nitrogen fixation may be limited in some species due to lack or insufficiency of rhizobia in the environment where they are grown. In such cases, inoculation with the required specific rhizobia may be needed. Nitrogen fixation is also reduced by moisture stress due to reduction in leghamoglobin in nodules, specific nodules activity, number of nodules and delay in nodule formation in leguminous crops. Lack in moisture may or may not reduce nutrient content, but reduces dry matter production considerably. There is ample amount of evidence to show that Nitrogen, Phosphorus and Potassium uptake is also reduced by insufficient moisture condition.

Intercropping with Nitrogen fixing trees in alley cropping systems are highly suitable for subsistent farmers with poor degraded sides. Leucaena-based agroforestry system has been reported to fix as much as 400-500 Kg Nitrogen/ha, which may symbiotically benefit crops growing in its association besides that of improving the soil fertility.

In contrast to the slow enrichment of soil fertility in traditional agroforestry system, the concept of alley cropping (hedgerow intercropping or avenue cropping) using fast-growing, Nitrogen-fixing trees, e.g. *Leucaena leucocephala* and *gliricidia sepium*, in the humid tropics can substantially increase soil fertility in 2-3 years. (Kang *et al.*, 1990). The Nitrogen fixing trees have higher concentration of Nitrogen in the leaves making them valuable for animal feed and fertilizers (Glover,1989).

2.4 MANAGEMENT SYSTEM IN AGROFORESTRY

Agroforestry systems will be able to mimic or replicate many of the nutrient-cycling and favourable environmental influences found in natural forest ecosystem, while generating the exportable outputs achieved with agricultural systems (Kidd. and Pimentel, 1992). In general, early assessments of the potential benefits of agroforestry were based largely on the assumption that it is possible to evaluate existing information on forestry and agriculture and extrapolate from it (Huxley, 1983, Nair, 1984), and partly based on the observation of traditional agroforestry systems which show increase growth of understorey vegetation (Charreau. & Vidal, 1965; Felker,1978). However, in some cases where proper management practices were not done, a number of negative effects have also been recognised, such as competition for moisture, excessive shading, allelopathy etc. For regular productivity on sustained manner, the knowledge of appropriate management system, thus, plays and important role.

2.4 (a) : Tree Management

In general management of trees in agroforestry depends upon choice of species, bio-physical causes of land, labour and capital. It includes all operations that are required to get desire products. However, when woody legumes are incorporated into the system, the profitability of tree fodder production is higher because of the low cost of maintenance.

Leucaena is known to be tolerant for alkaline soils to a certain degree. Jayaram *et al.*, (2000), reported that a pot culture experiment was carried out to assess the relative tolerance of nine (9) MPTs to soil alkalinity. Nine (9) species, viz. *Acacia nilotica, Acacia auriculiformis, Acacia ferruginia, Albizzia lebbeck, Acacia indica,Cassia siamea, Casuarina equisetifolia, Leucaena leucocephala,* and *Samana saman* were used. In this report, it was found that *Casuarina equisetifolia* was recorded the highest tolerance (> 500m M LD 50 value), followed by *Acacia nilotica* and *Acacia auriculiformis.* (400-500m M) and the rest were tolerant under 400m M. This showed that the tolerance of Leucaena to alkalinity is limited to a certain degree.

Being a good coppicer, Leucaena has a high growth potentiality and forage yield. The coppice growth in 1.5 years is recorded to be equal to the original three years growth (Pathak *et al.*, 1981). Kang *et al.*, (1985) also reported that Leucaena hedgerows thrive well even with repeated five prunings annually for six consecutive years.

Duguma *et al.*, (1988) reported that yield trials were conducted in south western Nigeria to find out the effects of pruning intensities on *Leucaena leucocephala, Gliricidia sepium* and *Sesbania grandiflora* grown with maize and cowpea. Leucaena was given 20 pruning combinations consisting of five pruning heights (25, 50, 75, 100 & 150 cm), and four pruning frequencies (monthly, bi-monthly, tri-monthly and six-monthly). *Gliricidia* and *Sesbania* were given nine pruning combinations with three pruning heights (25,50, 100cm) and three pruning intensities (monthly, tri-monthly and six-monthly). According to this report, multiple pruning had no ill-effects on Leucaena.

Sen (1984) reported that in Ranchi, pollarding of Leucaena around crop fields in two rows provides highest annual forage yield. However, pollarding intensity and spacing were not mentioned here. Contrary to the positive effects obtained by systematic management of the tree, Rao *et al.*, (1991) in Hyderabad observed that roots from nearby Leucaena plots reduced the yield of sole crops treatment by 34 % compared with a similar treatment with no root interference. This indicates that below-ground interactions should also be considered as that of the aerial ones when intercropping is adopted.

According to Survey Report on the use of Nitrogen fixing systems in South East Asian Silviculture, volume yield of *Leucaena leucocephala* varies with spacing. More wood is produced at 2m x 2m than at closer spacings (Gordon & Wheeler, 1983). At Ibadan, *Leucaena leucocephala* (variety K-28) was grown on sandy Entisol at format 4m inter-row spacing. After establishment and when allowed to grew uninhibited for one year, the plants reached a height of over 7.5m and produced more than 88 tonnes of wood per hectare (Kang *et al.*, 1984).

Mineral nutrition of the plant may also be beneficial so that growth and production of the plant are regulated on a sustained basis. Inoculation of soil with an efficient strain of VAM fungus is known to increase phosphorous uptake and biomass production (Bagyaraj *et al.*, 1989, Naik Gaonker and Sreenivasa,1994). Lack of certain minerals has deleterious effects on the growth and development of the plant. According to Bussler (1963), Calcium deficiency led to the chlorosis of middle leaves and downward curling as had been observed by Simon (1978) in plant species other than *Leucaena leucocephala.* Calcium deficiencies in Leucaena species not only depress the growth of the stem and branches, but markedly reduced the calcium concentration in all parts of the plants. The decrease in calcium was more in roots than other parts. Pertaining to this, dye back syndrome was also assumed to be more prominent in later stages of growth.

(b) : Crop Management

In agroforestry systems, crop management is equally important as that of the tree components. Crop management mainly depends on the crops chosen which have a specific -

* Nutrient requirement.
* Water, light, space and other requirement.
* Soil and climatic conditions.

Maize is an annual plant mainly grown during the kharif season under rainfed conditions. It is a light-demanding crop. The temperature regimes and fertilisation (Nitrogen application) influence the growth rates of miaze. But faster growth rate adversely affected the dry meter accumulation and grain yield (Naresh Kumar & Singh, 2001). Similar report were obtained from Yellamanda Reddy and Sankara Reddi, 2000 that higer temperature during maturation of maize depressed the dry metre accumulation, while higher temperature over the normal increased growth during tasselling and silking. Singh (1983) reported that 21^0C for germination and 32^0C for growth are considered optimum. Time to tassel initiation decreases with increase in temperature from 15^0C to 25^0C but ovule number increases with increase in temperature.

The plant is highly sensitive to water stress during the initial stages of growth, vis. knee high stage, tasselling stage, grain formation and milk dough stage, is, most important for more production. The crop cannot withstand waterlogging at any stage of it growth. For ideal growth, about 50 - 70cm of annual rainfall is needed (Singh, 1983). It grows upto an elevation of 3000m.

In southern England, maize sown in March takes 40 days for emergence when the temperature is low due to snow cover but takes only 8 days when sown in late May. It is susceptible to frost and very cold condition induces slow growth and development.

It is a heavy feeder crop and responds well to fertilization. Hybrid and composite varieties exibit their yied potential only when supplied with adequate quantities of nutrients at proper time. According to Naresh Kumar and Singh (2001), growth rate increases with increase in Nitrogen application. As against this report, a field experiment was conducted to study the resudual effect of Phosphorus at 4 rates (0,13,26 and 39 kd Phosphorus/ha) preceeding crop of wheat having succeeding crops of cowpea, maize and lentil. It was found that grains yield of maize did not increase significantly with P applied to wheat (Vig and Saroa, 2001). Nutritional deficiency of N,P,K and Zn is quickly shown by the crop and therefore, it is regarded as an 'Indicator Plant' as long as soil nutrient status is concerned.

2.5 LEUCAENA AS MULCH AND ITS EFFECT ON SOIL PRODUCTIVITY

There has been a great deal of research studies to show that the overall productivity (biomass) of an agroforestry system is generally greater than that of an annual system although not necessarily greater than that of a forestry or grassland. Moreover, conventional methods of preventing the loss of soil and water on slopes can be usefully supplemented by tree planting (Young, 1989).

The aspects of soil temperature and water status are particularly important in the early stages of crop growth. Mulching helps in conserving moisture by reducing evaporation losses, adds quick decomposing organic matters, protects the surface against the beating action of rain drops and erosive action of wind and movement of soil and rocks. Favourable physico-chemical changes in soil properties take place due to incorporation of organic materials.

The influence of different trees under silvipastoral systems after ten year plantation as compared to non-tree situation (open) on soil fertility build up and water retention properties showed a favourable trend (Hazra, 1990). There is also widespread evidence that vegetative barriers composed of trees, grasses or other species tend to reduce aggregate soil loss from sloping agricultural fields. This is rightly proved by Sajjaponjse (1992) in South East Asia that contour hedgerows reduced soil loss by 49% - 89% compared with conventional farming, which had incurred erosion levels ranging from 5 - 413 t. ha $^{-1}$ in three years. However, there is a paradoxical situation that in some areas, the annual crop yields in the alleys on slopes do not show any advantage compared with open-field results, even on a per-planted area basis. Busacca *et al.,*(1993) claimed that soil loss was not clearly or simply related to the slope gradient or elevation, but in reality, nearly every tonne of soil lost at the mid-slope is replaced by soil from above. This conclusion was made after monitoring of 137 Caesium, which was deposited naturally as radioactive fallout.

Budelman (1989) reported the effects of leaf mulches of *Leucaena leucocephala*, *Gliricidia sepium* and *Flemingia macrophylla* on moisture and temperature on sandy well-drained ferratic soil in Ivory Coast. According to this report using students t-test, all the averages turned out to be significantly different from each other at the P = 99.9 % Confidence Level except for the difference in humidity under the mulches of *Gliricidia sepium* and *Flemingia macrophylla*, which is significantly different at the 95% level. This shows that each of the mulch material has a specific soil temperature and soil humidity range.

The beneficial effects of using pruned biomass for soil improvement have been studied at Chalimbana, Zambia in 1987. In this research project, *Leucaena leucocephala*, *Flemingia congesta* and *Sesbania sesban* were interplanted with maize. The result showed that yields of maize from plots treated with tree prunings and inorganic fertilizers were higher than that of treatment with fertilizer alone (ICRAF, Annual Report, 1989).

Kang *et al.*, (1990) reported that hedgerow intercropping using fast growing Nitrogen fixing trees, e.g. *Leucaena leucacephala* and *Gliricidia sepium* in the humid tropics can substantially increase soil fertility in 2-3 years. More detailed results were given by Pathak & Gupta (1987) that a two-year old plantation of Leucaena added 5.6 g/ha of organic matter and caused an increase in water retaining ability, CEC, bulk density and tilth; and a decrease in Phosphorus of soil besides an improvement in the yield of successive grain/forage crop. Jha (1990) also reported increase in organic Carbon, available Potassium and Phosphorus of soil under silvipastoral system combining *Leucaena leucocephala* and Napier grass at Ranchi.

Leucaena forms a canopy of foliage that totally shades out weeds. Dry matter production in the leaves is large and soon improves the fertility and physical condition of the soil.

Old leaves fallen from trees can damage tender crop plants and block their photosynthetic processes. On the contrary, leaves of most of the legumes are small in size, decompose fast and add a large quantity of humus and nutrients to the soil. According to a survey report on Nitrogen fixation, Domingo (1983) reported that in South East Asia, decomposition of Leucaena leaves is complete within two weeks to form humus. The slow release of organic nutrients also allows the crop a better chance to absorb them, which, if released quickly, would be leached.

Dried leaves of Leucaena are estimated to contain about 2-4.3 % Nitrogen and 1.3-4.0% Potassium. In the assessment of case study based on actual records, it has been estimated that the quantity of Nitrogen applied to the land through 2500 Kg of Leucaena is about 60 Kg/ha, and each Kilogram of Nitrogen is able to increase maize yields by 60 Kg (Liebhardt,1983). Rachie (1983) stated that about 2/3rd of the Nitrogen in Leucaena biomass is contained in the leaves and twigs harvested whereas only 1/3rd is in the stemwood.

However, Yamoah *et al.,* (1986) reported that in 120 days, the Nitrogen released from the leguminous cuttings ranges from about 46%-96%. This indicates that when branches and leaves are used as mulch, most of the Nitrogen become available to the associated crop during the growing season. On the other side, Bhardwaj *et al.*, (1992) from decomposition studies in tropical agroforestry systems, revealed a high mass loss of *Leucaena leucocephala, Eucalyptus* species and *Prosopis juliflora* during 274 days of exposure to decomposition.

When Leucaena and cereals (maize) are interplanted in an agroforestry system, it has been assumed that the yield of maize grain can be increased upto 80% because of the added Nitrogen provided by the Leuceana trees (Rachie, 1983 ; Torres, 1983 ; Liebhardt, 1983). The prunings as Nitrogen source appeared to be most effective when incorporated than when applied as surface mulch. This can be attributed to the fact that ammonical Nitrogen is easily volatilised during the process of mineralisation (Evensen, 1982).

A marked increase in productivity of Pigeon pea *(Cajanus cajan*), Til (*Sesamum indicum*), Castor (*Ricinus communis*) and Jowar (*Sorghum vulgaris*) under Leucaena was reported by Singh (1983). Kang *et al.*, (1981) and Torres (1983) suggested interplanting of maize with Leucaena species in Nitrogen deficient soils. Tomashevskaya and Lugovskaya (1970) also recorded improved uptake of Phosphorous and Potassium by cereals in the presence of legumes.

Rao and Wesley (1989) reported the findings of hedgerow intercropping of *Gliricidia sepium, Cassia siamea* and *Leucaena leucocephala* with maize and cowpeas at Machakos field station which indicates that an agroforestry system based on hedgerow intercropping may be productive under semi-arid condition even using Gliricidia and Leucaena, which are being considered more suitable for humid zones.

It thus seems that an agroforestry system of combining Leucaena and maize is a common practice for planting on the contour on slopes to serve a dual purpose of conserving soil and water resources in addition to that of the productive roles. Planting on the contour, leaving the maize residues, and applying Leucaena mulch limit soil erosion to less than 1t/ha/yr (Nair, 1984 ; Lal, 1989). This is in contrast to the no-fertilizer maize system, which has an assumed erosion rate of 30 t/ha/yr. However, Rawat (1997) suggested application of mulch at the beginning of a rainy season in order to aid infiltration, rather than at the end of the rains when it can only reduce the rate of drying out during the following dry season. The same trend is found by Pereira & Jones (1984) in Kenya coffee and annual plant (maize and beans) yields increased when organic mulch was applied before the rains.

2.6 BIOMASS PRODUCTION

Trees with higher biomass production produce more Oxygen, which is one of the benefits of growing Fast Growing Nitrogen Fixing Trees (FGNFTs) from the environmental point of view. It is believed that Leucaena increases Nitrogen of the soil mainly through leaf fall. The beneficiaries of this microsite improvement is thus the plant itself and the intercrops.

The giant Leucaena are known to produce large amounts of biomass. The variety K-8, when planted with a density of 5000 trees/ha yielded

7.5 tonnes of forage/ha at 1.5 years of age (Pathak & Patil, 1980). A biomass production (forage & fuelwood) of 74.3 t/ha/yr by Leucaena was observed by Pathak (1987), and 2400 Kg/ha by Rachie (1983).

At Rajkot in 1985, rainfall received was only 30% of normal precipitation. Experience of alley cropping showed total failure of grain production of three leguminous crops tried in the system. In the sole crop plots, production was limited to 0.5 $t.ha^{-1}$ - 1.7$t.ha^{-1}$ of green fodder. However in alley cropped plots, Leucaena hedgerows produced over 5 $t.ha^{-1}$ of green fodder (Anon. 1986).

Khan & Pathak (1996) carried out a study to predict biomass production of Leucaena. From the basic attributes taken such as height, CD and dbh, it was found that variation in biomass increases upto 6.5 years and then declines with maturity.

Kang *et al.*, (1985) reported the ability of Leucaena to withstand repeated five prunings in a year for 6 consecutive years. They further stated that though the potentiality that as forage is high, the biomass yield in the subsequent prunings was lower. This findings was supported by Duguma *et al.*,(1988). According to this report, *Leucaena leucocephala, Gliricidia sepium* and *Sesbania grandiflora* wre intercropped with maize and cowpea. The tree species, after giving different pruning frequencies and pruning heights, gave variable results. The biomass, drywood and nitrogen yields were in the order Leucaena > Gliricidia > Sesbania.

It also yields highest forage per unit production (4.036 t/ha) as against 74.3 t/ha/yr reported by Pathak (1987) at 5 years rotation. The main reason for the difference in biomass yields seems to be the difference in harvesting time and intensity. In a High Density Energy Plantation experiment carried out at Surendrabag (Gujarat), *Leucaena leucocephala* (K-8) and Eucalyptus hybrid were kept at a distance of 60cm x 60cm and 40cm x 40cm on 8 hectare area of land. The resulting biomass through selective cutting after the 4th year was 112.5 t/ha/yr. However, in such cases, the density is maintained at 25,000 trees/ha (Patel, 1988).

In a greenhouse investigation conducted to predict phosphorous concentration in the soil solution for Vesicular Arbuscular Mycorrhiza (VAM) activity, it was reported that VAM inoculation of *Glomus aggregatum* enhanced phosphorous uptake but did not benefit plant for biomass production (Bagyaraj & Machado, 1996).

The suitability of four tree species such as, Subabul,Sissoo, Hardwickia and Albizzia had been studied for use in dry zone silvipasture and to determine the relative forage productivity. According to this study, Subabul was found the best, attaining a mean height of 4.08m and a girth of 14.68cm after two and half years, which was a highly significant growth compared to other species tried. These studies reveal the distinctive ability to produce more forage than other species.

2.7 SPATIAL EFFECTS IN AGROFORESTRY SYSTEMS

Intercropping in an agroforestry demands application of judicious management practices of the components involved, the tree crops in particular. Spacing affects various morphological and physiological aspects of the intercrops. the effects of trees on the associated crops.

Sheikh & Hag (1986) studied the effect of poplar rows on the yield of sugarcane in Peshawar valley. The poplars depressed the sugarcane crop 0-10m away from the trees. The yield was 80 $t.ha^{-1}$ elsewhere, while average yield from the study area was 75 $t.ha^{-1}$.

In 5-year old hedgerow system of either leguminous trees (*Leucaena leucocephala* + *Cajanus cajan*) or grass (*Paspalum conjugatum*) on an Ustic kandihumult of 21-35% slope in Thailand, Turkelboom *et al.*, (1993) reported reduction in rice yields of greater than 50% in the upper alley zone, compared with the middle and lower areas.

Yield reduction is regulated even when competitions between the components is reduced. Solera (1993) excluded both above-ground and below-ground hedgerow competition by intensive pruning and installation of 150cm deep plastic barriers at 30cm from the outer lines of hedgerows. He reported that the spatial pattern of yields, which was higher on the lower rows within the alley than those of the upper ones, remained unchanged. A similar result with the rapid development of terrace associating with reduction in crop yield in the upper alley zones were also found by many workers (Agus,1993; Garrity *et al.*,1995). This indicates that soil fertility may be a limiting factor for the difference in crop yields in the different alley zones.

The progressive decline in crop productivity as rows approach the hedgerow in hedgerow intercropping is also another common incidence as has been observed by Salazar *et al.*, (1993) for upland rice, which is less frequently observed in case of maize which has a more neutral response. This condition can be attributed to the aerial and ground competition between the hedgerows and the associated crops.

Shading effect is always encountered with trees having larger crown sizes. According to Anon. (1997), a study was conducted in Kandi area of Punjab where yields of different field crops were compared. The tree species viz. *Leucaena leucocephala* and *Acacia nilotica* were spaced at 3 x 1m and 3 x 3m respectively. Though the yield of wheat and rapeseed was higher in the initial stages, pruning was suggested due to shading effect from the fourth year. The produce of total biomass of *Leucaena leucocephala* was 1564 q/ha, small firewood of 651 q/ha and fodder, 913 q/ha. The shading effect was attributed to closer spacing and larger crown size with growth.

Khybri *et al.*, (1988) reported that a more stable and uniform yields with Eucalyptus hybrid was obtained on the yield of crops when *Grewia optiva, Morus alba* and Eucalyptus hybrid having 5 x 5m spacing @ 100 trees/ha with control (open). CvRr-21 of wheat and Cv Akashi of paddy were used with ten years observations. This findings also goes well with the report by Anon. (1997). However, the shading effect can be reduced by adopting low cutting heights (15-30cm) as suggested by Torres (1983) in his quantitative hypothesis based on available information.

The grain yield of wheat was reported to be higher at farther distance (10m & 8m) from the tree and lower grain yield was obtained at closer distance from the tree (6m, 4m and 2m). This implies that closer spacings cause more or less competition. The overall grain yield of wheat was highest under Subabul.

Alvarez *et al.*, (1984) were also in the opinion that wider spacing between the hedgerows of Leucaena and maize produces higher grain yield. This was obtained when single hedgerows of Leucaena intercrop was established at 5m apart. This is because of the fresh herbage yield from subsequent growth over four cutting periods which were applied to the single hedgerows were comparatively higher than those of the tripple hedgerows.

CHAPTER-3
MATERIALS AND METHODS

Since the practice of shifting cultivation has brought forth direct and indirect negative impacts on the environmental and socio-economic conditions in Mizoram, The experiment was carried out during 2000-2001 which was basically aimed to assess the suitability of an agroforestry system to replace this traditional system of farming. In this experiment, 2-year old Subabul *(Leucaena leucocephala)* was used as the tree component and maize *(Zea mays)* as an agricultural crop.

The aim of the experiment was to study "Effect of different spacings on the growth performance of Subabul *(Leucaena leucocephala* Lam.de Wit) and productivity of maize *(Zea mays* L.) in a hill agroforestry system in Mizoram".

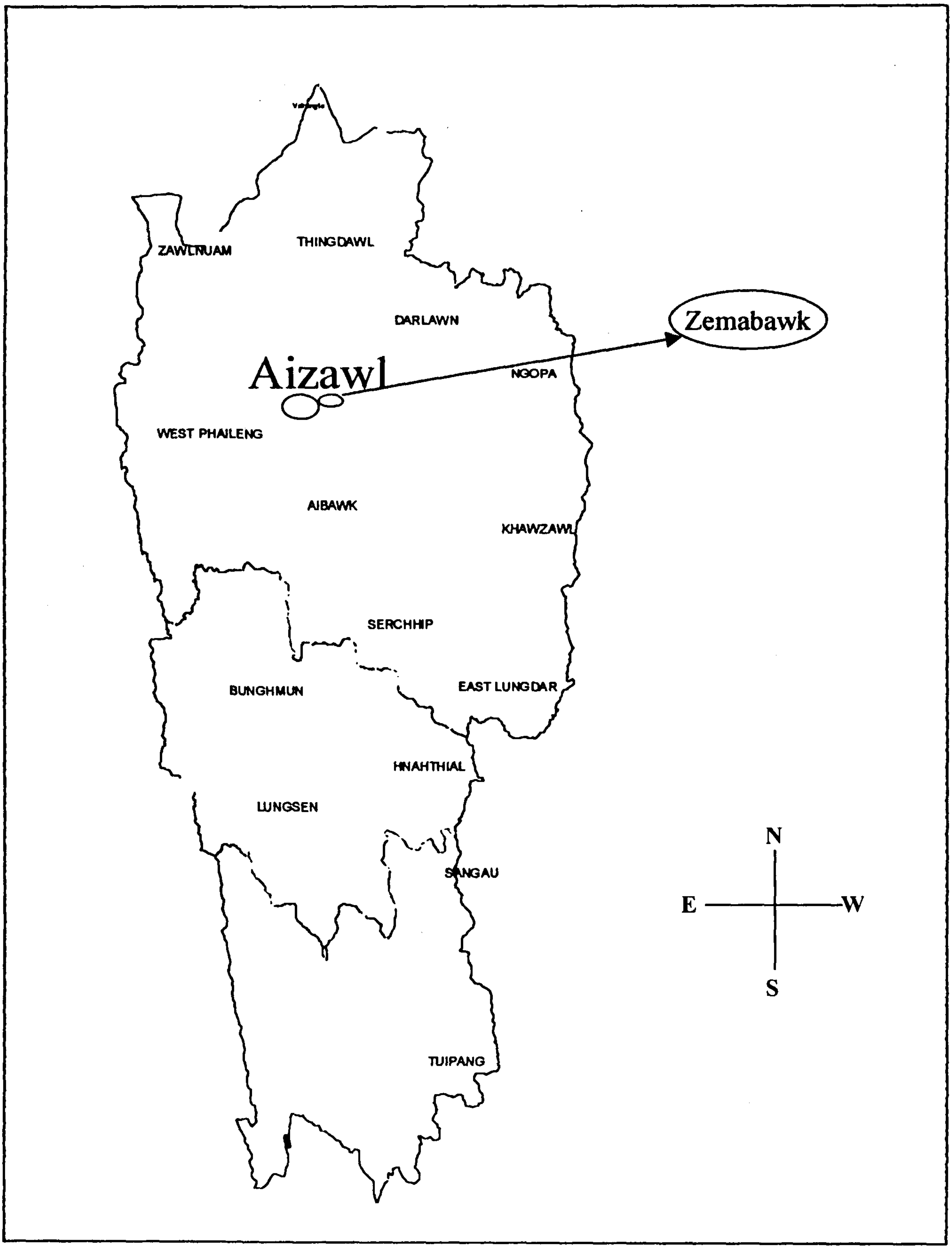
3.1 SITE DESCRIPTION

The experiment was carried out at Zemabawk which is about 3 kms away from the state capital, Aizawl. It lies within 21°58' and 24°35'N latitudes and 92°15' and 93°29'E longitudes, having and elevation of 1132m (3715 ft) from the mean sea level. It has an annual rainfall of 325cm. Summer and winter temparature ranges are recorded as 20°C-30°C and 11°C-23°C respectively.

Topographically, the site can be regarded as sloppy having a south-western aspect in the upland areas of Zemabawk.

According to the soil test result carried out before planting of maize, it was found that the texture of the soil was sandy clay (60.85% sand, 6.91% silt and 32.13% clay). The pH of the soil also found slightly acidic (5.3). The soil type can also be grouped under the order Ultisols.

Fig. Location Map of Experimental Site.



3.2 EXPERIMENTAL DESIGN AND TREATMENTS

The experiment was carried out following Randomised Block Design (RBD) which were replicated three times. Four different spatial treatments including control(6m x 6m, 3m x 3m, 4m x 4m & sole crop plots) were given for each replication so as to result in 12 sub-plots. The size of each sub-plot was 12m x12m. All in all, there were 12 sub-plots in the whole experimental area of 48m x 36m.

Since the tree component Leucaena was already established, the ground vegetation was cleared using dao, spade, etc. before sowing of maize.

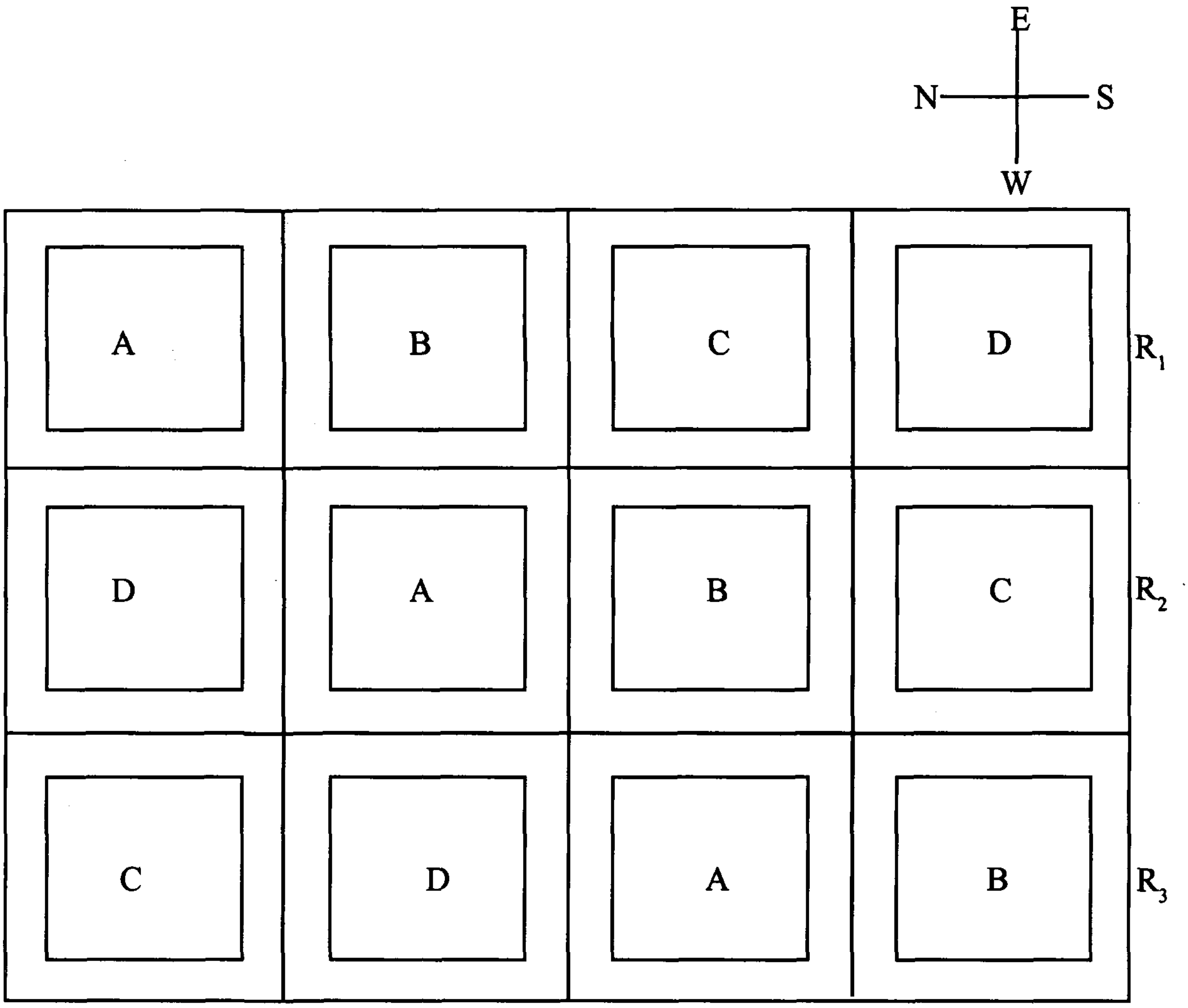
As there was late monsoon shower, Composite maize(variety Ganga-5) was sown as intercrop in the middle of May at the rate of 2-3 seeds per hill. The spacing of maize was kept same for all the treatments, i.e. 60cm x 40cm (Row to row = 60cm and Plant to Plant = 40cm). As a whole, there were three control sub-plots in which sole maize was sown with the same spacing.

3.3 SOIL ANALYSIS

To assess the change in soil physical and chemical condition during the study period, soil analyses were done twice, i.e before planting of maize and after harvest.

Samples were taken from each sub-plot at a depth of 10-15cm with the help of Soil Auger. The first samples were collected in early May and then analysed. The soil texture was determined by hydrometer method. The results showed that the physical condition of the soil was sandy loam (60.85% sand, 6.91% silt and 32.13% clay) and was classified under the order Ultisols, which remained rather unchanged after the second analysis

Plate No. 1 :2-year old Leucaena stand during September,2000.



DESIGN - RANDOMISED BLOCK DESIGN

TOTAL EXPERIMENTAL AREA - 48m x 36m

SUB-PLOT SIZE - 12m x 12m

TREATMENTS :

A = Leucaena (6m x 6m) + Maize (60cm x 40cm)
B = Leucaena (3m x 3m) + Maize (60cm x 40cm)
C = Leucaena (4m x 4m) + Maize (60cm x 40cm)
D = Control (Maize alone - 60cm x 40cm)

FIG. 2 : LAYOUT OF THE EXPERIMENT

Plate No. 2: Leucaena intercropped with Maize as long as physical condition is concerned. However, the findings regarding the chemical condition will be represented later on.

The parameters used for determination of the chemical status of the soil were contents of organic Carbon, Nitrogen, Phosphorus, Potassium. To assess the above chemical properties/parameters, the following methods were used :-

* **Organic carbon :-**
  Organic carbon content was determined by Walkley & Black Rapid Titration Method.
* **Nitrogen :-**
  Determination of the content of Nitrogen was carried out by Kjeldahl's method.
* **Phosphorus:-**
  Available phosphorous was determined by Bray & Kurtz method.
* **Potassium :-**
  Determination of Potassium content was done by employing Mongan's Method using Flame Photometer.
* **Soil pH :-**
  pH of the soil was worked out using digital pH meter.

3.4 ASSESSMENT OF GROWTH AND YIELD

3.4.1: GROWTH PARAMETERS TAKEN ON LEUCAENA

Since the experiment was done with established stand of Leucaena plants, growth attributes, such as height, basal thickness and biomass production were taken at monthly intervals to determine the growth pattern.

Height:-

The height of the tree was taken by measuring the length of the plant starting from the base just at the ground level upto the uppermost tip using thread, which was again measured with a scale.

Basal thickness :-

This was determined by winding a thread round the tree at the ground level, which after marking the point, was then measured with a scale.

Biomass production :-

Determination of biomass production was done by taking the dry weight of the whole plant.

3.4.2 : YIELD PARAMETERS TAKEN ON MAIZE

The parameters used for determination of the yield of maize include :-

Number of leaves :-

Fully - opened leaves from the plants were counted after visual observation.

Number of cobs :-

From the bearing plants, the number of cobs formed were counted.

Grains per cob :-

The total number of grains per cob in the bearing plants were counted and recorded.

Biomass production :-

After uprooting the whole of the plants from each sub-plot, their respective dry weights were taken.

CHAPTER-4
RESULTS

This chapter deals with the presentation of data based on field observations and laboratory findings. The growth and yield attributes taken on the biotic components (the tree crop and the intercrop) are summed up in tabular forms for an orderly interpretation.

4.1 : GROWTH PARAMETERS OF *LEUCAENA LEUCOCEPHALA*

As has been mentioned before, an established stand (2-year old) of Leucaena had been used in the experiment. The parameters observed on Leucaena were thus concentrated to growth attributes, such as -

(a) Plant height

(b) Basal diameter

(c) Biomass production

4.1 (a) : Plant height of Leucaena -

The growth pattern of trees with regard to height was given priority as the trees were in the initial stage of fast growth. Observations for determination of plant height were done at monthly intervals which were recorded in centimeter. Measurement of all plants within each sub-plot was done right from the beginning of the study period, i.e. October, 2000 upto September, 2001. The mean height for all treatments on monthly basis is represented in Table - 1.

According to the data, the height of Leucaena in October, 2000 ranged from 341.85 cm to 360.89 cm, the least height being observed in 6m x 6m plot and the highest one in 3m x 3m spacing. The same trend of difference was observed in the following months but with unstable degrees.

In September 2001, the highest mean growth in height was observed in 3m x 3m plot (365.83 cm), followed by 4m x 4m plot (358.93 cm), and 6m x 6m spacing attained the least mean height with 348.53 cm.

TABLE - 1

HEIGHT OF LEUCAENA (IN CM) AS AFFECTED BY DIFFERENT SPACINGS AT MONTHLY INTERVALS (OCT, 2000 - SEPT, 2001)

Treatment (Tree Spacing in metre)	2000			2001								
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept
A (6m x 6m)	341.85	343.05	343.54	343.87	344.39	344.81	345.07	345.58	345.97	346.83	347.71	348.53
B (3m x 3m)	360.89	361.74	362.30	362.48	362.62	362.77	362.97	363.21	363.78	364.67	365.10	365.83
C (4m x 4m)	353.74	354.58	355.16	355.46	355.60	355.80	356.04	356.26	356.89	357.59	358.30	358.93
SE m ±	0.67	0.65	0.57	0.61	0.59	0.61	0.38	0.56	0.62	0.62	0.65	0.80
CD (P=0.05)	1.85	1.80	1.58	1.69	1.64	1.69	1.05	1.55	1.72	1.72	1.80	2.22

It can be seen from the table that different spacing treatments had significant effects on the plant height of Leucaena. The spacing of 3m x 3m, which previously recorded maximum height was found to continue its superior growth performance as compared to other treatments of 4m x 4m and 6m x 6m spacing. Moreover, a relatively faster growth rate was observed with 6m x 6m and 3m x 3m spacings during the initial period of experimentation when compared with the latter stages.

4.1 (b) : Basal diameter of Leucaena -

Basal diameter of Leucaena as affected by different spacing treatments taken at monthly interval between October, 2000 and September, 2001 has been shown in Table - 2.

In October 2000, basal diameter of Leucaena ranged from 2.40 cm to 3.32 cm, which can be regarded as the initial figures. However, it can be assumed that spacing treatments had already affected the growth pattern of Leucaena upto a certain degree with the fact that there were differences among the treatments as far as basal diameter is concerned. This assumption was supported by the findings in the latter months with the same kind of proportional difference.

In September 2001, growth in the base ranged from 2.70 cm to 3.42 cm. The mean basal diameter ranged from 2.89 cm in October 2000, which was observed on 4m x 4m plot, to 3.38 cm in September 2001 observed on 3m x 3m plot.

As a whole, maximum basal growth was found in 3m x 3m plot. The least growth was found with 4m x 4m spacing. The figures remained rather unchanged throughout the whole study period.

It can also be seen from the table that though there was variation in basal growth of Leucaena due to different spacing treatments, the differences at the interval of a month were all found to be non-significant which is in contrast with the growth in height.

TABLE - 2

BASAL DIAMETER OF LEUCAENA (IN CM) AS AFFECTED BY DIFFERENT SPACINGS AT MONTHLY INTERVALS (OCT, 2000 - SEPT, 2001)

Treatment (Tree Spacing in metre)	2000			2001								
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept
A (6m x 6m)	3.26	3.28	3.28	3.29	3.29	3.30	3.30	3.30	3.31	3.31	3.32	3.33
B (3m x 3m)	3.29	3.30	3.31	3.31	3.32	3.32	3.33	3.35	3.35	3.36	3.37	3.38
C (4m x 4m)	2.19	2.93	2.95	3.0	3.01	3.02	3.04	3.04	3.04	3.05	3.06	3.08
SE m ±	0.19	0.18	0.18	0.14	0.15	0.14	0.14	0.15	0.14	0.14	0.13	0.13
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

4.1 (c) : Biomass production of Leucaena -

Biomass production was worked out by taking the dry weights in grams. The data resulting from the effect of different spacings on the biomass yield (above-ground and below-ground parts) are presented in Table - 3.

It can be seen from the table that closer spacing (3m x 3m) gave maximum plant dry weight (216.16 gms. DM) followed by 4m x 4m spacing, and the least production was observed with 6m x 6m spacing (198.34 gms. DM). Maximum mean dry weight of biomass was also found with 3m x 3m plot successively followed by 4m x 4m and 6m x 6m spacings as had been observed with other growth parameters taken on Leucaena.

It can also be made clear from the table that variation in the final stage among the treatments was found to be significant though it was lower than the previous results obtained before planting of the intercrop.

4.2. YIELD PARAMETERS OF MAIZE

The parameters taken on maize were done at the time of harvest in August, 2001. With the experiment being aimed to assess the effects of spacing on the yield performance of intercrop (maize), the factors taken on maize included the yield attributes, such as -

(a) Number of leaves/plant

(b) Number of cobs/plant

(c) Number of grains/cob

(d) Biomass production

4.2 (a) : Number of leaves/plant-

The data collected on the number of leaves as affected by different treatments are depicted in Table - 4. It would be worth mentioning that since there was

TABLE - 3

BIOMASS PRODUCTION OF LEUCAENA (IN GMS) AS AFFECTED BY DIFFERENT SPACINGS

Treatment (Tree spacing in mm)	Oct - 2000	Sept - 2001	Mean %
A (6m x 6m)	125.86	198.65	57.83
B (3m x 3m)	149.29	219.14	46.78
C (4m x 4m)	128.07	204.26	59.49

SE m ±	11.62	27.3
CD (P = 0.05)	N.S	N.S

no additional fertilisation provided to the crops; the yield was found to be comparatively lower than the normal management practices.

It is clear from the figures that the mean number of leaves differed from 8.66 to 9.33 per plant in different spacing treatments. The 6m x 6m treatment gave highest yield with an increase of 3.66 percent over control plot. This is followed by 4m x 4m and control treatments with the mean number of leaves of 9 each. It is worth keeping in mind that closest spacing (3m x 3m) resulted in lowest yield of intercrops as has been represented in Table - 4 with lesser figure (8.66) than the control plot as against the growth pattern of Leucaena.

4.2 (b) : Number of cobs/plant -

The figures representing the mean number of cobs per plant is shown in Table - 5. As has been explained before, the number of cobs founded was relatively low owing to the no- fertilizer treatment. However, the mean yield of each replication ranged from 1 to 4 in number. The lowest production being found in the third replication of 3m x 3m spacing while the highest was found in the second replication of 4m x 4m spacing.

As has been recorded in the table, 6m x 6m spacing gave maximum yield (mean yield of 2.66) with the increase percentage of 14.16 over control. This is followed by 4m x 4m spacing treatment and control (mean yield of 2.33 each). The closest spacing (3m x 3m) yielded least with the mean yield of 2 which is significantly lower than other treatments and control plot.

Contrary to the theoretical situation, control plot gave production which was not much different from that of the other treatments. Moreover, though the increase percentage of 14.16 over control was obtained with 6m x 6m spacing, the particular treatment still failed to reach the level of significance.

4.2 (c) : Number of grains/cob -

The data representing the number of grains/cob/plant in Table -

TABLE - 4

NUMBER OF MAIZE LEAVES PER PLANT AT 30 DAS, 60 DAS AND AT HARVEST AS AFFECTED BY F LEUCAENA

Treatment (Tree Spacing in metre)	3 DAS *		60 DAS *		AT HARVEST	
	Mean no.of leaves per plant	% increase over control	Mean no.of leaves per plant	% increase over control	Mean no.of leaves per plant	% increase over control
A (6m x 6m)	8	-	10	15.62	10	-
B (3m x 3m)	7	-	9	14.06	10	-
C (4m x 4m)	10	12.34	11	17.18	6	-
D (Control)	9		8		10	
SE m $\pm$	1.22		1.56		1.35	
CD (P=0.05)	NS		NS		NS	

* DAS - Days after sowing

Plate No. 3: Maize cob at harvest

TABLE - 5

NUMBER OF MAIZE COB/PLANT AT HARVEST AS AFFECTED BY DIFFERENT SPACINGS OF LEUCAENA

Treatment (Tree spacing in metre)	Mean no. of Maize cob/plant	% increase over control
A (6m x 6m)	2.66	14.16
B (3m x 3m)	2.0	-
C (4m x 4m)	2.33	-
D (Control)	2.33	

SE m ± 0.93
CD (P = 0.05) N.S

TABLE - 6

NUMBER OF MAIZE GRAINS/COB AT HARVEST AS AFFECTED BY DIFFERENT SPACINGS OF LEUCAENA

Treatment (Tree spacing in metre)	Mean no. of maize grains/cob/plant	% increase over control
A (6m x 6m)	113.33	11.84
B (3m x 3m)	104.66	3.28
C (4m x 4m)	105.33	3.94
D (Control)	101.33	

SE m ± 18.20
CD (P = 0.05) N.S

6 shows that the figures in each replication differ from 80-130. From the table, it can be seen that maximum mean yield was obtained with 6m x 6m spacing of trees (113.33). It is also worthnoting that this increase gave more production of 11.84 percent over control. The 4m x 4m spacing gave the mean figure of 105.33, closely followed by 3m x 3m spacing treatment with 104.66. These two treatments showed the same trend in production having increase percentage of 3.94 and 3.28 respectively.

The non-tree situation in the control plot gave lowest yield as has been shown in the table. However, there was no significant difference in the number of cobs/plant due to various spacing treatments including the control plot.

4.2 (d) : Biomass production of maize -

The data collected at harvest for biomass production is presented in Table - 7. The same pattern of variation was observed among the treatments regarding biomass production.

As has been focussed in Table - 7, 6m x 6m spacing yielded maximum dry weight of biomass (53.34 gms.) with an increase of 6.53 from the control plot. 4m x 4m treatment ranked second as long as biomass production is concerned. It can be seen from the table that the mean biomass yield in 4m x 4m is 53.30 gms., having 6.45 percent increase over control plot. The 3m x 3m spacing treatment ranked third (50.07 gms.) followed by the control plot (42.56 gms.).

TABLE - 7

BIOMASS PRODUCTION OF MAIZE AT HARVEST AS AFFECTED BY DIFFERENT SPACINGS OF LEUCAENA

Treatment (Tree spacing in metre)	Mean dry weight (gms) of biomass	% increase over control
A (6m x 6m)	53.34	25.32
B (3m x 3m)	50.07	17.64
C (4m x 4m)	53.30	25.23
D (Control)	42.56	

SE m ±	2.07
CD (P = 0.05)	5.06

There were contrasting differences among the treatments as against the differences observed in other parameters taken. These differences obtained in biomass alone thus reached the level of significance.

4.3 SOIL FERTILITY STATUS

Improvement in soil fertility status was assessed through testing for the soil Nitrogen, Phosphorus, Potassium, Organic Carbon and pH levels. The results obtained were represented in separate tables.

It is evident from the tables that though there were favourable changes in the soil nutrient status with all the treatments, the increase in Nitrogen level was found to be proportionally less than the other nutrient status. 4m x 4m plot gave best result with 38.63 % increase over control.The same kind of improvement was also observed in other soil factors taken while the control plot was found to give worse results comparing with the other plots. It is also clear from the table that the degree of soil improvements for different soil factors were different among treatments.

TABLE - 8

CHANGES IN CHEMICAL STATUS OF TOP SOIL (15 CM DEPTH) AS AFFECTED BY DIFFERENT SPACINGS OF LEUCAENA

Treatment (Tree Spacing in metre)	Nitrogen (%)			Available Phosphorous (kg/ha.)			Available Potassium (kg/ha.)			Organic Carbon			pH		
	Oct 2000	Sept 2001	% increase	Oct 2000	Sept 2001	% increase	Oct 2000	Sept 2001	% increase	Oct 2000	Sept 2001	% increase	Oct 2000	Sept 2001	% increase
A (6m x 6m)	1.96	2.31	17.85	11.2	13.21	17.94	211.0	220.0	4.26	1.28	1.35	2.63	5.5	5.5	-
B (3m x 3m)	2.85	3.13	9.82	16.8	17.76	5.71	194.0	214.0	10.30	1.39	1.42	2.81	5.6	5.8	3.57
C (4m x 4m)	1.64	1.70	3.65	12.15	2.16	0.08	188.0	178.0	-	1.29	1.33	2.62	5.3	5.2	-

	Nitrogen	Available Phosphorous	Available Potassium	Organic Carbon	pH
SE m ±	0.2	0.67	9.53	0.12	0.16
CD (P=0.05)	0.63	2.13	NS	NS	NS

CHAPTER-5
DISCUSSION

In this chapter, discussion is made for each growth and yield parameter in the order of biological establishment in the experimental plot. Critical analysis of data obtained after field inspections has been presented here for the successive summarisation and concluding part.

5.1 : PLANT HEIGHT OF LEUCAENA :

Starting from the month of October 2000, Leucaena plant height was studied every month upto September, 2001. According to the data presented in the preceeding chapter, the mean differences among the spacing treatments were significantly variable. Close spacing of 3m x 3m plot was found to give maximum mean height (360.89 cm), followed by 4m x 4m treatment with 353.74 cm of mean height, and a comparatively lower degree of height was recorded with 6m x 6m treatment (341.85 cm). Similar observations have been reported by Djikman (1950) that the rate of growth of Leucaena is optimum under close spacing receiving full sunlight. The same kind of difference among treatments was observed to be continued till september, 2001 which shows that the rate of growth was more or less same regardless of the spacing treatments.

More specifically, the mean growth in height among treatments was found to be 0.75 cm during the first three months (October -December,2000). The rate of growth was found highest with 6m x 6m treatment (0.56 cm) while equal rate of growth was observed with 3m x 3m and 4m x 4m spacing (0.47 cm each). This is attributed to the fact that though rainfall received during these months were less, the water retained in the sub-soil level was efficiently utilized resulting in better growth.

Following this, the plant growth in the latter months (January-May, 2001) was slightly lower in which case, insufficient moisture condition was assumed to be one of the reasons. But from June onwards, plant height was improved little by little. It is thus evident that water availability plays an important part in determining plant growth. However, there were some variations in the rate of

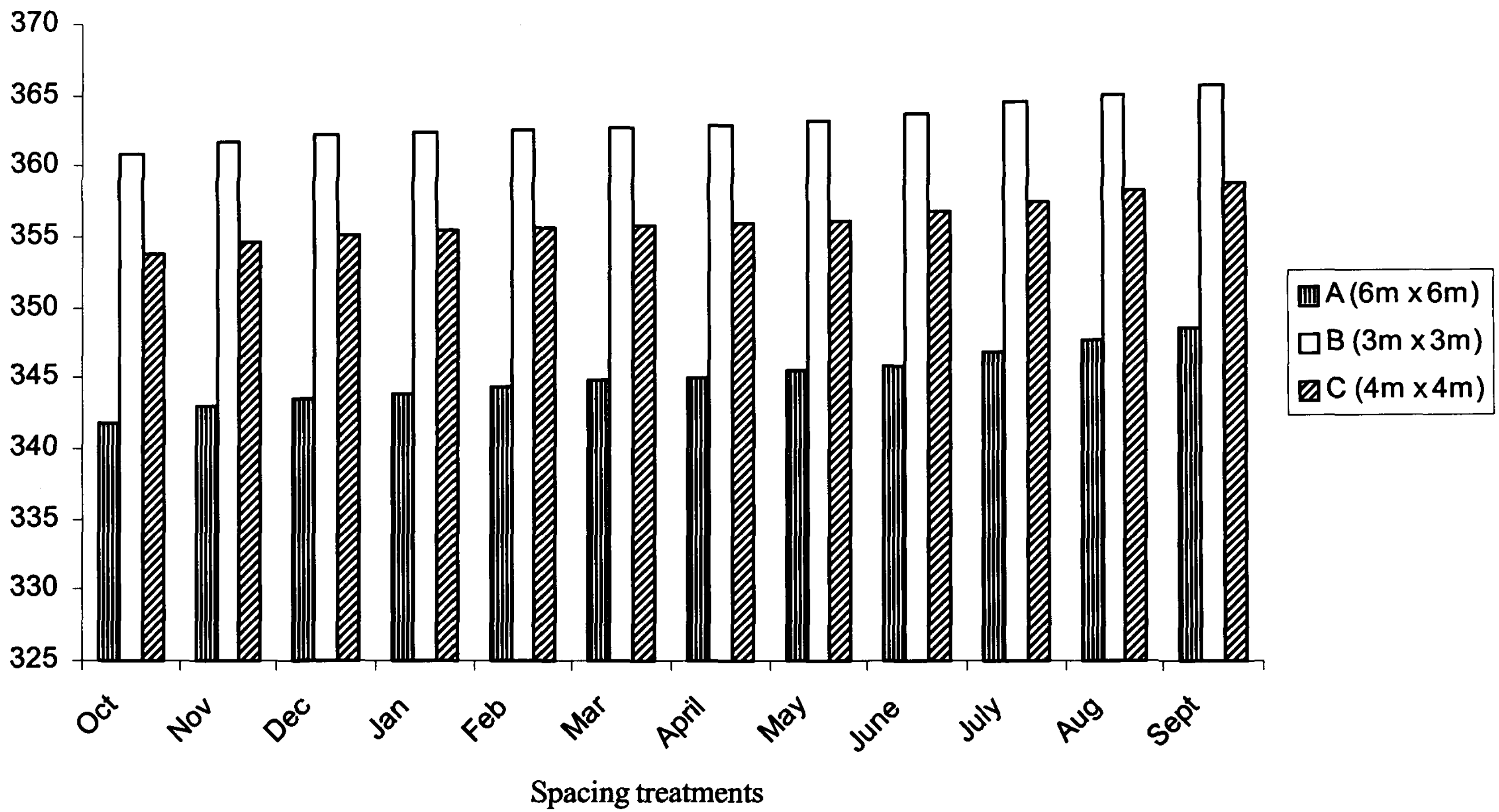


Fig. 3 : Effect of spacing treatments on the growth in height of Leucaena at monthly intervals

growth under different treatment conditions.

It is also important to note that the monthly variations among treatments were all found to be significant even during the period when plants gave minimum growth. The reason for this may be that the 2-year old Leucaena plants were in the initial phase of attaining faster growth in height.

5.2 : BASAL DIAMETER OF LEUCAENA :

Observations regarding Basal diameter were also made on Leucaena along with the measurement of height. These acitivies were done at monthly intervals as has been mentioned.

As a whole, there was no significant differences observed in the basal growth as affected by different spacings. This might be due to the fact that plants used more resources for producing more growth in height than the basal growth. The nutrients and water uptake of the plant is concentrated towards lengthening of the stem (pole) and as such, the mean growth in height is always more than the growth in height at this stage.

The mean growth rate per month during the initial two months (October-November,2000) was found to be 0.02 cm which was more than the figures obtained during the following months from December 2000- May 2001. The basal growth was more pronounced from June, 2001 with an average growth of 0.01 cm per month. This indicates that the stunted growth could also be due to inadequate water supply during the drier period of winter and spring months.

The 3m x 3m spacing, which gave maximum growth in height was also ultimately found to produce maximum basal diameter ranging from 3.29 cm in October, 2000 to 3.38 cm September 2001, the 6m x 6m spacing ranked second with 3.26 cm in the beginning of the observation to 3.33cm in the final stage. The least diameter of the base was found with 4m x 4m spacing (2.89 cm - 3.08 cm during the course of experimentation.)

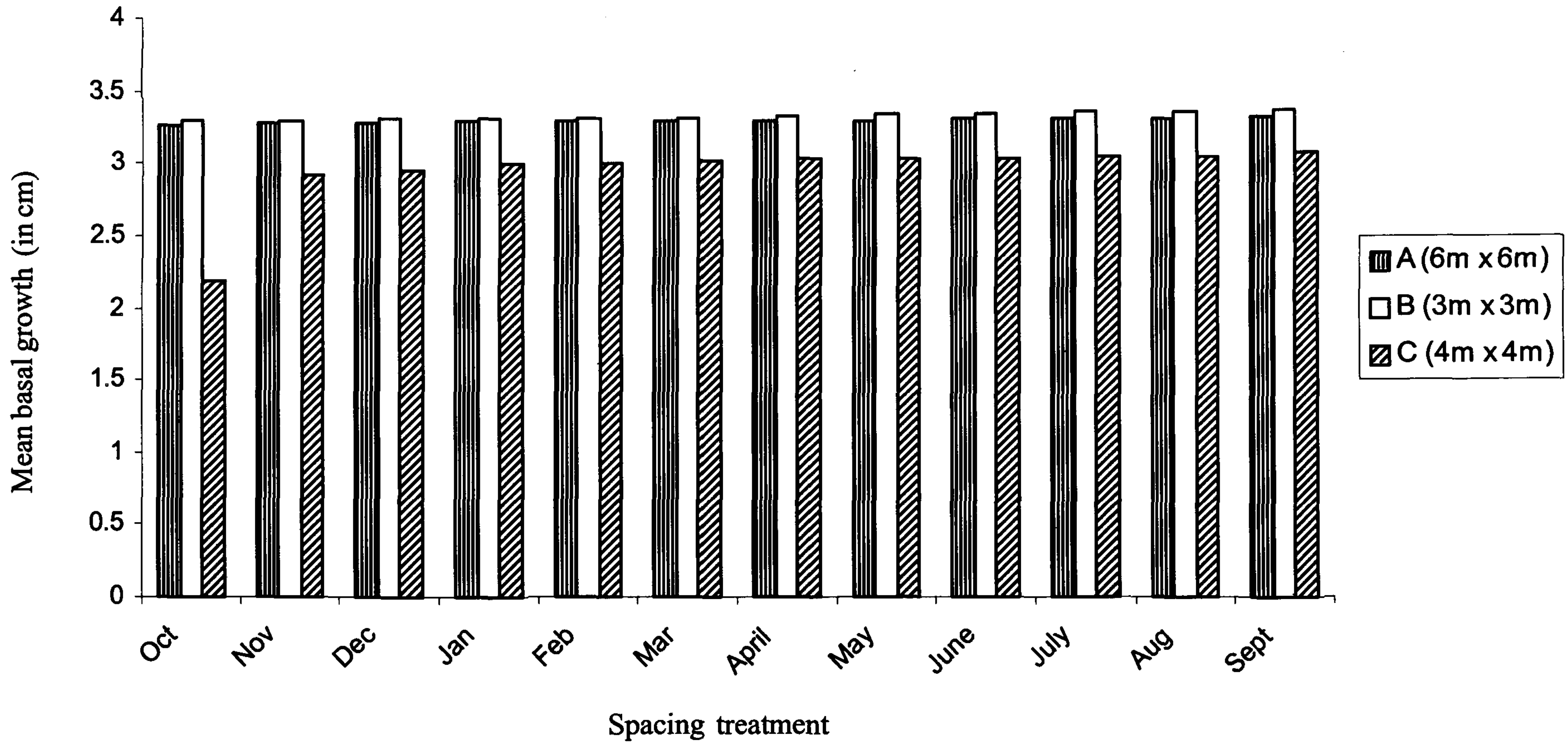


Fig. 4 : Effect of spacing treatments on the basal growth of Leucaena at monthly intervals

5.3 : BIOMASS PRODUCTION OF LEUCAENA :

Biomass production was assessed by taking the dry weight of Leucaena at the beginning and end of the experimental period. The first samples were taken in September, 2000 while the second samples were taken in October, 2001.

It was found that spacing treatments brought certain changes in the biomass production. Significant increase was noticed in all the plots though the level of production was variable among different treatments.

As had been presented in Table - 3, maximum biomass of 148.18 gms. was found with 3m x 3m spacing at the initial stage followed by 4m x 4m spacing with 128.33 gms., and the least yield being observed with widest spacing of 6m x 6m (124017 gms.). The amounts of biomass produced in each treatment were found to be in the same order as that of the previous observations.

Since biomass yield includes both aerial and underground parts of the plants, closest spacing of 3m x 3m plot was supposed to give maximum rate of increase in biomass as in the cases of basal and height growth. But a relatively higher rate of increase was obtained with 4m x 4m plot (75.26 gms.) followed by 6m x 6m plot (74.17 gms.) and 3m x 3m plot (67.08 gms.).

This implies that though closer spacing is found to have positive effects on the height and basal growth, it did not effectively influence the underground growth as much as the aerial ones. It was also observed that though a considerable rate of increase was found with 4m x 4m treatment, the rate was not significant enough to make change in the overall production.

5.4 : MAIZE YIELD COMPONENTS :

The yield parameters taken on maize included number of leaves/ plant, number of cobs/plant, number of grains/cob/plant and biomass production. The first

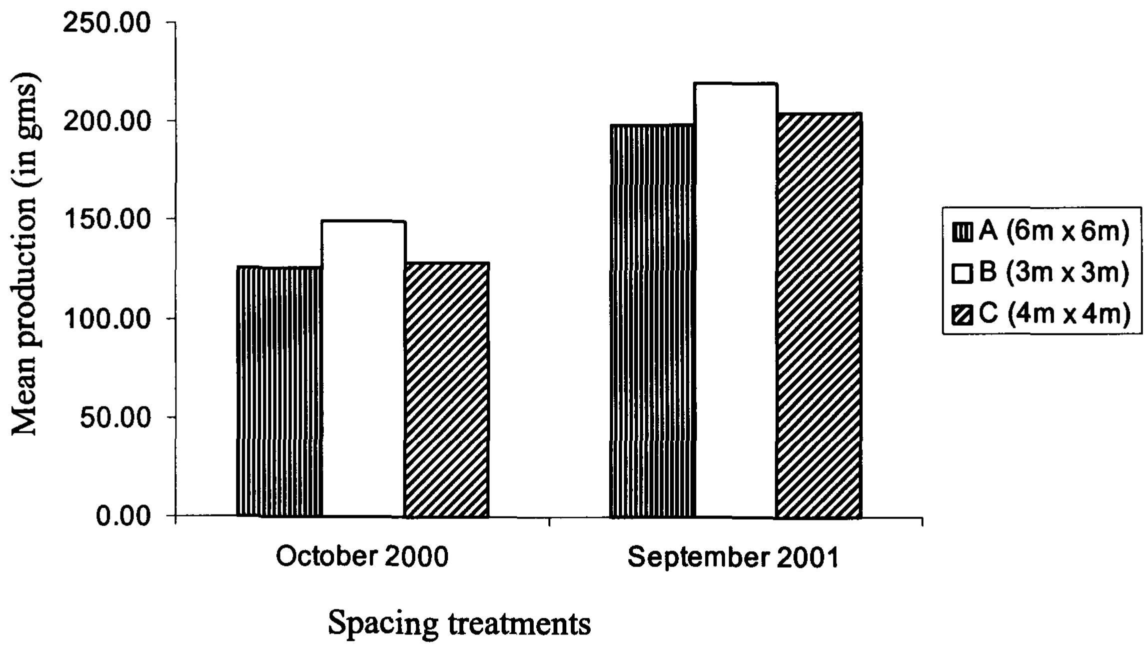


Fig. 5 : Effect of spacing treatments on biomass production of Leucaena

parameter was carried out at monthly intervals from the date of sowing. Since the growing period of maize lasted for about 3 months, observations were done three times. The remaining yield-determining factors were done at harvest.

5.4 (a) : Number of leaves -

In general, the number of leaves supposed to be formed by maize plants was virtually completed by the 30th day. It was found that spacing treatments had no apparent significance upon the number of leaves at monthly intervals. Maximum number of leaves were formed in the 4m x 4m plots and in control during the first thirty days. In the second observation done at 60 days after sowing, all the treatments showed progress in the number of leaves formed except the control plot which rather showed negative trend owing to a slight decrease in plant density resulting from termite infections.

The mean number of leaves per plant at harvest remained almost the same for all treatments. No significant increase was observed at this stage. This is accountable to the fact that the plants were in the production stage.

5.4 (b) : Number of cobs/plant -

The number of cobs formed at harvest was observed by actual counting. The widest spacing of 6m x 6m treatment was found to have maximum mean number of cobs per plant. This is followed by 4m x 4m and control treatments with the same result. The reason for higher degree of cobs formation in the 6m x 6m spacing treatment may be met owing to the occurence of competition between the trees and crops in closer spacing treatments.

5.4 (c) : Number of grains/cob -

A similar pattern of increase in maize grains was found with wider spacing at harvest. There was no marked difference found among the rest of the treatments regarding the number of grains per cob.

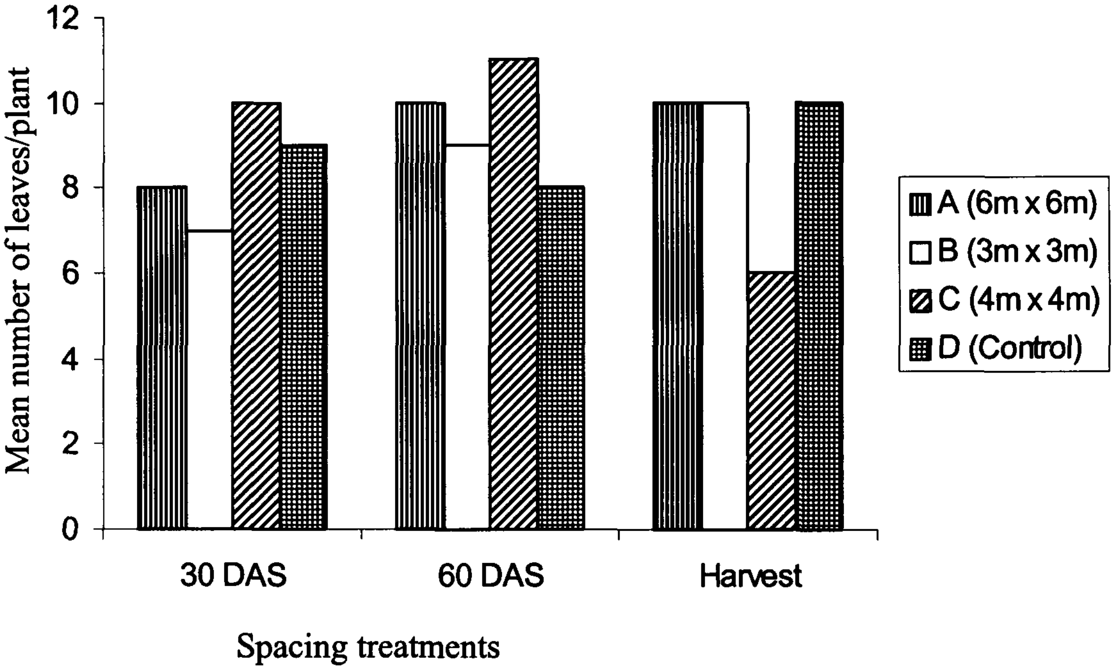


Fig. 6 : Effect of spacing treatments on number of leaves/plant at monthly intervals

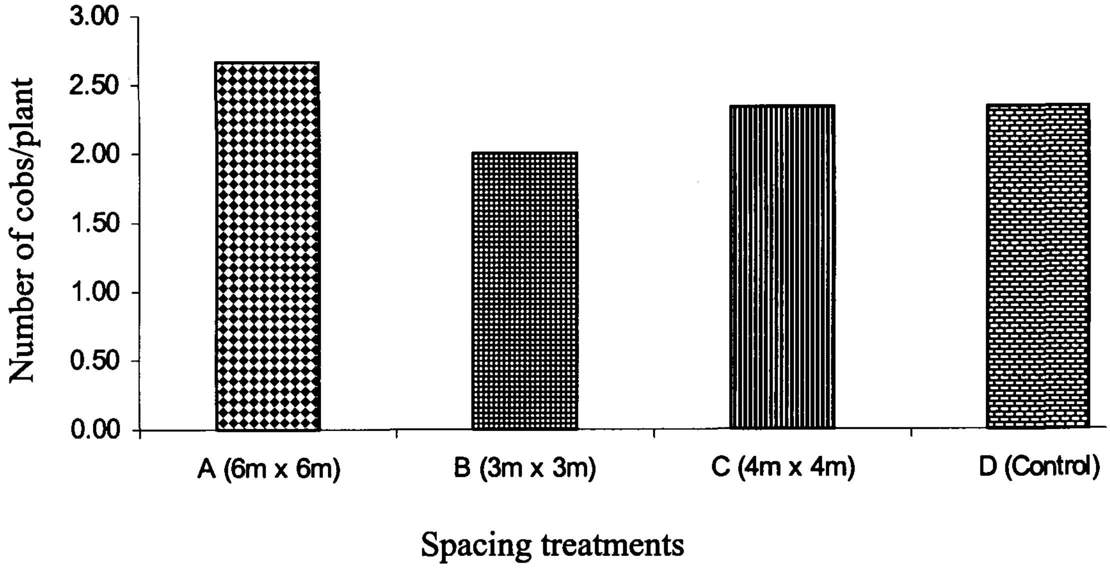


Fig. 7 : Effect of spacing treatments on the number of maize cobs formed

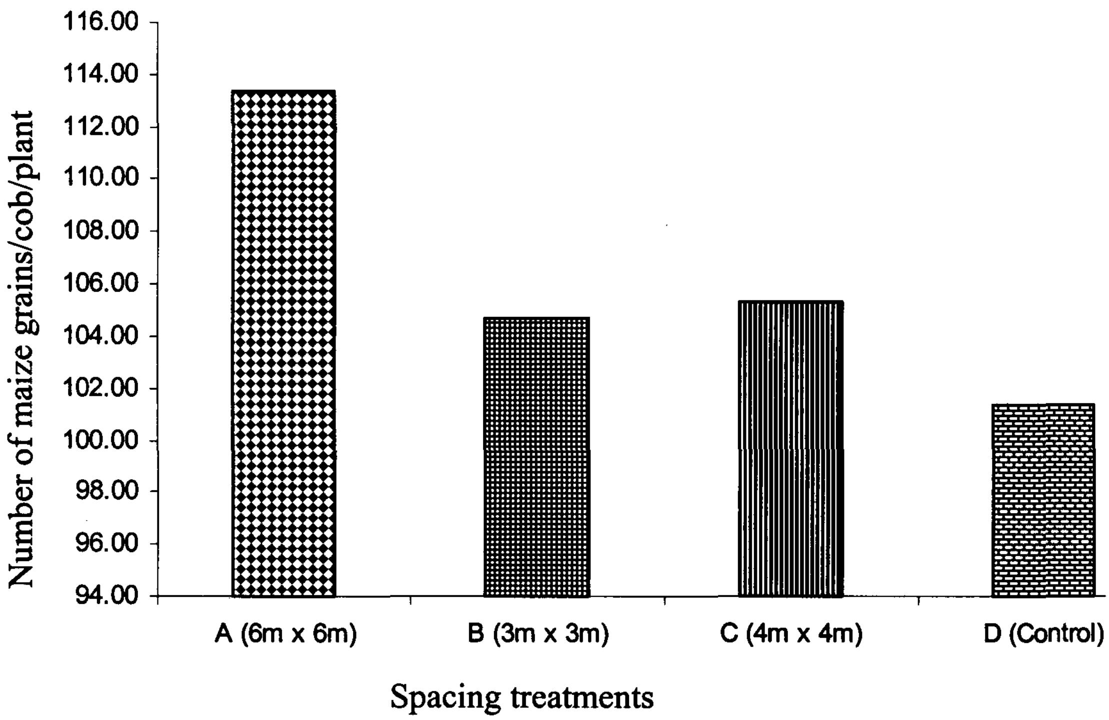


Fig. 8 : Effect of spacing treatments on the number of maize grains/cob/plant

5.4 (d) : Biomass production -

With respect to biomass production, a similar trend of difference was observed among different spacing treatments. Maximum biomass production was noticed in 6m x 6m spacing. The 4m x 4m spacing, though not produced more cobs, was found to give highest rate of increase over control

5.5 : SOIL IMPROVEMENT :

Soil fertility changes were determined in terms of the status of Nitrogen, Phosphorus, Potassium, Organic Carbon and pH. Increase in soil Nitrogen, available Phosphorus and Organic Carbon contents was observed in all the treatments and even more so in 4m x 4m spacing treatment.

Though there was improvement in these three soil nutrient condition including the control plot, the degree of change was hardly noticeable.

The closest spacing of 3m x 3m resulted in maximum increase with regard to the soil Phosphorus content. On the contrary, the control plot showed decrease in available Potash content. The soil pH was also found to be increased except for the control plot which showed a slight decrease. This may be accrued to the reason that the soils are highly leached and continuous cropping always results in lowering the soil pH when there is no proper vegetative cover.

Improvement in the soil Nitrogen content was comparatively lower than the other soil aspects. This condition is not so uncommon since the trees were not matured enough to form sufficient root nodules. Besides this, soil inoculation with rhizobia was not done to facilitate Nitrogen fixing process.

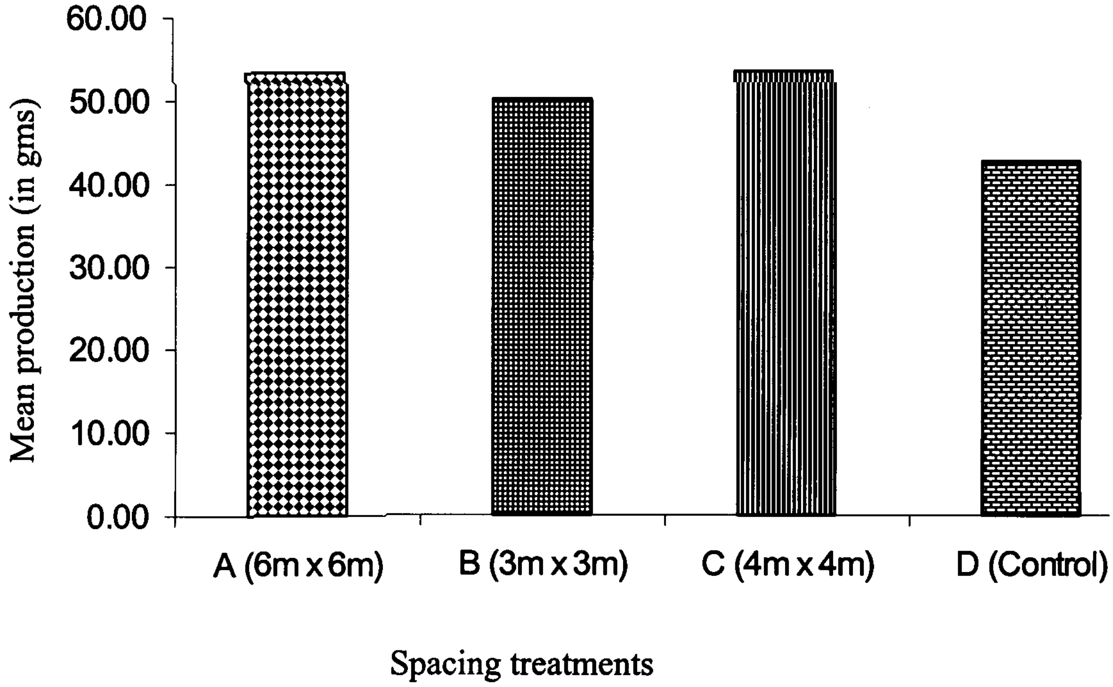


Fig. 9 : Effect of spacing treatments on biomass production of maize

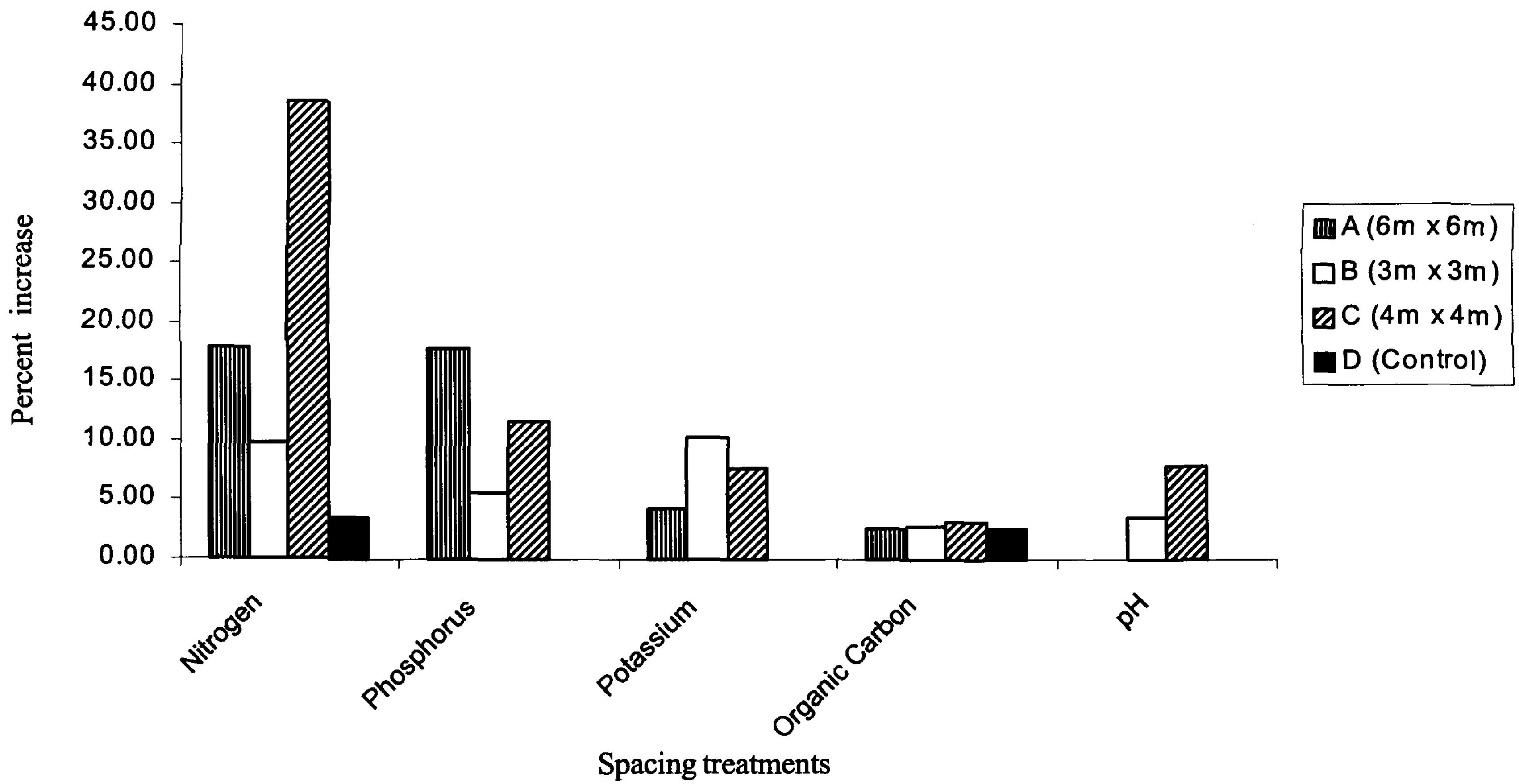


Fig. 10 : Effect of spacing treatments on the chemical status of the soil

CHAPTER-6
SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

An agroforestry system having *Leucaena leucocephala* and maize as the tree and crop components was implemented on research basis to work out the feasibility of this particular tree-crop combination in practical situation. The research experiment was entitled "Spacing effect of *Leucaena leucocephala* (Lam.) de Wit on the growth and yield behaviour of maize (*Zea mays* L.) as a hill agroforestry system in Mizoram.

The experimental plot lies within Zemabawk area which is about 5 kms from Aizawl. The whole experimental area is 36 x 48 sq.m having 12 sub-plots of 12 x 12 sq.m equal sizes. The experimental plot was laid out following Randomised Block Design having three replications and four treatments. Three different tree spacings of 6m x 6m, 3m x 3m and 4m x 4m and control with no tree were used as treatments.

In order to meet the objectives, growth components of Leucaena such as :

(a) Plant height
(b) Basal diameter
(c) Biomass production

and yield parameters of maize such as :

(a) Number of leaves/plant
(b) Number of cobs/plant
(c) Number of grains/cob
(d) Biomass production

were studied during the experimental period.

Besides these, soil fertility assessment was also carried out by comparing the Nitrogen, Phosphorus, Potassium, Organic Carbon and pH status of the soil taken at the beginning and end of the research course.

From the observations and analysis of data collected upon the above factors, the following points can be briefed out -

1) Leucaena growth with regard to height was found to be sifgnificant among the three different spacing treatments with 3m x 3m spacing attaining maximum mean height, followed by 4m x 4m and 6m x 6m in the order of ascendance.

2) The mean growth in basal diameter of Leucaena was comparatively lower than the growth in height. The treatments with more density (ie. 3m x 3m) produced maximum growth, followed by 6m x 6m and 4m x 4m respectively. Water availability also seems to play an important role in determining the growth pattern of Leucaena plants.

3) Biomass production of Leucaena was also observed highest in 3m x 3m treatment as against the highest rate of increase observed in 4m x 4m treatment. This indicates that closer spacing does not equally increase the underground production as that of the aerial factors both of the aspects are considered for the assessment of biomass production.

4) Growth attributes of maize regarding the number of leaves at 30 days intervals showed that most of the leaves were formed during the initial stages of crop growth. Moreover, there was no increase in maize number of leaves as affected by the spacing treatments over control plot.

5) Other yield factors for maize were also being observed. The results indicated that wider spacing of the tree species resulted in better performance of intercrops as long as cob formation, number of grains in the cobs and biomass yield are concerned. Maximum yields were obtained in 6m x 6m, followed by 4m x 4m and 3m x 3m spacing treatments.

6) Different spacing treatments were found to be favourable changes in soil fertility status. The chemical nutrients such as Nitrogen, Phosphorus, Potassium and pH were found to be increased under closer spacings of the tree components

when compared with the wider spacings. However, no mark increase was observed with the control plot.

From the results being obtained after carrying out the experiment of combining Leucaena leucocephala and maize with different spacing treatment, it can be concluded that wider spacing of 6m x 6m spacing treatment was found to give best results in terms of crop productivity. Agroforestry systems in general, are also found to be beneficial and sustainable compared with the sole crop production.

CHAPTER-7
FUTURE PROSPECTS AND SUGGESTIONS

FUTURE PROSPECTS AND SUGGESTIONS

The beneficial effects of Leucaena interplanting with maize have been reported by various research workers worldwide. This experiment also supports the findings obtained over the past years. Though most of the relevant factors were being covered to determine the productivity of this particular tree-crop combination in hilly areas, there are still some aspects which were not being studied under this research. The most important ones which need to be assessed are thus mentioned below-

1) From this research study, it was found that established trees attaining faster growth in heights were in the stage of causing competition effects to the intercrops which is assumed to result in lower yield of maize. Therefore, the reason for this low production may need to be justified.

2) The data being used for this study were collected during the period of only one year. It is thus suggested that longer duration of experimentation should be carried out to get more accurate and reliable results.

3) It is also apparent that if fertilizers were provided, higher output could be achieved. More concerted efforts should be directed towards the study of fertilizer effect on the crop productivity.

4) The ability of Leucaena in improving the soil fertility status is another important aspects which also needs further studies.

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