

**EFFECT OF DIFFERENT SPACINGS ON THE GROWTH BEHAVIOUR
OF *LEUCAENA LEUCOCEPHALA* (LAM.) DE WIT AND ITS EFFECT
ON *ZINGIBER OFFICINALE* ROSE. PRODUCTIVITY IN
ANAGROFORESTRY SYSTEM OF MIZORAM.**

THESIS

**SUBMITTED TO THE NORTH EASTERN HILL UNIVERSITY
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MASTER OF SCIENCE IN FORESTRY
(**SPECIALIZATION IN AGROFORESTRY**)**

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**DEDICATED TO MY BELOVED PARENTS
FOR THEIR UNENDING LOVE**

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CERTIFICATE

*I certify that the Thesis entitled " Effect of different spacings on the growth behaviour of *Leucaena leucophala* (Lam.) De wit. and the productivity of *Gingiber officinale* Rose. under agroforestry system of Mizoram ". Submitted by Miss Lalrinsangi 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 his 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 Lalrinsangi all success in life.

Aizawl
The 27th Nov 2000


27/11/20
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CHAPTER - I

INTRODUCTION

INTRODUCTION

I.I. GENERAL :

Geographically, Mizoram lies between 21°58' to 24°35' North latitudes and 92°15' and 93°29' East longitudes, covering an area of 21,087 sq.kms. In the North the state is bounded by Cachar district of Assam state and Manipur state, and on the east by the Chin Hills. On the southern side, it is bounded by the Arakan Hill Ranges of Myanmar and on the Western side, the Chittagong Hills of Bangladesh from the International border. Tripura state borders the western side in contiguity with Bangladesh.

The general topography is mostly hilly with precipitous slopes forming deep gorges culminating into several streams and rivers. By and large, almost all the hill ranges traverses in the North-South direction.

A typical tropical climate is obtained in the lower altitudes at the foot hills and valleys, whereas in the mid region with large coverage, the sub-tropical moist climate prevails, while in the upper reaches temperate climate is experienced. The summers are generally warm and wet, but winters are cool and dry. Pre-Monsoon rains occur during March-April whereas regular monsoon commences from June and continues till October. The annual rainfall ranges between 1700 mm to 1700 mm spread over eight to ten months. Although Mizoram receives heavy rains, prolonged dry spells and occasional drought conditions are not uncommon, due to the porous nature of the soil and low carrying capacity of the hilly terrain. In the southern part of Mizoram, the rainfall is higher and decrease towards the north.

The total recorded population of the state as per 1991 census was 6,89,756, the rural population is of the order of 3,71,810 (53.90%) while the urban population is 3,17,946 (46.10%) About 71.15% of the working population finds engagements in agriculture activities (Statistical Abstract, Department of Agriculture and Minor Irrigation, Mizoram. 1997-1998). About 35% of the workers are provided employment directly or indirectly by the state government whereas less than 2% people are engaged in secondary industrial activities and transformation. The age old practice of jhum cultivation is carried out annually by a large number of people living in rural areas. Important crops grown are Paddy, Ginger, Banana, Pineapple, Sugarcane, Tung, Coffee and vegetables.

1.2. FOREST :

In Mizoram, the forest consists of reserve forest and unclassed state forest. The forests cover three types namely, tropical with evergreen, tropical semi-evergreen and montane sub-tropical pine-forest. About 58% of the forest are unclassified state forest is controlled by the District Councils. Most of the unclassed state forest are managed by the village councils.

Out of the geographical area (21.087 sq.kms) of the state, 15,935 sq.km is recorded as forest (State Forest Report. 1997). The actual forest covers of the state is 18,775 sq.km which constitutes 89.1 percent of the geographical area. In 1995 Assessment the total forest cover in the state is 18,576 sq.km. An increase of 1999 sq.km of forest cover has been observed in 1997 assessment (State forest report 1997) compared to the previous assessment, this is due to regeneration in abandoned shifting cultivation areas. Mizoram has also 884 sq.km

protected areas, including two national parks viz., Murlen National Park, Phawngpui National Park and four wildlife sanctuaries namely, Dampa, Khawnglung, Ngengpui and Tawi wildlife sanctuary (National Wildlife Database Cell, WII. 1999).

There is no sawmill or wood-based industry in the state. Moreover, working plan have not been prepared even for reserved forest, and harvesting is done only by thinning in plantation and bamboo forest. Felling and experts permits are given for harvesting and sale from private areas. The state has extensive bamboo areas from where considerable quantity of bamboo is harvested on three years rotation for support to HPC Paper Mill near Silchar.

The forest department is reported to have raised 1.76 lakh hectares of plantations since 1958 and private individual 8130 hectares plantations, part of which have reached harvestable age. The state forestry action plan, 1995 indicates that the total requirement for housing etc. is about 1.58 lakh cubic meter in 1995, and is likely to rise to around 3.10 cu.m. in 20 years time. Similarly, fuelwood requirement was 12.62 mm. cu. m. in 1995, and likely to rise to 24.80 million cu. m. in 20 years (M.S. Swaminathan research foundation, 1998).

1.3. EXISTING LIVELIHOOD SYSTEMS IN MIZORAM HILLY ENVIRONMENTS - SHIFTING CULTIVATION :

Shifting cultivation is an agricultural practice widely prevalent and significantly practiced in Mizoram and is also known as jhum cultivation. Under this practice basically involved are selection of a piece of land, cutting down of trees or bushes partially or fully, burning of the cut down growth after allowing it to dry and there after sowing seeds in drills, made with stick, without using

plough or animal power. Such virgin lands give good crops for 1 or 2 years and thereafter, start declining, first on account of progressive degradation of naturally available fertility of a virgin soil and later due to loss of top soil through accelerated erosion. The land is abandoned after one or two years of cultivation and shifting cultivators move to a new patch and repeat the same process. After certain duration of follow period, the abandoned land rehabilitates itself with vegetative growth and becomes available for falling a similar onslaught all over again. The follow period is between 3 to 4 years in Mizoram. This depends on the total land available for shifting cultivation in a particular village or in other words, the pressure on land due to increasing needs of population of a particular village.

The local communities practice shifting cultivation in the hilly slopes over an area of about 40,000 hectares annually in different districts (Statistical abstract, Department of Agriculture and Minor Irrigation, 1997-1998). On the other hand, National Remote Sensing Agency, Hyderabad, has indicated that the area affected by shifting cultivations is about 3,76,000 ha. out of the total degraded lands of 4,07,100 ha. spread over all over the state against the total geographical area of 21,087 sq.km.

About 71.15 % of the working population involve in shifting cultivation. (Statistical abstract, Department of Agriculture and Minor irrigation, Mizoram 1997-1998) which is till today common in Mizoram and is becoming less sustainable as cultivation cycles are shortened due to population pressures. Once this cycles goes below 10-12 years it seems that it is no longer an economic form of agriculture compared to possible types of settled agriculture. A reduction in the length of Jhum cycles has a number of adverse environmental consequences. It reduces the biodiversity and increase

the rate of erosion, apart from its unfavourable economic consequences for the cultivator. As shifting cultivation is the major mode of farming, the land has become moderately productive and cause enormous social cost in the form of loss of nutrients, soil and forest lever. Even with little portion of settled farming (about 21,500 ha) it produces less than a third of the food requirement of the state (Upadhyaya and Jha, 1997). Jhumming system of farming on hill slopes without any soil and water conservation measures fails even to meet the minimum food requirement of the people who practise it (Singh and Prasad 1980). Since the major constraints to agricultural production in Jhum lands are related to soil and water productivity, the development and management of the land and water resources should become the primary objective towards the improvement of farming system.

1.4. SUSTAINABLE LIVELIHOODS SYSTEMS ALTERNATIVES :

Agroforestry, a form of planned follow lands had been suggested as a substitute for the follow lands of shifting cultivation in modern sedentary agriculture due to increasing human population pressure. In the words of King and Chandler (1978) Agro-forestry is "a sustainable land management system which increases the overall yield of land combined with the production of crops (including tree crops) and forest plants and animals simultaneously or sequentially on the same unit of land and applies management practices that are compatible with the cultural practices of the local population". Nair (1984) has defined Agro-forestry as "A landuse system that involves deliberate retention introduction or mixture of trees or other woody perennials in crops or animal production to benefit from the resultant ecological and economics intersections". Recently, ICAR (Annual report 1999-2000) has mentioned that "Agro-forestry 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 consequential on the same unit of land and at the same time meet the ecological as well as socio-economic needs of the people".

As shifting cultivation is one of the most important causes of deforestation and degradation concern about the environment and the need to stem the tide of deforestation and degradation has renewed focus on ameliorating the ill effects of shifting cultivation. Agroforestry has a potential in these areas. It may well prove to be the land use option which harmonizes the ecological considerations with the Socio-economic imperatives of the situation. Keeping these in view the experiment was conducted with multipurpose tree such as *Leucaena leucocephala* intercropped with Ginger with the objectives of maximum land use system and amelioration of basic food production problems such as soil fertility, decline, soil erosion, weed control and supply of useful products such as food, fodders, fuel-wood in Mizoram.

1.5. OBJECTIVES :

The specific objectives of the experiment were -

- (1) To study the effect of different spacing of *Leucaena leucocephala* on growth and yield attributes of intercropped Ginger.
- (2) To study the appropriate spacing of *Leucaena leucocephala* on the basis of its dynamics of growth.
- (3) To find out suitable agro-forestry models for substituting shifting cultivation.

CHAPTER - II
REVIEW OF LITERATURE

REVIEW OF LITERATURE

Intercropping in Agroforestry is a system in which crops are grown in between rows of woody shrubs, which are pruned periodically during the cropping season to prevent shading and to provide green manure and or match to the areable crops (Getahun, 1980, Kang *et al.*, 1981, Aness; 1982 Balasubramanian, 1983, Nair 1984). The largest branches are used for poles or fuelwood. In the dry season, the trees are allowed to regrow and draw nutrients from deep soil levels (Kang *et al.*, 1984) Intercropping provides greater stability of yield over different season, better use of growth resources better control over weeds, pests and diseases and surplus income to farmers (Aiyer, 1949).

Agroforestry Intercropping system is an adaptation and refinement of the bush follow system commonly practised by small scale farmers in Africa (Wilson and Kang, 1981). Encouraging results have been obtained from agroforestry intercropping studies conducted at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria (Hastman, 1981) where the practice originally acquired its name. The choice of deep rooting leguminous trees such as *Leucaena* not only lends a measure of the much needed drought resistance to the system, but also the canopy developed during the dry season could also control weeds (Kang *et al.*, 1984). Intercropping could consists of a component with high light requirement and the bottom of a component with low light requirement (Das and Chatterjee, 1976, Kundu and Chatterjee, 1981).

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

- (a) Additional income.
- (b) The undercrop and its by-products are extra yield.
- (c) Maximum land used.
- (d) Greater stability of yield over different seasons.
- (e) Better control over weeds, pests and diseases.
- (f) Better use of growth resources.
- (g) One crop provides physical support to the other crop.
- (h) Erosion control through providing continuous leaf cover over the ground surface.
- (i) It is the small farmers of limited means who is most likely to benefited.

Tree species select for agroforestry intercropping must however be easy to establish, fast growing, deep rooted, coppicious, have the ability to withstands frequent prunnings and be able to produce heavy and easily degradable foliage (Nelson and Kang, 1981).

2.2. PROPERTIES OF GINGER :

Ginger is the rhizome or root stock of herbaceous perennial *Gingiber officinale*. A native of South Eastern Asia. India is at present the largest producer of ginger in the world accounting for one third of the total world production.

It is herbaceous perennial with underground tuberous stems (rhizomes) which are used both as spice and medicine. The ariel leafy sheets are about 50 cm and the leaf blades are long and narrow. The inflorescene is normally borne on a separate stem arising directly from the rhizome. The flowers are bisexual. Pillai *et al.*, (1978) reported that flowering started in October and continued till early December, the

peak period being November. The flowers start opening at about 3 PM and anthesis occurs simultaneously. It takes about 20-25 days from initiation to full bloom and 23-28 days to complete flowering. The fruit, which is very rarely produced, is in the form of a thin walled capsule containing a number of small, black angular seeds. Ginger (*Zingiber officinale*) belongs to Zingiberaceae family.

Due to its pleasant pungent and spicy aroma ginger is used in the manufacture of a number of food products like ginger bread, confectionary, ginger-ale, curry powders, certain curried meats, tale sauce, in pickling and in manufactures of soft drink like cordials, ginger cocktail, carbinated drink etc.

The Ginger oil obtained from dry ginger powder is primarily used as a flavouring agent in confectionery, preservation and for soft drinks. Indian ginger contains about 2.5 percent volatile oil. Nowadays ginger oil can be extracted from fresh ginger also.

Dry ginger or ginger powder is used in manufacturing of ginger brandy, wine and beer in many western countries. A fine quality Oleoresin is obtained from dried powdered ginger by extraction. Ginger Oleoresin (Commercially known as Gingerin) contain about 18-20 percent 'Gingerol' which is the main pungent principle.

Ginger has basic antiseptic properties and is used as a carminative and stimulant. It is also used in veterinary medicine. (Singh and Singh.1996).

The dried rhizome of ginger is used as a spice hence the nutritive value of rhizome is given per 100g (Pruthi, 1979)

moisture	: 6.9g	sodium	: 0.03g
protein	: 8.6g	potassium	: 0.4g
fat	: 6.4g	vitamin A	: 175iu
fiber	: 5.9g	vitamin B ₁	: 0.85mg
phosphorous	: 0.15g	vitamin B ₂	: 0.13mg
iron	: 0.001g	niacin	: 1.9mg
food energy	: 380 calories	vitamin C	: 12.0mg

Sreekumar *et al.*, (1980) evaluated 30 ginger varieties for qualitative attributes and conducted that crude fibre content varied from 3.5 percent in variety Tura to 6 percent in variety Jorhat. Their findings showed that varieties having high dry ginger recovery had low fibre content and vice-versa. Oleoresin content varied widely among the types ranging from 3.0 percent in variety Poona to 10.8 percent in Rio-de-Janerio. Oil content of recently released varieties viz. Suprabha, Suruchi and Surabhi varies from 1.9 to 2.1 percent (Edison, 1991).

The yield of ginger depends upon varieties, agroclimatic condition, care and management of cup. Nair *et al.*, (1978) studied the performance of eleven (11) varieties and concluded that Nadia gave highest yield of green ginger (4933.5 kg/ha) and dry ginger (1021 kg/ha). The yield of dry ginger was highest from Wynad region as compared to that of volatile oil from Kalimpong and Oleoresin from the Nilgirs (Krishnamurthy *et al.*, 1977). Panigrahi and Patra (1985) reported 220 q/ha in Thingpui and 229.5 q/ha in PGS -35 variety under Orissa condition. Mohanty *et al.*, (1981) recorded highest yield with varieties Rio-de-Janerio and China (239 g/Plant) in a varietal trial with twenty eight varieties. The survey of dry ginger varies from 20-22 percent.

In 1989-1990, India produced 1,56,120 tonnes ginger on an area of 53,000 hectares giving a yield of 2,883 kg per hectare. In 1992-1993 production is 1,60,000 M.T (Spice board, 97). In Mizoram during 1998-99 ginger production is 23128 M.T on an area of 4864 hectares and In 1999 - 2000 production is 16189 M.T on an area of 3405 hectares (Statistical abstract Department of Horticulture. 1999-2000).

2.1. PROPERTIES OF *LEUCAENA LEUCOCEPHALA* :

Leucaena leucocephala discovered by Prof. James Brewbeaker of the University of Hawaii in 1960 and tried in the Philippines grows a metre a year. It has been chemically found to be a good species for quality paper and also can be used as firewood and charcoal. It is a source of protein rich fodder which can restore the confidence of million of dairy formers in dry areas. Its nitrogenous rich foliage can be an effective source of improving the degraded soil, It has a unique role to play in preventing soil erosion.

It has a high fuel value. In two years, the plants acquire height of 9 to 10 metres with a girth or diameter of 6cm at breast height. Each plant yields around 6 kg straight thick wood and 1.5 kg then top wood and branches. The field per hectare is about 75 tonnes. The stubbles should, however, be cut 15 to 20 cm from the ground level for good regeneration ever year.

It also yields good quality timber, solid strong wood becomes available after five to six years. For forest plantation, 10 to 12 months old seedlings/saplings raised in polythene bags should be used. The trees reach a height of 15 to 16 metres with a girth/diameter of 25 to 30

cms at breast height. The wood has a density of 0.75 and can be used for girders, thick poles and posts.

The experimental evidences showed that *Leucaena leucocephala* inter cropped with agricultural crops and fodder grasses increases total field of food grains, fodder fuelwood and enrich the soil (Solanki and Ram Newaj, 1997). Besides, it helps break impervious subsoil layer, improve water percolation and prevent surface runoff (Anon, 1980, Nair, 1984). *Leucaena* is a deep rooted plant, with an aggressive top root that can penetrate deep into the soil and thus enable the plant to withstand drought (Jiang, 1982)

Leucaena leucocephala is small to medium sized tree up to 10m in height. It has brownish has brownish bark, leathery leaves, small, whitish 'powder puff' flowers and bunches of straight, flat, brown pods. The pods are typically 10-15 cm long, 1-2 cm wide. Seeds are dark brown with hard test (Jha, 1995). It forms symbiotic relationship with *Rhizobium loti*, the nitrogen fixing bacteria (Halliday and Somasegaran, 1983). The *Rhizobium* penetrate young rootlets and multiply to form nodules. The nodules usually occur on rootlets in the aerated surface soil layers.

Leucaena coppices well and it can coppice on a yearly rotation for more than 30 years in humid zones (Meelink, 1989). It coppicing ability allows repeated harvests for firewood, timber and foliage (Brewbaker, 1984). Pathak *et al.*, (1982) reported that the coppice shoot growth in 1.5 years has been found to be equal to the original 3 years growth of trees thus indicating high coppice growth potentiality and forage yield in this plant. Coppice growth is much more vigorous than seedling growth because the new shoots are served

by a well developed root system. *Leucaena* has many advantages such as, leached plant nutrients are recycled from sub soil, provide biologically fixed nitrogen to the companion crop, provide favourable conditions for soil macro and micro-organisms, provide prunnings, applied as mulch, and shade during the fallow period to suppress weeds, protect soil against erosion and provide fuelwood, fodder and its seeds are often used as human food (Ngambeki and Wilson, 1983).

2.3 EFFECT OF SPACING IN AGRO-FORESTRY :

Different spacing treatments can also have a great influence on the growth and Biomass production when tested on *Leucaena leucocephala* (Gupta *et al.*, 1996) with particular reference to survival percentage, dry matter percentage, basal diameter, height, weight of fresh leaves and wood and production of dry leaves and wood. Jha *et al.*, (1990) reported that *Melia azadirach* as best combination for Niger because at 2 x 2m spacing it gives slightly less yield than in combination of *Tectona grandis* which is planted at 4 x 4m spacing. Nada gaudar (1989), Shannan *et al.*, (1990), Zainalo (1990), also reported appropriate spacing between trees as per their silviculture requirement favours growth of the trees as well as productivity of the crop spacing trials were also conducted in various lingo growing areas and it was conducted that a closer spacing of 20cm and 35cm between rows and 15 to 20cm within rows are optimum (Singh, 1996).

Owadally *et al.*, (1982) recommended 38.1 x 38.1cm spacing for rainfed crop for a plant population of 60,000 /ha. Ginger intercropping with perennial crops such as citrus, coconuts, black-pepper and coffee can make the use of marginal land economic (Hebbax, 1977 and Nayar, 1976).

Randhawa *et al.*, (1972) reported that, when ginger was planted at 12 spacing ranging from 15 x 20 to 30 x 50cm. The highest yields resulted from 20 x 20 cm and 20 x 30 cm spacing. Large rhizomes (150 gm with 4-6 buds) gave higher yields than small ones (60g, with 2 buds).

Singh and Prasad (1989) also reported, results of intercropping study in *Leucaena* with annual cereal and legumes. The observation revealed that narrow spacing (2 x 1m) of *Leucaena* performed better over the wider spacing (3 x 1m) in total green as well as dry matter yield. Teosinip, Jowar and maize in association with cowpea sown as intercrops between subabul line (2 x 1m) gave on an average maximum green foliage yield (2.36 - 22.6 tonnes /ha).

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

Singh *et al.*, (1990) also reported that tree species (Eucalyptus) when grown at different spacing effect the yield of wheat and paddy. The yield of wheat was highest at 5-10m distance from the tree and lowest at 0-1m distance. Paddy yield was also highest at 5-10m distance and lowest at 0-1m distance at 10 years average.

Performance of two rhizomatous crops i.e. Ginger and Turmeric was studied by Jaswal *et al.*, (1993) under rainfed conditions in pure stands and as intercrops with 5-years old poplars planted at three spacings viz. 5 x 5m, 5 x 4m and 5 x 3m. The average illumination

below the canopies was 53, 46 and 38 % of incident radiation respectively. Both crops performed better as intercrops than as pure stands. Survival was inversely correlated to light intensity. Plant height, tillers per plant and leaves per plant in Ginger and leaf length and leaf breadth besides plant height in turmeric were significantly enhanced when intercropped. The rhizome length, rhizome breadth, yield per plant and yield per ha. in ginger exceeded under poplars but showed a drastic reduction under the closest poplar spacing. In turmeric, the trend for the first two characters was the same, whereas yield per plant as well as yield per ha. were slightly greater in the open than under 5 x 3 m spacing. Dry matter content varied significantly with spacing.

2.4. SOIL IMPROVEMENT BY LEUCAENA :

Leucaena is ideally suited for Agroforestry system. In Agroforestry system tree foliage are cut and utilised as green manure. The nutrient are released from prunnings. Pathak and Gupta (1987) studied organic matter addition through leaf litter in 2 years old leucaena plantation to be 5.6 t/ha. annually, which improved tilth, cation exchange capacity, water holding capacity, bulk density, brings down soil pH from alkaline to normal and improved the field of successive crops.

Leucaena plantation on Calcareous wasted lands with pH 9.5, after 4 years reduced the soil pH upto 8.0, besides, increasing soil organic matter and enrichment of major nutrients (Pathak, 1997).

In some parts of Asia, Leucaena and *Sesbania grandiflora* are among legumes recognised as efficient soil fertility restorers (Guevarra, 1976, Anon, 1977). Gil *et al.*, (1982) investigated the effect of leucaena foliage as source of green manure. The results

demonstrated the usefulness of leucaena foliage as a source of green manure 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 soils properties - increasing aeration, water retention, and cation exchange capacity. An experiment on soil nutrient changes under *Leucaena leucacephala* in different planting durations-Immediate (1 year), short term (3 years), Mid term (9years), long term (45years) Plantings, showed that available Nitrogen, Phosphorus and Potassium levels increased with time 11%, 8% and 24 % under short term and 33 %, 42 % and 27 % under mid-term duration respectively (Jha *et al.*, 1991).

Hauser and Kang (1992) reported that six years of alley cropping with *Leucaena leucacephala*, the organic carbon level in the surface soil declined to a very low level in the control (No tree) treatment (0.57 %C), as compared with alley cropping Plot (0.94% C). High soil organic Carbon level was, however, maintained under the *Leucaena leucocephala* hedgerow (91.23 %C).

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

Besides GLM, biological nitrogen fixation (BNF) is yet another important attribute of *Leucaena*. Under favourable year-around growing conditions, nitrogen fixation rates as high as 500-600 kg/ha/yr. have been measured (Guevarra, 1976) in Hawaii. However, lower yields of 100-200 kg/N/ha/year (equivalent to 50-100 kg Ammonium Phosphate/ha/year) have similarly been measured (Halliday, 1984) in Hawaii.

CHAPTER - III

MATERIALS AND METHODS

MATERIALS AND METHODS

During 1999-2000 one field experiment was conducted at Zemabawk, Aizawl, Mizoram. The experiment was based on Agroforestry intercropping system with a view to find suitable alternative to shifting cultivation which is a major mode of cultivation and is unproductive and very harmful way of cultivation. The aim of this experiment was to study "Effect of different spacings on the growth behaviour of *Leucaena leucocephala* (Lam.) de wit and its effect on *Gingiber officinale* Rose. productivity in an Agroforestry system of Mizoram".

3.1. EXPERIMENTAL SITE AND SOIL :

The study was conducted at Zemabawk which is situated at the North part of Aizawl town and is about 3km North of Aizawl the capital of Mizoram. Zemabawk lies in between 92° 15' to 93° 29' E Longitude and 21°58' to 24° 35' N latitude with an altitude of 1132 metres ie. 3715 feet, with an average rainfall of 235 cm Summer temperature varies from 21° to 30°C where as the winter temperature varies from 11° to 23°C

The texture of the soil in the experimental area, before sowing of Ginger was analysed in soil testing Laboratory, Department of Agriculture and minor Irrigation. Government of Mizoram and was found to be sandy clay having 61.9 % sand, 7.20% silt and 30.84% clay with an average pH value of 5.34.

Plate No. 1



Plate No.2.



Plate No. 1 & 2 : One year old *Leucaena leucocephala* before sowing of Ginger.

3.2. EXPERIMENTAL DESIGN AND TREATMENTS :

The experiment was carried out following Randomised Block Design (RBD) with three replications. Four treatments were allocated in each replication. As such there were 12 treatments in the field experiment i.e. 12 plots including control. The size of each plot measured 12m x 12m therefore, the entire field was 36m x 36m. One year old *Leucaena leuccephala* (subabul) was used for the treatment and they are of different spacing. In the first block spacing is 6m x 6m and in the second block spacing is 3m x 3m and in the third block spacing is 4m x 4m which were replicated three (3) times. Altogether there were 87 number of plants. These were intercropped with Ginger (*Zingiber officinale* Rose.) and there were three control plots of Ginger alone (25cm x 25cm) randomised within overall layout.

Ginger (variety-Nadia) was taken as intercrop and was sown at 25cm x 25cm, in mid April.

3.3. FIELD LAYOUT :

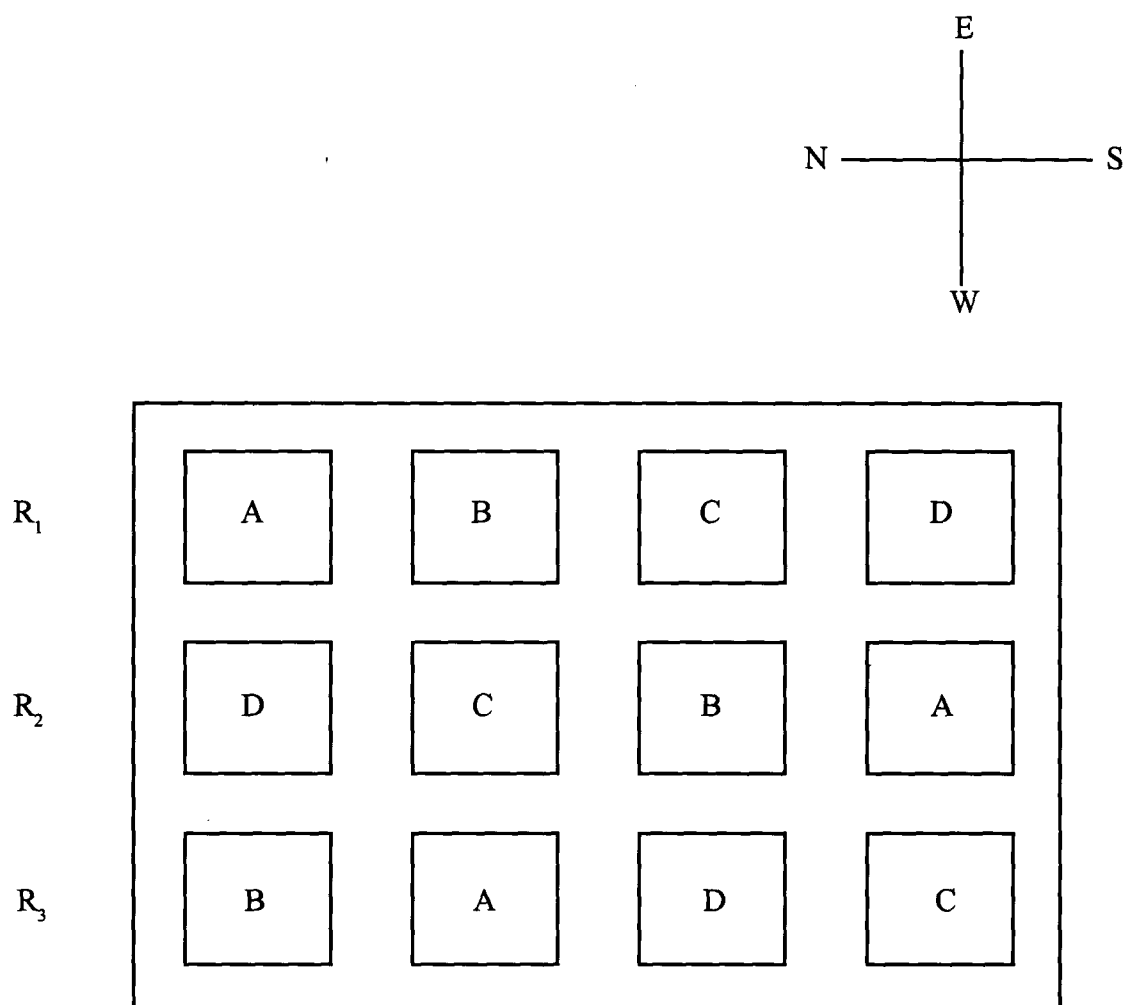


FIG.1 : PLAN OF LAYOUT OF THE EXPERIMENT DESIGN - RANDOMISED BLOCK

TOTAL EXPERIMENTAL AREA - 48m x 36 m

PLOT SIZE - 12m x 12 m

TREATMENTS :-

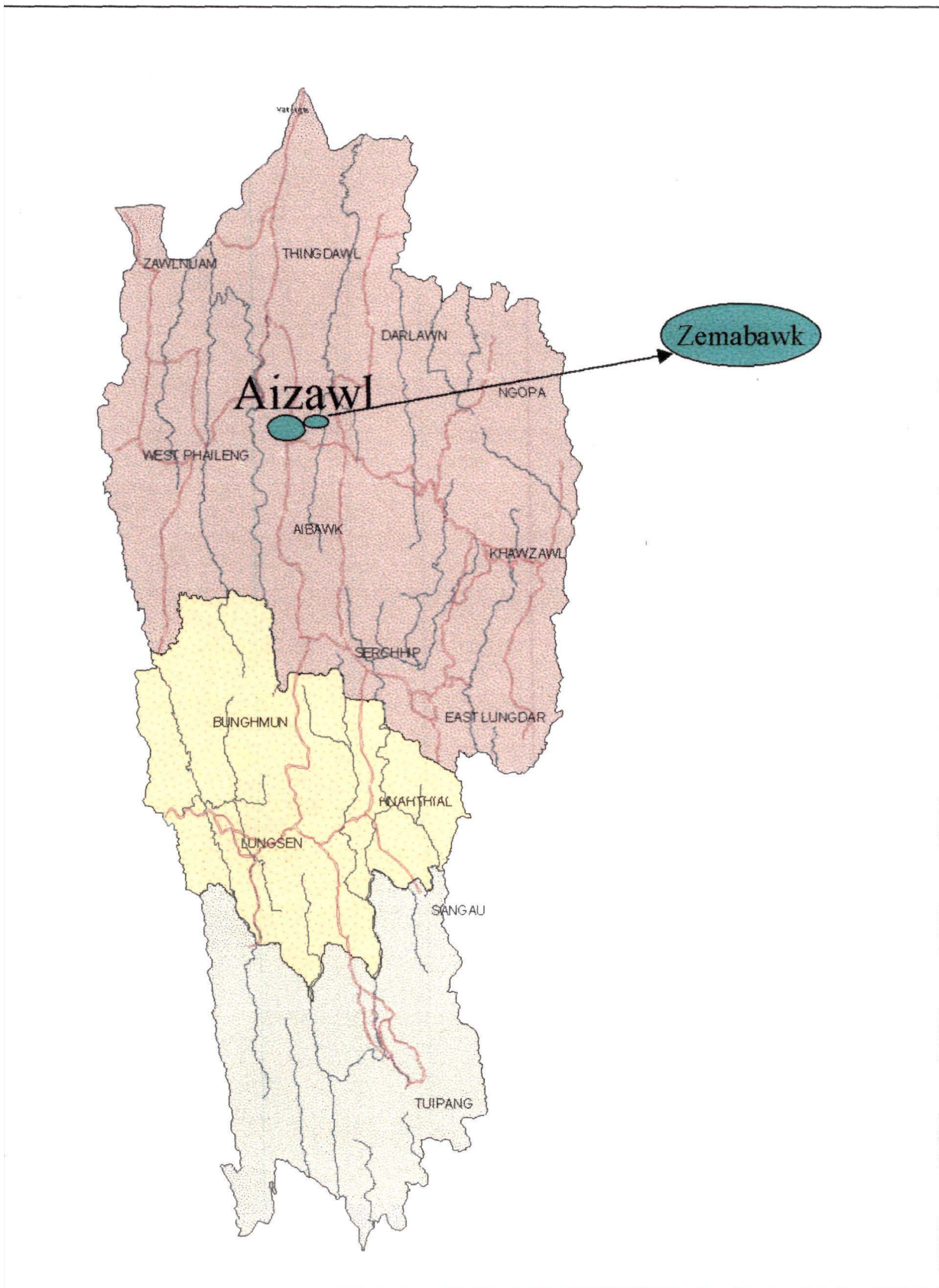
A = Leucaena (6m x 6m) + Ginger (25cm x 25cm)

B = Leucaena (3m x 3m) + Ginger (25cm x 25cm)

C = Leucaena (4m x 4m) + Ginger (25cm x 25cm)

D = Control (Ginger alone 25cm x 25cm)

Fig - II Location Map of Experimental Site.



3.4. DETERMINATION OF CHEMICAL CHARACTERISTICS OF SOIL :

To determine the chemical status of soil the soil samples of the experimental site was analysed for pH, organic carbon and available P and K contents.

3.4.1. pH :

The pH of the soil was determined in 1:2 soil water suspension using digital pH meter.

3.4.2. Organic Carbon :

Organic carbon was determined by Walkley and Black rapid titration method as described by Piper (1966) and the result were expressed in terms of percentage.

3.4.3. Available Phosphorus :

The available soil Phosphorous (P) was extracted with 50.5m sodium bicarbonate solution adjusted at pH 8.5 (Olsen *et al.*, 1954) and was then determined by Stannous Chloride reduced ammonium molybdate method in Hcl system (Jacksen, 1979).

3.4.4 : Available Potassium :

Available Potassium (K) was extracted from 5 gm of soil by shaking with 100ml of 1N ammonium acetate solution for half an hour and then the extracted was filtered (Merwin and Peech, 1951).

Potassium content was determined with the help of flame photometer.

3.5. PARAMETER COLLECTED :

3.5.1. Parameters Collected on Ginger crop.

(1) Plant height :

Observation on the height of the Plant was started at 75 days after planting and continued upto 198 days at an interval of 30 days. The height of the plant was measured from the ground level to the terminal unfolded leaf and the mean values were calculated in terms of Centimeters.

(2) Number of leaves/Plant :

The fully opened leaves of tagged plants from each plot were counted in each plant and their average values were estimated.

(3) Number of tillers/clump :

Number of tillers from tagged Plants were recorded at 75 days after planting and continued till harvest at regular interval of 30 days.

(4) Yield :

The fresh weight of the rhizome from the five selected plants were recorded at the time of harvesting and the result thus obtained were represented in grams (gm).

3.5.2. Parameters collected on Leucaena :

1) Tree heights :

Tree heights were taken from the bottom to the tip of the tallest branch using metre scale at Monthly interval.

2) Diameters of tree :

The diameter was taken from the breast of the tree above one inch from the ground level with the help of thread which was again measured with a metre scale.

3) Biomass production :

Shoot dry weight was measured one year after transplanting and after harvesting Ginger.

3.6. METHOD OF STATISTICAL ANALYSIS :

The experiment was laid out under Randomised Block Design. The data recorded during the course of investigation were analysed by the analysis of variance method (Cochran and COX, 1965, Panse and Sukhatme, 1978) and the significance of difference sources of variation were tested by error mean square using Fisher Shedecor 'F' Test of probability at 0.05 percent level of significance. The results have also been represented graphically whenever considered necessary.

CHAPTER - IV

EXPERIMENTAL FINDINGS

EXPERIMENTAL FINDINGS

In this chapter an attempt has been made to present the entire findings obtained during experimentation, which have been arrived after subjecting the data to a statistical analysis and interpretation. The data are presented in tables and illustrations for clear and easy understanding.

4.1 HEIGHT OF GINGER :

The pattern of growth in height of ginger plant in a leucaena and ginger combination is reflected in table 1. and Fig. 3.

4.1.1. First stage :

It is evident from table 1 that there was a significant difference in ginger plant height (cm) at 75 days after planting under different spacings of leucaena. maximum height of ginger plant was recorded (9.52 cm) in treatment A (6m x 6m) leucaena spacing and minimum plant height (5.40 cm) in control plots. Height of ginger plant at 6m x 6m leucaena spacing and 3m x 3m leucaena spacing were highly significant over control. However, height of ginger plant at 4m x 4m leucaena spacing shows significant as compared to control.

4.1.2. Second stage :

It can be seen from table 1 that ginger plant height at 105 days of planting ranged from 8-15 cm. The effect of different treatments on plant height differs significantly over control at 105 days after planting. It would be seen from the data that maximum height was recorded at 6m x 6m leucaena spacing (14.32 cm) and minimum plant height was recorded (8.4 cm) in control.

Table 1 : Height of ginger (cm) as affected by different spacings of *Leucaena leucocephala*.

Treatment (Tree spacing in m)	Days after planting				
	75	105	135	165	195
A (6m x 6m)	9.52	14.32	17.61	19.95	23.70
B (3m x 3m)	9.08	12.42	14.32	18.80	22.10
C (4m x 4m)	7.89	10.73	13.77	17.62	20.72
D (Control)	5.40	8.40	11.84	15.97	17.97
SEm \pm	0.23	0.50	0.47	0.51	0.51
CD at 5%	1.04	2.23	2.13	2.28	2.30

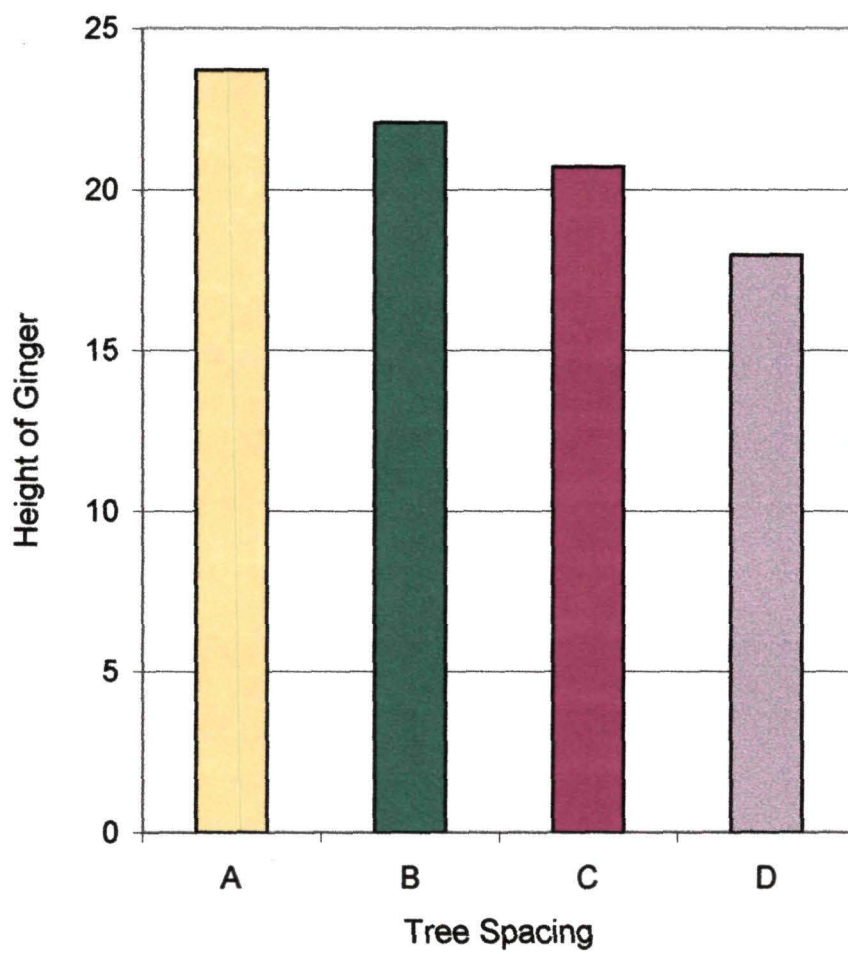


Fig. 3 : Height of Ginger (cm) as affected by Different spacings of *Leucaena leucocephala* at 195 days after planting

4.1.3. Third stage :

It would also be seen from table 1 that the mean effect on ginger plant height by different leucaena spacings ranged from 11-18 cm. The effect of different treatments on plant height of ginger exhibited a significant influence over control at 135 days after planting. It would be seen from the data that maximum height (17.61cm) was recorded with treatment A (6m x 6m) and minimum plant height (11.84 cm) was recorded in control. Treatment A (6m x 6m) was highly significant over the rest of the treatment. Whereas, 3m x 3m leucaena spacing (14.32 cm) and 4m x 4m leucaena spacing (13.77 cm) were significant as compared to control (11.84 cm).

4.1.4. Fourth Stage :

It can be seen from table 1 that after 165 days of planting, different spacings of leucaena shows significant difference in ginger plant height. It would be evident from the table that mean maximum height of ginger (19.94 cm) was observed in treatment A (6m x 6m) and minimum height of ginger (15.97 cm) was recorded in control plots. However, 4m x 4m leucaena spacing (17.62 cm) was non-significant over control (15.97 cm). Treatment A (6m x 6m) and treatment B (3m x 3m) were highly significant over control (i.e., treatment B).

4.1.5. Fifth Stage :

It would also be seen from table 1 that the mean effect on ginger plant height by different leucaena spacing exhibited a significant influence over control at 195 days after planting. It would be seen from the data that maximum height of ginger (23.7 cm) was recorded at 6m x 6m leucaena spacing (i.e., treatment A) and minimum height of ginger (17.97 cm) was recorded in control plots.

4.2. NUMBER OF TILLERS PER CLUMP :

The effect of different leucaena spacings on number of tillers per clump of ginger at various stages of growth are presented in table 2, Fig. 4.

4.2.1. First Stage :

It can be seen from table 2 that number of tillers per clump of ginger after 75 days of Planting, there was no appreciable impact of various spacings of leucaena in number of tillers per clump of ginger (Table.2). However, it would be seen from the data that maximum number (0.73 nos.) of tillers per clump of ginger was recorded with treatment A (6m x 6m) and minimum number were recorded with Control (0.4 nos). At this stage of growth the various treatment failed to bring any significant effect on the number of tillers per clump of ginger.

4.2.2. Second Stage :

It is evident from table 2 that there was a significant difference in number of tillers per clump of ginger at 105 days after planting under different spacings of leucaena . Maximum number of tillers per clump of ginger (1.13) were recorded with Treatment A (6m x 6m) and minimum number of tillers per clump were recorded with Control (0.66). 6m x 6m leucaena spacings (1.13) was highly significant over the rest of treatments, 4m x 4m (0.86) was also significant when compared with Control but 3m x 3m (0.8) was non-significant over Control (0.66).

4.2.3 Third Stage :

It can be seen from table 2 that after 135 days of planting different spacings of leucaena shows no significant difference in number of tillers

Table 2 : Number of tillers per clump of ginger as affected by different spacings of *Leucaena leucocephala*.

Treatment (Tree spacing in m)	Days after planting				
	75	105	135	165	195
A (6m x 6m)	0.73	1.13	1.46	2.20	2.80
B (3m x 3m)	0.53	0.80	1.33	1.93	2.60
C (4m x 4m)	0.60	0.86	1.40	1.93	2.46
D (Control)	0.40	0.66	1.06	1.60	2.26
SEm \pm	0.08	0.05	0.10	0.16	0.14
CD at 5%	NS	0.25	NS	NS	NS

NS = Non-significant.

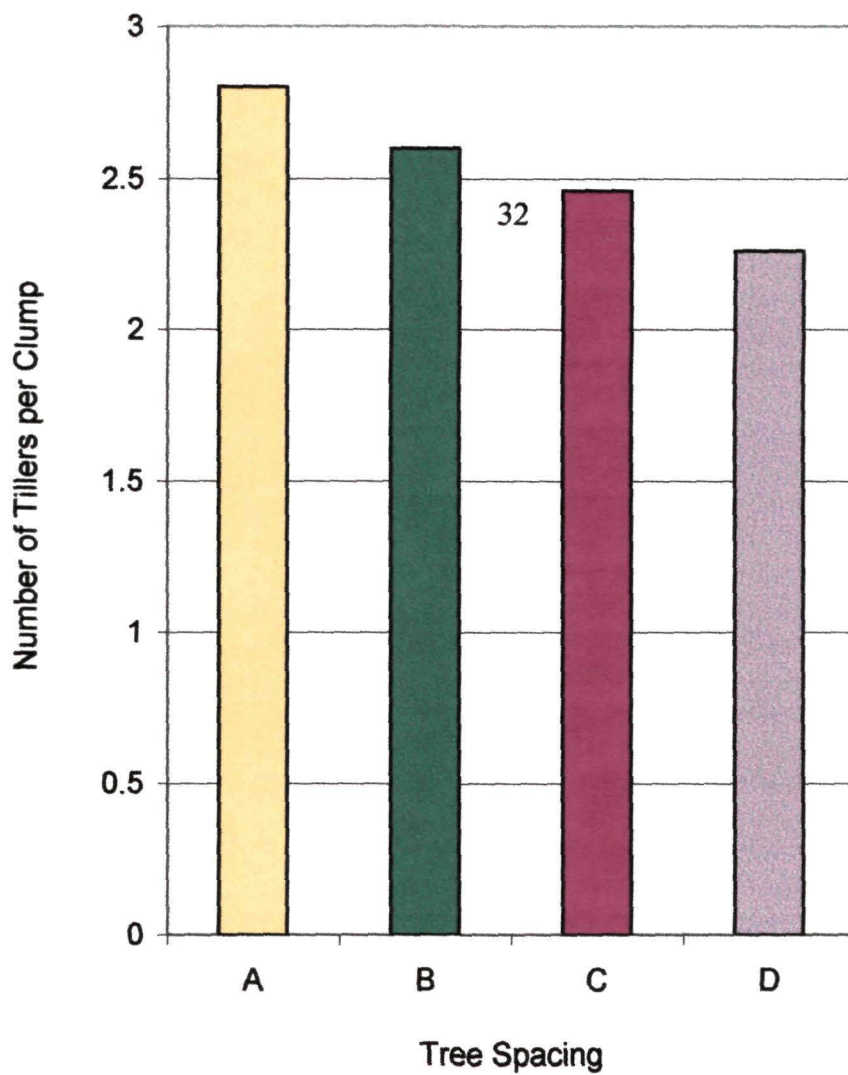


Fig. 4 : Number of Tillers per clump as affected by Different spacing *Leucaena leucocephala* at 195 days after planting

per clump of ginger. It would be seen from the table that the mean number of tillers per clump of ginger ranged from 1 to 2 in which maximum number of tillers per clump of ginger (1.46 nos.) were found in treatment A (6m x 6m), followed by 4m x 4m (1.4 nos.), 3m x 3m (1.33 nos.) and Control (1.06 nos.).

4.2.4. Fourth Stage :

It would also be seen from table 2 that the effect of different treatments after 165 days of planting show no significant variation in number of tillers per clump of ginger under different spacing of leucaena. However, it would be evident from the table that maximum number of number of tillers per clump were recorded with 6m x 6m (2.2 nos.) and minimum number were recorded with Control (1.6 nos.).

4.2.5. Fifth Stage :

It would also be seen from table 2 that the mean effect on number of tillers per clump of ginger exhibited no appreciable impact of various treatments of leucaena in number of tillers per clump of ginger plant at 195 days after planting. It would be seen from the data that the mean number of tillers per clump ranged from 2 to 3 in which maximum numbers of tillers per clump (2.8 nos.) were found in 6m x 6m, followed by 3m x 3m (2.6 nos.), 6m x 6m (2.46 nos.) and control (2.26 nos.). The various spacing of leucaena failed to bring any significant effect on the number of tillers per clump at this stage of growth.

Plate No. 3



Plate No. 4

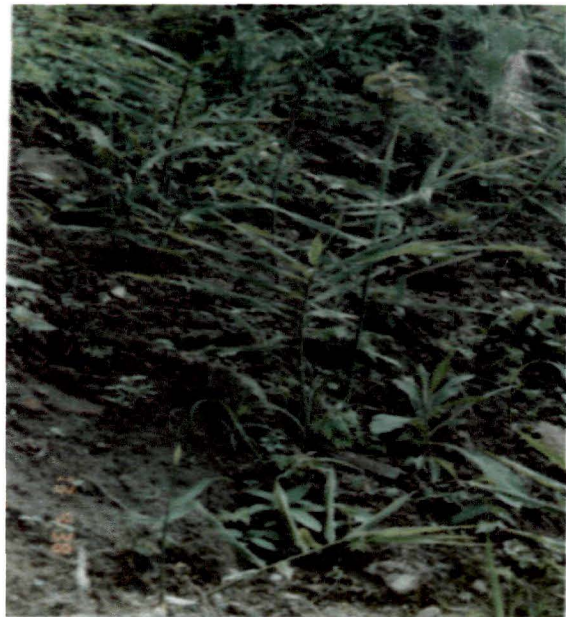


Plate No. 3 & 4 : Ginger + *Leucaena leucocephala*

4.3. NUMBER OF GINGER LEAVES PER PLANT :

The results on number of ginger leaves per plant affected by different leucaena spacings are presented in table 3 and Fig. 5.

4.3.1. First Stage :

It is evident from table 3 that there was no significant difference in number of ginger leaves per plant under different spacings of leucaena. However, maximum number of leaves per plant were recorded (2.33 nos.) with Treatment A (6m x 6m) and minimum number were recorded with control (1.4 nos.).

4.3.2 Second Stage :

It can be seen from table 3 that after 105 days of planting there was significant difference in number of ginger leaves per Plant under different spacings of leucaena . Maximum number of ginger leaves were recorded in (4 nos.) in 6m x6m leucaena spacing and minimum number were recorded with control (1.93 nos).The effect of treatments A (6m x 6m) on number of ginger leaves per plant was highly significant over other treatments as compared to Treatment D (control).

4.3.3. Third Stage :

It can be seen from table 3 that the number of ginger leaves per plant after 135 days of planting ranged from 5 to 8. The effect of different treatments on number of leaves per plant differ significantly. It would be seen from the data that maximum number were recorded (7.53 nos.) with 6m x 6m leucaena spacing and followed

Table 3 : Number of ginger leaves per plant as affected by different spacings of *Leucaena leucocephala*.

Treatment (Tree spacing in m)	Days after planting				
	75	105	135	165	195
A (6m x 6m)	2.33	4.00	7.53	7.86	8.33
B (3m x 3m)	2.00	2.93	6.93	7.40	8.40
C (4m x 4m)	1.93	2.33	5.66	6.73	7.20
D (Control)	1.40	1.93	5.53	6.60	7.00
SEm \pm	0.34	0.29	0.35	0.19	0.20
CD at 5%	NS	1.01	1.21	0.66	0.69

NS = Non-significant.

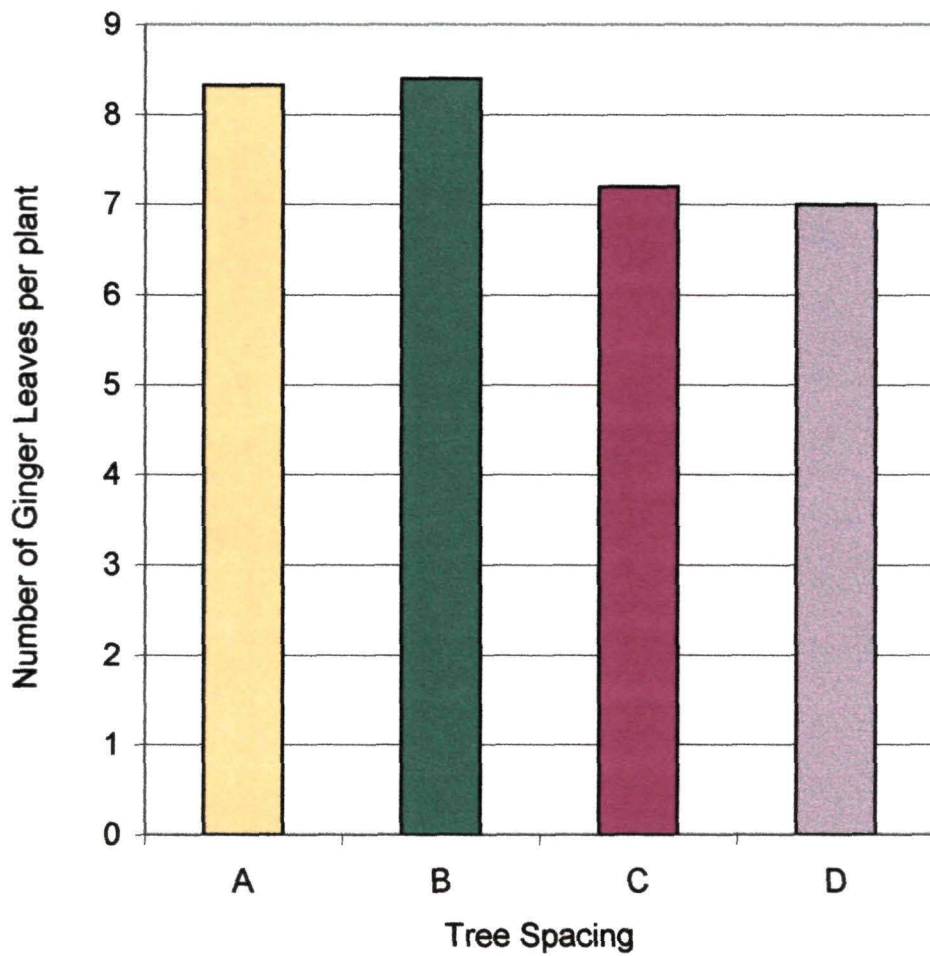


Fig. 5 : Number of Ginger Leaves per Plant as affected by Different spacings of *Leucaena leucocephala* at 195 days after planting

by 3m x 3m (6.93 nos.), 4m x 4m (5.66 nos.) and Control (5.53 nos.). Number of leaves per plant at 6m x 6m (7.53 nos.) was highly significant over the other treatments and 3m x 3m (6.93 nos.) when compared to Treatment D (Control) was significant and 4m x 4m (5.66 nos.) was non-significant when compared to Control (5.53 nos.).

4.3.4. Fourth Stage :

It can be seen from table 3 that, after 165 days of planting significant difference in number of leaves per plant of ginger under different spacings of leucaena were observed. Highest number of leaves were recorded (7.86 nos.) in 6m x 6m leucaena spacing, and lowest number of leaves was recorded (6.6 nos.) in control. However, 6m x 6m (7.86 nos.) leucaena and 3m x 3m (7.4 nos.) were highly significant as compared to Control (6.6 nos.) and 4m x 4m (6.73 nos.) does not show any difference when compared with Control (6.6 nos.).

4.3.5. Fifth Stage :

It would also be seen from table 3 that there was a significant influence on the number of leaves per plant of ginger under different spacings of leucaena after 195 days of planting . It would be seen from the data that highest number of leaves were recorded with 6m x 6m leucaena spacing (8.33 nos.) and lowest of ginger number of leaves was recorded with Control (7 nos.).

6m x 6m (8.33 nos.) leucaena spacing and 3m x 3m (8.4 nos.) were highly significant as compared to control (7 nos.). However, 4m x 4m (7.2 nos.) does not show any significant difference when compared with Control (7 nos.).

4.4. YIELD OF GINGER (g) :

The ginger planted on April as an intercrop between different spacings of leucaena was harvested on October and the yield of tubers/g/plot are shown in table 4 Fig.6. It may be seen from the table that there was significant influence of leucaena spacing on the yield of ginger. Maximum tuber yield 29.33 g/plot was recorded in 6m x 6m spacing followed by 27.4 g/plot in 3m x 3m, 26.46 g/plot in 4m x 4m and 24.06g/plot in control, when compared with control (i.e treatment D) all the treatments show significant influence on the yield of ginger.

4.5. Height of *Leucaena leucocephala* (cm) :

The result pertaining the height of leucaena plants as affected by different spacings at monthly interval are presented in table 4, Fig 8. It can be seen from the results that the variation in leucaena plant height as affected by different spacings under agro forestry system was found to be significant from October, 1999 to June, 2000. Within these period maximum height was recorded in 3m x 3m (316.6 cm) which was followed by 4m x 4m (310.2 cm) and the least being 6m x 6m plot (287.4 cm), within these period 3m x 3m spacing was highly significant as compared to the rest of treatments, where as 4m x 4m was significant as compared to 6mx6m spacing. However, in the month of May and June, 2000 both 3m x 3m spacing and 4m x 4m spacing were highly significant as compared to 6m x 6m spacing.

The plant height in July to September, 2000 show no appreciable effect on the height of leucaena by different treatments. However, within these period maximum plant height (359.2cm) was recorded with 3m x 3m spacing followed by 4m x 4m (353.2 cm) and 6m x 6m (340.8cm).

Table 4 : Yield of ginger (gm) per plot as affected by different spacings of *Leucaena leucocephala*.

Treatment (Tree spacing in m)	Yield (gm) per plot
A (6m x 6m)	29.33
B (3m x 3m)	27.40
C (4m x 4m)	26.46
D (Control)	24.06
SEm \pm	0.60
CD at 5%	2.08

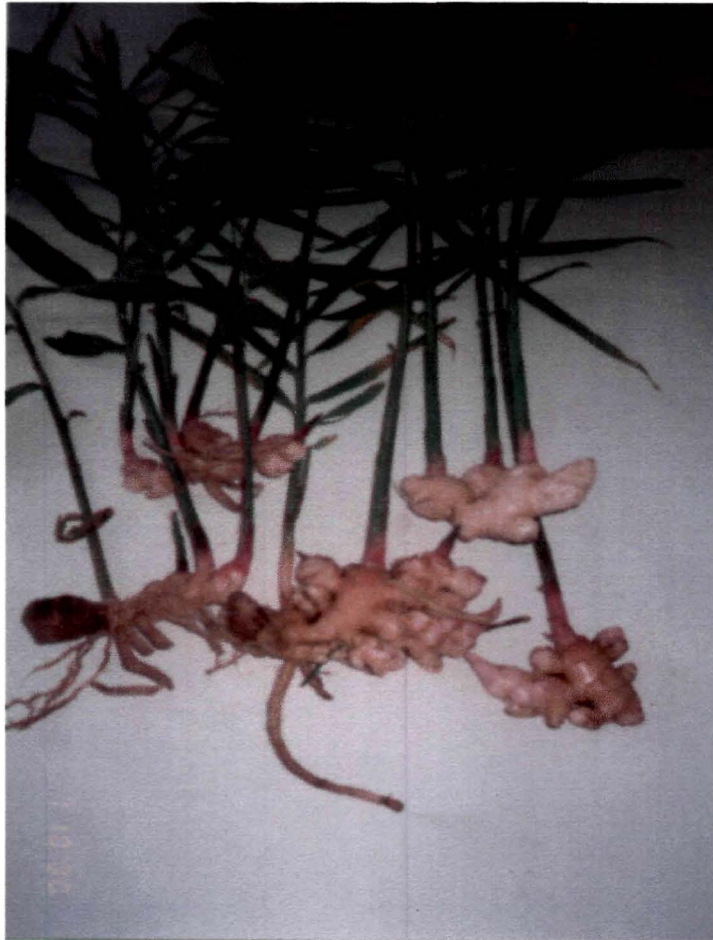


Plate No. 5 : Ginger Rhizome after harvest

Table 5 : Height (cm) of *Leucaena leucocephala* as affected by different spacings.

Treatment (Tree spacing) in m	1999			2000								
	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug	Sept
A (6m x 6m)	151.18	153.3	154.42	158.5	164.44	173.96	186.92	220.2	287.4	315.2	330.2	340.8
B (3m x 3m)	213.46	215.08	215.78	219.82	225.2	229.6	236.2	257.6	316.6	336.4	348.6	359.2
C (4m x 4m)	190.26	192.14	192.8	198.5	204.62	210.3	217.26	243.0	310.2	326.8	343.6	353.2
SEm \pm	5.15	4.89	5.33	4.88	4.45	4.79	4.75	4.30	5.30	9.41	6.75	5.67
CD at 5%	27.28	25.94	28.25	25.90	23.59	25.38	25.20	22.83	28.12	NS	NS	NS

NS = Non-significant.

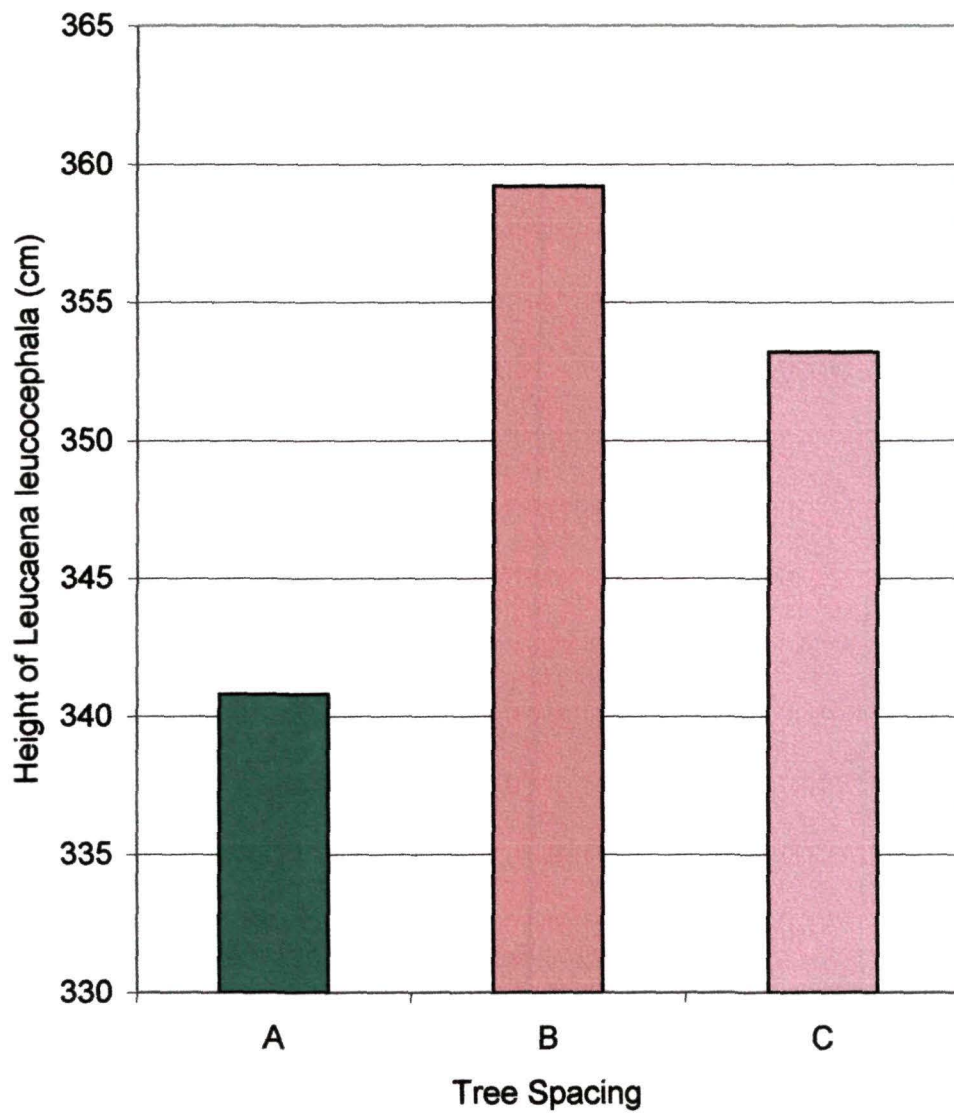


Fig. 8 : Height of *Leucaena leucocephala* (cm) as affected by different Spacing

4.6. BASAL DIAMETER (cm) of *Leucaena leucocephala* :

Leucaena basal diameter was measured at monthly interval in the experimental field, the effect of spacings at monthly interval under agroforestry system from October, 1999 to September, 2000 has been presented in table 6. A perusal of the results indicated that the basal diameter of plant vary significantly due to spacing, where as in October and December, 1999 the effect of treatments on basal diameter was found to be non-significant.

In November, 1999 leucaena basal diameter ranged from 2 to 3 cm which was found to be significant. Maximum basal diameter was observed in 6m x 6m spacing (2.54cm) which was highly significant over the rest of treatments. However, in 3m x 3m (2.29 cm) and 4m x 4m (2.10 cm) were found statistically at par with each other.

From January to September, 2000 another significant difference were observed on leucaena basal diameter. In January, 2000 6m x 6m spacing and 3m x 3m spacing were significant over 4m x 4m spacing, maximum basal diameter was recorded in 6m x 6m spacing (2.71 cm) and followed by 3m x 3m (2.55 cm) and the least basal diameter was recorded in 4m x 4m spacing. From February to June, 2000 leucaena basal diameter was found to be significant. Maximum basal diameter was observed in 6m x 6m spacing (3.14 cm) which was highly significant over the rest of treatments and 3m x 3m spacing (3.06 cm) was found to be non-significant as compared to 4m x 4m spacing (2.67 cm). Another significant difference due to treatments on leucaena basal diameter was observed in July to September, 2000. Maximum basal diameter was recorded in 3m x 3m spacing (3.26 cm) and followed by 6m x 6m spacing (3.25 cm) and the least basal diameter was recorded in 4m x 4m spacing (2.95 cm) and 6m x 6m spacing and 3m x 3m spacing were found to be significant as compared to 4m x 4m spacing.

Table 6 : Basal diameter (cm) of *Leucaena leucocephala* as affected by different spacings.

Treatment (Tree spacing in m)	1999			2000								
	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug	Sept
A (6m x 6m)	1.76	2.54	2.68	2.71	2.73	2.78	2.88	3.03	3.14	3.18	3.21	3.25
B (3m x 3m)	1.69	2.29	2.54	2.55	2.58	2.62	2.65	2.73	2.86	3.06	3.13	3.26
C (4m x 4m)	1.48	2.10	2.35	2.44	2.51	2.55	2.57	2.61	2.67	2.76	2.89	2.95
SEm ±	0.04	0.05	0.06	0.01	0.02	0.02	0.03	0.04	0.05	0.05	0.04	0.05
CD at 5%	NS	0.26	NS	0.05	0.10	0.10	0.15	0.21	0.26	0.26	0.21	0.26

NS = Non-significant.

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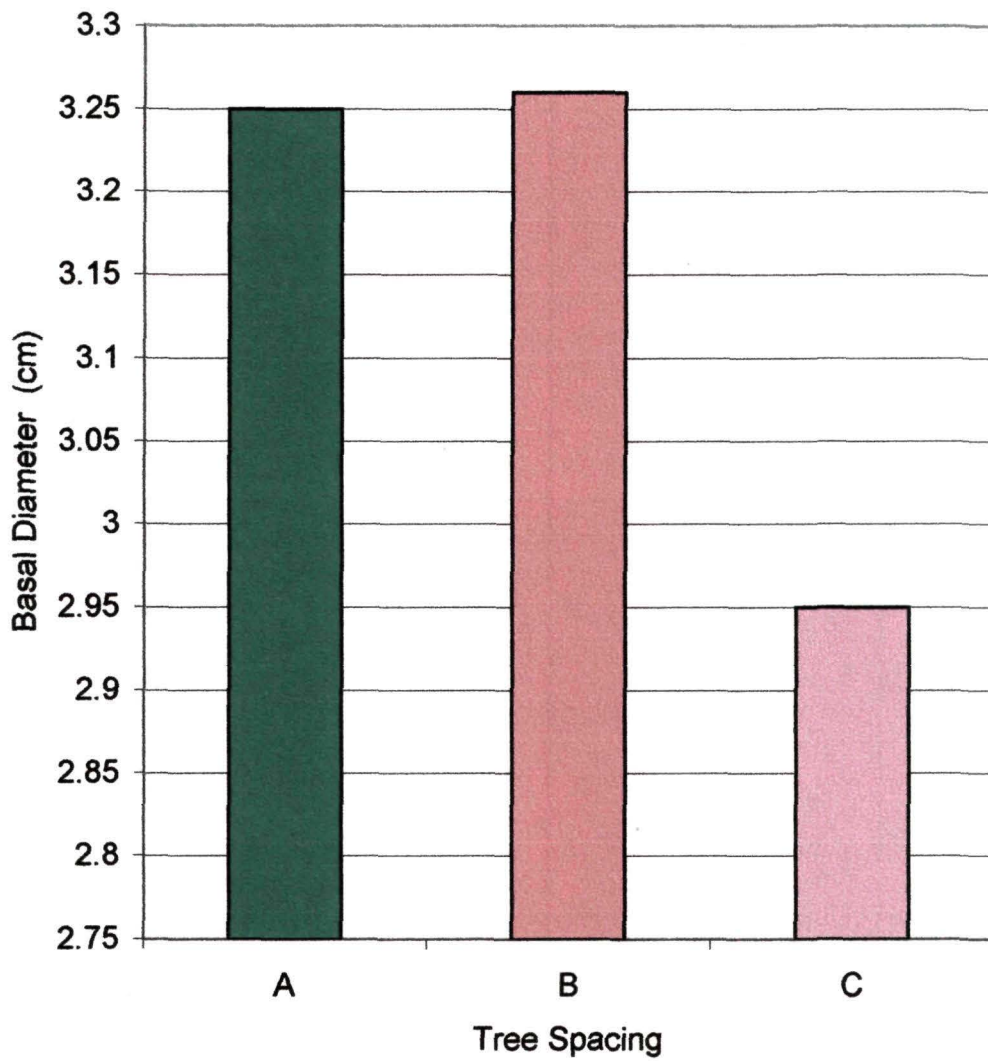


Fig. 9 : Basal Diameter(cm) of *Leucaena leucocephala* as affected by different Spacing

4.7. SHOOT DRY WEIGHT (g) of *Leucaena leucocephala* :

The data on the effect of spacing on shoot dry weight in *Leucaena leucocephala* at September, 1999 and October, 2000 are presented in table 7 and Fig. 10. It can be seen from the table that the shoot dry weight of leucaena during September, 1999 and October, 2000 did not show any difference under different treatments. It is evident from the table that the effect on shoot dry weight by different treatment at September, 1999, maximum shoot dry weight of leucaena was recorded in 3m x 3m spacing (103 gm) followed by 4m x 4m spacing (90 gm) and minimum shoot dry weight was found in 6m x 6m spacing (65 gm).

Similarly, it can be seen from the same table that effect of different treatments at 2 years after transplanting i.e., October, 2000 also not exhibit any marked variation due to spacing. Maximum shoot dry weight was observed in 3m x 3m spacing (160 gm) followed by 4m x 4m spacing (149 gm) and the least being 6m x 6m spacing (125 gm).

Table 7 : Shoot dry weight (gm) of *Leucaena leucocephala* as affected by different spacings.

Treatment (Tree spacing in m)	September 1999	October 2000
A (6m x 6m)	65	125
B (3m x 3m)	103	160
C (4m x 4m)	90	149
SEm \pm	12.82	13.50
CD at 5%	NS	NS

NS = Non-significant.

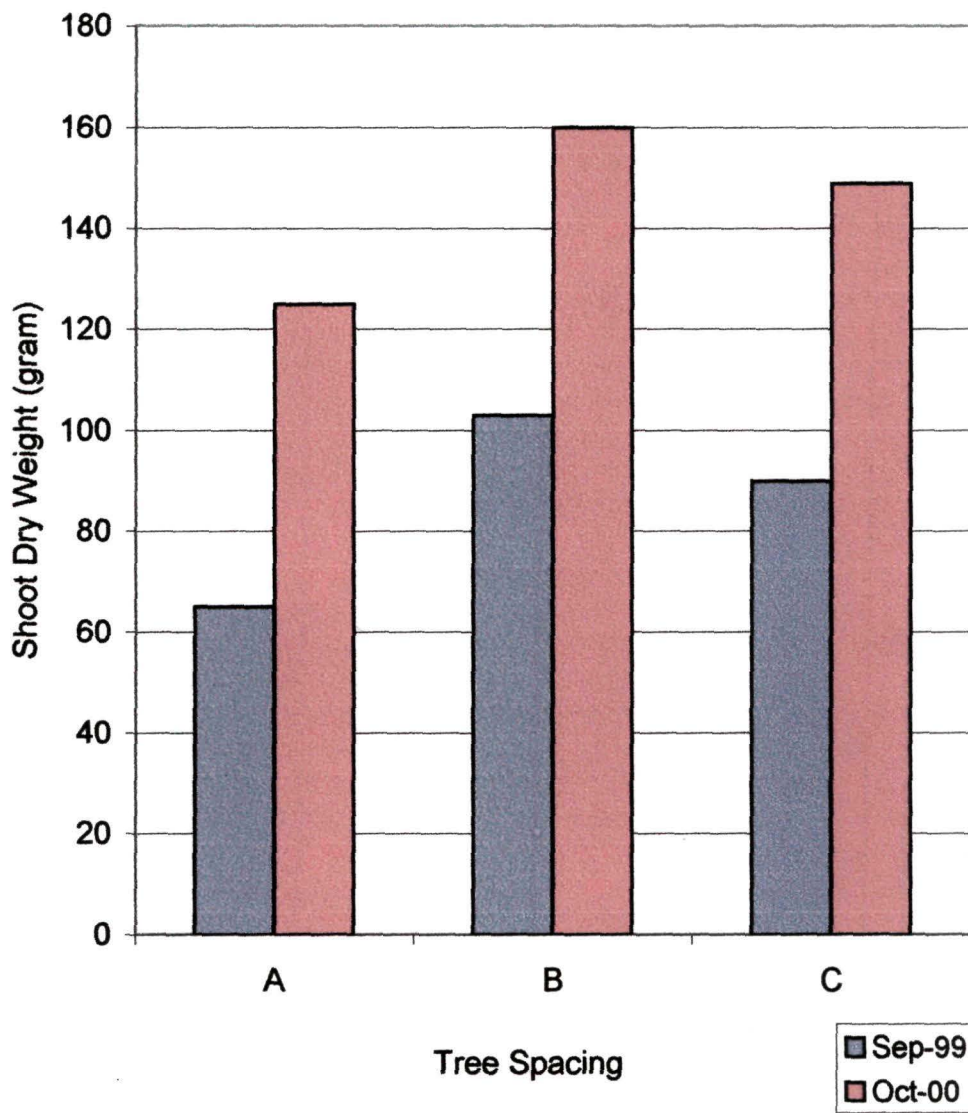


Fig. 10 : Shoot Dry Weight of *Leucaena leucocephala* as affected by different Spacing

CHAPTER - V

DISCUSSION

DISCUSSION

5.1. GROWTH PARAMETERS OF GINGER :

The significant increase in ginger plant height (Fig. 3) over the control plots suggested the beneficial effects of *Leucaena* on the intercropped Ginger. Maximum height was observed in 6m x 6m plot (23.7 cm), followed by 3m x 3m plot (22.1 cm) in which both the treatments shows significant difference in their height as compared to control plot. This assumption found support from the work of Brewbaker (1975) who reported that 'Salvadorian' type of *leucaena*, can released more than 550 Kg N, 225 Kg P and 550 Kg K, which help the intercropped plants (maize) to attain highest growth under narrow spacing. Therefore, narrow spacing i.e. 3m x 3m was found to give better condition for the growth of Ginger as well as wider spacing i.e. 6m x 6m as compared to control plots.

Number of Ginger leaves was also found to be significant after 105 days of planting. Highest number of leaves was observed in 3m x 3m plots and followed by 6m x 6m plot (Fig 5) which can be again related to the effect of *leucaena* plants. Since the availability of nitrogen in the soil was more under narrow spacing of *leucaena* as compared to the other two spacing. Escalda (1980) has attributed this variation in the number of leaves to the availability of *leucaena* plants to yield nitrogen approximately 500-600 Kg N/ha./year. The decline of leaves count under control plot was due to the absence of *leucaena* component and thus the plot were deficient in nitrogen content in the soil. On the contrary, better green leaves count under narrow spacing was due to the effect of *leucaena* spacing as also supported by Rosecrance and Brewbaker (1992).

Maximum number of tillers per clump was observed in 6m x 6m plots (Fig 4) followed by 3m x 3m plots, 4m x 4m plots and control plots. The decline number of tillers per clump was observed in control plots which was due to the absence of leucaena, being a nitrogen fixing tree and proved beneficial of the intercropped, besides yielding foliage and fuelwood (Anon, 1984). Other workers like Alvarez and Arturo (1984), reported that, leucaena, when will established as hedges they improve the soil condition by releasing more nitrogen, which acts as organic fertilizer on the growth and yield of intercropped. Significance of nitrogen fixing trees for improving the overall growth performance of intercrops have been stressed by Krishnan and Toky (1993) and Mahajan *et al.*, (1996)

5.2. Yield of ginger :

The variation in Ginger yield under different treatments was due to the effected of leucaena spacing. Highest yield was observed under 6m x 6m plots and followed by 3m x 3m plots (Fig 6). All the treatment plots give higher yield as compared to the control which suggested the beneficial effect of leucaena trees on the crop. Flores (1975) and Leviste (1976) citing the work of Brewbaker also reported that the intercropped plant (maize) yield was increased by 133% when fertilized with leucaena green leaf manure as compared to control plots.

The most possible reason for the higher yield of ginger obtained when planted under leucaena was due to the improved soil fertility as a result of the fixation of nitrogen through root nodules, and in later stages on growth, through green leaf manure leaf dropping and root decomposition. Brewbaker (1984) observed that leucaena provides more than just nitrogen, mineral elements such as phosphorous and potassium absorbed by the roots from deep soil also became incorporated into the foliage. This foliage upon falling or incorporation into the soil lead to an increase in soil nutrient levels and therefore enhanced crop

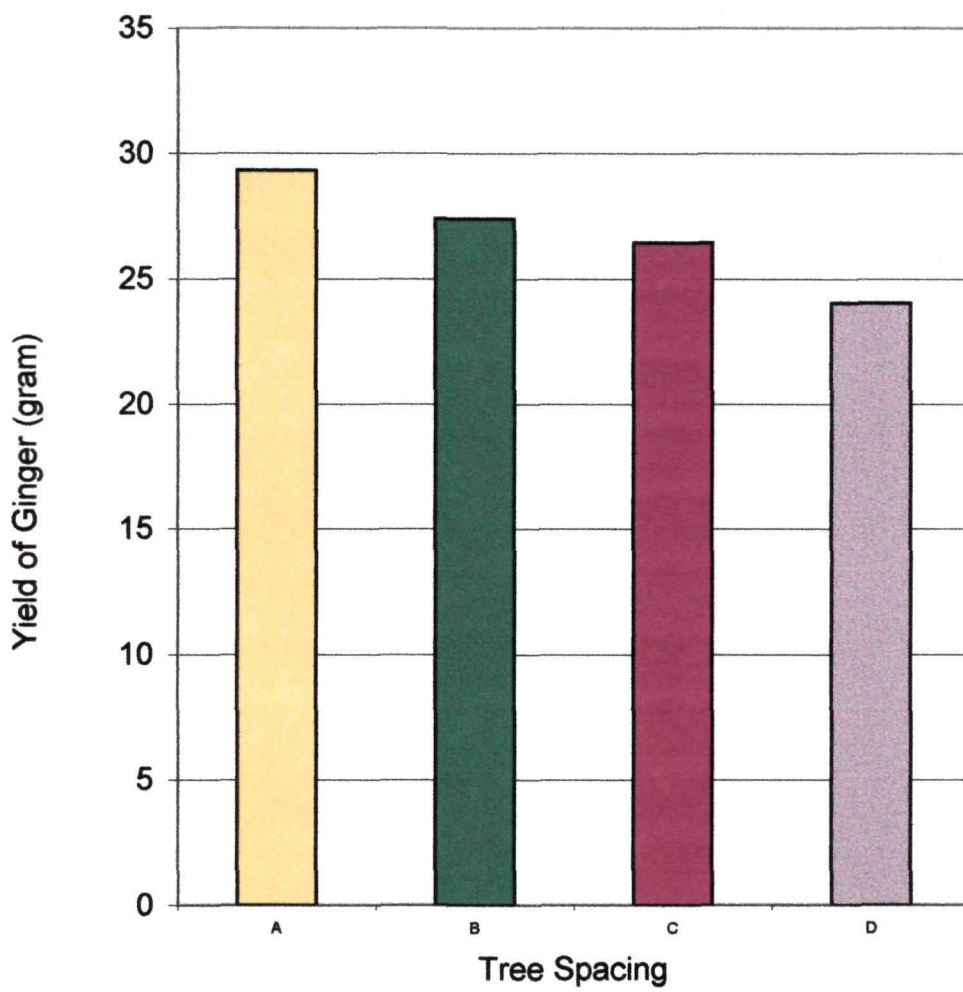


Fig. 6 : Yield of Ginger (gram) as affected by Different spacings of *Leucaena leucocephala*

performance. Besides, the improved crop performance could be done to reduced N-leaching under legume intercropping as opposed to single crop system (Singh *et al.*, 1981; Yadav, 1981)

5.3. GROWTH PARAMETERS :

5.3.1. LEUCENA PLANT HEIGHT :

Leucena Plant Height was measure at monthly interval during the experimental period (Oct, 1999 - Sept, 2000). Since there was no irrigation, rainfall plays and important role in boosting up the growth of leucena plant especially during the rainy seasons. During April to Septembe, 2000 the plant height boosted up as more rainfall was received (Fig 7) (rainfall, temp).

There was a significant differences in plant height of leucena as effected by treatments during Oct, 1999 to June, 2000. But from July to September, 2000, there was no significant differences. It was found that the mean height of leucena at 3m x 3m treatment showed maximum height (359.2 cm) followed by 4m x 4m (353.2 cm) and 6m x 6m (340.8 cm) (Fig 8). This showed that plant height of leucena increase with decrease in space. Similar observation have also been reported by Lulandala *et al.*, (1995), who have also reported that the growth of leucena at this early stages decrease under wide spacing. Mohatkar *et al.*, (1985) in Madurai, Tamil Nadu also reported the same observation Djikman (1950) reported that the rate of growth of leucena is optimum under closer spacing receiving full sun, more so under high temperature once it has become established.

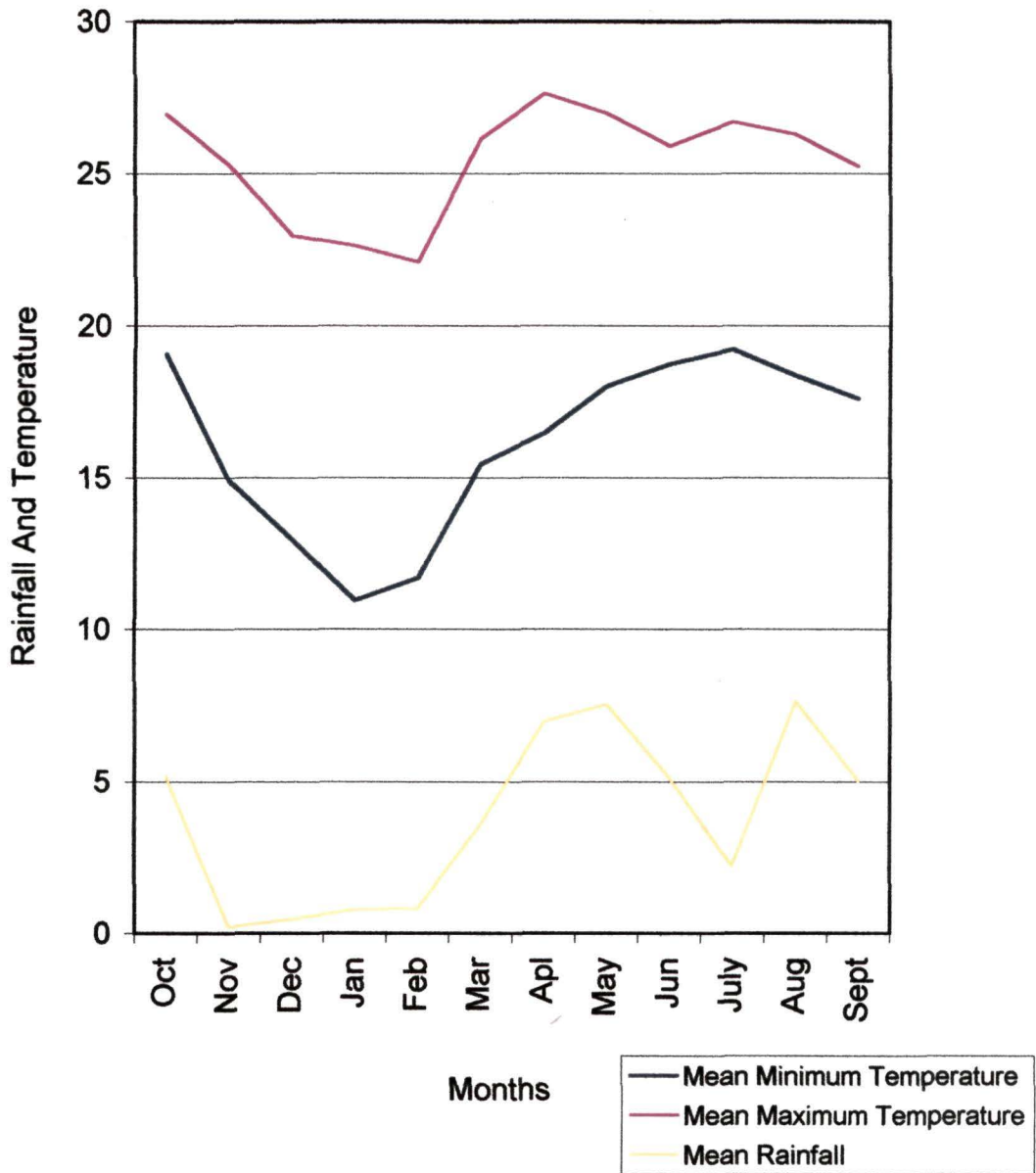


Fig.7 : Monthly Variation in Mean Maximum and Mean Minimum Temperature °C and Monthly Mean Rainfall (cm) from Oct 1999 to Sept 2000 of Aizawl,

5.3.2. BASAL DIAMETER OF LEUCAENA :

The basal diameter of leucaena was also measured at monthly interval during October, 1999 there was no significant difference in basal diameter as affected by treatments but from November, 1999 to September, 2000, significant difference in basal diameter was noticed.

The mean basal diameter of leucaena was found to maximum in 3m x 3m plots (3.26 cm) followed by 6m x 6m (3.25 cm) and the minimum basal diameter was observed in 4m x 4m (2.95 cm) (Fig 9). This shows that the narrow spacing has still influences the increase in basal diameter of leucaena. This vigour of growth and increase in basal diameter have also been reported by Wilson and Kang (1980), and Kang *et al.*, (1981). But from October, 1999 to August, 2000 (Table 6) basal diameter leucaena was maximum in 6m x 6m treatment followed by 3m x 3m treatment, this could be due to increase in initial longitudinal growth in the plants than the horizontal growth. Guevarra (1976) have attributed this type of behaviour in the growth of leucaena to the intensive division of optical meristem at the shoot apices of the plant influencing the longitudinal growth over the lateral or horizontal growth.

5.3.3. SHOOT DRY WEIGHT OF LEUCAENA :

Shoot dry weight of leucaena was observed two times, first observation was done in the month of September, 1999 and second was done in the month of September, 2000. There was no significant difference on shoot dry weight. However, maximum weight was observed in 3m x 3m plots (103g and 160g) followed by 4m x 4m plots (90g and 149g) and the minimum weight was observed 6m x 6m plots (65g and 125 g) (Fig, 10). The treatment means shows higher yield of Leucaena shoot in closer spacing. This views finds support from the work by Mbekeam and Bassman (1991).

5.4. CHEMICAL STATUS OF THE SOIL :

Soil pH, organic carbon, potassium and phosphorus content of the plot showed increased in the top soil after harvesting ginger as compared to before planting ginger (Table 8). This phenomenon suggested that the beneficial effect of leucaena in increasing fertility of the soil. Hu Tai-wei *et al.*, (1984) in China reported that soil nutrient reserve (0-30 cm) content under Leucaena increased in available nitrogen, phosphorus and potassium at a rate of 5.52, 1.67, 13.94 kg 1 ha/year on an average respectively after 4-5 years of growth.

Table 8 : Chemical status of the soil.

	Before planting ginger	After harvesting ginger
	September 1999	September 2000
pH	5.62	5.82
O.C %	1.33	1.41
P	18.06	19.36
K	127.24	135.08

CHAPTER - VI

SUMMARY

SUMMARY

Field Experiment was conducted to study the effect of different spacings on the growth behaviour of *Leucaena leucocephala* (Lam.) de wit and its effect on *Gingiber officinale* Rose. productivity in an Agroforestry system of Mizoram at Zemabawk about 5 Kms from Aizawl Town. In this experiment, three different spacings of Leucaena was taken as treatments (3m x 3m, 4m x 4m, 6m x 5m) in which ginger was taken as intercropped and sown at a spacing of 25cm x 25cm covering the whole experimental field. Control plot was also made where ginger alone was sown. The experiment was laid out in Randomised Block Design having three (3) replications. The whole experimental area was 1728 sq. cm in which the size of one plot was 144 sq.m. Different growth component of leucaena and ginger were studied. The results were subjected to Analysis of variance to find the effect of luecaena spacings on both growth and yield components. The growth parameters on leucaena were recorded at monthly intervals and for ginger at 30 days interval growth parameters were recorded.

The major findings of the investigation were as follows :

(1) Height of ginger as affected by intercrop leucaena were statistically significant and the highest growth was found in 6m x 6m spacing, followed by 3m x 3m, 4m x 4m and the least been found in control.

(2) Number of ginger leaves per plant were found to be significant after 105 days of planting, and the maximum number was recorded in 3m x 3m spacing as compared to 4m x 4m and 6m x 6m spacing.

(3) Number of tillers per clump of ginger at 75 days after planting and 135 days upto 195 days after planting were statistically non- significant, but

after 105 days of planting it was found to be significant. The highest number was recorded in 6m x 6m spacing as compared to other treatments.

(4) The yield of ginger was recorded highest at 6m x 6m spacing of leucaena (29.33g). followed by 3m x 3m (27.4g), 4m x 4m (26.46g) and the lowest being control (24.06g).

(5) The growth of leucaena regarding height as affected by different spacings after two years of planting were found to significant from October, 1999 to June, 2000 from July to September, 2000 it was non-significant, but it was observed that the highest growth was found in 3m x 3m spacing, followed by 4m x 4m and the least been found in 6m x 6m spacing.

(6) Basal diameter of leucaena as affected by spacings were found to be statistically significant from November, 1999 to September, 2000. The maximum was recorded at 3m x 3m spacing followed by 6m x 6m and 4m x 4m spacing.

(7) Shoot dry weight of leucaena was statistically non-significant but the maximum weight was recorded at 3m x 3m spacing before planting ginger and after harvesting ginger.

(8) Soil fertility status such as percentage of organic carbon, phosphorus, potassium and pH was improved which was found to be due to the ability of soil improvement by leucaena.

This experiment has therefore depicted the beneficial effects of *Leucaena leucocephala* intercrop with Ginger. Leading to improved crop yield due to improved soil fertility status. Therefore, intercropping of Ginger along with *Leucaena* can be taken up for improving the quality as well as increasing the quantity of Ginger under agroforestry systems in Mizoram.

CHAPTER - VII

CONCLUSION

CONCLUSION

From our findings, it can be concluded that leucaena plays a positive role on ginger growth and yield components. Its nitrogen fixing ability helps in increasing the good yield of ginger compared to the control plots. Leucaena being a very fast growing species, it attained mean height as high as 35.2 cm during two years period. Ginger height and Number of tillers per clump were observed best under 6m x 6m spacing, it was due to the fact that the well established leucaena plants compensated the nitrogen to the intercrops. The good yield and growth components was not only because of nitrogen supply by leucaena plants, but also due to the soil binding capacity of the species owing to their well developed root systems in hilly slopes (Kaushal and Dhanda, 1988).

Considering all the beneficial aspects of leucaena under the present study, it is suggested to grow ginger along with leucaena under agroforestry systems. This will satisfy to a greater extent in various conditions of judicious land management, soil conservation and production for the hill slopes. To improve both the quality and quantity of ginger it is suggested that ginger should be planted with leucaena at wider spacing (6m x 6m). ✓

In the present study, growth behaviour of *Leucaena leucocephala* and effect of leucaena spacing in ginger productivity had major limitations. Since, the study was only for a period of one year, to draw same concrete results a long term research should be carried out. For better understanding on the growth behaviour of leucaena and intercrops with their interactions, study on production of biomass, fodder, fuel, timber should be undertaken. Besides, research is also needed on nutrient requirements, contribution of nutrients to the soil by Leucaena, shading effect and their management, this could yield information in some specific areas of uncertainly making appropriate guidance to improve the practices

more effective and more widely applicable and enable the farmers to attain optimal productivity on a sustained basis.

BIBLIOGRAPHY

BIBLIOGRAPHY

- Aiyer, A.K.Y.N. (1949), Mixed Cropping in India. *Indian Journal Agricultural Science*. 19, pp. 439-543.
- Alvarez, F.R. and Arturo, C.A., (1984) : The effect of intercropped *Leucaena leucocephala* (Lam) de wit as organic fertilizer on the growth and yield of corn. *Leucaena Research Report*. No. 5 : pp 1-10.
- Anon., (1977). *Leucaena promising forage and tree crop for the tropics*. National academy of Sciences. Washington D.C., National Academy Press.
- Anon., (1980). *Firewood crops : Shrubs and trees for energy production*. National Academy of Sciences, Washington D.C. National Academy Press.
- Anon., (1982). International Institute of Tropical Agriculture. Annual Report for 1981, Idaban, Nigeria.
- Anon., (1984). *Leucaena; promising foliage and tree crop for the tropics*. Second edition. National Research Council. National Academy Press. pp 1-160.
- Anon., (1984). Report of sub-group of forest and soil, Government of India. Ministry of Environment and Forest, New Delhi.

- Balasubramaniam, V., (1983). Alley Cropping : can it be an alternative to chemical fertilizers in Ghana ? An invited paper presented at the National Maize Workshop held at Kwadeso Agriculture College, Kumasi, Ghana, February 1-3, 1983.
- Brewbaker, J.L., (1975). Giant Ipil-Ipil. Promising source of fertilizer, feed and energy for the Philippines. AID agricultural seminar serial; USAID, Manila. In : Escalda, R.G.(1980) Manipulation of Cultural Practices for Ipil-Ipil (*Leucaena leucocephala*) for maximum organic production and its effect on the intercropped cassava. PCARR funded Research Project Technical Report. Department of Agronomy and soil science, Visayas State College of Agriculture, Baybay, Leyte, Philipines : p.34.
- Brewbaker, J.L., (1984). Guide to the systematics of the genus leucaena. In : National Research Council, 1984. Leucaena : Promising foliage and tree crop for the tropics. Second Edition. National Academy Press, Washington D.C.
- Chauhan, V.K., Sood, S.K., Bhargava, J.N., and Mishra, V.K. (1995). Effect of differernt trees on yield of rainfed wheat crops. Annuals of Forestry. Vol. 3. No. 2, pp 147-151.
- Djikman, M.J., (1950). Leucaena, a promising Soil Erosion Control Plant. Econ. Bot. 4,337-349. In : Ngambeki and Wilson (1983). Economic and on-farm evaluation of Intercropping with *Leucaena leucocephala*. IITA 1980-1983. Activity Consolidated Report.
- Edison, Sand Johny, A., Kallapurackal (1991). *Indian Cocoa, Arecanut and Spices Journal*. Vol.16. No. 4. pp. 138-144.

Escalda, R.G., (1980). Manipulation of Cultural Practices for Ipil-Ipil (*Leucena leucocephala*) for maximum organic matter production and its effect on the intercropped cassava. *PCARR funded Research Project Technical Report*. Department of Agronomy and Soil Science Visayas State College of Agriculture, Baybay, Leyte Philipines. p.34.

Flores, L.B.,(1975). Ipil-Ipil new promising fertilizer. *Forest and farms*. 8. p-4.

Getahum Amare, (1980). Alley Cropping in the humid and sub-humid tropics. State of the art and recommendations. International Institute of Tropical Agriculture and International Development Research Centre Agroforestry Project, Progress Report. October, 1980.

Gill, A.S., and Patil, B.D., (1982). *Leucaena* foliage as a source of green manure. *Leucaena research report*. Vol. 3. 2a.

Gill, A.S., Patil, B.D., (1984). *Leucaena* leaves as a source of manure, *Leucaena research report*, Vol. 5. p. 26.

Government of Mizoram, (1997). *Progress Report of Forestry in Mizoram, 1990*, Department of Environment and Forest, Aizawl.

Government of Mizoram, (1997 - 98). *Statistical Abstract*, 1997 - 98, Department of Agriculture and Minor Irrigation, Aizawl.

Government of Mizoram. Statistical abstract Department of Horticulture, Aizawl, 1999-2000.

Guevarra, A.B. (1976). Management of *Leucaena leucocephala* (Lam) de wit for maximum yield and nitrogen contribution to intercropped corn. In : Evensen, C.I.L. (1982). Synopsis of *Leucaena* /Maize leaf manure study, University of Hawaii. p-6.

Guevarra, A.B., (1976). Management of *Leucaena leucocephala* (Lam) de wit for maximum yield and nitrogen contribution to intercropped corn. An unpublished Ph.D desertation. In: Evensen, C.I.L., (1982). Synopsis of *Leucaena*/maize leaf manure study, University of Hawaii (Unpublished). p 6.

Gupta, R.K., Agarwal, M.C., and Nirmal Kumar (1996). Growth and biomass production in *Leucaena leucocephala* under high density plantations on degraded lands of Doon Valley. *Indian Forester*, 122 (3), pp 241-245.

Halliday, J. and Somasegaran, P. (1983). Nodulation, Nitrogen fixation and Rhizobium strain affinities in the genus *Leucaena*. In : *Leucaena research in Asia Pacific Region, Proceedings of Workshop held in Singapore, 23-26 November. 1982.*

Halliday, J., (1984). No title. In : National Research Council (NRC), 1984. *Leucaena promising forage and tree crop for the tropics. Second Edition, National Academy Press, Washington D.C.*

Handbook of Indian Agriculture. Vikas Singhal (1997). Vikas publishing house PVT. Ltd, pp. 359-361.

Hartman, E.H., (1981). Land development and management in tropical Africa. In : Nair, P.K.R., (1984). *Soil Productivity aspects of Agroforestry*, ICRAF, Nairobi.

Hauser, S. and Kang, B.T. (1992). Nutrient dynamics, maize yield and soil organic matter in alley cropping with *L. leucocephala*. In proceeding International symposium on Dynamics of organic matter in Relation to the sustainability of Agricultural systems. KVL, Leuven, Belgium.

Hebbax, R.A. (1977). *Indian Coffee*. Vol - 41 p - 1.

Hu-ta-wei, wei-Er Cheng Tse-An Shen., (1984). Changes in soil nutrients after forage harvest of *Leucaena leucocephala*. *Leucaena Research Report*, Vol. 5. pp 66 -67.

Indian Council of Agriculture Research. *Annual Report* (1999-2000). New Delhi, pp. 20-21.

Jackson. M.L. (1979). *Soil Chemical Analysis*, Prentic Hall of India, New Delhi.

Jaswal, S.C., Mishra, V.K. and Verma, K.S. Intercropping Ginger and Turmeric with poplar (*Populus deltoides* G-3 Marsh). *Agroforestry system* (1993). Vol 22. pp 111 - 117.

Jha, L.K., and Sen, P.P. *Social forestry*, Himalyan Publishing house. p-40.

Jha, L.K., G. Jha and Srivastava, K.K., (1990). Evaluation of tree species under agroforestry system. *Recent research in Ecology, Environment and Pollution*. Vol. 5, Today and Tommorow's Publishers, New Delhi. pp 389-394.

Jha, M.N., Dimri, B.M. and Gupta, M.K., (1991). Soil nutrient changes in *Leucaena leucocephala* planting of different durations. *Leucaena research reports*, Vol. 12, pp 42-45.

- Jha, L.K. (1995). *Advances in Agroforestry*, APH publishing Corporation, Ansari road, Darya Danj, New Delhi. pp 476-482.
- Jiang Houming, (1982). *Introducion and trial Planting of Leucaena in China.*
In : *Leucaena Research in the Asian - Pacific Region. Proceedings of workshop held in Singapore, 23-26 November 1982.* IDRC Pub. No.211.
- Kang, B.T., Sipkens, L., Wilson, G.F., and Nangju, D., (1981).
Leucaena leucocephala (Lam.) de wit prunings as nitrogen source for maize (*Zea mays* L.) *Fertilizer Research* Vol.2. pp 2-79-287.
- Kang, B.T., Wilson, G.F, and Lawson, T.L., (1984). *Alley Cropping a stable alternative to shifting cultivation.* IITA, Ibadan, Nigeria.
- Kang, B.T., Wilson, G.F. and Sipken, L., (1981). *Alley Cropping Maize (Zeamays L.) and Leucaena (Leucaena leucocephala Lam.) in Southern Nigeria. Plant and Soil, 63 : 165-179.*
- Kaushal, P.S. and Dhanda, R.S. (1988). *Performance of Subabul in Punjab.*
In : Kholá, P.K. and Seghal, R.N. (eds). *Trends in tree Sciences.* pp 46-49.
- Krishnamurthy, N., N. Lois, V.S. and C.P. Natarajan (1977), *Journal of food and Science Technology.* Vol. 14. No 3.
- Krishnan, B. and Toky, O.P. (1993). *Significance of nitrogen fixing woody legume trees in forestry.* *Indian forester, 119 (2) pp 126-132.*

- Leviste, C.A., (1976). Ipil-Ipil, a timely versatile tree brings hope to developing nations. Proceedings of the first Regional Agriculture and Resources System Research Congress for Southern and Central Regions. pp. 5-11.
- Lulandala, L.L.L., Munishi, P. K. T. and Maliondo, S.M. (1995). Effect of spacing management regime on leucaena fodder yield and nutrient removal in alley cropping systems in Tanzania. *International Tree Crops Journal*. Vol 8. pp 129-337.
- Mahajan, V., Gupta, H.S. and Sharma, B.K. (1996). Population development in maize suitable for North Eastern Hill Region. *Technical Bulletin Report*, ICAR for NEH Region, Narapani, Meghalaya. pp 1-13.
- Mbekeani, Y. and Bassman, J., (1991). Effect of spacing on light interception and biomass partitioning in a *Leucaena*/maize alley-cropping system. Chitdze Agricultural Research Station, Lilongwe, Malawi.
- Meelink, W.H.H. (1989). Management of trees for fuelwood and fodder production on small farms. In : Promotion of fodder and fuelwood trees, Hegde, N. G., Relwani, L.L., and Kelkar, V.D. (eds.) BAIF, Pune.
- Merwin, A. and Peech, J. (1951). Soil analysis. Soil Science. Soc. Amer. proc. 15 :225 -229.
- Mohanty, D.C., R.C.Das and Y.N. Sharma (1981). *Orissan Journal of Horticulture*, Vol. 9. No. 1. pp 15-17.

- Mohatkar, L.C. and Relwani, C.L., (1985). Effect of Plant population stubble height and number of cuttings on the growth, seed, forage and firewood production in *Leucaena leucocephala* var. K-28 in the semi-arid climate of Madurai, Tamil Nadu, India. *Leucaena Research Report*, Vol. 6. pp 40-42.
- Nadagaudar, B.S. (1989). Agroforestry system in the tropical and sub-tropical parts of India. Summer Institute of Social Forestry for Rural Development. H.A.V, Hissar. pp 13-26.
- Nair, V.R., V.K. Sasidhar and N.Sadanandan (1978). *National seminar on Ginger and Turmeric*. pp. 24.
- Nair, P.K.R., (1984). Soil productivity aspects of Agroforestry. *Science and practices of Agroforestry series No. 1*. ICRAF, Nairobi.
- National Wildlife Database Cell, Wild-life Institute of India, Chadrabani, Dehra Dun (1999).
- Nayar, T.V.R., (1976). *Indian Coffee*. Vol. 40. pp 2-3.
- Ngembeki, D.S. and Wilson, G.F., (1983). Economic and on farm evaluation. Alley cropping with *Leucaena leucocephala*, IITA, 1980-1983. Activity consolidated report.
- Olsen, S.R., Cole, C.V. Watanabe, P.S. and Dean, L.A., (1954). Estimation of available phosphorus by extraction with sodium bicarbonate. USDA citao. p 939.

Owadally, A.L.M., Ramtohum and Heerainy, I.M. (1982). Horticulture Abstract. Vol. 52, No. 10. p 6895.

Panigrahi, V.C. and G.K. Patra (1985), *Indian farming*. Vol 35. No. 5. pp 3-4.

Panse, V.C and Sukhatme, P.V. (1978). Statistical Method for Agricultural workers, ICAR, New Delhi.

Patel, A., and Raju Iyer (1981). Kubabul- A multipurpose tree. *Eastern economist*. Vol. 77. No. 19. p 873.

Pathak, P.S., Patil, B.D., Gupta, S.K. and Deb Roy. R. (1982). Leucaena cultivation improves soil fertility, *Leucaena research report*. Vol. 3. p 37.

Pathak, P.S., and Patil, B.D., (1982). Leucaena research at the Indian Grassland and Fodder Research Institute (IGFRI). pp 83-88.

Pathak, P.S. and Gupta, S.K. (1987). Soil amelioration role of leucaena in the Agroforestry system proc. int. workshop on Agroforestry for rural needs, New Delhi.

Pathak, P.S., (1997). Promising practices. ICAR News, Vol. 3 (2), pp 2-3.

Pillai, P.K.T., G. Vijaya Kumar and M.C. Nambiar (1978). *Plantation Crops*. 6 : 1.

Piper, C.S. (1966). Soil and Plant Analysis Hans. Publ., Bombay, India, pp 368.

Prasad, Arjun, (1993). Competition studies on tree crop association with *Leucaena* under farm forestry, Annual report, CSWCRTI, Dehra Dun, p 76.

Pruthi, J.S. (1979), *Spices and condiments*. National Book trust, India, New Delhi. pp. 132-137.

Randhawa, K.S., Nandpuri, K.S., Bajwa, M.S. Studies on the comparative efficiency of different sizes of seed and spacings on the yield of ginger. *Journal of Research India* (1972). Vol - 9 (2). pp 239-241.

Rao, Y.S. (1990). *Wastelands News*, “why, what, how and where of Agroforestry in the Asian Pacific Region. “Vol. v. No.3, February - April, pp. 19-25.

Shannon, D.A., Kabuluapa, K.N. and Ngoyi, M.L. (1990). Alley cropping established in maize yields, AFNETAN, News Letter. Vol. 2, pp 6-7.

Singh, A.P., and Prasad, N.K., (1989). AICRP for research on forage crops. Annual report, main centre, Ranchi, RAU., Ranchi.

Singh, A. and Prasad, R.N., (1980). Soil and water Conservation technology for Jhumland. ICAR Research Complex, Shillong.

Singh, A. and Prasad, R.N., (1981). Soil and water Conservation Technology for Jhumland. ICAR Research Complex. Shillong.

Singh, G., Arora, Y.K., and Narain, R. (1990). Agroforestry system in hill region. In : Agroforestry research. p 18.

- Singh, M.P., and Tewari, D.N. (1990). Agroforestry and wasteland. Anmol publications. New Delhi. p 33.
- Singh, V.B. and Singh, Kriti. (1996). Spices, New Age International publishers. pp 58-60.
- Solaniki, K.R. and Ram Newaj, (1997). Leucaena based agroforestry system in the semi-arid region of India. National Research centre for Agroforestry, Jhansi.
- Sreekumar, V., G. Indrasenam and M.K. Mammen (1980). *Proceedings of the National Seminar on Ginger and Turmeric*, held at Calicut during 8-9 April, 1980. pp. 47-49.
- Swaminathan, M.S. Research foundation (1998). *A blue print for sustainable Agriculture and Rural Development*, Chennai - 600113, pp 1-8, 13-15.
- Upadhyaya, K.K. and Jha, L.K., (1997). Mizoram Agriculture : Financial viability of Agroforestry. *Indian journal of Agricultural Economics*. 52 (4) : pp. 772-782.
- Wilson, G.F, and Kang, B.T., (1981). Developing a stable and productive biological cropping system for the humid tropics. In : Ngambeki, D.S. and Wilson, G.F. (1983). Economic and on-farm evaluation of alley cropping with *Leucaena leucocephala*. IITA, 1980-83 activity consolidated report.

Yadav, R.L., (1981). Intercropping pigeon pea to Conserve fertilizer nitrogen in maize and produce residual effects on sugarcane. In : Yadav, R.L., (1982). Minimizing nitrate - nitrogen leaching by parallel multiple cropping in long - duration raw crops. EXPL. Agric., Vol. 18 pp 37-42.

Zainalo, A. Cole (1990). Rice/Cassia alley cropping in the Gambia, AFNETAN, News Letters, Vol. 2, pp 6-7.