GROWTH AND YIELD OF MAIZE AS AN INTERCROP WITH LEUCAENA, AND WITH BURIED LEUCAENA LEAF LITTER IN AN AGRO-FORESTRY TRIAL IN MIZORAM

By

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

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SCHOOL OF LIFE SCIENCES
NORTH-EASTERN HILL UNIVERSITY
MIZORAM CAMPUS, AIZAWL, INDIA
2001.

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I certify that the Thesis entitled " ***Growth and Yield of Maize as an intercrop with Leucaena, and with buried Leucaena leaf litter in an Agro-forestry trial in Mizoram".*** *Submitted by Miss Rebecca Lalmuanpuii in partial fulfilment for the Degree of Master of Science in forestry (Specialization course in Agroforestry) to the North Eastern Hill University, Shillong embodies the record of original investigation carried out by her under my supervision. She has been duly registered and has successfully completed all her papers. The Thesis presented is worthy of being considered for the award of the M.Sc.Degree. Further, this work has not been submitted for any degree of any other University nor has it been published in part or full.*

I wish Miss Rebecca Lalmuanpuii all success in life.

Aizawl
The 17th December 2001

(Dr. D.PAUL)
Supervisor

ACKNOWLEDGEMENT

At the foremost, I express my deep sense of gratitude to Almighty God for giving me good health and opportunity to carry out the research works and guiding me throughout the course of my studies.

I am very much grateful to my supervisor Dr. D. Paul, Lecturer, Department of Forestry, NEHU, Mizoram Campus for his benevolent guidance and constant encouragement during the coure of my studies and research works.

I am also extremely thankful to Prof. L.K. Jha, Head of Department Forestry, Dr. U.K. Sahoo, Lecturer, Department of Forestry, NEHU, and other faculty members of the Department for their valuable advise and their kind help during the course of my studies.

My special thanks are also due to Mr. H. Thankhuma, Deputy Director, Extension Section, Directorate of Agriculture, Government of Mizoram for his kind understanding and providing facilities in typing out my Thesis. I also thank Mr. Martin. N. Rothanzama and J. Lalhmingthanga for their efficient typing and untiring help.

The kind cooperations and assistance during the course of my studies and field works rendered by my classmates, K. Zohmingliani, Julie Zodinpuii, Phinderilin Kharmujai, Israel Lalremruata and Charseng Ch. Marak are also thankfully acknowledged.

Last but not the least, I offer my heartful thanks to my Parents for their countless prayers and their endless cooperation and help during the course of my studies and research works.

Dated Aizawl (REBECCA LALMUANPUII)

The...19th Dec...2001.

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CHAPTER-I
INTRODUCTION

INTRODUCTION

1.1 Historical Perspective of Agro-forestry:-

Growing crops and trees together is not a new concept. Historically this practice existed in tropical and sub-tropical Countries since long, although the term Agro-forestry was coined only at the time of establishing the International Council for Research in Agro-forestry (ICRAF) during 1977.

It is a new word used in place of Shifting cultivation, Agri-silviculture or the Taungya system (Steward, 1981). These traditional forms of cultivation are still practice in countries under different socio-economic and environmental conditions in Africa, Central and South America, Oceania, South-East Asia, etc. One form or another of agro-forestry has been practice in China since ancient times. The Han Dynasty (206 BC-220 AD) administrators recommended the development of forests together with the raising of livestock and crops according to different site conditions (Zhu *et al.*, 1993). In Java, agro-forestry was introduced in 1883 by Buurman Van Vrede when establishing a teak plantation in Pekalongan Forest District (Hartono, 1981). The system is recognised as the Tumpangsiri or Taungya system. The integration between forestry and agriculture has been adopted in Egypt long before the term "Agro-forestry" was coined (EL-Lakany, 1987). It has also been reported by Olufenai (1987) that a form of agro-forestry system called "Taungya" started in 1927 in moist regions of Nigeria.

From time immemorial to a limited extent, a combination of food crops and forest crops had been adopted in land management by the farmers throughout the world. The setting up of the International Council for Research in Agro-forestry by the Food and Agricultural Organisation (FAO) in 1878 is a landmark in the developmental history of agro-forestry (Jha, 1991).

In India, agro-forestry is commonly practised by the hill dwellers of Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Tripura, Bihar, Karnataka, Madhya Pradesh and Orissa. It has also been reported that the system of raising trees along with agricultural crops has been in vogue in Forest Department for over 100 years (Taungya cultivation). The Hindu, a National newspaper of India, in its 6th November, 1937 issue included the feature as, "a scheme known as agro-forestry, which was a combination of agriculture and forestry, was adopted at the meeting of the Central Fodder and Grazing Committee of the Imperial Council of Agricultural Research (present ICAR) which met at New Delhi". It further stated that the Committee strongly approved the scheme. The Country Report for India presented at the Eight World Forestry Congress, 1978 has also shown that agro-forestry has been practised successfully in different states of India during the last 50 years.

Agro-forestry is the word now widely used to describe the cultivation of trees as an integral part of cropping or livestock systems. Though the term has only been coined in recent years, the practice of growing of trees in association with crops and animals has a long tradition in many parts of the world.

1.2 Science of Agro-forestry:-

Although agro-forestry is neither an invention nor a new concept, the practice of combining tree species with crops as a new applied science is of recent origin.

As a concept, agro-forestry is the synthesis of much of the experience and scientific knowledge acquired in the past from the disciplines of agriculture, forestry, ecology, soil science and rural socio-economics (Sharma,1996).

In agro-forestry, co-existence of farm and forestry is adopted on a scientific basis and consequently the total yield of land is raised significantly.

A combination of appropriately selected woody components and herbaceous crops essentially contributes to both productivity and sustainability of the farming system on marginal and sub-marginal lands by increased production of organic matter, maintaining soil fertility, reduction of water and wind erosion and creating a micro-climate favourable for associated crops and livestock. Further, integration of farmers into tree management processes has a salubrious effect in making the farmers conscious of the importance of the tree cover for the sustainability of the farm production.

An appropriate agro-forestry system should have the potential to control erosion, maintain soil organic matter and physical properties, augment, nitrogen fixation and promote efficient nutrient cycling (Young, 1989).

The science of agro-forestry is increasingly accepted and promoted as an alternate approach to land use which generates steady income for subsistence farmers. Large areas of uplands which are only partially cultivated can be made to return higher yield per unit area under a combination of suitable crops/legumes/fodder with trees. These system can generate several positive environmental impacts like improvement in hydrological balance, improvement of physical properties of soil favourable to improved infiltration, retention capacity and indepth percolation of surface runoff and reduction of sedimentation of rivers and streams, etc., recycling of nutrients, creation of favourable micro-climatic condition conductive to higher food production, maintaining balance in oxygen-carbon-dioxide, atmospheric temperature and relative humidity.

An efficient agro-forestry system would aim at systematically developing integrated land use systems and practices where the positive interaction between trees and crops is encouraged and maximised. This seeks to achieve a more productive, sustainable and diversified output from the land than is possible with the conventional mono-cropping system.

1.3 Agro-forestry-its definition:-

As is well known, Agro-forestry implies cultivation of agriculture crops in conjunction with tree crops in the same unit of land. Due to its wide scope, Agro-forestry has been defined by several researcher across the world in different ways. Westley (1999) had very correctly pointed out that researchers might define agro-forestry practice differently depending upon the focus of their work.

According to Bene *et al.*, (1977) - Agro-forestry is defined as "a sustainable land management system, which increases the yield of the land, combines production of crops (including tree crop) and forest plants and / or animals simultaneously or sequentially, on the same unit of land, and implies management practices that are compatible with cultural practices of the local population."

Lungdrean and Raintree (1983) have opined that agro-forestry is a collective name for land use systems and technology where woody perennials (tree, shrubs, palms, bamboos, 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 an ecological and economical interactions between the different components. Sinha (1985) stated that Agro-forestry is "the technique of raising agricultural crops in combination with forest crops in the same unit of land and at the same time so as to maximise production from land. It is a system of interplanting following the principle of multiple use of land resource".

Hocking (1991) has stated that, "it is the land use system particularly suitable for resource poor marginal land and even for wasteland. Because such land is usually cultivated by poor and small farmers." Thus, it is an alternative of shifting cultivation which has caused overexploitation of forests and caused excessive soil erosion. Agro-forestry is integration of woody perennials with arable crops as an alternate land use system in tropical world. A more precise definition of agro-forestry is - "a land use that involves deliberate retention, introduction or mixture of trees or other woody perennials in crop/ animal production fields to benefit from the resultant ecological and economic interaction" (Rao and Mac Dicken,1999).

According to the definition given by ICRAF, (1983) - "Agro-forestry is a collective word concerned with agriculture, horticulture, silviculture, livestock, fishery, sericulture, etc. Besides, this definition is very comprehensive and covers all aspects of forestry on farm lands (farm forestry also)."

The Annual Report (1999-2000) of Indian Agricultural Statistics Research Institute (ICAR) defines Agro-forestry as "the science of designing and developing integrated self-sustainable land management system, which involves introduction/retention of woody components including trees, shrubs, bamboos, canes, palms, along with agricultural crops including pastures/animals simulteneously or sequentially on the same unit of land, and at the same time meets the ecological as well as socio-economics needs of the people".

The definitions however, outline the broad boundaries of agro-foresty and the typical characteristics of the systems :-

* Agro-forestry normally involves two or more species of plants (or plants and animals) at least one of which is a woody perennials;

* An agro-foresty system has two or more outputs;

* The cycle of an agro-foresty system is always more than one year.

* Even the most simple agro-forestry system is more complex ecologically, than a mono-cropping system.

Thus, agro-foresty can be generally defined as "a systematically developing land use systems and practices where the positive interaction between trees and crops is maximised".

1.4 Agro-forestry - Its Importance :-

Agro-forestry is gradually, but firmly, establishing itself as an accepted discipline of scientifi study amongst agricultural and forestry scientists. Developing suitable agro-forestry systems for different agro-climatic conditions has become necessary in view of fast decline in forest resources. Global land resources are fixed. In view of competing demands for land (agriculture, industries, communication, etc.), it is not possible to increase the land under agriculture for food and fodder production; and under forestry for timber production. On the contrary, land under agriculture and forests is shrinking because some areas are getting converted to wasteland due to high rates of erosion, salinisation, water-logging, etc. and some area used for other essential

forest cover. A large number of important tree species like *Shorea* species, *Terminalia* species, *Toona ciliata, Gmelina arboria, Casssia fistula, Schima wallichii,* etc are destroyed in the process of burning and clearing (Nadagoudar *et al*, 2000).

In Mizoram, shifting cultivation which is also known as Jhuming is still the principal mode of livelihood and 43,707.00 ha. of land is under shifting cultivation (Statistical Handbook of Mizoram, 2000) Farmers grow rice , maize and millets along with cucumber, pumpkin, potato, cabbage, turnip, chillies and onion to meet the demand of cereals and vegetables, tapioca is also planted on farm fields. Fruits namely orange, banana, papaya, pineapple are grown in the State(Solanki and Bisaria,2000). Shifting cultivation (Jhuming) being a dominant land use practice, provides sustenance to the tribal inhabitants with the field crops can help in increasing the yield of field crops.

In agro-forestry, every part of the land is considered suitable for plants that are useful. Emphasis is placed on perennial, multi-purpose crops that are planted once but yield benefits over a long period of time. Furthermore, systems of agro-forestry are designed for beneficial interactions of crop plants, and to reduce unfavourable interactions. They are designed to reduce the risks associated with agriculture, small scale or large scale, and to increase the sustainability of agriculture. Agro-forestry practices normally help conserve, and even improve the soil.

Agro-forestry includes a recognition of the interactions of crops,both favourable and unfavourable. The most common interaction is competition, which may be for light, water, or soil nutrients. Competition invariably reduces the growth and yield of any crop. Yet competition occurs in mono-culture as well and this need not be more deleterious in agro-forestry systems. Interactions may be complementary as in the case of trees, pasture, and foraging animals, where trees provide shade and/or forage, and animals provide manure.

Agro-forestry systems take advantage of trees for many uses, to hold the soil, to increase fertility through nitrogen fixation, or through bringing minerals from deep in the soil and depositing them by leaf-fall, to provide shade, construction materials, foods and fuel. Agro-forestry systems may be thought of as principle parts of the farm system itself, which contains many other sub-systems that together define a way of life. In short, this programme will help in raising the total yield of land considerably in comparison to traditional system of land management where dichotomy between forestry and agriculture/ horticulture/animal husbandry operates.

Every year approximately 400 to 600 sq. km of tree covered area is cleared for jhuming (Garbyal, 1999) which is a primitive method and unproductive method of cultivation and increases land degradation and progressive loss of soil productivity leading to gradual economic impoverishment of the rural communities. In view of these problems adoption of appropriate agro-forestry system would be helpful in finding suitable alternative to shifting cultivation.

Farmers of Mizoram raise Teak and Gomari as a tree crop for generation of income. But the farmers are not getting adequate returns due to long distance transportation, handling and other difficulties. So, agro-forestry with proper selection of tree species, cash crops, fodder, fruit trees and medicinal plants and bamboo will be highly remunerative with returns accruing at short span. Agriculture alone will not be sustainable in long run without tree cultivation with adequate mixed plantations.

Practice of agro-forestry in hilly state like Mizoram will improve soil and moisture conservation by arresting soil erosion as well as storing water through deep rooted massive root system. The tree clad area will certainly increase the atmospheric humidity and enrich the water table at the micro-level. The practice of agro-forestry has to be carried out in such a way that tree line along the contour arrests both soil and surface run-off water thus acting as barrier on the slopes.

Growing multipurpose tree species under agro-forestry practice improve both water and forest produce availability for the people besides improve soil fertility. Growing trees under the agro-forestry practice will provide life support system to the tribals living below poverty line for whom agro-forestry will be a boon and ensures regular income. Besides, meeting the subsistence needs of the tribals, agro-forestry will enable the jhumias to wean away from the age old unscientific practice which is so prevalent in the North - Eastern States but show a way to permanent settled cropping practice.

For hilly terrain, maintenance of optimum vegetal cover is crucial for natural resource management. Thus, the socio-economic well being of the people would be the first logical step towards balanced management of natural resources. Thus, agro-forestry land use help in conserving the natural resources and making the hills productive. Besides, it can amist in increasing the area under production of food, fuel and shelter for the ever increasing population. From these point of view, agro-forestry as an agrarian practice, reflects a ray of better hopes in this direction.

1.5 Problem of Shifting Cultivation :-

In the North Eastern parts of the Country in general and Mizoram in particular, the practice of shifting cultivation is an age old practice and with the present population pressure, this form of agriculture is proving to be a strong deterrent to conservation efforts and a threat to the existing forest cover. A large number of important tree species like *Shorea* species, *Terminalia* species, *Toona ciliata, Gmelina arboria, Casssia fistula, Schima wallichii,* etc are destroyed in the process of burning and clearing (Nadagoudar *et al*, 2000).

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Until recently, potential of these agro-forestry practices to solve land use problems and enhance productivity was not recognised by researchers and extension agencies. The recent past years evidenced a surge of interest in implementing agro-forestry development programmes. Agro-forestry has been popularised among decision makers as a conservation farming solution to sustain productivity of the fragile hill agro-ecosystems (Garrity,1995). Consequently, there is an enormous demand for sound agro-forestry technology.

In Mizoram, traditional farming system which is commonly known as "Jhuming" or "Shifting cultivation" occupies a distinct places in the Mizo economy. The old practice dies hard (Anonymous,1997). It constitutes a vital part of the socio-economic network of Mizo life.But traditional forms of agro-forestry is also practiced in the state of Mizoram by the farmers in their own way which include different combination of trees and food crops. The most common agro-forestry system is intercropping of *Oryza sativa* (Paddy) along with the plantation of *Tectona grandis* (Teak). Another prominent agro-forestry system is the combination of horticultural crops / agricultural crops like *Oryza sativa* (Paddy), *Zea mays*(Maize) and vegetables along with*Albizzia procera* or *Aleurites fordii* (Tung).

Additionally, some improvements to jhum cultivation are also been tried in several places under a centrally sponsored jhum control project (Jha and Lalramnghinglova, 1996).

The present experiment of agro-forestry is based on tree crop interaction and the study was carried out in a plot having one year old *Leucaena leucocephala*. *Leucaena leucocephala* is a leguminous and is able to fix atmospheric nitrogen. Maize *(Zea mays* L.) which is the second most important staple food crop of local people was selected as the agricultural component to be introduced in the interspace between the tree species.

1.6 Objectives :-

The present study was being carried out with the following objectives :

(1) To investigate the chemo-edaphic (soil pH, soil conductivity, soil moisture and soil nutrients),

(2) To estimate and compare the yields of maize (*Zea mays* L.) under the following treatments,

(a) Intercrop with Leucaena

(b) Intercrop with Leucaena along with buried Leucaena litter.

(c) Control (without Leucaena or buried litter).

(3) To determine an appropriate viable alternative from the treatments above as a model of agro-forestry with better economic returns.

CHAPTER -II
REVIEW OF LITERATURE

REVIEW OF LITERATURE

2.1 Aspects of Agro-forestry :-

A number of research works has been conducted on various aspects of agro-forestry. Tree-crop interaction in agro-forestry practices (Harsh and Tiwari,1993). Agro-forestry models as alternative to jhum (Jha,1995). The growth behaviour of trees have been carried out by many researchers (Mohan, 1992). According to Nwoboshi (1981), agro-forestry is a step ahead of traditional agricultural and has the potential to increase the productivity of land by bringing it under multiple land use.

Agro-forestry is an integration of woody perennnials with arable crops as an alternate land-use system in tropical world. Demand for food and fuel can be met through sustainable land use systems of agro-forestry. A typical agro-forestry system will allow economic and ecological interaction between woody and non-woody components and also to increase, sustain and diversify the total land output (Nair,1989). Among different components, there should be positive interaction between trees and crops. An economically viable agro-forestry model is expected by the farmers.

The choice of species to be identified for planting under an agro-forestry programme is of the utmost importance. The species should be multipurpose, fast growing and capable of improving the environment without lowering the productivity. In interplantation cropping systems, the species should be selected in such a manner that there is no likelihood of root competition between the agricultural crops and tree species for nutrients or available water, in order to obtain a successful yield of crop and tree biomass together. Mishra (1979) recorded the successful cultivation of maize, ragi and rice in conjunction with *Dalbergia sissoo* and *Tectona grandis.*

According to Vergara (1982), some legume trees have a taproots which give them a much better capacity to anchor and stabilize the soil and greater ability to recover and absorb moisture and nutrients from the deeper subsoil. Furthermore, legume trees usually have small leaflets which decompose more rapidly and enable the nutrients to return more quickly to the soil surface to maintain productivity. Also, small leaves allow sunlight to reach interplanted low level food crops. Finally, legumes have the ability to fix atmospheric nitrogen through the symbiotic activity of the Rhizobium and supply nitrogen to the trees themselves and to the interplanted food crops. Normally, in degraded lands nitrogen fixing species are more desirable than non-nitrogen fixing ones (Chaturvedi,1993).

A large number of nitrogen fixing tree species are now available in agro-forestry plantation for example:- *Acacia(nilotica), Albizzia (procera),Casuarina (equisetifolia),Leucaena (leucoephala), Prosopis (juliflora)* and *Sesbania (grandiflora)*, etc.

These nitrogen fixing trees assume special importance in agro-forestry system as a source of green manure, fodder and in soil amelioration (Brewbaker, 1986). The most widely used NFT species in agro-forestry are probably the excellent fodder shrubs in genera *Gliricidia* and *Leucaena*, both of them restricted, presently to less acid soils of the warm tropics (Kang *et al.*,1986).

Appropriate agro-forestry system have the potential to control erosion, maintain soil organic matter and physical properties, augment nitrogen fixation and promote efficient nutrient cycling (Young,1989). According to Reynolds *et al.*,(1988), on sloping land, when leguminous trees species are planted along the contours, the trees limit soil erosion. Tree foliage (prunings) can be used as mulch and fertilizer for food crops, and /or for animal feed.

Micro-site enrichment through improvement in the soil organic matter and mineral nutrient pools is an important attribute of trees and shrubs in agro-forestry (Altieri *et al.*,1987).

The prunings (GLM- green leaf manure) as nitrogen source appeared most effective when applied as surface mulch. This can be explained in terms of faster rate of mineralization of the incorporated GLM, within 1-3 weeks (Weeraratna,1982).

Foliage of some NFT's contain considerable nitrogen which when mixed with soil improved the soil nitrogen status (Jha and Sharma,1993). The addition of tree leaves and branches as mulches to soil has been shown to improve site micro-environmental conditions (Budelman,1989) and increase the productivity of agricultural crops (Duguman *et al.*, 1988;Gutterridge, 1990; Onion *et al.*,1990; Tiraa and Asghar, 1990; Yamoha and Burleigh,1990). It has also been reported that mulch from leaf litter can protect soils erosion, decrease weed growth, release nutrient to the soil via decomposition, and moderate soil moisture loss and temperature fluctuations (Budelman, 1988,1989; Montagnini *et al.*, 1993). Legumes under favourable condition can fix from 40 to 194 kg/ha/year of elemental nitrogen from the atmosphere.

The intercropping is not only superior in increasing production but also very effective in conservation of soil and water (Verma *et al.*,1984). Tree foliage can be used as mulch and fertilizer for food crops (Reynolds *et al.*,1988). According to Noordwijk and Dommergues (1990) root of nitrogen fixing trees have more nodules, when they are in close contact with roots of non-nitrogen fixing plants. This increased nodulation may lead to the direct transfer of nitrogen to the non-nodulatory plants. The mulch system supplied nitrogen to the arable crop and hence the yield increased (Konwar *et al.*,1988). The leguminous shrubs and trees have great influence in building up soil nitrogen, soil organic matter and some of them also help in improving other soil nutrients through leaf litters (Jha,1995). Nitrogen fixing trees assume special importance in agro-forestry systems as a source of fodder and green manure, resulting in soil amelioration (NAS,1979). Litterfall from Populus and Leucaena added an appreciable quantity of organic matter to the soil (Gupta, Suman and Rout, 1993).

Utilizing wastelands for the production of biomass through the growth of under exploited plants will have positive effect. Some of these plants tend to reclaim bad soils (Gujral,1984; Singh *et al.*,1986d; Vasudevan *et al.*,1986).

2.2 *Leucaena leucocephala* in Agro - forestry:-

Leucaena leucocephala is a tropical, leguminous, fast growing, drought resistant tree with fairly deep tap root system. It belongs to the family Leguminaseae. It has a range of varieties from tall and slender (upto 20 m tall) to bushy types (upto 5 m) with deep roots of upto 2.5 m (Djikman, 1950).

Research have been carried out on *Leucaena leucocephala* in an agro-forestry system. It has been studied as an ideal tree for agro-forestry system (Jha, 1995).

Leucaena leucocephala generally referred to as Leucaena is a multipurpose tree, Pathak *et al.*,(1977) and Relwani *et al.*,(1989) reported that the importance of *Leucaena leucocephala* a nitrogen fixing tree as a top feed. *Leucaena leucocephala* is easy to establish, with rapid growth, very vigorous coppicing ability and high foliage production (Gill and Patil, 1985). In view of this, the present experiment was initiated by associating Leucaena as a top feed nitrogen fixing tree with high yielding perennial cereal forages to work out the suitable companion cropping. Leucaena being erect and compact in nature it permits the associated crop/component to grow better and practically there is no shade effect of hybrid napier (Patil and Gill,1981).

By virtue of its fast growth, *Leucaena leucocephala* is being tried in agro-forestry and Silvipastoral system. The species is of high significance as it helps in maintaining the nitrogen balance in the soil. The nitrogen is being fixed by rhizobium which is associated with the root system in the form of root nodules. Rhizobium is reported to have substantially increased the height growth of the seedlings (Prasad *et al.*,1984).

Leucaena introduction in agro-forestry systems has provided an excellent opportunity in rural areas to meet the multiple demands of nutritious forage, firewood, timber, pulp wood, soil amelioration, nurse crop, etc. The organic matter addition through leaf litter in a 2 year plantation has been found to be 5.6 t/ha.which improve tilth, cation exchange capacity, water holding capacity, bulk density, brings down soil pH from alkaline to normal and improves the yield of successive grain/forage crops. Its use as a fertilizer has been found to give 104.7 percent nitrogen equivalence. Its use as leaf manure equivalent to 30,60 and 90 kg nitrogen/ha. has given a yield improvement of oat forage upto 121.9, 143.6 and 178.2 percent respectively. In agro-forestry systems, it has provided a complementary effect on the crops by partial shading and yield improvements (Pathak and Gupta, 1993).

Leucaena foliage can also be used as organicfertilizer (Brewbaker, 1975; Palled *et al.*, 1983). Its high foliage yield (Bottenberg, 1981) and efficient nitrogen fixation ability (NAS, 1984) can contribute significantly toward soil conservation and improvement. Unlike quick growing trees, the Ku-babul does not exhaust or deplete the soil, on the other hand, it enriches on account of its nitrogen-fixing ability. The dry leaves of this tree can also be used as a source of organic manure. It is reported that it adds more than 500 kg atmospheric nitrogen per hectare per year, which would be equivalent to

1078 kg urea, and appreciable quantity of organic matter. It has a high ability for restoring fertility of denuded grasslands (Patil and Iyer,1981).

The National Research Centre (NRC,1984) has identified the use of Leucaena to benefit the soil by increasing its nitrogen content, rebuilding tilth and surface texture with organic matter, breaking up compacted soil layers, thereby improving soil aeration and water absorption and reducing runoff, insulating the soil from sun, rain and wind reducing soil slippage and erosion.

Pathak and Gupta (1987) have reported organic matter addition through leaf litter in 2 year old Leucaena plantation to be 5.6 t/ha. annually, which improved tilth, cation exchange capacity, water holding capacity and bulk density, brought down soil pH from alkaline to normal, and improved the yield of successive crops. Bottenberg (1981) reported the use of its green leaves as manure to improve the yield of rice. Weeraratna (1982) found that the release of nitrogen following leaf application started in the first week and completed within 3 weeks.

Leucaena leucocephala is rated as the fastest- growing leguminous tree species in low land tropics. Under specific situations it outyields any other known fast-growing firewood, nutritious forage, pulp and green manure while conserving the soil and improving the environment under various system of agro-forestry, its use has been identified to provide fallow improvement in shifting agriculture, recovery to grasslands, green manures, complementary efforts on grain crop production, wind and fire-breaks, nurse crop, etc. (Van Den Beldt and Brewbaker, 1985). Studies on agro-forestry systems at the Indian Grassland and Fodder Research Institute, Jhansi have indicated the potentials of this species for green manure, complementary to crops, fallow improvement, biomass optimization and forage and firewood availability besides soil amelioration (Pathak and Patil, 1982; Pathak *et al,*1985; Pathak, 1986). (Gill *et al,* 1982) investigated the effect of Leucaena foliage compound to Sesbania foliage as source of green manure. The results demonstrated the usefulness of Leucaena foliage as a source of green manures (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 properties, increasing aeration, water retention, and cation exchange capacity.

Leucaena leucocephala have potential to improve the soil fertility by improving in physical and nutrients parameters of the soil. *Leucaena leucocephala* plantations 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). The ku-babul does not exhaust the soil but on the other hand, it enriches it on account of its nitrogen fixing qualities. The dry leaves of this tree can also be used as fertilizer (Vohra,1981).

The experimental evidences showed that *Leucaena leucocephala* intercropped with the agricultural crops and fodder grasses increases total yield of food grain, fodder, fuelwood and enrich the soil (Solanki and Ram Newaj, 1997).

2.3 Maize (*Zea mays*) in Agro-forestry :-

Maize (*Zea mays*) occupies an important place among the cereals throughout the world. It is used both for food as well as fodder. It forms the second most important food crop coming only next to paddy in the North-Eastern States of the country. Maize is extremely popular as a companion crop in Mizoram. It is grown mixed with paddy (*Oryza sativa*) in the jhum lands. For maize, a good nitrogen supply is important during vegetative growth, but the nitrogen requirements are less during flowering and ripening, and reduced shading has a higher relative importance (Nygren and Jimenez,1993). Maize growing under alley cropping has been shown to experience a significantly higher nitrogen availability under the alley cropping treatments. *Erythrina poeppigiana* than in the sole crop controls due to higher nitrogen mineralization in the soil and uptake of nitrogen released from the mulch (Haggar, 1991). The result of the mulch experiment conducted by Montagnini *et al.*, (1993) suggest that tree leaf mulches played a significant role in maize seedling growth. It has also been reported that the addition of mulch of leguminous leaves has a positive influence on maize growth (Hussain *et al.*,1990; Kaufusi and Asghar, 1990; Tiraa and Asghar, 1990). According to the study conducted by Grewal *et al.*, 1992, combination of Leucaena with maize gave significantly higher net returns as compared to pure maize. Legume in maize as intercrop is reported to generate yield advantage (Singh *et al.*, 1978).

Green manure studies with Leucaena on maize required only 3 crops of maize to mine the Nitrogen-down to the 1 t/ha. level (Evensen, 1984). Scientists have investigated the use of *Leucaena leucocephala* with maize as an alternative low nitrogen input system, in which maize yield can be sustained at a relatively low level without nitrogen input (Guevarra., 1976., Kang *et al,* 1981; Ngambeki *et al.*, 1983).

The use of Leacaena 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 International Institute of Tropical Agriculture (IITA.) which had the same density has also been reported (Anonymous, 1982a).

The use of Leacaena as green manure for maize applied on the soil surface has 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.

Addition of Leucaena green leaf manure (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 nitrogen addition, while with no addition of prunings, maize grain yields declined. Higher maize grain yields were obtained by supplementation with low nitrogen rates of 20-80 kg N/ha. depending on variety and soil (Kang *et al.*, 1984). 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 experiments in Hawaii and Philippines have also shown that Leucaena foliage placed around maize can boost maize yield with increases similar to those achieved with manure or organic fertilizers (Guevarra, 1976). 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).

CHAPTER-III

STUDY AREA, MATERIALS AND METHODS

STUDY AREA, MATERIALS AND METHODS

3.1 Study area :-

3.1.1 Location:- Lying in the north-eastern corner of India, Mizoram has a geographical area of 21,087 sq. km. and it lies in between 20^0 58'- 24^0 35' N latitudes and 92^0 15'- 93^0 29' E longitudes. The slope is ablong where as the length is 320 kms. and breadth is 160 kms. and is mostly mountainous and hilly with precipitous slopes having a forest cover of 18,775 sq.km. which is 89.03 percent of the total land area (Statistical Handbook, Mizoram, 2000).

The field experiment was carried out in Zemabawk which is situated at the outskirt of Aizawl city, capital of Mizoram. (Figure-I).

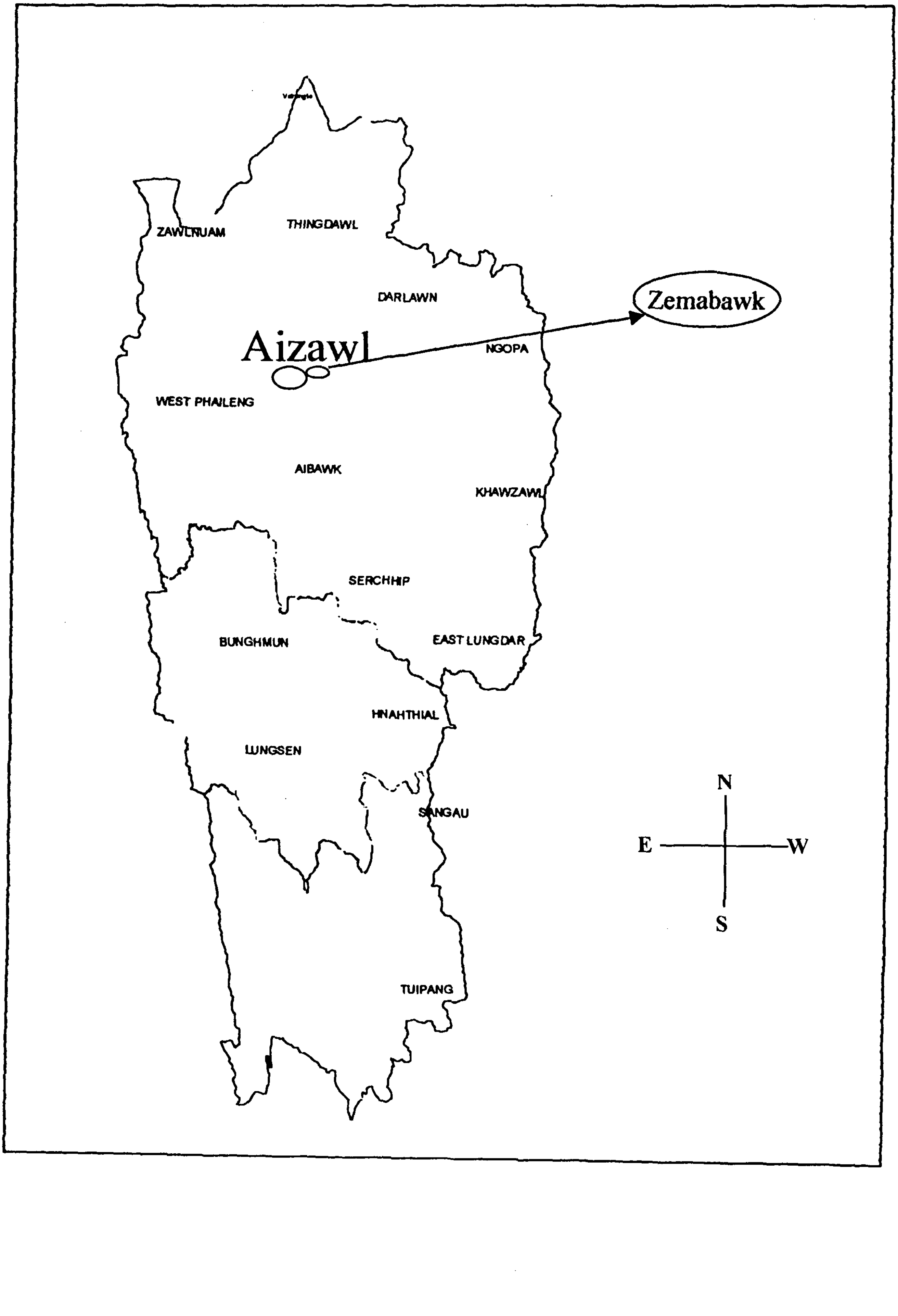
3.1.2 Climate:- Owing to its location, Mizoram generally enjoys comfortable climate.It is humid tropical, characterised by short and dry winter, long summer with average annual rainfall of 250 cm. The winter temperature ranges from 11^0 C to 21^0 C and the summer temperature ranges from 20^0 C to 29^0 C.

3.1.3 Soils:- The soils of Mizoram is mostly acidic, low in organic carbon, low in available phosphorous and medium in potash content while almost all the crops thrive well in Mizoram condition.

3.1.4 Site description:- The study was carried out at Zemabawk which is situated at the northern part of Aizawl city, the capital of Mizoram. Zemabawk lies in between 92^0 15' to 93^0 29'E longitude and 21^0 58' to 23^0 35'N latitude with an altitude of 982 m with an average rainfall of 250 cm. The area of the site is approximately 1350 sq.m and the site is moderately sloped.

The experiment was carried out in one year old established *Leucaena*

Fig. Location Map of Experimental Site.



leucocephala. *Zea mays* was selected as an agricultural crop introduced in the interspace between the tree species.

3.2 MATERIALS AND METHODS

3.2.1 Design and layout of the experiment:-

The experiment was carried out in one year old established *Leucaena leucocephala* plot having a spacing of 3m x 2m following randomised block design (RBD). The experiment field was divided into three equal blocks in which the three treatments were randomly replicated. Therefore, there are nine (9) number of plots. Of the 2 *Leucaena leucocephala* plots, one was cropped with maize (*Zea mays* at 60cm x 40cm) directly, while the other was cropped along with buried *Leucaena leucocephala* leaf litter at the rate of 100 gm fresh leaves per metre plants having the same spacing (60cm x 40cm) as above. The control plot was cropped with maize alone having the same spacing (60 cm x 40cm). Each plot have three replications.(Figure-II). The treatments and control were as under:-

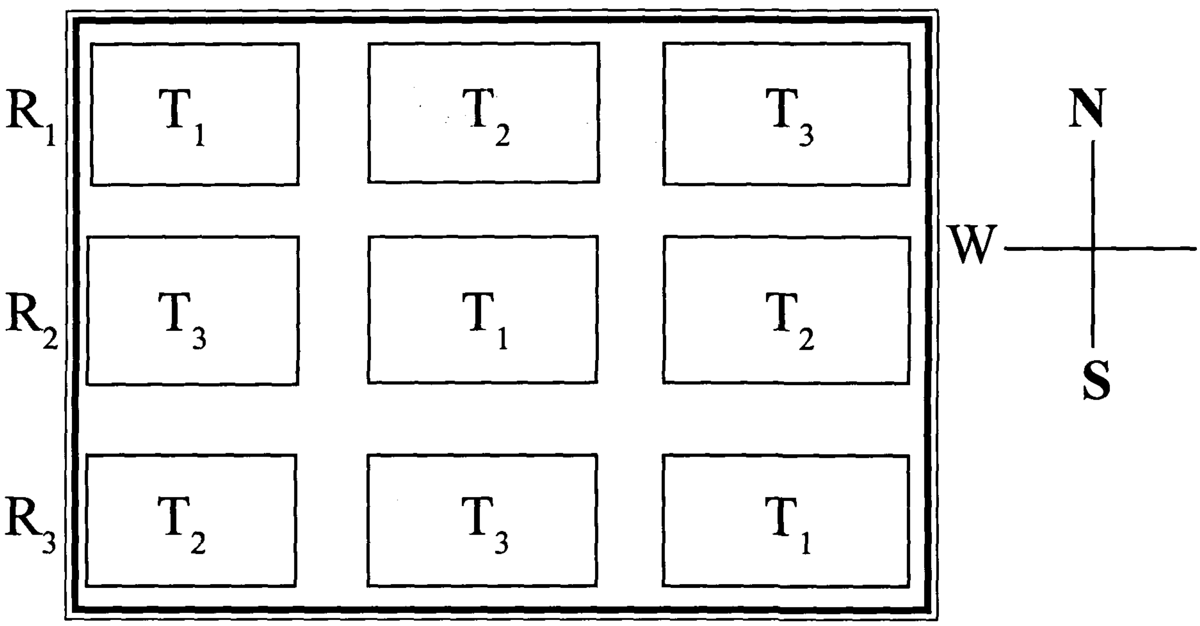
T_1 = Maize (60cm x 40cm)*Leucaena leucocephala* (3m x 3m)

T_2 = Maize (60cm x 40cm) with buried Leucaena litter +*Leucaena leucocephala* 3m x 2m)

T_3 = Control (Maize alone 60cm x 40cm)

Zea mays L. (Variety - Vijay Composite) was sown in the month of April 2001 in between the interspaces of *Leucaena leucocephala*. The spacing for maize was uniform for all the plots (60cm x 40cm) row to row and plant to plant respectively. The control plots had the same number of maize plant as in the experimental treatment, but did not have any *Leucaena leucocephala* plant.

Fig. II Layout of the Experiment



T1 = Maize(60 cm x40 cm)*Leucaena leucocephala* (3m x 3m)
T2 = Maize (60 cm x40 cm) with buried Leucaena litter +*Leucaena leucocephala* (3mx2m)
T3 = Control(Maize alone 60 cm x 40 cm)
Plot size = 15 m X10 m
Experimental area= 1350 sq.m.

3.3 Sampling programme :-

A forthnightly sampling programme was originally envisaged but due to financial constraints it had been restricted to monthly sampling. The parameters are as follows:

3.3.1 Matereological data :- Daily records for rainfall and temperature was collected from the Directorate of Agriculture, Government of Mizoram. The monthly means were calculated as such for the study period, i.e. November, 2000-August, 2001.

3.3.2 Physico- edaphic factors :- The physico-edaphic factors accounted for the experimental plots were soil moisture and soil temperature. Measurements were taken during each sampling occasion

(1) Soil moisture :- Soil samples were collected monthly at a depth of 30 cm and the collected samples were properly tagged and sealed in plastic packets and were taken to the Laboratory. Soil moisture loss on drying to constant weight was determined for100gms of fresh soil. The soil moisture content was expressed as percent fresh weight and calculated as follows:

$$M\ (\%) = \frac{FW - DW}{FW} \times 100$$

where,

M = Moisture

FW = Fresh weight

DW = Dry weight.

(II) **Soil temperature :-** Soil temperature was recorded at a depth of 0-15cm by using a mercury in glass thermometer.

3.3.3. Chemo-edaphic factors :- The Chemo-edaphic factors accounted for the experimental plots were soil pH, soil conductance, soil nitrogen, soil phosphorous and soil potassium.

(a) **Soil pH :-** The soil pH was measured by using a Systronics double electrode digital pH meter (Model-331). Soil suspension in distilled water in the ratio of 1:5 was stirred by using magnetic stirrer for 5 minutes and allowed to settle before the readings were recorded. The Soil pH measurement was done in the Laboratory of Forestry Department, NEHU, Mizoram Campus, and in the Soil Testing Laboratory of Directorate of Agriculture, Government of Mizoram, Aizawl.

(b) **Soil Conductance :-** Soil Conductance was determined by using microprocessor conductivity meter (LF-320). The soil suspension in distilled water in the ratio of 1:5 was stirred for 5 minutes and allowed to settle before the readings were recorded, soil conductivity determination was done in the Laboratory of Forestry Department, NEHU, Mizoram Campus and in the Soil Testing Laboratory, Directorate of Agriculture, Government of Mizoram, Aizawl.

(c) **Soil Nitrogen :-** The derived soil samples (after the moisture content determination) were ground and sieved. The soil samples were subsequently used for the estimation of nitrogen (Kjeldahl method) and the estimations were done in the Laboratory of Forestry Department, NEHU, Mizoram Campus and in the Soil Testing Laboratory, Department of Agriculture, Government of Mizoram, Aizawl.

(d) Soil Phosphorous :- The soil samples were estimated by using Bray and Kurtz method and the estimatimation were done in Laboratory of Forestry Department, NEHU, Mizoram Campus and in the Soil Testing Laboratory, Department of Agriculture, Government of Mizoram, Aizawl.

(e) Soil Potassium :- Estimations for soil potassium for each treatment was done by using Flame photometer method. The estimations were done in the Laboratory of Forestry Department, NEHU, Mizoram Campus and in the Soil Testing Laboratory, Department of Agriculture, Government of Mizoram, Aizawl.

3.3.4. Biotic-factors :-

The growth behaviour of tree species (i.e. *Leucaena leucocephala)* and agricultural crop (i.e. *Zea mays* L.) selected was studied for one year.

Various growth parameters recorded in *Leucaena leucocephala* are :-

(i) Girth of Stem :- Girth of stem of Leucaena was measured at the base of the plants. Measuring tape in centimeter (cm) scale was used for recording the collar thickness of the plants.

(ii) Plant height :- Leucaena height was measured with the help of a metre scale from the base of the plants upto the longest tip of the leaves in each treatment. The height of the plants were recorded for all plants every months during the study period.

(iii) Number of branches :- The number of branches per plants in different plots were counted every month. The number of branches were averaged for each plot and recorded.

Various growth parameters estimated in *Zea mays* are :-

i) **Plant height :-** Height of maize plants were measured and recorded in all the treatments at every one month interval from May, 2001 to August, 2001. The measurements were done from the base to the longest tip of the top leaves by using a meter (m) scale. The mean height of maize was taken for each replication of the treatment.

ii) **Girth of stem :-** Stem girths of maize were also measured monthly. Girth measurement was done at tha base of the plants near the ground level with the help of a centimeter (cm) scale.

iii) **Number of leaves :-** The number of leaves per plant in different plot were counted monthly. The number of leaves were averaged for each plot and recorded.

iv) **Yield :-** Number and weight of maize cobs, number of grains per cob, weight of grains per cob and the total yield of maize per plot were calculated and recorded.

3.4 Statistical Analysis :-

The experiment was laid out under Randomised Block Design. The data recorded on various growth perameter and soil perameter during the course of investigation were analysed by the analysis of variance method (ANOVA-2 way) and the significance of difference sources of variation were tested by error mean square using Fisher Shedecor 'F' test of probability at 0.005 percent level of significance.

CHAPTER-IV
RESULTS

RESULTS

In this chapter, an attempt has been made to present the entire findings obtained during the course of investigation. These are presented with the help of appropriate tables and illustrations for clear and easy understanding.

4.1. Abiotic factors:-

The results of the abiotic factors estimated during the present investigation are grouped under three categories :-

(i) Meteorological factors - Maximum and minimum temperature, and rainfall.

(ii) Physico-edaphic factors - Soil moisture and Soil temperature.

(iii) Chemo-edaphic factors - Soil pH, Soil conductivity, Soil Nitrogen (N), Soil Phosphorous(P) and Soil Potassium (K).

4.1.1 Meteorologial factors:-

Meteorological data were collected from the Directorate of Agriculture, Government of Mizoram, Aizawl. The daily records of the meteorological factors as obtained were averaged for their monthly values. The daily temperature and rainfall records were added and calculated. The monthly fluctuations of the meteorological factors are shown in Table-I.

(i) Temperature :- During the experimental period (i.e. November, 2000 - August, 2001), mean monthly maximum temperature varied from a lower range of 24.41° C (December, 2000) to a higher level of 32.61° C (April, 2001). Mean monthly minimum temperature recorded was lowest in January, 2001 (10.35° C) and highest in July, 2001 (22.46° C).

Months / Parameters	2000		2001							
	November	December	January	February	March	April	May	June	July	August
Mean maximum temperature (⁰ C)	27.16	24.41	24.91	27.74	30.67	32.61	30.59	29.45	30.87	29.12
Mean minimum temperature (⁰ C)	18.92	12.41	10.35	13.77	19.07	21.08	21.71	22.15	22.46	21.11
Mean total rainfall (mm)	20	Nil	Nil	45	58	58	362	494	247	326

Table I :- Monthly records meteorological data during the study period.

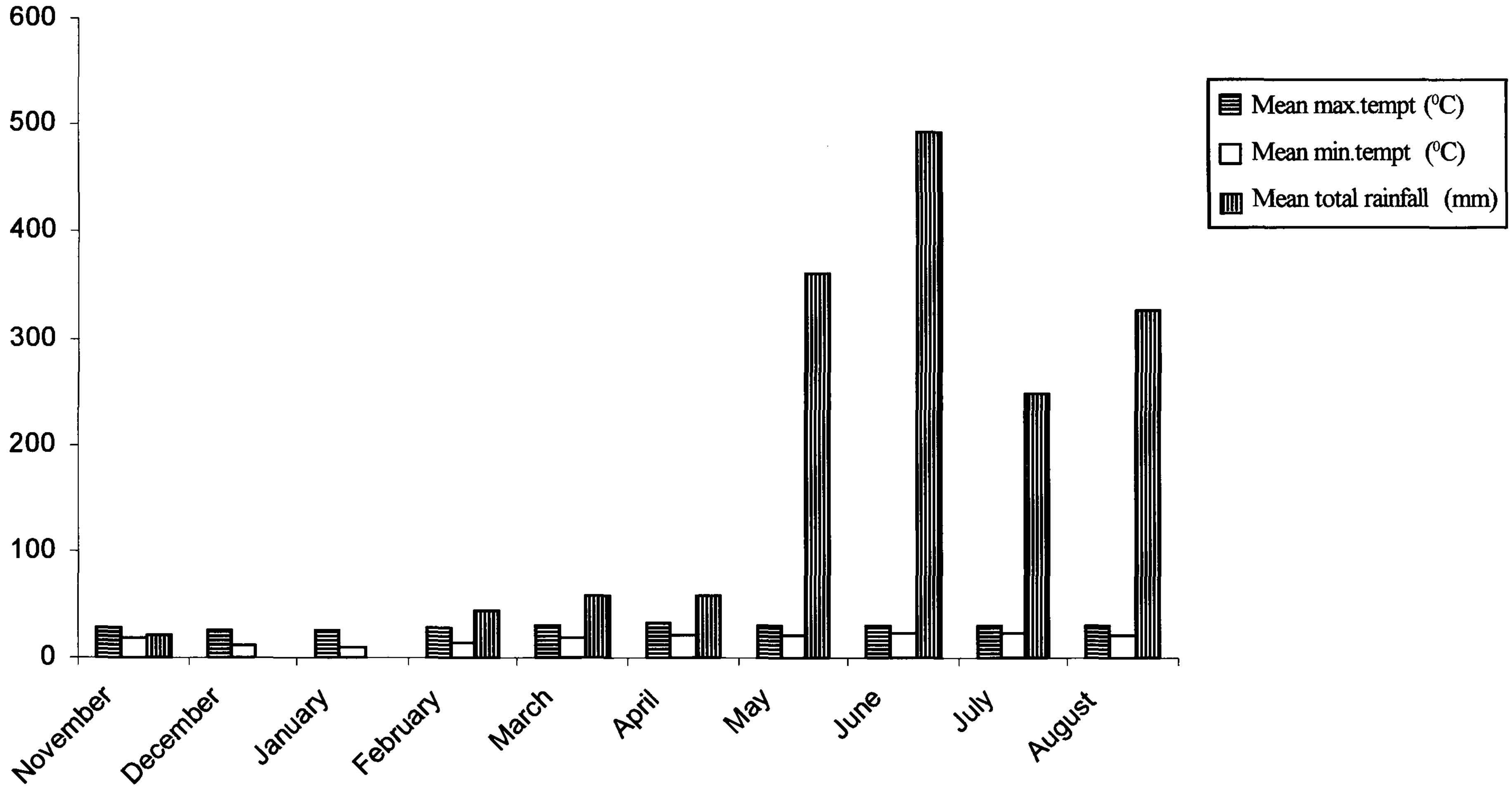


Figure III :- Monthly records of Meteorological data during the study period.

(ii) Rainfall :- During the study period, mean minimum monthly rainfall (20 mm) was recorded in the month of November, 2000. There was no rainfall in the months of December, 2000 and January, 2001. Mean monthly maximum rainfall (494 mm) was recorded in June, 2001..

4.1.2 Physico-edaphic factors:-

The physico-edaphic factors which were included in the study are Soil moisture (%) and Soil temperature (° C).

(i) Soil moisture (%) :- The monthly records of Soil moisture under different treatments during the study period are shown in Table - II. The moisture content of the soil was lowest in the month of January, 2001 (8.11%) probably due to no rainfall and the highest soil moisture content was observed in the month of June, 2001 (9.18%). It was observed that rainfall influenced the moisture content of the soil, the more rainfall, the higher the moisture content.

(ii) Soil temperature (° C) :- The monthly variation of mean Soil temperature of the site during the experimental period are shown in Table - III. The Soil temperature recorded at 0-15 cm depth showed the highest peak of 26.16° C in the month of April, 2001 and lowest 20.52° C in the month of January, 2001. As there was no rainfall during December, 2000 and January, 2001, the temperature also gradually increased from February, 2001. However, with the onset of rainfall, the temperature slowly increases from the month of May, 2001.

Months / Treatments	2000		2001							
	November	December	January	February	March	April	May	June	July	August
T_1	9.1	9.14	8.11	8.87	8.95	8.4	8.95	9.18	8.97	9.08
T_2	9.06	8.98	8.5	8.96	9.00	8.56	9.04	9.10	9.07	9.18
T_3	8.84	9.33	8.66	9.09	9.18	8.43	9.09	8.66	8.75	9.16
SE m$\pm$	0.28	0.17	0.15	0.42	0.129	0.27	0.018	0.14	0.16	0.09
CD(P=0.005)	NS	NS	0.41	NS	NS	NS	0.049	0.38	NS	NS

NS = Non-significant

Table II:- Monthly records of Soil moisture (%) under different treatments during the study period.

Treatments \ Months	2000		2001							
	November	December	January	February	March	April	May	June	July	August
T_1	21.86	20.73	20.73	22.43	24.06	26.16	23.66	21.8	22	21.3
T_2	21.1	21.03	20.52	22.3	24.26	26.13	23.96	21.93	21.53	21.36
T_3	21.31	20.86	21.10	22.2	24.23	26.2	23.66	21.73	21.76	21.86
SE m$\pm$	0.40	0.30	0.25	0.08	0.34	0.44	0.33	0.26	0.23	0.27
CD(P=0.005)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Non-significant

Table III:- Monthly records of Soil Temperature (^{0} C) under different treatments during the study period.

4.1.3 Chemo-edaphic factors :-

The chemo-edaphic factors which were included in the study are Soil pH, Soil conductivity, Soil Nitrogen (N), Soil Phosphorous (P) and Soil Potassium (K).

(i) Soil pH :- The mean monthly records of Soil pH value of the site during the experimental period are shown in Table -IV. The highest pH value recorded was 5.53 in the month of November, 2000 under the Control plot and lowest recorded was 4.4 in the month of June, 2001 under Leucaena leaf litter buried treatment. The overall soil reaction was found to be acidic throughout the experiment in all the plots.

(ii) Soil Conductivity :- The mean monthly records of the Soil conductivity value of the different treatments during experimental period are shown in Table -V. The lowest value of Soil conductivity (8.26) was observed in the month of August, 2001, and the highest value (13.98) was observed in the month of December, 2000.

(iii) Soil Nitrogen (%) :- The amount of Nitrogen present in the soil under different treatments were estimated in percentage and are shown in Table -VI. Highest percentage value was recorded in the month of April, 2001 (0.94 %) in respect of Leucaena treatment and lowest percentage value was recorded in March,2001 (0.65 %) in respect of Control plot.

4.2 Biotic - factors :-

The results of the biotic factors accounted during the present investigation are as follows :

Treatments \ Months	2000		2001							
	November	December	January	February	March	April	May	June	July	August
T_1	5.3	5.2	5.03	5.05	4.86	4.7	4.8	4.66	4.7	4.6
T_2	4.9	5	5.06	4.81	4.7	4.5	4.63	4.6	4.4	4.5
T_3	5.53	5.43	5.3	5.26	5.26	5.2	5.06	5.1	5.1	5.2
SE m$\pm$	0.12	0.12	0.11	0.1	0.12	0.10	0.12	0.18	0.09	0.1
CD(P=0.005)	0.33	N.S	N.S	0.27	0.33	27	N.S	N.S	0.24	0.27

NS = Non-significant

Table IV:- Monthly variation of Soil pH in the experimental plot under different treatments during the study period.

Treatments \ Months	2000		2001							
	November	December	January	February	March	April	May	June	July	August
T_1	13.9	13.98	13.6	12.9	12.06	12	12.03	11.13	9.83	8.26
T_2	13.8	13.9	13.4	12.6	12.16	11.9	11.53	9.93	9.46	8.93
T_3	13.9	13.86	13.1	12.46	11.93	12.9	12.03	10.9	10.3	9.3
SE m$\pm$	0.12	0.21	0.41	0.49	0.50	0.28	0.40	0.41	0.25	0.46
CD(P=0.005)	NS	NS	NS	NS	NS	NS	NS	NS	0.69	NS

NS = Non-Significant

Table V:- Monthly variation of Soil Conductivity in the experimental plot under different treatments during the study period.

Treatments \ Months	2000		2001							
	November	December	January	February	March	April	May	June	July	August
T_1	0.68	0.70	0.72	0.73	0.75	0.76	0.78	0.79	0.79	0.81
T_2	0.73	0.74	0.77	0.87	0.94	0.94	0.92	0.93	0.92	0.94
T_3	0.68	0.69	0.69	0.67	0.65	0.71	0.71	0.72	0.81	0.67
SE m $\pm$	0.19	1.41	0.018	0.18	0.12	0.08	0.08	0.07	0.89	0.09
CD (P at 0.005)	NS	NS	0.04	NS	NS	NS	NS	NS	NS	NS

NS = Non-Significant

TableVI : - Monthly variation of Soil Nitrogen (%) under different treatments during the study period.

Treatments \ Months	2000		2001							
	November	December	January	February	March	April	May	June	July	August
T_1	15.26	15.3	15.5	15.46	15.56	15.36	15.4	15.5	15.5	15.43
T_2	15.1	15.16	15.3	15.43	15.7	15.56	15.53	15.7	15.66	15.76
T_3	15.13	15.3	15.16	15.23	15.2	15.23	15.23	15.33	15.43	15.4
SE m $\pm$	0.22	0.30	0.33	0.36	0.36	0.31	0.41	0.41	0.45	0.49
CD (P at 0.005)	NS	NS	NS	NS	NS	NS	NS1	NS	NS	NS

N.S = Non-Significant

Table VII: - Monthly variation of Soil Phosphorous (kg/ha.) under different treatments during the study period.

Months / Treatments	2000		2001							
	November	December	January	February	March	April	May	June	July	August
T_1	149.95	149.96	149.73	149.67	150.07	150. 06	150. 04	149.99	150. 10	150.13
T_2	149.96	150.02	150.03	150.06	150.09	150. 05	150. 13	149.75	149.8	149.96
T_3	149.93	149.98	149.88	149.86	149.71	149.91	149.88	149.71	149.84	149.76
SE m $\pm$	0.11	0.044	0.26	0.2 9	0.14	0.081	0.109	0.18	0.20	0.22
CD (P at 0.005)	NS	NS	NS	NS	NS	NS	NS1	NS	NS	NS

N.S = Non-Significant

Table VIII: - Monthly variation of Soil Potassium (kg/ha.) under different treatments during the study period.

4.2.1 In *Leucaena leucocephala* :-

(i) **Plant height of Leucaena :-** The monthly mean records of the plant height (cm) are shown in Table -IX. The increase in plant height ranged from 133.68 cm to 209.02 cm in different treatments during the study period. The results indicated that the effect of treatments on plant height was found to be a non-significant.

(ii) **Stem Girth of Leucaena :-** The monthly mean records of the increase in stem girth (cm) are shown in Table - X. The increase in stem girth ranged from 4.88 cm to 7.43 cm in different treatments during the study period.

(iii) **Number of branches in Leucaena :-** The monthly mean records of the number of branches are shown in Table- XI. The number of branches increased from 5.95 to 6.98 during the study period and it can be seen from the table that, it did not show much difference under different treatments.

4.2.2 In *Zea mays* :-

(i) **Plant height of maize :-** It can be seen from the data (Table -XII) that the monthly mean increase in plant height ranged from 28.33 cm to 191.26 cm in different treatments during April to August, 2001. Maximum increase in plant height was observed during May, i,e. after one month of sowing. It was also observed that highest increase in plant height was obtained in the plot treated with Leucaena leave litter than the other plots (i.e. Leucaena + maize and Control - maize alone).

(ii) **Stem girth of maize :-** The data (Table - XIII) shows that the monthly mean increase in stem girth ranged from 1.96 cm to 5.10 cm in different treatments during the month of April to August, 2001. the mean

Months / Treatments	2000		2001							
	November	December	January	February	March	April	May	June	July	August
T_1	133.68	135.51	137.85	140.7	144.2	150.61	159.45	173.63	189.63	202.00
T_2	139.18	141.85	144.36	147.78	151.36	156.98	168.13	182.20	199.61	209.02
SEm$\pm$	5.80	5.81	5.84	5.46	5.56	5.60	5.22	5.17	8.05	5.65
CD(p=0.005)	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S

N.S = Non-Significant

Table IX : - Monthly variation of plant height (cm) of Leucaena under different treatments during the study period.

Treatments \ Months	2000		2001							
	November	December	January	February	March	April	May	June	July	August
T_1	5.1	5.44	5.55	5.6	5.7	5.82	6.13	6.80	7.36	7.43
T_2	4.88	5.09	5.17	5.3	5.42	5.66	5.98	6.58	7.03	7.28
SEm $\pm$	0.03	0.04	0.1	0.05	0.08	0.05	0.08.	0.05	0.05	0.12
CD(P=0.005)	0.12	0.17	N.S	0.21	N.S	N.S	N.S	0.21	0.21	N.S

N.S = Non-Significant.

Table - X :- Monthly variation of stem girth (cm) of Leucaena under different treatments during the study period.

Months / Treatments	2000		2001							
	November	December	January	February	March	April	May	June	July	August
T_1	5.95	6.01	6.07	6.13	6.16	6.23	6.27	6.40	6.53	6.76
T_2	6.05	6.09	6.22	6.26	6.32	6.56	6.61	6.8	6.86	6.98
SEm -+	0.40	0.41	0.43	0.39	0.40	0.43	0.43	0.42	0.37	0.26
CD(P=0.005)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

N.S = Non-significant.

Table XI :- Monthly variation of number of branches in Leucaena under different treatments during the study period.

Months / Treatments	2001				
	April	May	June	July	August
T_1	29.21	101.37	139.9	190.52	190.55
T_2	30.97	102.69	141.49	191.19	191.26
T_3	28.33	100.97	139.4	189.64	189.65
SE m$\pm$	1.38	0.32	0.33	0.40	0.40
CD(P=0.005)	NS	0.88	0.92	1.11	1.11

NS = Non-Significant

Table XII:- Monthly variation of plant height (cm) of maize under different treatments during the study period.

Treatments \ Months	2001				
	April	May	June	July	August
T_1	1.98	2.98	3.80	4.98	5.03
T_2	2.09	3.06	3.78	5.04	5.10
T_3	1.96	2.91	3.63	4.88	4.96
SE m$\pm$	0.02	0.03	0.04	0.03	0.02
CD(P=0.005)	0.05	0.08	0.11	0.08	0.05

NS = Non-Significant

Table XIII:- Monthly variation of stem girth (cm) of maize under different treatments during the study period.

maximum increase in stem girth was recorded in the plot treated with Leucaena leaf litter (5.10 cm) and mean minimum increase was recorded in the Control plot (4.96 cm).

(iii) Number of leaves in maize :- The data (Table-XIV), shows the monthly mean variation of leaves. The mean number of leaves was found to be 4 (four) in all the treatments in the month of April. Variation in number of leaves was observed from the month of May. The mean maximum number of leaves per plant ie, 12.15 and 12.23 was observed in the month of July and August in the plot treated with Leucaena leaf litter. The mean minimum number of leaves ie. 10.1 at the end of the study period was observed in the Control plot.

(iv) Yield of maize :-

(a) Number of cobs :- The data in Table -XV shows the number of cobs after harvest from different treatments. It was observed from the study that almost all the plants bore only one cob. In Control plot, there were some plants which failed to bear even a cob. The mean maximum number of cobs (182.53) was recorded in the plot treated with Leuceana leaf litter buried and the mean minimum number of cobs 177.87 was recorded under Control plot.

(b) Weight of cobs (kg) :- The mean weight of cobs under different treatrments are shown in Table - XVI. It was observed that the mean maximum weight of cob recorded was 0.22 kg under Leucaena leaf litter buried treatment followed by 0.16 kg under Leucaena treatment. Mean minimum weight of cob recorded was 0.14 kg under the Control plot.

(c) Number of maize grains per cob :- The mean number of maize grains per cob under different treatments are shown in Table- XVII. It was observed that the mean maximum number of grains per cob (397.2) was recorded

Months / Treatments	2001				
	April	May	June	July	August
T_1	4.25	7.23	9.56	11.25	11.28
T_2	4.83	7.8	10.41	12.15	12.23
T_3	3.67	6.03	8.42	9.9	10.1
SE m$\pm$	0.31	0.30	0.29	0.27	0.24
CD(P=0.005)	0.86	0.83	0.80	0.75	0.67

NS = Non-Significant

Table- XIV :- Monthly variation of number of leaves in maize under different treatments during the study period

Treatment	Number of cobs
T_1	181.63
T_2	182.53
T_3	177.87
SE m$\pm$	1.00
CD (P=0.005)	2.77

Table XV :- Number of maize cobs under different treatments.

Treatments	Weight of cobs (kg)
T_1	0.16
T_2	0.22
T_3	0.14
SE m$\pm$	0.01
CD (P=0.005)	0.02

Table XVI :- Weight of cobs under different treatments.

Plate No.-I
Maize intercropped with Leucaena
in the experimental plot.

Plate No. -II
Maize Plant in the experimental plot
(Control plot - Maize alone)

Plate No.-III
Filling of pits with Leucaena leaf litter (fresh leaf at the rate of 100 gm/pit) in the experimental plot.

Plate No. -IV
Maize intercropped with Leucaena, and with buried Leucaena leaf litter in the experimental plot.

Plate No.-V
Maize cob before harvest
in the experimental plot.

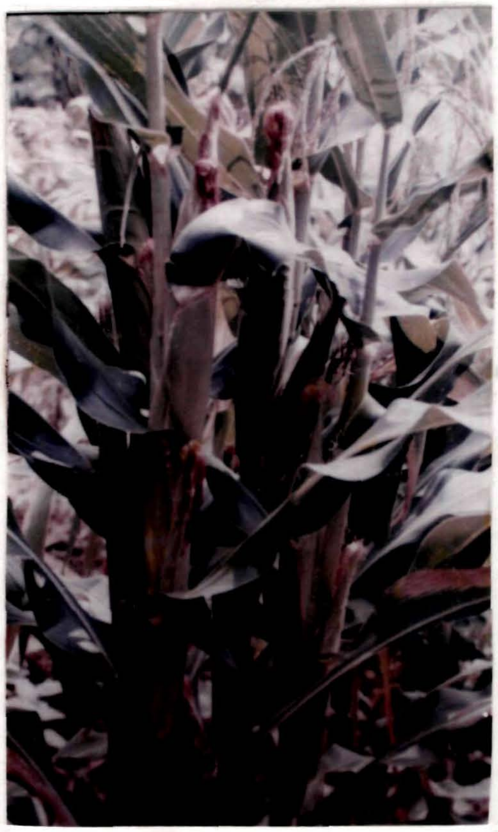


Plate No. -VI
Maize cobs harvested from
the experimental plot.

under the treatment of Leucaena leaf litter buried and mean minimum number of grains per cob recorded was 337.11 under Control plot.

d) **Weight of maize grains per cobs (gms)** :- The data in Table - XVIII shows the weight of grains per cob from different treatments. The mean maximum weight of grains per cob (76.01 gms) was observed under the Leucaena leaf litter buried and the mean minimum weight of grains per cob (72 gms) was observed under the Control plot.

e) **Total yield of maize cob per plot (kg)** :- The data depicted in Table-XIX are the total yield of maize cob after harvest from different treatments. It can be observed that the total yield of maize cob was highest (35.04) under the plot treated with Leucaena leaf litter buried and lowest in the Control plot.

Treatments	Number of grains/cobs
T_1	360.10
T_2	397.2
T_3	337.11
SE m$\pm$	6.86
CD (P=0.005)	19.01

Table XVII :- Number of maize grains/cobs under different treatments.

Treatments	Weight of grains/cobs
T_1	74.23
T_2	76.01
T_3	72
SE m$\pm$	0.56
CD (P=0.005)	1.55

Table XVIII :- Weight of grains/cobs (gms) under different treatments.

Treatments	Total yield of cobs
T_1	33.5
T_2	35.04
T_3	30.66
SE m$\pm$	1.12
CD (P=0.005)	3.10

Table XIX :- Total yield of cob/plot (gms) under different treatments.

CHAPTER-V
DISCUSSION

DISCUSSION

From time immemorial, jhuming is the most primitive method of cultivation practised in Mizoram. This age old traditional practice which is still the lifestyle of the majority of the people has caused immense damage to the fragile soils and precious forest cover. If jhuming continues, the time for complete devastation of the forest cover is not far off. The ecological balance will be disturbed and the environment will become unhealthy and unproductive. Therefore, there is an urgent need to develop more productive and ecologically sound agricultural technologies.

In order to restore the depleting biodiversity and to ensure better income potential to poor farmers, agro-forestry could be most sustainable cultivation practice in providing forest produce, fodder and non-timber forest products.

The present investigation entitled "Growth and yield of maize as an intercrop with Leucaena, and with buried Leucaena leaf litter in an agro-forestry trial in Mizoram" was carried out.

To develop an appropriate alternative to burning of the slash, which is done in the jhum cultivation. The experiments aimed at determining the effect of incorporation of laef litter arising from continued inputs from the tree components of the agro-forestry system on the yield of an intercrop and compare such yields with controls.

Appropriate agro-forestry system have the potential to control soil erosion and maintain soil organic matter. According to Altieri *et al.*, 1987, tree foliage (prunings) can be used as mulch and fertilizer for food crops, and/or for animal feed. Micro-site enrichment through improvement in the soil organic matter and mineral nutrient pools is an important attribute of trees and shrubs in agro-forestry.

The prunings (GLM-green leaf manure) as nitrogen source appeared most effective when applied as surface mulch. This can be explained in terms of faster rate of mineralization of the incorporated GLM, within 1-3 weeks (Weeraratna, 1982). Legume trees usually have small leaflets which decompose more rapidly and enable the nutrients to return more quickly to the soil surface to maintain productivity (Vergara, 1982).

Foliage of some NFT's contain considerable nitrogen which when mixed with soil improved the soil nitrogen status (Jha and Sharma, 1993). The addition of tree leaves and branches as mulches to soil has been shown to improve site micro-environmental conditions (Budelman, 1989) and increase the productivity of agricultural crops (Duguman *et al.*, 1988; Gutterridge, 1990; Onion *et al.*, 1990; Tiraa and Asghar, 1990; Yamoha and Burleigh, 1990). It has also been reported that mulch from leaf litter can protect soils erosion, decrease weed growth, release nutrient to the soil via decompositon, and moderate soil moisture loss and temperature fluctuations (Budelman, 1988, 1989; Montagnini *et al.*, 1993). Tree foliage can be used as mulch and fertilizer for food crops (Reynolds *et al.*, 1988). The mulch system supplied nitrogen to the arable crop and hence the yield increased (Konwar *et al.*, 1988).

5.1 Growth and yield attributes of maize :-

Growth rate interms of height (cm), stem girth (cm) and number of leaves per plant of maize crop was observed to be significant under different treatments. (Table-XII, XIII, and XIV, Fig: IV, V and VI). Maize was observed to be fast growing crop in association with Leucaena.

Yield of maize such as number of cobs, weight of cobs, number of maize grains per cob, weight of maize grains per cob and total yield of maize cob per plot were recorded at the time of harvest and presented in Table -XV, XVI, XVII, XVIII and XIX. In comparison to the growth and yield of maize under different treatments, it was seen that the highest growth rate

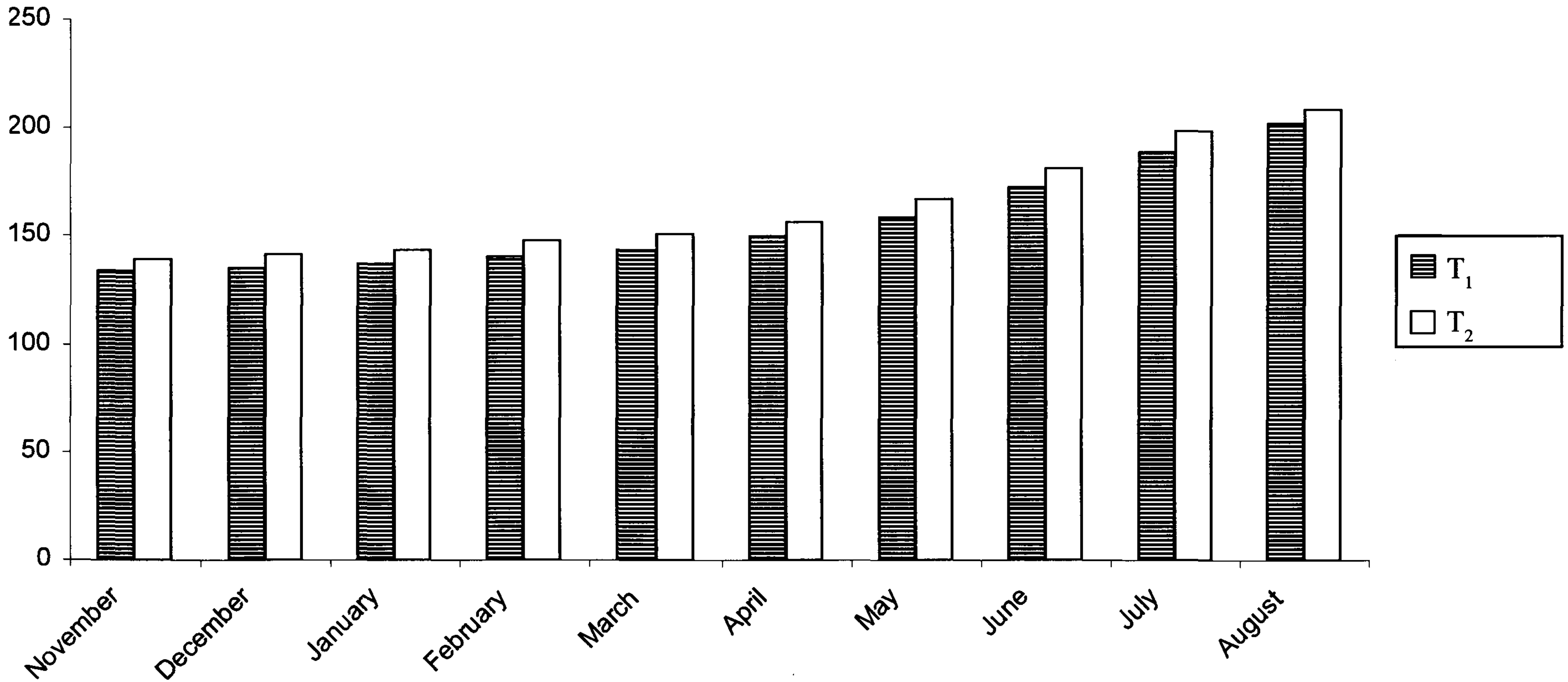


Figure IV :- Monthly variation of plant height (cm) in Leucaena under different treatments during the study period.

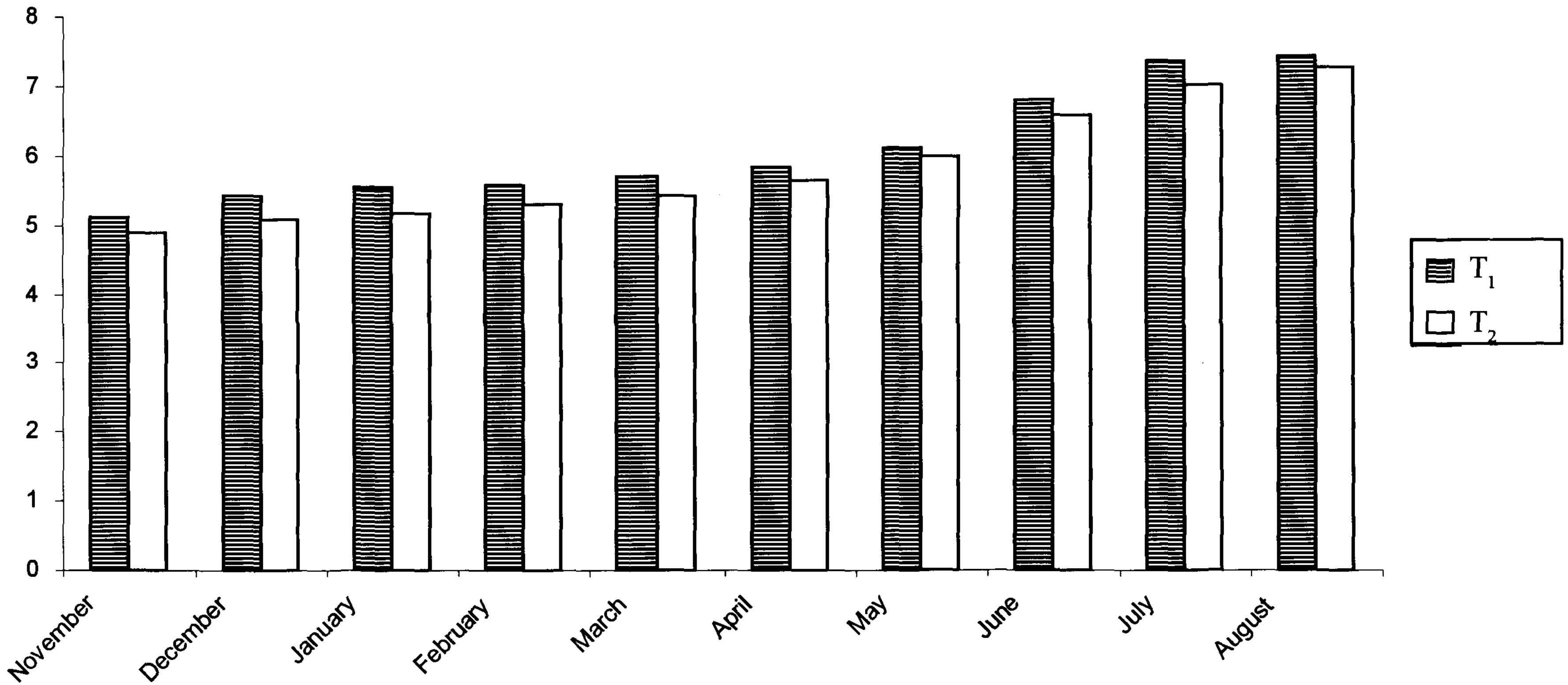


Figure V :- Monthly variation of stem girth (cm) in Leucaena under different treatment during the study period.

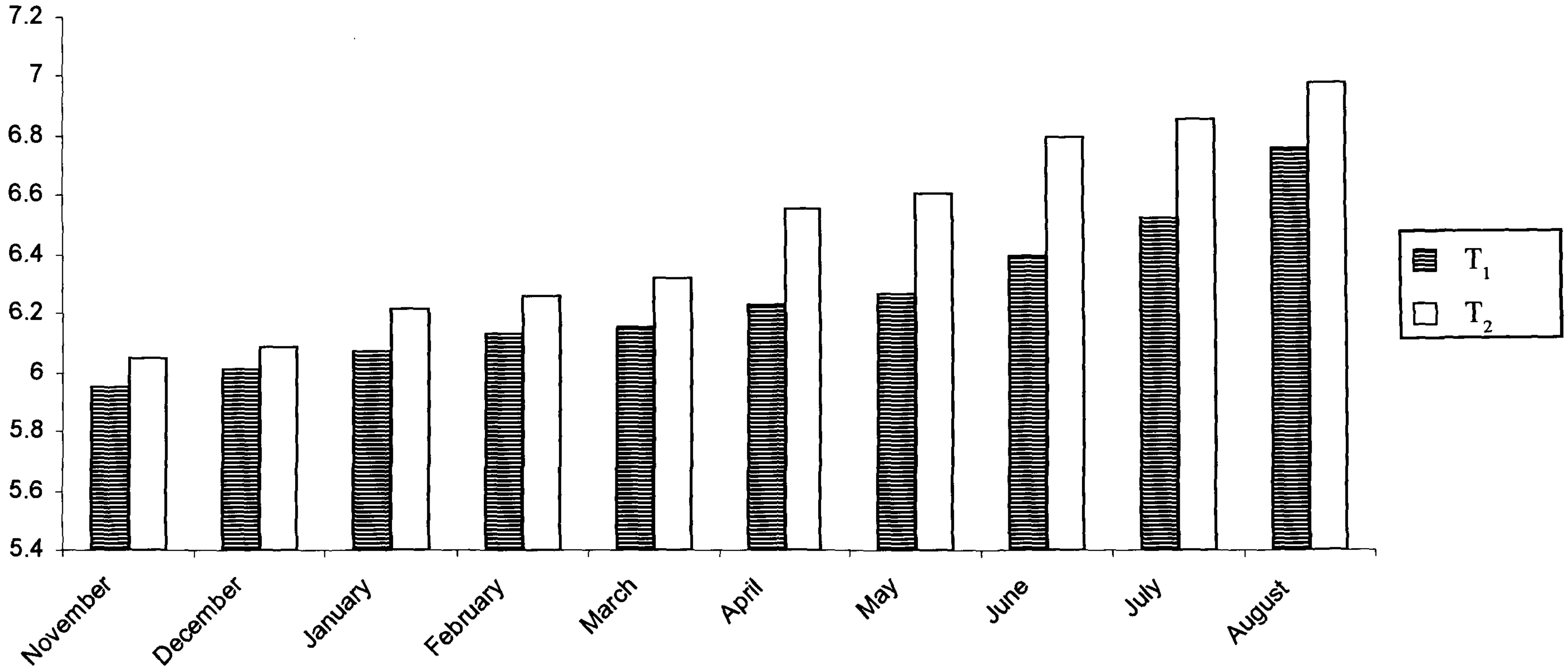


Figure VI :- Monthly variation of number of branches in Leucaena under different treatments during the study period.

and highest yield was obtained in the treatment intercrop with Leucaena along with buried Leucaena leaf litter. The minimum growth rate and minimum yield was obtained in the Control plot (maize alone) which was in accordance to the work of Kang (1981), Flores (1985), Leviste (1976) and Ssekabembe (1984).

According to Pathak *et al.*, (1979), the agro-forestry potential of Leucaena was identified for providing a complementary beneficial effect on the yield of cereal crops. Gill and Patil (1983,1985) further observed the beneficial effect of Leucaena intercropping with forage crops.

The mulch system supplied nitrogen to the arable crop and hence the yield increased (Konwar *et al.*, 1988). It is also reportd that litter of nitrogen fixing species exhibits faster decomposition rates and enhances release of nutrients (Sharma *et al.*, 1997, George and Kumar, 1998). It is logical to presume that the benefits of underground nitrogen fixation by Leucaena plants are better utilized at close proximity to the resource.

5.2 Growth attributes of Leucaena :-

Growth rate interms of height, stem girth (cm) and number of branches were recorded at a monthly interval for a period of approximately one year starting from November, 2000 upto August, 2001. The data on height (cm), stem girth (cm) and number of branches are shown in Table IX, X and XI and in Figure VII, VIII and IX. As shown in the tables and figures, the growth rate interms of plant height, stem girth and number of branches of trees were found to be non- significant and comparatively slow. This may be due to the fact that, the absence of rainfall and low temperatures hindered the growth of the trees. It is also important to note that, the hindrance of growth could also be due to the heavy infestation of grassy and broad-leaved weed species during November, 2000 to March, 2001 before sowing maize crop. However, from March, 2001 onwards, the trees attained better growth in their growth attributes.

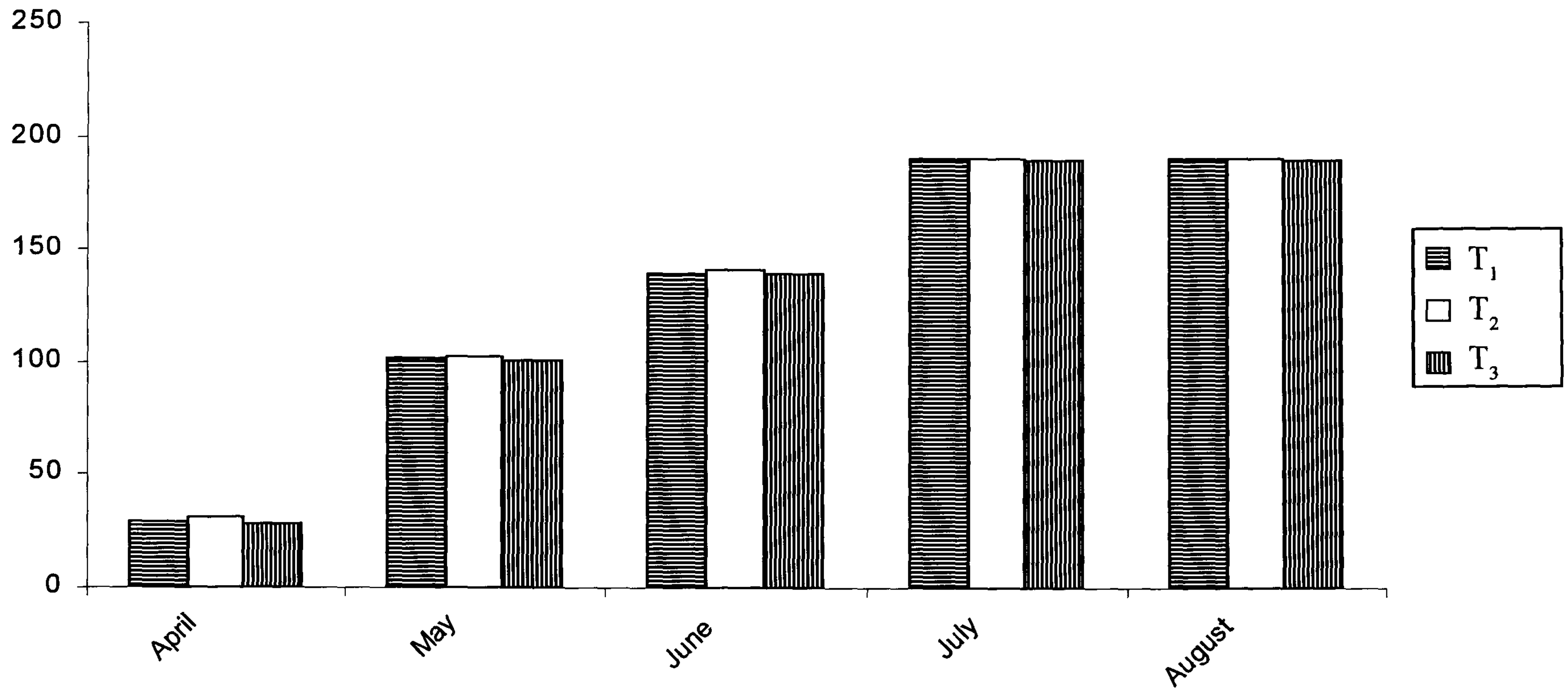


Figure VII :- Monthly variation of plant height (cm) in Maize under different treatments during the experimental period.

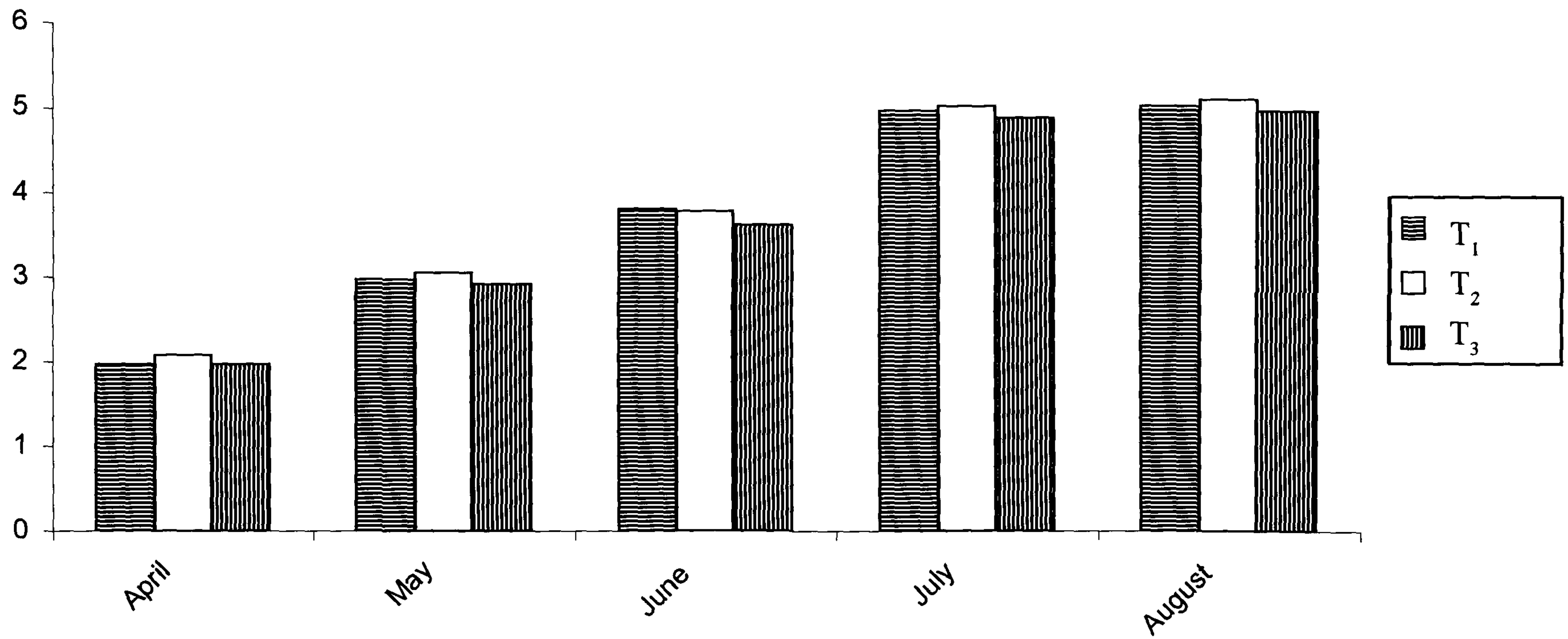


Figure VIII :- Monthly variation of stem girth (cm) in Maize under different treatments during the study period.

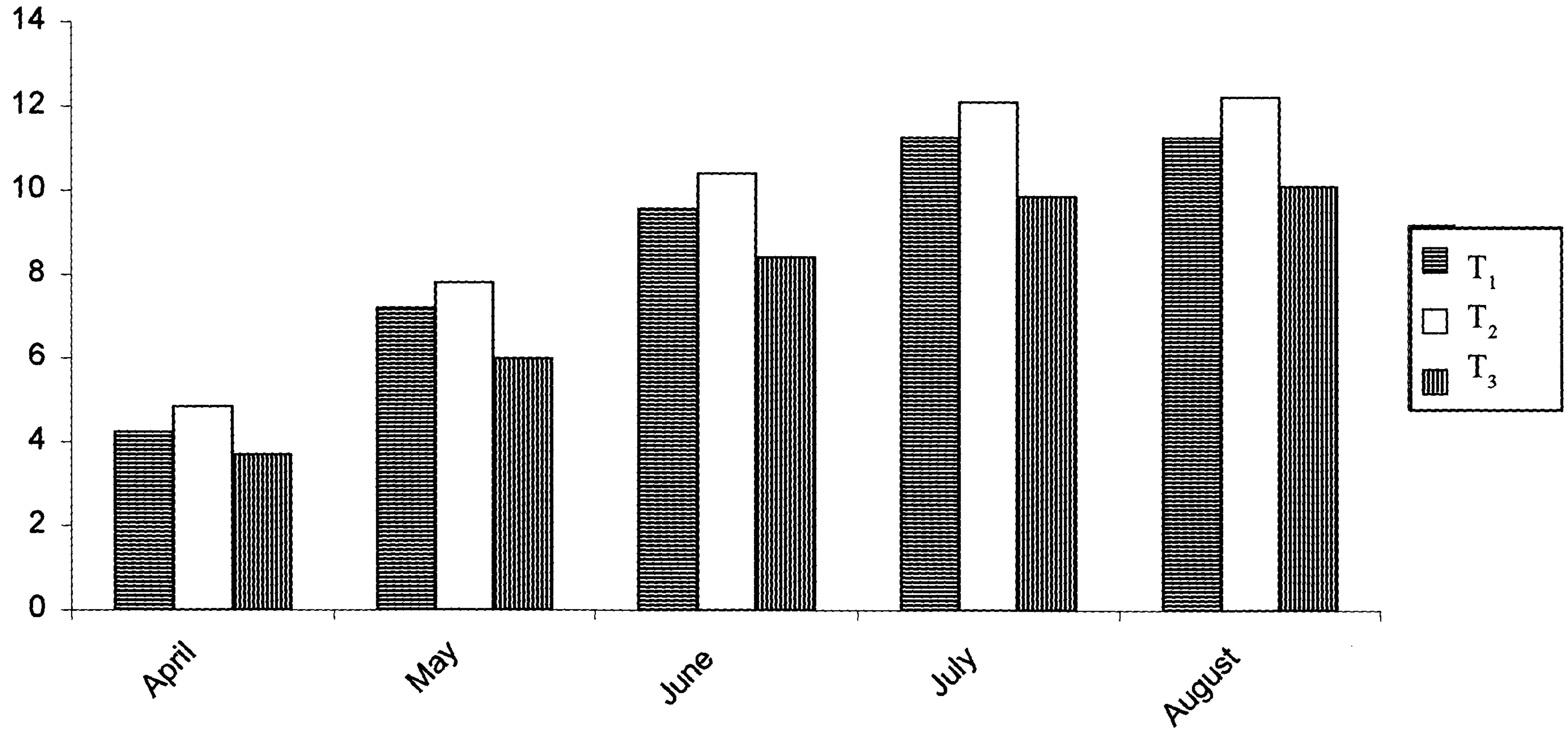


Figure IX :- Monthly variation of number of leaves in Maize under different treatments during the study period.

Considering the limitation of time and financial constraints, the present study is a feeble attempt. However, it is observed from the study that there is a beneficial relation in intercropping of nitrogen fixing trees along with an agricultural crops.

CHAPTER-VI
SUMMARY

SUMMARY

An experiment was carried out to study the growth and yield of maize as an intercrop with Leucaena, and with buried Leucaena leaf litter in an agro-forestry for trial in Mizoram. The study was carried out from the month of November, 2000 to August, 2001. The experiment was laid out in Randomised Block Design having 3 treatments and 3 replications (viz :-T_1= Maize grown with Leucaena, T_2 = Maize grown with Leucaena and Leucaena leaf litter buried, and T_3= Maize alone - Control plot).

It was observed from the experiment that there is a beneficial relation between Nitrogen fixing tree intercrop with maize. The various growth attributes of maize such as plant height (cm), stem girth (cm) and number of leaves per plant were recorded monthly till the time of harvest. The yield of maize such as number of cobs, weight of cobs (kg) number of maize grains per cob, weight of maize grains per cob (gm), and total yield of maize under diferent treatments were recorded after the harvest. In the growth attributes of Leucaena, plant height (cm), stem girth (cm) and number of branches were recorded monthly. The data obtained were subjected to ANOVA (Analysis of variance) to see the effect of different teatments of Leucaena on the growth and yield of maize. The significance was tested by calculating the critical difference (CD) at 5 % level, wherever 'F' test was found significant.

The prominent findings can be summarised as follows :-

(i) Soil fertility status such as Soil Nitrogen, Soil Phosphorous, Soil Potassium, Soil pH and Soil Conductivity was improved due to the ability of soil improvement by Leucaena.

(ii) In respect of plant height, stem girth and number of leaves in maize observed at monthly interval, the plot treated with Leucaena and Leucaena leaf litter buried recorded the best performance. The yield of maize, such as number of cobs, weight of cobs, number of maize grains per cob, weight of maize grains per cob and total yield of maize was found to be maximum under the plot treated with Leucaena and Leucaena leaf litter buried and minimum under the Control plot.

(iii) The plant height, stem girth and number of branches in Leucaena observed during the study period indicated that there was no noticeable difference in regard to height, stem girth and number of branches.

Thus, the experiment has shown the beneficial effects of Leucaena leucocephala intercrop with maize leading to improved crop yield due to improved soil fertility status under agro-forestry system in Mizoram.

CHAPTER-VII
CONCLUSION

CONCLUSION

To meet the daily needs of the rising population, land resources have to be managed so as to yield the maximum productivity per unit land. This can be achieved by agro-forestry, i.e, by integrating forestry with agriculture, but if the system of agro-forestry is to improve and take its place among the other systems of land management practised in the forestry tropics, more attention must be given to the needs, aspirations, problems and cultural traditions of the people.

Keeping in view the results and discussion of the experiment, Leucaena seems to be a desirable species combination in the agro-forestry system due to its nitrogen fixing ability and its well developed root system. It plays a positive role on the growth and yield of maize and also helps in binding the soil together which reduces soil erosion in hilly slopes.

The system has a long term economic dimension and also offers an efficient and economic form of management, especially in view of the growing costs of cultural practices and the increased use of fertilizers and pesticides in modern agriculture. However, the system has yet to be analysed over a long term to clearly define its benefits and sustainability, as also the impact of trees on soil fertility.

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