STUDIES ON TREE-CROP COMPATIBILITY AND GROWTH PERFORMANCE OF FIELD CROPS AND SOIL MOISTURE CONSERVATION AS AFFECTED BY DIFFERENT MULCHES UNDER HILLY TERRAIN OF MIZORAM

By

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*I certify that the thesis entitled " **Studies on tree-crop compatibility and growth performance of field crops and soil moisture conservation as affected by under hilly terrain of Mizoram**" submitted by Shri P.C. Vanlalhluna, for the* ***Degree of Doctor of Philosophy*** *of Mizoram University, Aizawl embodies the record of original investigation under my supervision. He has duly registered and the thesis presented is worthy of being considered for the award of the Ph. D Degree. The work has not been submitted for any degree of any other University.*

AIZAWL ***(U.K. SAHOO)***

The 28th September, 2007 *Supervisor*

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Chapter – I

General Introduction

Traditional farmers retain certain trees and shrubs in their crop production systems to restore soil fertility exhausted by cropping (Moorman and Greenland, 1980; Getahun *et al.,* 1982). The growth of these trees, shrubs and crops depend on the available reserve of growth resources such as light, water, nutrients, space etc. in the study system and thus, there will be influence of one component on the performance of the other components and vice-versa. The influence of one over the others ultimately affect the system as a whole and this is referred to as tree-crop interaction. These interactions may be positive (complementary) or negative (competitive). The balance between these positive and negative effects determines the over all effect of the interactions in a given agroforestry combination. The knowledge of these interactions will be helpful in proper management of agroforestry systems for sustained production of multiple outputs.

The low productive and less efficient shifting cultivation and its negative impact on the environment has become a global concern (Nair, 1984; Dale *et al.,* 1993). Several workers have given special emphasis to agroforestry, an alternative means of shifting cultivation, which can be implemented for rehabilitation of jhum areas (Kang *et al.,* 1981). Agroforestry offers possible solutions to enhance productivity through temporal and spatial intensification in a country like India where the possibility of bringing more land under cultivation is limited and holdings are smaller. The yield advantages through agroforestry have been reported by many workers (Bulson *et al.,* 1997; Rana and Saran, 1998) and the advantage of intercropping in agroforestry systems are often attributed to the fact that different crops complement each other and make better use of resources when grown together rather than separately. Besides, intercropping also acts as insurance for resource poor farmers in terms that if one crop fails, they get some yield from another crop. Intercropping plays important role in suppression of weed growth. The shade reduces weeds especially light demanding ones.

Tree-crop compatibility is very important for optimum and sustained productivity. It also helps in the improvement of soil moisture regime. The organic matter added by trees to the soil nevertheless increases water-holding capacity and the shade of trees reduces the evaporation resulting in higher soil moisture near trees. The soil moisture content under the hedge rows of *Leucaena leucocephala* and *Flemingia macrophylla* was reported higher than maize rows in an intercropping during dry periods, indicating no apparent competition for moisture between the hedge rows and the maize plants (Chirwa *et al.,* 1994). Similarly, higher soil moisture under *Prosopis cineraria* in arid regions of India has been reported (Puri *et al.,* 1994). The trees continuously contribute to soil organic matter through shedding of their leaves and decayed of roots. The organic matter improves soil structure, water holding capacity and aggregate stability thereby favouring microbial activities. The shade of trees also reduces the decomposition rate of soil organic matter. Further, the losses of nutrients through leaching get minimized due to interception and absorption of nutrients by tree root system. Obviously, the higher yield of agricultural crops under trees is attributed to the improvement of soil fertility and conservation of soil moisture (Puri *et al.,* 1994; Jaimini and Tikka, 1998).

Growing trees along with agriculture or cash crops is now becoming very popular among the farmers throughout India. By doing so, the farmers get the cash crop benefits besides good returns from the trees in the form of timber, fuel wood and fodder etc. Intercropping with trees under rain fed ecosystem ensures better stability in yield and minimizes risk of crop loss due to weather aberrations (Basavaraju and Gururaja, 2000). Therefore, the knowledge of these tree-crop interaction and compatibility will be very helpful in proper management of agroforestry systems for sustained production of multiple outputs.

Nevertheless, the integration of trees, crops and animals has been traditionally raised together on small farms as early as 206 B.C. The Chinese Han Dynasty administrators during this period had first recommended the development of forests together with the raising of livestock and crops. In Mizoram, agroforestry is relatively recent in origin and a nascent science. Growing of trees along with green hedges like *Leucaena leucocephala* and *Cajanus cajan* with a diverse crop varieties are being advocated as an alternatives to shifting agriculture by the state agriculture department; however, no trial is being made to substantiate their claim on the beneficial aspects of these systems. Under the New Land Use Policy (NLUP) and Self Sufficient Program (SSP) the state government has been trying to popularize the farmers various agroforestry trees suitable for the state, which may be tried with different crop combination.

The old age practice of ‘jhum’ (local name for shifting cultivation) has evolved in the state of Mizoram as a reflex to certain inherent difficult physiological characteristics of the land, which renders agricultural operations like hoeing or ploughing unsuitable. About 80% of the total population engaged in jhumming is living in rural areas. Because of the fast increasing population rate, there is decline in the jhum cycle, thus making the land less productive, consequently adversely affecting the economy of those living in the rural areas. In a study undertaken by Forest survey of India, it was estimated that during 1987-1997, an area of about 0.38 million hectare has been affected by shifting cultivation in Mizoram. Though this system of cultivation had many ill effects, it is still widely practiced due to the fact that it is well compatible with the local physical environment, steep and undulated topography, socio-economic and cultural factors, physiographic remoteness and isolation, lack of awareness and unfavorable environment (Singh and Singh, 2000).

In the past, the jhum cycle was about 20-25 years, however, in the present day situation it is reduced to a mere 5-6 years and at some places even to a 2-3 years due to high population pressure ad reduced acreage of available land. This reduction has lead to severe soil erosion, landslides, deforestation and ecological imbalance in many places. The shortened fallow period do not allow the land to recuperate fully, as a consequence it adversely affect the vegetation composition, soil moisture regime, soil fertility level, crop productivity thereby deteriorating further the socio-economic condition of the jhummias. According to a report, every year approximately 400-600 sq. km. of tree-covered area is cleared for jhumming (Garbyal, 1999) causing tremendous loss to biodiversity, top loss fertile soil. Various agroforestry models have been advocated by many workers (Tejwani, 1993; Pathak and Singh, 1999; Solanki, 1999) for the hills as substitutes to the primitive method of shifting cultivation. Unfortunately, the people does still not accept these models widely, the reasons for which could be many but the most important are the inaccurate choice of species and model of cultivation and cultural practices (Solanki *et al*., 2000).

Soil erosion and landslides are frequent occurrence in Mizoram, which cause serious loss of topsoil, reduced crop production potential, lower surface water quality and damaged drainage networks. Soil quality, structure and texture can be affected by the loss of soil. The breakdown of aggregates and the removal of smaller particles or entire layers of soil or organic matter can weaken the structure and even change the texture. Textural changes can in turn affect the water holding capacity of the soil, making it more susceptible to extreme condition such as a drought. The agents of soil erosion are water and wind, each contributing a significant amount of soil loss each year. The impact of raindrops on the soil surface can break down soil aggregates and disperse the aggregate material. Lighter aggregate materials such as very fine sand, silt, clay and organic matter can be easily removed by the raindrop splash. Loss of fine sand, silt, clay and organic particles from sandy soils serves to lower the moisture holding capacity of the soil. As organic matter decreases, soil aggregate stability, the soil's ability to hold moisture, and the cation exchange capacity declined. This in turn, increases the erodibility of the soil and compounds the problem. Soil erosion potential is increased if the soil has no or very little vegetative cover of plants and/or crop residues. Soil erosion thus can have a significant, negative impact on crop yields, especially in years when weather conditions are unfavourable. As soil erosion continues, the soil is further degraded. Poor soil quality is reflected in decreases in organic matter, aggregate stability, phosphorus levels, and potential plant available water. The net result is a decrease in soil productivity. Lal *et al.* (1999) suggest that there is a strong correlation between soil quality and erosion, i.e. soil quality affects the rate of erosion and the erosion affects the quality of a soil. Eroded soil has inferior water relationships because erosion that typically results in decreased infiltration, water storage, plant water availability, and increased runoff.

In Mizoram, as in other hilly areas, the nutrient status of the soil is reported poor. The land is therefore unable to support crops without the external supply of nutrients. Many of the studies carried out show that the soil improves its nutrients content before slashing and after burning (Tawnenga, 1990). The amount of fertilizers required to improve the same increase in NPK and to support the crop would cost very high that a poor farmer cannot afford to go by it. Besides, each time a crop is cultivated, it results in less nutrients, further, the field is vulnerable to leaching and run off linked with heavy and prolong monsoon. This subsequently affects the plant growth adversely. In fact, soil erosion is totally responsible for the decline in land quality. The range and magnitude of the soil erosion would depend on the type of crops, degree of slope, cropping system and tree-crop interaction. There is also paucity of information on the tree-crop growth in relation to degree of soil degradation in Mizoram. To tackle these biophysical problems, it is imperative to look into the cultivation of leguminous trees, which will be able to transform the atmospheric nitrogen into readily usable form to be used by the plants and also the crops. However, in situation where leguminous trees species are advantageous, they may not be even the best choice if other characteristics such as competition for light, moisture, soil nutrients and others products such as food, fuel wood, fodder etc. are considered. Therefore, it is also essential to try some non-leguminous trees species along with the field crops to know the best tree-crops combination.

The field crops, which are practiced along with the jhum in Mizoram, include mainly paddy (upland variety) and other cereals such as sorghum, maize, millet etc. Various types of vegetables such as tapioca, colocasia, sweet potato, ginger, turmeric, tobacco, chilies, sesame, beans and castor are also cultivated. Seeds of vegetables like pumpkins and cucumber are dibbed near bigger stones to support the plants. The types of vegetable cultivated mainly depend upon the food habit and need of a particular family. Among the various field crops, the tuberous crops such as ginger and turmeric are very promising and popular cash crops, which however, are highly nutrient depleting crops. The growth of these tuberous crops requires external supply of nutrients. The use of chemical fertilizers can enhance the crop yield but extensive use of synthetic fertilizers causes changes in physiology and normal functioning of soil fauna responsible for the formation of humus, thus causing tremendous leaching and in decline of soil productivity. The situation can be improved by adopting improved package of practices, particularly *in situ* moisture conservation by mulching and/or using various tree species.

Mulch may be referred to as any material on the soil surface, which helps to check evaporation and improve soil water content. Application of mulches results in additional benefits like soil moisture conservation, moderation of weeds, adds organic matter to the soil and increase the crop production (Sharma *et al.,* 2001; Singh *et al.,* 2002; Agarwal *et al.,* 2003). Continuous crop production in dry region using water harvesting together with manuring and mulching have been reported to significantly increase soil organic matter content, soil moisture retention, enhanced steady state infiltration rates and reduced bulk density (Gupta, 1983) helping in the improved yield of test crops (Chovatia *et al.*, 1992;

Tejedor *et al*., 2002). Soil conditioning for improved moisture retention as well as efficient use of water in crop production (Larson *et al*., 1983) is necessary if crop yields are to be enhanced. The role of mulches in regulating microclimatic variables particularly soil temperature, soil moisture and wind effects in agroforestry systems is prominent in the early stages of crop growth (Sharma and Parmar, 1998). Through agroforestry practices numerous benefits (environmental, economic and social) can be obtained of which soil and water conservation is among the important benefits that are noteworthy (Omoro and Nair, 1993; Mc Intyre *et al.,* 2000).

There have been several reports in which mulching have been used by indigenous communities to improved the site quality and crop production (Tacio, 1991; Lasco, 1999). Similarly, there are several materials (either vegetative or synthetic) that can be used effectively for mulching. The relative efficacy of different mulches (both quality and quantity) has also been tried on different crops by some workers (Mohanty *et al.,* 1990; 1991; Sharma *et al.,* 2001; Dinesh Ku mar *et al.,* 2003). The choice of mulching materials, however, would depend on their easy availability, costs and effectiveness in improving the soil conditions. Effect of mulches on the productivity of maize has been reported elsewhere (Mathews *et al.,* 1992; Montagini *et al.,* 1993; Singh *et al.,* 2002). However, these studies do not focus on the systematic intercropping of trees as practiced in agroforestry systems.

Although there have been some efforts towards rehabilitating ‘jhummias’ in Mizoram, proper understanding to various biophysical and socio-economics aspects in relation to agroforestry is extremely lacking. The cultivation of various multipurpose trees in association with agriculture crops, which is of prime importance to this unique state have not been yet undertaken. It is necessary to understand interaction and compatibility between trees and crops with respect to their growth behaviour, soil productivity and conservation, soil and water erosion and other related issues. Besides, the relative efficacies of different mulch types in retaining soil moisture and improving productivity nevertheless would help in prescribing suitable agronomic and cultural measures in the agroforestry systems of this hilly state. Keeping these in view, the present investigation is undertaken with the following objectives:

(a) to find out compatibility in tree-crop combination from crop and soil productivity view point,

(b) to estimate nutrient status of the soil and crop productivity under different tree-crop combinations,

(c) to study the relative efficacy of different mulch materials such as rice straw, weeds and subabul leaves on the soil moisture retention ability and crop yield of ginger and turmeric, and

(d) to estimate the relative efficacy of different quantities (6, 8, 10 tones/ha) of mulch materials on the soil moisture retention ability and crop yield of ginger and turmeric.

Chapter-II

Review of Literature

Agroforestry is not a new concept. The growing of food crops with the trees are an age-old practice all over the country including North East India. The slashing of forest floor for slash-and-burn agriculture practice nevertheless have affected the trees and resulted in further degradation of the land/ecosystem in the hill agroecosystem, thus the importance of agroforestry for better land utilization had recently been realized in North East. In this context, ICAR centre for NEH region at Barapani during the past few years has undertaken several works on agroforestry such as soil, food and fodder, jhum and watershed based farming systems (Singh, 1981; Singh, 1986; Jha and Singh, 1991). In the recent past it has also advocated a 3-tier system of tree crop at the hilltop, horticulture in the middle and opening of terrace at the bottom. Singh and Pandey (1989) and Singh and Singh (1989) suggested various stages and measures of shifting cultivation for North Eastern region, however, these stages and measures were not well accepted by the farmers mainly because these were not similar to the traditional practice and not location specific. A detailed account of the traditional agroforestry practices prevailing in North-Eastern region has been reviewed by Solanki (1999). Similar account on indigenous farming system based on complex agroforestry system adopted by the farmers in jhum areas of different North East states has been documented (Pathak and Singh, 1999). Some of these systems were also analyzed for their energy inputs and outputs and pattern of crop yields (Mishra and Ramakrishnan, 1981; Toky and Ramakrishnan, 1982). A brief description of the agribiodiversity and traditional practices followed in Mizoram is given by Sahoo *et al*. (2005)

Trees have been raised with crops in India since the earliest times (Negi, 1993). There has been innumerable research works carried out on agroforestry to develop sustainable farming systems for various agroclimatic zones of the country. Research work on the agroforestry was initiated during the late 1990's in India. Some of the forerunner on agroforestry research in the country was the Indian Grassland and fodder Training Institute, Jhansi, Central Soil and Water Conservation Research and Training Institute, Dehradun, Central Arid Zone Research Institute, Jhodpur and ICAR Complex for the North Eastern Hill Region (Chaundawat and Gautam, 1993).

Agroforestry system keeps the land almost continuously covered, thus improves the infiltration rate of soil, reduce soil erosion and build up the fertility status of the soil. Besides, intercrops or tree foliage may be utilized as mulch in the system. Mulch which is an organic material is spread on ground to suppress annual weeds and when applied around the base of trees/crops it helps in water retention, absorption and also adding nutrients. According to Young (1989) and Nair (1993) soil conservation is possible when soil erosion is reduced substantially as well and soil gets more fertility accumulated. Organic residues like straw, compost and farmyard manure (FYM) have been successfully used to improve soil tilt and increase the proportion of water stable crumbs in soil by various workers. However, the possibility of forest residue for improving organic matter content of agriculture soil has not been evaluated (Chauhan, 1991). Foliage of some NFT's contain considerable nitrogen which when mixed with soil improves the nitrogen status. A substantial amount of organic matter returns to the soil through leaf fall and together with other plant parts and hence heterotrophic remains forms the litter. The role of leaf and litter fall in the forest floor is of a great importance for the fertility of a soil. It has been demonstrated that the litter fall has its importance in regulating the nutrient cycling and soil development (Ebermayer, 1876; Muller, 1887). Lull (1964) reported that litter is the upper decomposed layer of the organic debris composed of freshly fallen materials. Fallen leaves and other senescent plant parts not only recycle nutrients but also perform most of the functions of mulch in the agricultural system.

During the past few years, several workers have contributed to the agroforestry research, major emphasis were made to find out best tree-crop compatibility in agroforestry systems, therefore a lot of work pertaining to tree-crops interaction (Harsh and Tejwani, 1993), alley cropping (Singh, 1995; 1996), agroforestry model as an alternative to 'jhum' or shifting cultivation (Solanki, 1999), fodder trees of India, nitrogen fixing trees species (George and Kumar, 1998), combine tall C_4 crop with a short C_3 crop in intercropping, legume intercropping in cereal (Singh *et al.,*1978), trees and shrubs growing in agroforestry system (Nair, 1993), use of multipurpose trees (Nair, 1981; Fonzen *et al.,* 1985; Tejwani, 1993), dry matter production and nutrient cycling (Sharma and Ambasht, 1986; Sharma *et al.,* 1994; 1995). Litter fall decomposition and nutrient dynamics (Sharma *et al.,* 1997ab), soil productivity and conservation (Dadhwal and Narain, 1988), legume and non - legume plant interaction (Ladd *et al.,* 1986) in agroforestry systems have been carried out. Besides the role of trees and woody perennials and legumes in soil productivity and conservation (Solanki, 1999), their rooting pattern and root interactions (Basavaraju and Gururaja, 2000) are fairly documented.

Several workers have also emphasized on the inclusion of multipurpose tree species in different agricultural systems to maintain a favourable balance between input and output ratio of energy (Nair and Varghese, 1979; Fonzen and Oberholzer, 1985; Johnson and Nair, 1985; May *et al.,* 1985; Shankaranarayan *et al.,* 1986). The role of trees in soil productivity and conservation (Mongi and Huxley, 1979), the role of woody perennial legumes and opportunities offered by them (Brewbaker and Hu, 1981; Nair *et al.,* 1984), amount of nitrogen fixed by the tree legumes (Pak *et al.,*1977; Felker, 1978) rooting pattern and root interaction of woody species (Halle *et al.,* 1978). Besides, there are also a number of reports available on aerial biomass (Pathak *et al.,* 1981; Deb Roy, 1987), economic evaluation (Mishra and Ramakrishnan, 1981; Swaminathan and Ravindram, 1994) ameliorative effect (Singh and Singh, 1989), structure (Sundriyal *et al.,* 1994), growth behaviour (Sharma and Purohit, 1996; Singh, 1996), farm trial (Ko Kewe, 1990; Harsh and Tejwani, 1993) indigenous farming (Singh *et al.,* 1989; Singh and Pradhan, 1993), soil productivity and conservation (Gawende *et al.,* 1974; Narayan, 1986; Dadhwal and Narain, 1988; Khanna and Mathur, 1993), contour and peripheral bund (Nema *et al.,* 1980; Goel and Singh, 1986) on various agroforestry models elsewhere.

The integration of trees into the agricultural land base through tree-crop intercropping systems has already shown great potential in other temperate regions, where they can contribute to the adoption of sustainable agricultural practices (Thevathasan *et al*., 2004). Research activities conducted at the University of Guelph in Ontario during the past 15 years, have demonstrated the high potential of intercropping in terms of benefits such as water-quality enhancement, carbon sequestration, and biodiversity conservation (Thevathasan and Gordon, 2004). Increased tree growth has been observed in plantation mixtures of hardwood seedlings and herbaceous legumes (Haines *et al.,* 1978; Van Sambeek *et al*., 1986; Dupraz *et al*., 1999). Crop yield can vary depending on associated tree species (Dhyani and Tripathi, 1999; Gillespie *et al*., 2000).

A lot of work has been done on the physical and chemical characteristics of soil in intercropping systems, e.g. the soil structure (Hoyt and Hargrove, 1986; Calkins, 1991; Karlen *et al.,* 1999; Glover *et al.,* 2000), soil moisture (Calkins, 1991; Merwin *et al.,* 1994; Walsh *et al.,* 1996), nutrient status and pH (Hoyt and Hargrove, 1986; Calkins, 1991; Hipps and Samuelson, 1991). The results show that the physical indices of soil have been improved by cover crops and less by tillage. An increase in the soil organic C by vegetative ground covers has also been reported (Hogue and Neilsen, 1987; Hipps and Samuelson, 1991). Grasses and N_2 fixing plants like legumes have often been reported to enhance the soil quality. Grasses, in general, have an extensive root system and their positive influence on the physical (Oades, 1984; Haynes and Francis, 1993; Carter *et al.,* 1994; Haynes and Beare, 1997) and biological properties of soil (Drury *et al*., 1991; Haynes and Beare, 1997) is well known. Grasses can also prevent the leaching of agrochemicals (Wiedenfeld *et al.,* 1999). The most important property of legumes as a cover crop may be their positive influence on nitrogen cycling (Hoyt and Hargrove, 1986; Breland, 1994; Wagger *et al*., 1998). Besides grasses, legumes have also been reported to positively affect the physical (Hoyt and Hargrove, 1986; Mullen *et al.,* 1998), and biological (Doran *et al.,* 1987; Kirchner *et al.,* 1993; Haynes and Beare, 1997; Mullen *et al.*, 1998) characteristics of soil.

According to Kennedy and Smith (1995) the maintenance of viable and diverse microbial communities in soil is essential to sustainable agriculture. Microorganisms decompose organic matter, release nutrients into plant-available forms and affect the soil aggregation, thus having an essential role in the nutrient cycling and formation of the soil structure (Sparling, 1997; Stenberg, 1999). Though it has not been possible to have any critical values for the microbial characteristics in good soil, many authors consider microbial action to be, due to the fast rate of turnover, a sensitive indicator and an early predictor in changes in the soil processes and soil quality (Campbell *et al*., 1992; Sparling, 1997; Torstensson *et al*., 1998; Stenberg, 1999; Bending *et al.,* 2000). The interactions between plants and soil microbes comprise of a complex network of both positive and negative influences. Fine root production has a substantial influence on the building up of soil carbon storage. Cover crops have long been recognized in agriculture in this respect (Hoyt and Hargrove, 1986; Wagger *et al.,* 1998). There are plant-induced quantitative and qualitative variations in the fine root production and carbon flow to the soil, however, different plant species maintain a different microbial biomass and activity (Haynes and Francis, 1993; Groffman *et al.,* 1996; Mullen *et al*., 1998). Soil microorganisms make nutrients available for plants via mineralization processes, but they also use belowground resources for their own growth and thus can be real competitors with plants (Korsaeth *et al*., 2001). The complexity of these interactions may also have important consequences for tree–crop interaction/compatibility. The site-specific competition, which is obvious in an intercropping system, is still inadequately known and the compatibility of tree species plays a key role in sustained production of the system.

Mulching is a common practice recommended for tropical smallholder farming systems, due to its ability to conserve soil and moisture and also suppress weeds. Some mulch with low C:N ratios provide nutrients for crop growth through rapid decomposition (Unger, 1994). Mulching is generally considered essential under rainfed conditions to make moisture available to the crops. In tuber crops, mulches have been found to lower soil temperatures while conserving soil moisture retention (Sonia Aggarwal *et al.,* 2003). In certain cases food crops are planted directly in a low growing cover crop with minimum soil disturbance (Akobundu, 1980), which helps in smothering weeds and helping soil conservation and maintenance of soil fertility. Results of live mulch trials are enumerated (Akobundu, 1980; Mulongoy and Akobundu, 1985; Tomar *et al.,* 1992; Ossom *et al.,* 2001; Unger, 2001). It was found that maize, cowpea and rice grown with *Arachis prostrate, Indigofera spicata, Centrosema pubescent* and *Psophocarpus palustris proved* most beneficial to each other in term of crop productivity and soil quality improvement. Dry matter yield in forage legume used in live and *in situ* mulch systems can range between 1500 and 7500 kg/ha in Africa (Skerman, 1977; Mulongony and Akobundu, 1985), with N yields ranging from 30 to 300 kg/ha per year. Wilson (1978) reported increased yield and improved quality of tomatoes when grown with an *in situ* mulch of *Pueroria phaseoloides.* Lal *et al.* (1978) observed that use of *in situ* mulches of *Centrosema pubescens, Puerorea phaseoloides* and *Stylosanthes guianensis* over *a* 2-year period increased the yields of cowpea, soya bean, maize and cassava.

Mulches can either be inorganic, organic, or living. The inorganic form usually consists of clear or black plastic sheets tucked into the ground. The organic forms include straw, leaves, compost, newspaper, used coffee grounds, sawdust, tree bark etc. Living mulches are usually patches of various species of clover or vetch, and all tend to be nitrogen fixing. Mulches can affect crop yields by influencing weed cover, soil moisture, nutrients, and pH (Gliessman, 1998). By reducing weed cover, mulches can have a positive impact on crop yields. Organic mulches are reported to conserve soil moisture, which allows crops to withstand longer drought periods (Gliessman, 1998). Organic mulches further add nutrients to the soil. On the contrary, living mulches can remove nutrients from the soil. Many studies have shown the positive effect of mulches on crop yields (Kamara, *et al.,* 2003; Carter *et al.,* 1992). Organic mulches retain soil moisture, allowing crops to have good yields especially during drought periods (Gliessman, 1998).

Mulching as one of the weed control measures is also extensively used in agriculture throughout the world (Gupta, 1991). Organic mulches are more popular in cropping systems, as because they suppress weeds, while at the same time reduce soil tillage under any tillage system (Bilalis *et al.,* 2003). Weed seed germination, which is regulated by soil moisture and temperature, can be affected by both quality and quantity of mulches. Many studies have reported soil increase moisture retention in mulched plots compared with unmulched plots (Edwards *et al.,* 2000; Sharma and Acharaya, 2000). Crop residues overspread on soil surfaces decrease soil temperature in the hot season and maintain it again in autumn (Bristow, 1988; Duppong *et al.,* 2004).

Surface applied mulches provide several benefits to crop production through improving water, heat energy and nutrient status in soil, preventing soil and water loss, preventing soil salinity from flowing back to surface, and controlling weed (Tejedor *et al*., 2002). Literatures revealed that many materials have been used for research as mulch, such as plastic film, crop residue, straw, paper pellets, gravel sand, rock fragment, volcanic ash, poultry and live-stock litters, city rubbish, etc. However, plastic film and straw were used most commonly (Unger, 2001; Tejedor *et al*., 2002; Li, 2003; Berglund *et al.,* 2006). Few preliminary studies have been conducted to determine the effect of plastic film, straw and gravel mulches on the wheat production (Niu *et al*., 1998; Li *et al.,* 2004; Xie *et al*., 2006). These studies showed that mulch wheat increases grain yield in comparison with unmulched wheat. The main causative reasons for mulch increasing wheat yield are soil and water conservation, improved soil physical and chemical properties, and enhanced soil biological activity (Tumulhairwe and Gumbs, 1983; Tindall *et al*., 1991; Deng *et al*., 2006; Ramakrishna *et al*., 2006). However, the application of plastic film and straw mulch are restricted, since the widespread use of non degradable plastic film mulch over many years may damage the sustainability of the soil, and straw mulch did not always lead to high yield because of allelochemical effect on crop growth and lower soil surface temperature (Mao, 1998; Rahman *et al*., 2005). In recent years some studies were conducted on the effect of concrete mulch in controlling evaporation and upward movement of Na^+ and other salts (Mao and Tian, 1997; Li, 2001). However, there is no detailed report comparing the effect of plastic film, straw and concrete mulch on winter wheat growth in saline area.

Mulch can prevent soil salinity from flowing back to soil surface through reducing evaporation as the salt comes with water and goes with water (Zhang *et al*., 1996; Li *et al*., 2000; Tejedor *et al*., 2002). Fan *et al.* (1993) reported that the salinity level of the soil decreased from 0.44% to 0.07% after being mulched with straw for two years. Mao and Tian (1997) demonstrated that the concrete mulch has significant effect on decreasing salt content in maize and jujube fields. However, Niu *et al*. (1998) pointed out that kernels per spikes were increased due to plastic film mulch. Rahman *et al.* (2005) reported straw mulch treatments brought about significantly higher maize spikes per unit area and kernel weight per spike than no mulch treatment, but not in kernel weight. Concrete and plastic film mulch has similar effect on the yield components.

Fast growing leguminous species such as Mucuna (*Mucuna utilis*) and Kudzu *(Pueroria phaseoloides)* are proved very useful as cover crops for erosion control, weed suppression and for soil fertility restoration (Wilson *et al*., 1982). Crops such as sorghum and millet grown in association with *Acacia albida* grow better underneath it than when they are outside its canopy. This tree legume has the unusual habit of growing new foliage during the dry season and losing its leaves early in the rainy season. Nutrient contents in the leaf litter of *Acacia albida* directly below the tree canopy were found to be equivalent to 110 - 185 kg N/ha, 4 - 40 kg P/ha, and 220 - 275 kg Ca/ha (Weil and Mughogho, 1993). *Acacia albida* have been found to influence recycling of nutrients positively from the subsoil, help in accumulation of windblown organic residues and mineral rich soil particles near the tree trunk, and provide nutrient inputs when humans and livestock cluster under the tree during the dry season (Dommergues and Ganry, 1986; Dancett and Poulain, 1969).

Mulches of crop residues, minimum tillage and leguminous cover crops are promising technologies for improving nutrient and water use efficiency and sustaining high yields of maize, sorghum and cowpea in the sub-humid and humid/sub-humid transition zones (Lal *et al*., 1984; Juo and Kang, 1989). Maiti *et* *al.* (1985) also reported increase in growth parameters of ginger due to organic manure and inorganic fertilizer.

Gupta (1991) reported that continuous crop production in dry regions of India using water harvesting together with manuring and mulching has resulted in significant increase in soil organic matter content, soil moisture retention, enhanced steady state infiltration rates and reduced bulk density. Weeraratna *et al.* (1990) and Sonia Aggarwal *et al.* (1998) concluded that improved soil physical and fertility conditions due to application of mulch prior to planting were the main causes of the improved yields in the test crops like wheat and rice. A few reports on the use of organic mulches in some of the vegetable crops have also been documented (Mishra *et al.,* 1982). Mulches markedly influenced the growth and yield of ginger (Aggarwal *et al.,* 2003). The work done by Bhan (1976), Singh (1989) and Uttam *et al.* (1994) demonstrate the utility of straw mulch in enhancing the productivity of rainfed mustard. Beneficial effects of jalshakti (Singh, 1989) in increasing the yield of mustard have also been reported. Incorporation of organic manure into the soil results in typical soil conditions (Fried *et al.,* 1983) and thereby significantly increases the level of N fixation (Patterson and La Rue, 1983).

Use of organic mulch helps in reducing evaporation by moderating the temperature and conserving the soil moisture. Incorporation of organic matter has been reported to augment water retention capacity by improving physical environment of soil (Tomar *et al.,*1992), *Leucaena* having very high biomass production potential (Krishnamurthy and Mune Gowda, 1982) and fast decomposition characteristics (Mittal *et al.,*1992), can be used as organic mulch effectively. *Leucaena* leaves can be applied in the field as mulch just before maize harvesting initially to conserve soil moisture for proper germination of subsequent wheat crop and later on, this could be incorporated into the soil at suitable time (Mittal *et al.,* 1992).

According to the finding of Sterk and Spann (1997), mulch helps to reduce water erosion, lessens intense solar radiation, suppresses extreme fluctuations of soil temperatures and reduces water loss through evaporation, resulting in more stored soil moisture. Application of mulches reduces the incidence of weeds to a great extent (Agarwal *et al.*, 2003). Pandey *et al.* (2002) reported that the weed control treatment gave higher crop yield as compared to unchecked plots. Omoro and Nair (1993) reported that the soil losses from plots with mulches of *Cassia siamea*, *Glircidia sepium* and *Grevillea robusta* were significantly lower than those from the controlled plots. Similarly water run off from the mulched plots was lower than that of the control plot.

In a study by Unger (1978), sorghum grain yields increased with increased mulch rates. Similarly, mulched treatments of banana produced over three times more biomass than bare soil treatments (Mc Intyre *et al.,* 2000). This increase in biomass was likely due to improved soil fertility as a result of mulching since mulched treatments had higher concentrations of soil organic carbon, phosphorus and exchangeable potassium and magnesium. Incorporation of mulching materials to wheat improved the uptake of Ca and Mg at all growth stages. Further, mulching significantly improved the dry matter and grain yield of wheat at all growth stages (Sharma and Parmar, 1998). The findings of Montagini *et al.* (1993) revealed that growth of maize was highest under vegetative mulch treatments, while un-mulched control plots showed significantly inferior growth. Mathews *et al.* (1992) found significant correlation between the quantities of pruned biomass applied as mulch and the proportional increase in maize yields over the control treatments.

Studies on the use of foliage as mulch from trees reported so far have mainly addressed the effects of the mulches on soil fertility and productivity (Yamoah *et al.,* 1986, Kang and Mulongoy, 1987, Budelman, 1988) but not on the soil erosion aspects. 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 (Duguma *et al.,* 1988, Gutteridge, 1990),

Different types of mulches have also been tried by various workers for improving crop productivity and as measures towards soil conservation. For example, banana leaf was used as mulch for increasing ginger yield (Mohanty, 1977), green leaves of forest trees on ginger (Roy and Wamanan, 1988), green mulches for increasing yield of sweet potato (Ossom *et al.,* 2003), use of sisso leaves on turmeric (Jha *et al.,* 1983), use of gliricidia, rice straw and grasses on turmeric (Singh *et al.,* 1988; Mohanty *et al.,* 1990; 1991), various mulches on yield of mandarin (Shirgure *et al.,* 2002). A combination of mulching with dried leaves or straw and application of 2, 4, D or Atrazine (1 kg ai/ha) have been found increasing the ginger productivity and its high net return (Mishra and Mishra, 1982). Mulch as organic materials have helped in suppressing annual weeds while reducing soil moisture evaporation and increase in organic matter content of the soil (Sterk and Spaan, 1997). Besides, it helps in reducing water erosion, intense solar radiation, and extreme fluctuations of soil temperature (Budelman, 1988; 1989; Montagnini *et al.,* 1993) thereby creating favourable microclimatic conditions for the growth of plants. The relative efficacy of different mulches (both quality and quantity) has also been tried on different crops by some workers (Mohanty *et al.,* 1990; 1991).

It has also observed that trees grown under agroforestry systems attained higher growth as compared to the trees grown under forest condition (Singh *et al.,* 1988). Some studies (Onim *et al.,* 1990, Chattopadhyay and Patra, 1992) have reported that trees improved soil fertility with little or no reduction in crops yields. However, the choice of tree species depends upon climatic and edaphic conditions, maturity cycles, and compatibility with agricultural crops, local demands, and prices of wood in nearby markets and illicit felling by unsocial elements.

Plant neighbours can have both positive and negative interferences on each other, depending on the species involved and the nature of the factors limiting growth. Positive interferences in nature are rare and often masked by more important negative interferences (Radosevich and Osteryoung, 1987). The few positive effects reported by various authors include : the association of nitrogen-fixing symbionts to favour growth of tree species (Chatarpaul and Carlisle, 1983; Fortin *et al*., 1985) to diminish the adverse effects of excess soil water on tree growth, (Paavilainen and Paivanen, 1995; Penner *et al*., 1995; Jutras *et al*., 2004). Negative interferences could include limitation of light and nutrients (Wagner and Radosevich, 1991; Jobidon *et al*., 2003), Literatures on the effect of vegetation on crop seedling survival and growth shows that competition varies greatly depending on crop-tree species (Fredericksen *et al.*, 1993; Wagner *et al.*, 1996; Mitchell *et al.*, 1999; Reynolds *et al.*, 2002), seedling size (South *et al.*, 1999; Rose and Ketchum, 2003), vegetation composition (Cain, 1999; Coll *et al.*, 2003), site characteristics (Powers and Reynolds, 1999) and silvicultural treatment (Gemmel *et al.*, 1996 ; Haywood *et al.*, 1997). Wagner *et al.* (1999) also pointed out that competitive interactions between seedlings and surrounding vegetation is a dynamic process with strong temporal variations over the first two years after seedling establishment, which are determined by the pattern of seedling and vegetation development (Miller *et al.*, 2003).

The role of legumes in farming systems has been reviewed by various authors (Wilson, 1978; Mannetje *et al.,* 1980; Norman, 1982; Crowder and Chheda, 1982; Hague and Jutzi, 1984; Agishi, 1985). The primary role that legumes play is to fix atmospheric N_2 through their symbiotic relationship with *Rhizobium* spp., usually associated with the host's root system. This contributes nitrogenous compounds to the soil, either directly by nodule excretion, or indirectly by decomposition of root nodules and tissues. Nitrogen is also passed to the soil from the top growth through litter fall, though leaching by rain from aboveground parts and by deposition of excretory materials from herbivores both above and below the ground. This primary role of fixation of atmospheric N_2 leads to two dependent or consequential roles of legumes: (a) their capacity to increase soil fertility and (b) the generally high levels of protein in the herbage and hence its high forage or mulching quality. It is unlikely to be by chance that most legumes have acquired their ability to fix N. If one examines the ecological basis for the natural distribution of legumes in the world's floras, seldom one finds them at all common or highly productive in climax vegetations. However, they are frequently common and vigorous in successional situations, particularly where soil fertility or the availability of plant nutrients is low (Norris, 1964). Thus, legumes are often strongly associated with disturbed sites like road sides. As a result of this disturbance, when nutrients other than N are likely to be more available than usual, legumes compete effectively against those species that cannot fix N. This is presumably why most legumes retain a capacity to respond to such important secondary nutrients as P, since this is critically important for effective symbiosis.

Though cultivation of legumes enriches soil N (Agboola and Fayemi, 1972), the amount depends on the proportion of the legume N that is fixed and its distribution in various plant organs (Eaglesham *et al.,* 1982; Wood and Myers, 1987). Peoples and Craswell (1992) reported very low net contribution from legumes toward N enrichment in soil in many cases and negative in some. Chandel *et al.* (1989) reported negative N enrichment; however, such detailed studies on other soils and varieties are scanty. The legume intercropping have been shown improving organic carbon and available N and P status of soil substantially (Hazra and Pradeep Behari, 1993). Nitrogen fixation has been confirmed in about 650 trees and large shrub species belonging to nine plant families (Brewbaker *et al.,* 1990). A majority of them belong to family Leguminosae. The reported amounts of nitrogen fixed by trees shows a wide variation ranging from 10 kg for *Faidherbia albia* (Cornet *et al.,* 1985), 13 kg for *Gliricidia sepium* (Roskoski *et al.,* 1982) to 134 kg for *Leucaena leucocephala* (Sanginga *et al.,* 1989) on a per ha per year basis. In general, the fixed nitrogen is about 20-65% of the total plant nitrogen (Sanginga *et al.,* 1990; Schulze *et al.,* 1991).

Increase in nitrogen fertility by including trees in agroforestry systems has been achieved by the incorporation of pruning and fallen litter. Use of pruning as green manure or mulch is advocated in alley cropping systems (Kang *et al.,* 1981). Yamoah *et al.* (1986) observed an increase in maize yield when pruning of either *Gliricidia* or *Cassia siamea* were incorporated.

Growing trees on agricultural fields, combined with agricultural crops for augmenting biomass production per unit area is now becoming popular among the farmers. In return, the farmers get the cash crop benefits and also the returns from trees in the form of timber, fuel wood and fodder etc. In North East India, the farmers particularly the marginal farmers collect their various requirements from traditional agroforestry system. It has been observed that trees grown under agroforestry attained higher growth as compared to the trees grown in forest condition (Singh *et al.,* 1988). Mohsin *et al*. (1996) have reported that *P. deltoids* tree grown in stands treated with various *Mentha* and *Cymbopogon* spp. attained higher biomass than their pure stands whether at their juvenile (2 and 3 year) or advanced (6 and 7 year) ages.

In recent years, increasing concern over the environment is forcing horticulture, agriculture and forestry to search for alternative, sustainable production systems. The concept of sustainability is multi-dimensional and is defined according to Kennedy and Smith (1995) as "the adoption of practices that allow for the long-term maintenance of the productive capacity, the viability and quality of life, and conservation of the environment and resource base". Questions have been raised concerning the long-term impacts of repeated tillage, the application of pesticides and synthetic fertilizers on the soil quality (Ghadiri and Payne, 1986; Glenn and Welker, 1989; Meagher and Meyer, 1990; Hipps and Samuelson, 1991; Lipecki and Berbec, 1997; Goh *et al.,* 2001). The extend to which vegetative ground covers is used has been studied as one possibility towards sustainability (Bugg *et al.,* 1991; Calkins, 1991; Merwin *et al.,* 1994; Walsh *et al.,* 1996; Neilsen and Hogue, 2000). In this practice, the soil under the main crop is covered with another plant species. This, however, creates interspecific competition and one species may suffer because of resource competition or interference from another species (Anderson *et al.,* 1993). Interference is mainly understood as allelopathy (Tilman, 1990) and resource competition as a mutually negative interaction between species when they consume the same, limited resources (Grover, 1997).

Intensive studies of the interactions between trees and herbaceous plants have been carried out in agroforestry (Ong *et al.,* 1991; Ziehm *et al.,* 1992; Anderson and Sinclair, 1993; Alley *et al.,* 1999; Dupraz *et al.,* 1999), in the temperate and boreal forest plantations (Haines *et al.,* 1978; Davey and Wollum, 1984; Cogliastro *et al*., 1990). With the increasing interest in alternative production systems in orchards, the impact of herbaceous ground cover on fruit trees has been investigated (Meyer *et al*., 1992; Parker *et al.,* 1993; Merwin and Stiles, 1994; Creamer *et al*., 1996; Neilsen and Hogue, 2000). However, very little research has been done in the nursery field production of woody plants (Calkins, 1991), in which high growth capacity is needed, and even exponential nutrient loading for the seedlings is used to guarantee a good start after planting (Timmer, 1997). The repeated cultivations and synthetic inputs (pesticides and fertilizers), which belong to common production practices in nurseries, have increased concerns about the environment and financial benefits. These are forcing the industry to look at alternative production systems, of which the use of cover crops is of great interest (Calkins and Swanson, 1996). In tree crop competition especially where wide spacing is used, the competition for resources is mainly from the belowground, the aboveground a biotic factors, e.g. light, temperature and humidity are usually of minor importance (Ong *et al*., 1991; Casper and Jackson, 1997; Kochy and Wilson, 2000). In belowground competition, plants reduce the available soil resources, mainly water and mineral nutrients and decrease the growth and success of their neighbours (Casper and Jackson, 1997). The competition for water is believed to have an important role in competition between woody seedlings and herbaceous vegetation (Davis *et al*., 1999), even though contradictory results exist (Picon-Cochard *et al.,* 2001). In general, it has been suggested that root competition is more important than shoot competition and has a greater impact on plant performance (Wilson, 1988; Gerry and Wilson, 1995; Weiner *et al*., 1997). However, often the manner in which plants compete is not properly known (Caldwell *et al.,* 1985; Cahill and Casper, 2000). The suppression of tree growth has been a major problem when cover crops are used (Foshee *et al*., 1995; Calkins and Swanson, 1996; Walsh *et al.,* 1996; Alley *et al.,* 1999). To obtain successful tree cover crop combinations, it is important to find non or weak competitive cover crop species (Calkins and Swanson, 1995). Furthermore, it is not only important that the cover crop does not compete for water and nutrients with the tree, but it should not be allelopatic either (Weller *et al*., 1985; Putnam, 1986; Skroch and Shribbs, 1986), besides it should have a good weed suppression ability (Echtenkamp and Moomaw, 1989; Creamer *et al*., 1996), potential to positively affect the soil quality (Meagher and Meyer, 1990; Merwin *et al.,* 1994; Walsh *et al*., 1996). Legumes have been regularly studied as vegetative ground cover in order to improve the nitrogen economy of the plants and the overall soil quality (Hoyt and Hargrove, 1986; Bugg *et al.,* 1991; Ziehm *et al.,* 1992; Wagger *et al.*, 1998; Neilsen and Hogue, 2000).

The above review of literature reveals that although a lot of work has been carried out on trees in combination with agriculture crops elsewhere no work hitherto has been made in Mizoram. In Mizoram, shifting cultivation is the predominant form of agriculture although other land uses like traditional agroforestry, home garden, and terrace cultivation are also found. However, the cultivation of multipurpose trees in combination with agricultural crops as a measure for changing the age-old traditional jhum practice followed by Mizo people has not been undertaken. Similarly, the applications of appropriate mulch, which can enhance and increase crop productivity as well as help in soil moisture conservation, have not been studied. Therefore, a careful investigation incorporating different mulches and/or tree species need trial for obtaining sustainable crop production and conserving soil and water in the agroforestry system. The present study therefore seeks to understand the role played by legumes and non- legumes trees when grown with the important crops and the relative efficacies of various mulches in retention of soil moisture and improving ecosystem health.

Chapter-III

Study sites, climate, soil and methodology

3.1. Study sites

The study was carried out at Tanhril Campus of Mizoram University, which is located on the south-western part of Aizawl city, the capital of Mizoram. Tanhril Campus of the university is located about 15 kms from Aizawl city and lies between 23˚42′ to 23˚46′ N latitude and 92˚38′ to 92˚42′ E longitude (Fig 3.1). The site is moderately sloped on the up side and the slope gradually decreases towards downside. The average slope of the study site is about 25% and located at an altitude of 845 m with an average rainfall of 2500 mm. In Mizoram, only 7 % of the land is reported to have under 20 % slope while 72 % of the land is having more than 50 % slope, the former is ideal for sustainable crop production (Anon, 1992).

The state of Mizoram shares many of the attributes of mountainous regions elsewhere like remoteness, limited access, fragile, steep landscapes, high biodiversity, resilient farming system with limited option for change and independent but improvised people (Anon, 2002). The land of Mizoram has triangular shape, perched in the North-East India by Assam and Manipur in the North, Burma and Chittagong Hill Tracts in the South, Myanmar in the East and Tripura and Bangladesh in the West. The Tropic of Cancer passes through the middle portion of the state touching Aizawl, the study area. The agriculture practice in the site is completely rainfed.

An experiment farm was established in the site in the year 2003 by clearing the underground vegetation and small trees. The felled trees and shrubby vegetation were allowed to dried up and burnt. The site was then transplanted with approximately one-year old tree seedlings of *Alnus nepalensis, Melia azadirachta,* and *Gmelina arborea* following the experimental layout as detailed in Fig. 3.2. The crops like maize, ginger and turmeric were grown in the interspaces following uniform cultural treatments.

3.2. Climate

The climate of the area is humid tropical characterized by short and dry winter, and long summer. The temperature variation is small throughout the year. The mean summer and winter temperatures varied from 20˚ C to 30˚C and 8˚C to 18˚C respectively. The summer months are warm and wet whereas the winter months are moderate and dry. The rainy season lasts for about five months from May to September during which heavy rainfall occurs during June to August accounting nearly 89% of the total annual rainfall. Winter is somewhat cool. The monthly temperature and rainfall data of Aizawl, the capital city of Mizoram during 2003-2005 is given in Fig. 3.3 and 3.4.

On the basis of temperature and rainfall, the year can be divided into three seasons namely spring or mild summer (March to April), rainy or wet summer (May to October) and winter (November to February). May to October receives heavy rainfall although occasional showers occur in the months during November to February. July and August experience the wettest months while December and January experience the driest months. The highest temperature is recorded in the month of April. After that the temperature gradually decreases and becomes lowest in the month of December. During spring or mild summer season, the temperature normally ranges between 18°C to 25°C, while during rainy season or wet summer month, the temperature ranges between 18°C to 29°C and during winter season the temperature ranges between 11°C to 25°C. The annual rainfall is 2500 mm. (Fig. 3.3)

3.3. Soil

The soil of the study site, in general, is sandy loam, red brown in colour and acidic in nature. The soil pH ranged from 5.03 - 5.40. The particle fractionations and textural classes for the surface soil revealed that the study site had sandy loam soil. In general, the surface soil of the hilly terrains of Mizoram is highly leached, rich in iron, poor in bases, poor in potash and phosphorus due to heavy rainfall. The organic carbon content in the soil is also found inadequate.

3.4. Methodology

Keeping in view of the objectives set forth in the present research, two broad experiments *viz*. (a) species trial experiment and (b) soil conservation experiment were carried out as follows:

(A) Species-trial Experiment:

The experiment was laid down in RBD (Randomized Block Design) with three replications involving 15 sub plots as (3 x 3 plus 3 control (tree) + 3 control (crop) in each replication totaling 45 sub-plots. The variation in slope between the plots was minimal (<5%). The size of each sub-plot is 17.5 m x 17.5 m. Each sub-plot is separated by a boundary of 1 m wide. Thus each replication covered an area of 4986.75 sq. m and the whole study area for species-trial experiment was 14960.25 sq. m (Figure 3.2). The tree and crop components for species trial experiments was as follows:

(a) Tree species introduced: *Alnus nepalensis* (leguminous)
Melia azadirachta (non-leguminous)
Gmelina arborea (non-leguminous)

(b) Inter crops: Ginger (*Zingiber officinales*)
Turmeric (*Curcuma longa*)
Maize (*Zea mays*)

The spacing between row-to-row and plant-to-plant for all these three trees species was uniformly 2.5 m apart. However, the spacing between intercrops was slightly different (e.g. for ginger 20 cm x 30 cm, for turmeric 25 cm x 35 cm, and for maize 40 cm x 60 cm).

One-year-old healthy seedlings of *Alnus nepalensis* and *Melia azadirachta* grown raised in poly pots were procured from Shillong, Meghalaya and were transplanted to the research field by pit digging method in the third week of May, 2003 during rainy season at a distance of 2.5 m x 2.5 m a part respectively. The native species of *Gmelina arborea* seedling grown in nursery were also collected from Horticulture Department, Government of Mizoram at Thingdawl village and were planted in the field during the first week of May 2003 as per the other two species. For each species 56 seedlings were planted per sub plot. A sample of 10 seedlings from each species was thoroughly studied for their root characteristics, growth behaviour and biomass, before introducing into the experimental agroforestry plots. Pits of size 1 ft x 1 ft were dug and filled with sand, soil and farmyard manure in the ratio of 1:2:1 and the seedlings were transplanted in the dig in the third week of May 2003.

(B) Soil moisture Conservation Experiment:

Soil moisture conservation was evaluated by both (a) species mixture and (b) quality and quantity of mulches. The first part of the experiment was same as those of species trial experiment. The experiment does not involve the application of any mulch material. The second part of the experiment was laid down in RBD (Randomized Block Design) with three replications involving 18 sub plots as (1 tree species x 2 crop species x 3 mulch types x 3 mulch doses) in each replication totaling 54 small plots. The experiment was restricted only to *Gmelina arborea.* The size of the sub-plot of was similar to that of species trial experiment. The size of the plot was worked out from the main plots of the species trial experiment. An area of approximately 2.5 m x 2.5 m was marked from the main plots for evaluating the efficacy in yield due to quality and quantity of mulches without disturbing the objective of the first set of experiment. The details of tree/crop/mulch for soil moisture conservation experiment in the second part were as given below:

(a) Tree species introduced: *Gmelina arborea,*

(b) Inter crops : *Zingiber officinales, Curcuma longa*

(c) Mulches (type) : Rice straw, weeds, subabul leaves

(d) Mulches (Quantity) : 6 t/ha, 8 t/ha, 10 t/ha.

Mulches were applied to the plots immediately after sowing of the intercrops. Uniform cultural treatments were given to all the plots.

(C) Parameters evaluated:

(a) Growth performance:

Various growth attributes of trees such as plant height, collar thickness was measured for all the three trees species from different treatments at a 6 monthly intervals. Simultaneously, the growth attributes of the three intercrops such as tiller height, collar thickness, frequency of tiller, number of tillers in root crops under different treatments was measured a monthly intervals.

(b) Biomass production:

At a six monthly intervals, 2 seedlings of each tree species grown under a particular treatment from each replicated plot were excavated from the field preferably near the border, washed gently with water to remove the adhering soil particles. Careful attempt was made to fill back the area with the soil. Since excavation was done during crop harvest time, there was no damage to the field crop. Various root characteristics like lateral root spreading and vertical root length were recorded first and then seedlings were divided into various parts like shoots, leaves, tap root, fibrous roots and oven dried separately at 70°C until the constant weight was obtained. The above ground biomass, below ground biomass and root/shoot ratio on biomass was calculated. The seedling quality parameters such as sturdiness (the ratio height to collar diameter, root/shoot ratio and the ratio of fibrous root biomass to the total biomass) were computed. Biomass of individual components was worked out by using formula, Dry matter = Dry weight of sample/ Fresh weight of sample x Total Fresh weight. Biomass/root characteristic study is restricted only to two years period although initially it was planned for a three years period. The excavation of the seedlings caused problem causing its reduction to two years period.

(c) Crop yield:

The yield of root crops (i.e. ginger and turmeric) under different treatments was recorded at the end of each cropping season from all the plots.

(d) Soil parameters:

Various physico-chemical properties of the soil such as soil texture, moisture, pH, and N, P, K were estimated at 0-15 cm soil depth before, and after crop harvest in all the plots to see the changes in soil characteristics due to cropping. Soil moisture content was measured at a monthly interval. Soil moisture content and pH was determined from fresh soil samples following the methods as outlined in Anderson and Ingram (1993). A part of the soil sample was air-dried, and analyzed for total kjeldahl nitrogen, soil texture, available-P following semi-microkjeldahl method, molybdenum blue (Allen *et al.,* 1974) procedures. Soil texture was determined using a hydrometer.

(e) Soil moisture conservation:

Soil moisture content was determined at a monthly interval in all the plots from the soil samples collected from a depth of 0 -15 cm, properly tagged and sealed in plastic packets before being brought to the laboratory for analysis. Soil moisture loss on drying to constant weight was determined for 100 gm of fresh soil. The soil moisture percent was expressed as percent fresh weight and was calculated as moisture percentage (M%) = (Fresh weight – Dry weight) x 100 / Fresh weight. Soil moisture conservation/retention was expressed in term of moisture gain and was calculated as moisture gain percentage (%) = Difference in moisture gain due to species mixture or mulch over control treatment x 100 / Amount of moisture in the control treatment .

(f) Crop productivity:

Effect of type and quantity of mulch on the yield of the root crops (ginger and turmeric) was determined by assessing the number of tillers, survival percentage, and height of tillers etc. at a monthly intervals from crop sowing till cessation of growth, Crop yield (q/ha) was noted at the time of harvest from all the plots.

(D) Statistical methods:

The data obtained on various growth parameters were subjected to analysis of variance (ANOVA) to see the effect of species mixture on a particular treatment. Relative efficacies of different quality and quantity of mulches on crop growth characteristics and their productivity were also assessed using ANOVA. Coefficient of correlation (r) was found out to relate between soil moisture conservation with soil pH, N, P, K status at a particular time. T-test was made to find out the differences in soil moisture conservation due to species mixture and mulch application.

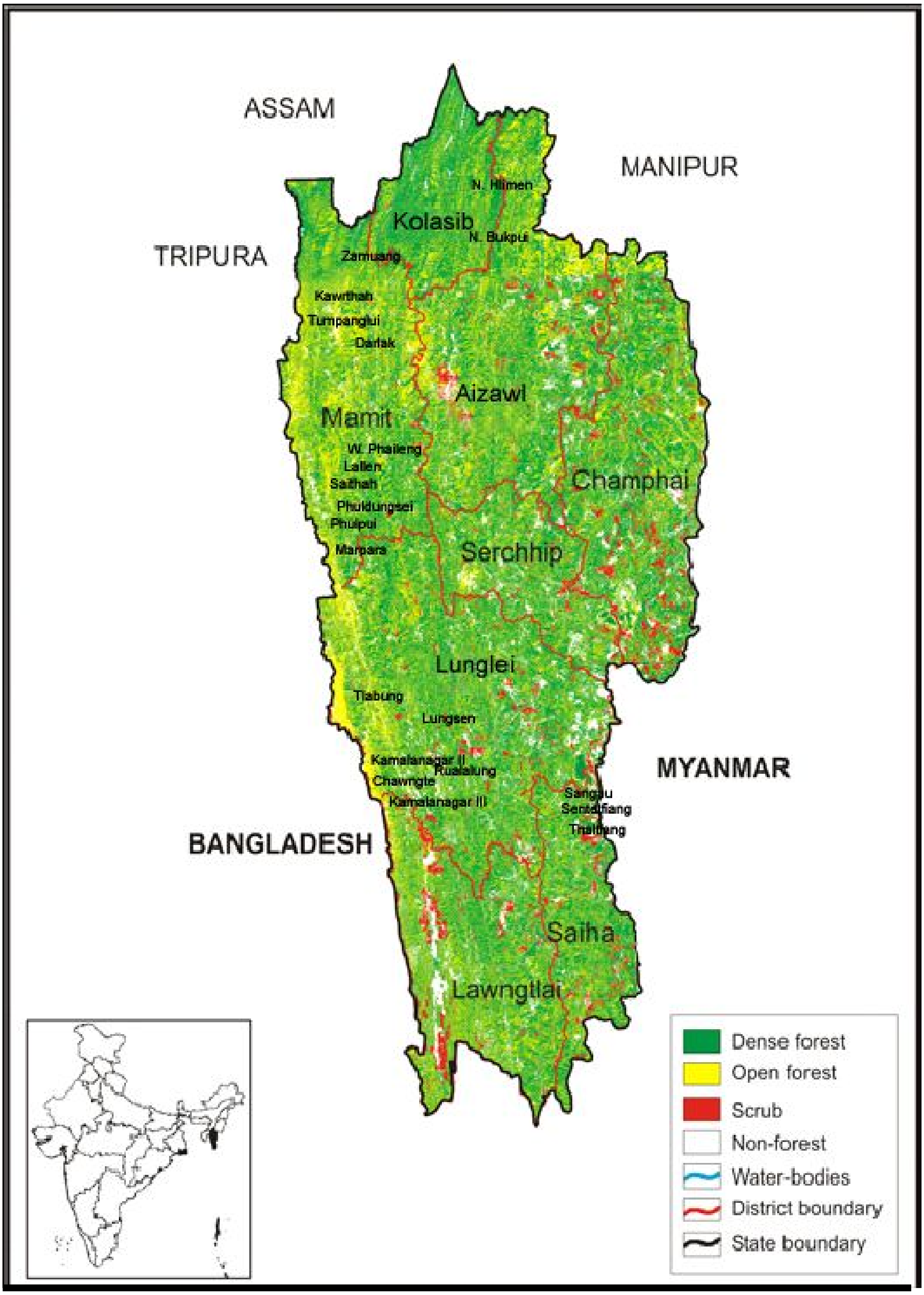
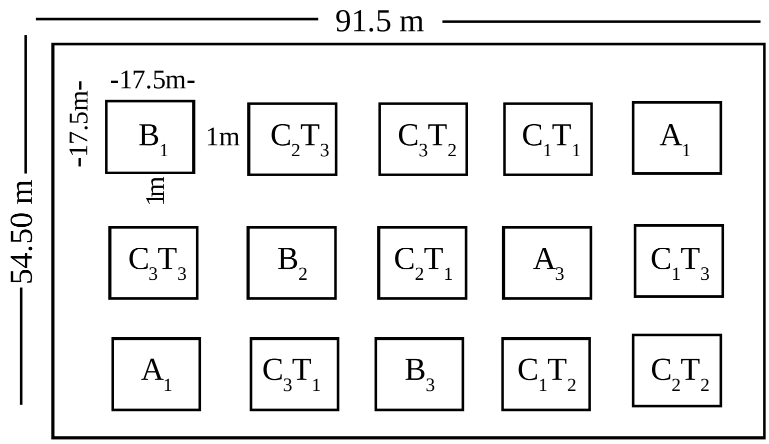


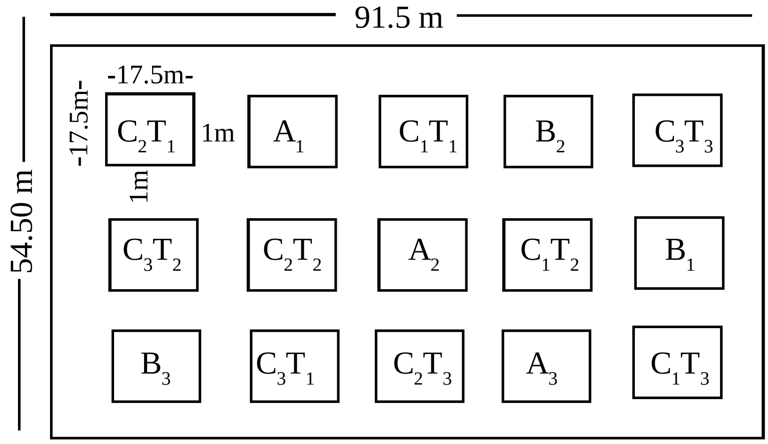
Fig. 3.1. Map of the study site in Mizoram

Lay out

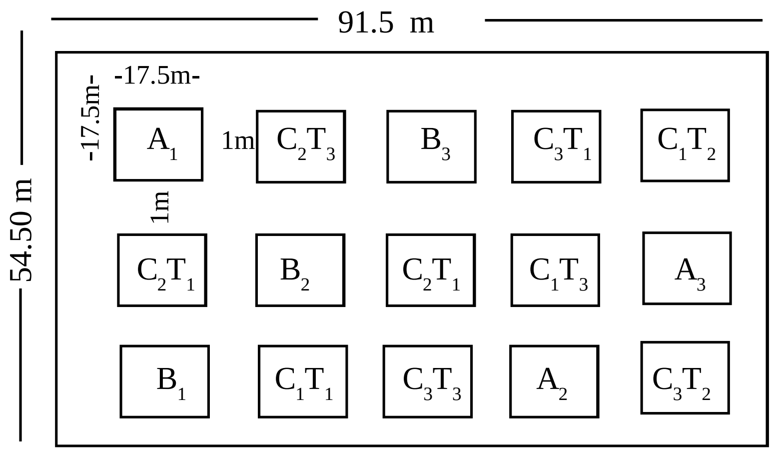
Replication: 1



Replication: 2



Replication: 3



Crop species: C_1- *Zinggiber officinale*, C_2- *Curcuma longa* & C_3- *Zea mays*

Tree species: T_1- *Alnus nepalensis*, T_2- *Melia azadirachta* & T_3- *Gmelina arborea*

Control : A_1- *Zingiber officinale*, A_2- *Curcuma longa* & A_3- *Zea mays*
B_1- *Alnus nepalensis*, B_2- *Melia azadirachta* & B_3- *Gmelina arborea*

Fig. 3.2 Experimental lay out for tree-crop compatibility and soil moisture experiments in the study site.

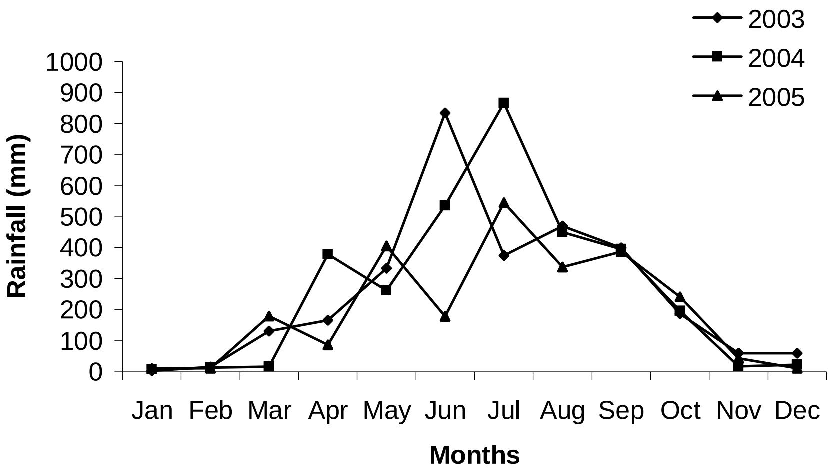


Fig. 3.3. Monthly average rainfall data (mm) in Aizawl during 2003-2005.

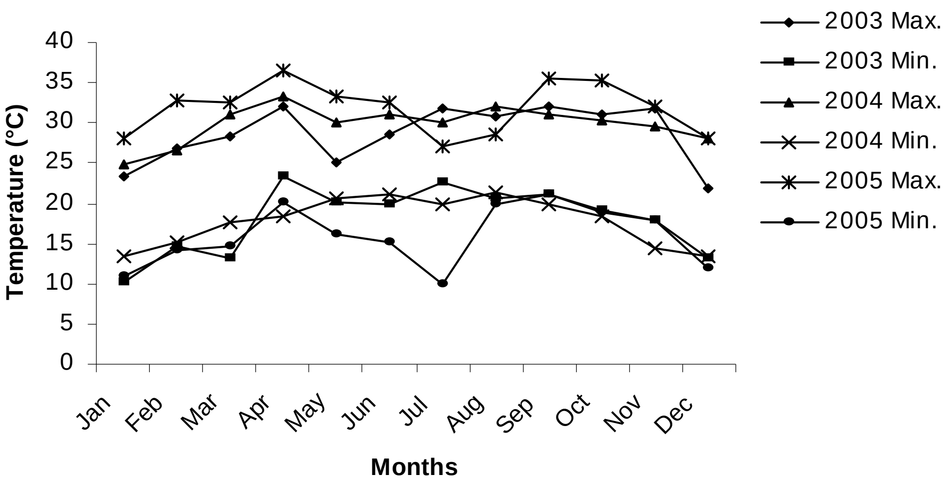


Fig. 3.4. Monthly average temperature (°C) in Aizawl during 2003-2005.

Chapter-IV

Growth performance and biomass production of trees as affected by different species mixture

4.1. Introduction

Multipurpose trees are an important component of any natural ecosystem. The potential of some multipurpose trees are exploited in sustainable farming systems like agroforestry. Planting multipurpose tree species (MPTs) has been a popular activity in the resent day agroforestry programmes world wide to meet the varied requirements of ever growing human population. Considering the edaphic and climatic conditions, the people over the years, have introduced various suitable drought, hardy and multipurpose tree species and shrubs for sustainable production under different spatial and temporal arrangements with the crops. No single species can grow well on all sites, tolerate all type of environment nor yield all type of products or services. The selection of MPTs in agroforestry systems therefore will depend on its ability to grow well under different species mixture and planting site. Usually, the multipurpose tree species preferred for agroforestry are NFTs because they are more suited to low nitrogen soils than some other multipurpose tree species, and their small, nitrogen rich leaves decompose rapidly in the soil.

The growth of multipurpose tree species in agroforestry system depends on the availability of growth resources like light, water, space and nutrients. In addition, the crop component does share the resources and therefore the performance of trees and crops in a system are interdependent and related to a biotic component as a whole. These are referred to as tree-crop interactions. These interactions may be positive or negative. The balance between these positive and negative effects determines the overall effect of the interactions in a given agroforestry combination. The knowledge of these interactions will be helpful in proper management of agroforestry systems for sustained production of multiple outputs.

In Mizoram, crops yield are low because of faulty cultivation practices. Shifting cultivation, which is the age-old, traditional farming system widely practiced in the state is reported to result in poor soil fertility, cause more soil erosion, runoff water and ultimately poor crop production. To solve these problems and replace them with a better and improved method of cultivation, a need is always felt to find out a suitable agroforestry system that can offer an alternative means of cultivation with positive impact on the environment and enhancing the basic natural resources leading to higher and suitable production.

Accepting the fact that some multipurpose trees have always influenced the growth performance of field crops in increasing the quantity and quality of crop yield, there has been a resurgence of interest among agriculturists, agronomists, ecologists and environmentalists alike to focus their studies to understand the suitable tree-crop compatibility in agroforestry system and their reproductive aspects. However, all multipurpose tree occurring in the state are not suitable for agroforestry aspect to give better crop yield, therefore the present study is carried out to understand the suitable tree-crop compatibility in the experimental farm.

4.2. Methodology

Three tree species *viz*. *Alnus nepalensis, Gmelina arborea* and *Melia azadirachta* were tried for their growth performance in three crops field *viz. Curcuma longa, Zea mays* and *Zingiber officinales* as per the layout mentioned in Fig. 3.2. One-year-old healthy seedlings of *Alnus nepalensis* and *Melia azadirachta* grown in nursery were procured from Shillong, Meghalaya and were transplanted to the research field by pit digging method in the third week of May, 2003 during rainy season at a distance of 2.5 m x 2.5 m a part respectively. Seedling was 20-30 cm height at time of transplanting. The native species of *Gmelina arborea* seedling grown in nursery were also collected from Horticulture Department, Government of Mizoram at Thingdawl Village and were planted in the field during the first week of May 2003 as per the other two species. For each species 56 seedlings were planted per sub plot. At the time of transplanting, plant height and collar thickness/diameter of the seedlings were recorded. The stem diameter at 5 cm from the stem base was measured. The root characteristics and biomass of the seedlings were studied.

The local varieties of ginger, turmeric and maize seeds collected from local market were sown in the research field by dibbling method at the end of March as per the layout mentioned in Fig. 3.2. Seeds and seedlings were not subjected to any pretreatment before sowing them directly in the field. No chemicals/control measures were also taken against pest and insects. All the tree seedlings and crops were left to grow under rainfed condition. The inter crops were harvested in the month of November. The detailed parameters evaluated and methods followed for this have been being discussed under methodology (Chapter III).

4.3. Results

4.3 (1) Tree height as affected by different species mixture:

The plant height of *Alnus nepalensis* was in the order of $T_1C_3>T_1C_2>T_1C_1>$ Control respectively. The maximum height (128.73 cm) was attained in T_1C_3 and minimum (86.13 cm) in control during a 3-year period (Table 4.1). The rate of growth of *Alnus nepalensis* was much slower during the first eighteen months after transplantation, and in the next eighteen months, its height increased at a faster rate. No significant difference in plant height was observed when between treatments and control in the 1st year (Table 4.1). By the end of both 2nd and 3rd year, the difference in plant height was quite conspicuous between control and other crop fields. The difference in plant height between treatments was significant ($P\leq0.05$) at 18 and 30 months only (Table 4.2).

Similarly, the plant height of *Melia azadirachta* was in the order of $T_2C_3>T_2C_2>T_2C_1>$ Control and their corresponding values were 380.33 cm, 362.26 cm, 356.53 cm and 339.06 cm respectively (Table 4.3). The plant height increments were generally not significantly affected by species mixture in the first year. However, it was significantly ($P\leq0.05$) affected between treatments compared to control during the last two years. Plant height was significantly increased with time and varied significantly ($P\leq0.05$) between crops for six monthly intervals (Table 4.4). Similar was the case in *Gmelina arborea* (Table 4.6).

Among tree species, *Alnus nepalensis* had a much slower growth rate, *Melia azadirachta* showed relatively a faster growth compared to *Gmelina arborea.*

Table 4.1. Plant height (cm) of *Alnus nepalensis* under different treatments over a 3-year period.

Treatments	Months					
	6	12	18	24	30	36
Control	25.06 ± 0.76	29.33 ± 0.07	33.16 ± 0.49	63.33 ± 2.00	72.53 ± 2.42	86.13 ± 1.10
T_1C_1	27.46 ± 0.48	32.53 ± 0.70	41.86 ± 0.29	74.73 ± 1.29	87.86 ± 0.63	106.46 ± 0.17
T_1 C_2	29.46±1.56	34.26 ± 0.59	46.46 ± 0.63	77.73 ± 3.84	92.73 ± 0.58	110.93 ± 0.67
T_1 C_3	35.66 ± .96	43.06 ± 0.46	58.53 ± 2.21	87.26 ± 1.55	108.53 ± 1.04	128.73 ± 1.35
CD ($P \leq 0.05$)	7.63	4.76	8.84	17.81	10.33	7.02

C_1= *Zingiber officinales*, C_2= *Curcuma longa*, C_3= *Zea mays*
T_1= *Alnus nepalensis* ,

Table 4.2. ANOVA (2-way, fixed effects model) on plant height of *Alnus nepalensis* under different treatments over a 3-year period

Source of variation	df	F-Ratio					
		6 months	12 months	18 months	24 months	30 months	36 months
Crops	3	1.825000	2.261261	7.013035*	1.236234	6.43503*	0.882139
Replication	2	0.325000	2.621622	6.581006*	4.134991*	13.33898*	1.889408
Crop x Replication	6	0.006667	1.072072	3.973929*	0.355240	8.90960*	0.495846

* Significant at $P \leq 0.05$

Table 4.3. Plant height (cm) of *Melia azadirachta* under different treatments over a 3-year period.

Treatments	Months					
	6	12	18	24	30	36
Control	34.46 ± 0.81	50.53 ± 0.98	74.06 ± 1.55	131.13 ± 1.90	236.26 ± 0.89	339.06 ± 1.34
T_2C_1	36.33 ± 2.86	54.06 ± 1.48	91.46 ± 1.68	140.93 ± 3.08	249.66 ± 3.62	356.53 ± 1.73
T_2 C_2	37.66 ± 2.44	60.33 ± 0.88	98.13 ± 1.09	148.26 ± 1.75	253.26 ± 3.17	362.26 ± 3.17
T_2 C_3	47.53 ± 1.28	69.33 ± 1.57	113.66 ± 2.13	165.53 ± 0.75	272.06 ± 1.55	380.33 ± 0.29
CD ($P \leq 0.05$)	15.11	9.43	12.34	15.25	19.12	10.44

C_1= *Zingiber officinales*, C_2= *Curcuma longa*, C_3= *Zea mays*
T_2= *Melia azadirachta*,

Table 4.4. ANOVA (2-way, fixed effects model) on plant height of *Melia azadirachta* under different treatments over a 3-year period

Source of variation	df	F-Ratio					
		6 months	12 months	18 months	24 months	30 months	36 months
Crops	3	13.96646*	20.93393*	55.38068*	24.02076*	23.90614*	62.84502*
Replication	2	1.06123	0.59295	0.75083	0.32293	1.53473	0.46120
Crop x Replication	6	1.89954	0.46149	0.50383	0.53003	0.45322	0.42098

* Significant at $P \leq 0.05$

Table 4.5. Plant height (cm) of *Gmelina arborea* under different treatments over a 3-year period.

Treatments	Months					
	6	12	18	24	30	36
Control	27.40 ± 0.52	42.26 ± 0.40	83.13 ± 0.69	128.06 ± 1.04	236.13 ± 0.58	342.33 ± 1.61
T_3C_1	30.06 ± 0.63	45.26 ± 0.96	89.73 ± 0.93	138.46 ± 0.83	245.33 ± 0.98	354.06 ± 1.57
T_3 C_2	34.33 ± 1.48	49.06 ± 1.17	95.13 ± 0.74	145.33 ± 1.04	252.33 ± 1.16	359.33 ± 1.07
T_3 C_3	39.26 ± 2.18	56.33 ± 1.44	110.66 ± 0.43	163.13 ± 0.78	269.33 ± 1.55	376.13 ± 1.24
CD ($P \leq 0.05$)	10.26	7.95	5.39	7.39	8.37	10.40

C_1= *Zingiber officinales*, C_2= *Curcuma longa*, C_3= *Zea mays*
T_3= *Gmelina arborea*

Table 4.6. ANOVA (2-way, fixed effects model) on plant height of *Gmelina arborea* under different treatment over a 3-year period

Source of variation	df	F-Ratio					
		6 months	12 months	18 months	24 months	30 months	36 months
Crops	3	15.82293*	12.91542*	61.31554*	123.8052*	70.61713*	62.61538*
Replication	2	1.66742	0.61871	0.60835	1.3596	0.43785	0.44178
Crop x Replication	6	0.92031	0.32627	0.10823	0.2799	0.45857	0.67890

* Significant at $P \leq 0.05$

4.3(2) Collar diameter as affected by different species mixture:

The collar thickness/diameter of *Alnus nepalensis* was in the order of T_1C_3>T_1C_2> T_1C_1> Control and maximum collar thickness (4.00 cm) was obtained in T_1C_3 and minimum (3.86 cm) in control during a 3-year period (Table 4.7). The difference in collar diameter of *Alnus nepalensis* between treatments was significant at 18 months and 30 months only (Table 4.8). The collar diameter increased significantly ($P \le 0.05$) with time.

Melia azadirachta and *Gmelina arborea* followed the same pattern i.e. C_3 > C_2> C_1> Control respectively. In *Melia azadirachta,* maximum (9.74 cm) collar thickness was observed in T_2C_3 and minimum (9.40 cm) in control (Table 4.9). In *Gmelina arborea,* maximum (9.61 cm) collar thickness displayed by T_3C_3 , followed by T_3C_2 (9.52 cm), T_1C_1 (9.44 cm) and minimum (9.30 cm) in control during a 3-year period (Table 4.11).

In *Melia azadirachta,* the difference in collar thickness was significant ($P \le 0.05$) between crops in 6, 18, 30 and 36 months, however, in *Gmelina arborea* the difference was conspicuous ($P \le 0.05$) after every six months beyond the first year (Table 4.12).

Table 4.7. Collar thickness (cm) of *Alnus nepalensis* under different treatments over a 3-year period.

Treatments	Months					
	6	12	18	24	30	36
Control	0.26 ± 0.01	0.53 ± 0.02	0.79 ± 0.04	1.01 ± 0.05	2.56 ± 0.09	3.86 ± 0.23
T_1C_1	0.29 ± 0.01	0.55 ± 0.01	0.85 ± 0.05	1.07 ± .07	2.64 ± 0.06	3.91 ± 0.21
$T_1 C_2$	0.31 ± 0.01	0.58 ± 0.02	0.92 ± 0.08	1.11 ± 0.06	2.67 ± 0.07	3.95 ± 0.20
$T_1 C_3$	0.33 ± 0.02	0.60 ± 0.03	0.98 ± 0.07	1.16 ± 0.06	2.71 ± 0.09	4.00 ± 0.08
CD ($P \leq 0.05$)	0.08	0.19	0.51	0.48	0.61	0.58

C_1= *Zingiber officinales*, C_2= *Curcuma longa,* C_3= *Zea mays*
T_1= *Alnus nepalensis*

Table 4.8. ANOVA (2-way, fixed effects model) on collar thickness of *Alnus nepalensis* under different treatments over a 3-year period

Source of variation	df	F-Ratio					
		6 months	12 months	18 months	24 months	30 months	36 months
Crops	3	1.825000	2.261261	7.013035*	1.236234	6.43503*	0.882139
Replication	2	0.325000	2.621622	6.581006*	4.134991*	13.33898*	1.889408
Crop x Replication	6	0.225000	1.072072	3.973929*	0.355240	8.90960*	0.495846

* Significant at $P \leq 0.05$

Table 4.9. Collar thickness (cm) of *Melia azadirachta* under different treatments over a 3-year period.

Treatments	Months					
	6	12	18	24	30	36
Control	0.32 ± 0.03	0.55 ± 0.01	1.32 ± 0.04	2.86 ± 0.08	5.48 ± 0.11	9.40 ± 0.08
T_2C_1	0.34 ± 0.02	0.58 ± 0.04	1.41 ± 0.06	2.92 ± 0.13	5.56 ± 0.10	9.54 ± 0.11
T_2 C_2	0.38 ± 0.04	0.62 ± 0.03	1.50 ± 0.06	2.96 ± 0.11	5.70 ± 0.06	9.62 ± 0.20
T_2 C_3	0.40 ± 0.01	0.64 ± 0.03	1.54 ± 0.07	3.04 ± 0.13	5.80 ± 0.09	9.74 ± 0.15
CD ($P \leq 0.05$)	0.23	0.26	0.49	0.89	0.73	1.09

C_1= *Zingiber officinales*, C_2= *Curcuma longa*, C_3= *Zea mays*
T_2= *Melia azadirachta*

Table 4.10. ANOVA (2-way, fixed effects model) on collar thickness of *Melia azadirachta* under different treatments over a 3-year period.

Source of variation	df	F-Ratio					
		6 months	12 months	18 months	24 months	30 months	36 months
Crops	3	2.862745*	2.237374	10.64694*	2.230887	16.58716*	9.10345*
Replication	2	6.382353*	0.060606	8.1420*	5.963303*	2.75229	1.83251
Crop x Replication	6	1.362745	2.222222	3.14398*	5.914373*	9.43119*	12.23645*

* Significant at $P \leq 0.05$

Table 4.11. Collar thickness (cm) of *Gmelina arborea* under different treatments over a 3- year period.

Treatments	Months					
	6	12	18	24	30	36
Control	0.36 ± 0.01	1.46 ± 0.10	1.40 ± 0.06	2.58 ± 0.07	5.42 ± 0.14	9.30 ± 0.04
T_3C_1	0.38 ± 0.01	1.64 ± 0.10	1.47 ± 0.04	2.67 ± 0.05	5.50 ± 0.08	9.44 ± 0.10
T_3 C_2	0.40 ± 0.02	1.73 ± 0.06	1.52 ± 0.04	2.71 ± 0.04	5.56 ± 0.11	9.52 ± 0.15
T_3 C_3	0.42 ± 0.01	1.89 ± 0.08	1.56 ± 0.06	2.75 ± 0.07	5.67 ± 0.04	9.61 ± 0.13
CD (P ≤0.05)	0.09	0.71	0.41	0.45	0.76	0.89

C_1= *Zingiber officinales*, C_2= *Curcuma longa*, C_3= *Zea mays*
T_3= *Gmelina arborea*

Table 4.12. ANOVA (2-way, fixed effects model) on collar thickness of *Gmelina arborea* under different treatments over a 3-year period

Source of variation	df	F-Ratio					
		6 months	12 months	18 months	24 months	30 months	36 months
Crops	3	1.195402	5.097696*	7.764012*	9.52083*	10.55782*	12.93878*
Replication	2	0.120690	1.580052	5.946903*	15.7783*	13.59184*	8.45714*
Crop x Replication	6	0.281609	1.337416	4.436578*	3.85417*	8.14966*	11.03673*

* Significant at P ≤ 0.05

4.3(3) Biomass production as affected by different species mixture:

Growth performance of *Alnus nepalensis* during 2nd year varied between treatments. Shoot biomass was maximum (7.95 g/plant) in maize plot, where as minimum (7.47 g/plant) in control. Shoot biomass showed progressive increase with time. Similar was the trend for total biomass (Table 4.13). Plant sturdiness was the order of maize > turmeric > ginger > control. The aboveground and belowground biomass increased with the seedling age. However, the belowground to aboveground ratio dry matter was more or less similar. A Similar pattern was observed in *Melia azadirachta* and *Gmelina arborea* (Tables 4.14 and 4.15).

The characteristics rooting ratio and biomass of different plant parts over a 2-year period under various treatments has been enumerated in Table 4.16. The highest vertical and horizontal root spreading was found in *Melia azadirachta,* followed by Gmelina *arborea* and least in *Alnus nepalensis.* In all the species, the vertical spreading was greater compared to the horizontal spreading. The field wise root spreading follow the pattern of maize > turmeric > ginger > control respectively.

The above and belowground biomass production varied between treatments. Maximum aboveground biomass production was found in *Melia azadirachta* and it ranged between 11.86 g/plant to 14.39 g/plant, followed by *Gmelina arborea* (11.81 g/plant to 14.40 g/plant) and minimum in *Alnus nepalensis* (10.70 g/plant to 12.18 g/plant) respectively (Table 4.16).

Similarly, below ground biomass production was maximum (9.86 g/plant to 11.85 g/plant) in *Melia azadirachta*, followed by *Gmelina arborea* (9.83 g/plant to 11.82 g/plant) and minimum (9.04 g/plant to 9.90 g/plant) in *Alnus nepalensis* (Table 4.16).

The order of the total biomass production in *Alnus nepalensis* showed a definite pattern i.e. $T_1C_3 > T_1C_2 > T_1C_1 >$ Control. A similar trend was observed in both *Melia azadirachta* and *Gmelina arborea.* However, the values were somewhat higher in *Melia azadirachta* compared to other two tree species. In all the species, the root characteristics parameters i.e. ratio of shoot length: root length, AGB : BGB ratio and plant sturdiness followed the same sequence i.e. $T_1C_3 > T_1C_2 > T_1C_1 >$ Control respectively.

The shoot biomass contributed substantially to the above ground biomass in all the species. The production of leaf biomass was somewhat higher in *Melia azadirachta* than in *Gmelina arborea* and *Alnus nepalensis*. The taproot biomass contributed maximally to the below ground biomass (Table 4.16). In *Melia azadirachta* and *Gmelina arborea,* leaves biomass and above ground biomass varied significantly ($P \leq 0.05$) between the treatments (Table 4.17).

The comparison of the biomass production in terms of shoot, leaves, tap root and fibrous and lateral root biomass were the order of *Melia azadirachta* > *Gmelina arborea* > *Alnus nepalensis* respectively. The analysis of variance showed significant ($P \leq 0.05$) variation in total biomass production (AGB + BGB) between the treatments under *Melia azadirachta* and *Gmelina arborea* (Table 4.17).

Table 4.13. Growth performance of *Alnus nepalensis* under different treatments

Treatment	Parameters	*	Months after transplantation			
			6	12	18	24
Control	Shoot biomass	4.64	5.10	5.25	6.47	7.47
	AGB	6.68	7.15	7.33	9.31	10.70
	BGB	4.22	4.93	6.09	7.40	9.04
	AGB/BGB ratio	1.58	1.45	1.20	1.25	1.15
	Total biomass	10.90	12.08	13.42	16.71	19.74
	Plant sturdiness	55.33	41.97	62.70	28.33	22.31
T_1C_1	Shoot biomass	4.90	5.23	5.59	6.65	7.82
	AGB	6.96	7.32	7.72	9.88	12.00
	BGB	4.32	5.98	6.57	8.04	9.71
	AGB/BGB ratio	1.61	1.22	1.17	1.22	1.23
	Total biomass	11.28	13.30	14.29	17.92	21.71
	Plant sturdiness	59.14	49.24	69.84	33.28	27.22
T_1C_2	Shoot biomass	5.06	5.29	5.69	6.74	7.90
	AGB	7.14	7.40	7.83	10.00	12.11
	BGB	4.38	6.03	6.60	8.13	9.79
	AGB/BGB ratio	1.63	1.22	1.18	1.23	1.23
	Total biomass	11.52	13.43	14.43	18.13	21.90
	Plant sturdiness	59.06	50.50	70.02	34.73	28.08
T_1C_3	Shoot biomass	5.15	5.31	5.74	6.88	7.95
	AGB	7.23	7.43	7.90	10.15	12.18
	BGB	4.41	6.08	6.80	8.29	9.90
	AGB/BGB ratio	1.63	1.22	1.16	1.22	1.23
	Total biomass	11.64	13.51	14.70	18.44	22.08
	Plant sturdiness	71.76	59.72	75.22	40.04	32.18

* at the time of transplanting

T_1= *Alnus nepalensis*, C_1= *Zingiber officinales,* C_2= *Curcuma longa,* C_3= *Zea mays*

AGB = Above ground biomass, BGB = Below ground biomass

Table 4.14. Growth performance of *Melia azadirachta* under different treatments.

Treatment	Parameters	*	Months after transplantation			
			6	12	18	24
Control	Shoot biomass	4.86	5.99	6.04	6.91	7.64
	AGB	6.92	8.08	8.23	10.21	11.86
	BGB	4.28	6.02	7.25	8.85	9.86
	AGB/BGB ratio	1.61	1.34	1.13	1.15	1.20
	Total biomass	11.20	14.10	15.48	19.06	21.72
	Plant sturdiness	91.87	56.10	49.63	43.56	36.80
T_2C_1	Shoot biomass	5.06	6.62	7.17	8.07	8.18
	AGB	7.16	9.82	11.43	13.66	13.95
	BGB	5.49	7.39	9.67	11.56	11.75
	AGB/BGB ratio	1.30	1.32	1.18	1.18	1.18
	Total biomass	12.65	17.21	21.10	25.22	25.70
	Plant sturdiness	93.20	64.86	51.85	44.60	37.50
T_2C_2	Shoot biomass	5.09	6.81	7.43	8.15	8.21
	AGB	7.18	10.08	11.70	13.75	14.03
	BGB	5.54	7.45	9.70	11.61	11.80
	AGB/BGB ratio	1.29	1.35	1.20	1.18	1.18
	Total biomass	12.72	17.53	21.40	25.36	25.83
	Plant sturdiness	97.30	65.42	53.62	45.38	37.74
T_2C_3	Shoot biomass	5.19	7.01	7.71	8.36	8.52
	AGB	7.31	10.31	12.01	14.04	14.39
	BGB	5.56	7.50	9.77	11.72	11.85
	AGB/BGB ratio	1.31	1.37	1.22	1.19	1.21
	Total biomass	12.87	17.81	21.78	25.76	26.24
	Plant sturdiness	108.32	73.80	59.32	47.50	38.13

* at the time of transplanting
T_2= *Melia azadirachta*, C_1= *Zingiber officinales,* C_2= *Curcuma longa,* C_3= *Zea mays*
AGB = Above ground biomass, BGB = Below ground biomass

Table 4.15. Growth performance of *Gmelina arborea* under different treatments.

Treatment	Parameters	*	Months after transplantation			
			6	12	18	24
Control	Shoot biomass	4.88	5.97	6.03	6.88	7.60
	AGB	6.96	8.08	8.20	10.16	11.81
	BGB	4.45	6.03	7.19	8.84	9.83
	AGB/BGB ratio	1.56	1.33	1.14	1.14	1.20
	Total biomass	11.41	14.11	15.39	19.00	21.64
	Plant sturdiness	28.94	59.37	45.84	43.11	36.07
T_3C_1	Shoot biomass	5.12	6.63	7.15	8.06	8.14
	AGB	7.24	9.93	11.37	13.60	13.88
	BGB	5.51	7.43	9.63	11.52	11.72
	AGB/BGB ratio	1.31	1.33	1.18	1.18	1.18
	Total biomass	12.75	17.36	21.00	25.12	25.60
	Plant sturdiness	27.59	61.04	48.26	44.90	37.37
T_3C_2	Shoot biomass	5.16	6.81	7.43	8.16	8.16
	AGB	7.30	10.17	11.67	13.73	13.97
	BGB	5.56	7.49	9.68	11.59	11.76
	AGB/BGB ratio	1.31	1.35	1.20	1.18	1.18
	Total biomass	12.86	17.66	21.35	25.32	25.73
	Plant sturdiness	28.83	62.58	50.08	44.43	37.65
T_3C_3	Shoot biomass	5.20	7.03	7.68	8.35	8.47
	AGB	7.35	10.44	11.95	13.98	14.40
	BGB	5.60	7.56	9.74	11.68	11.82
	AGB/BGB ratio	1.31	1.38	1.22	1.19	1.21
	Total biomass	12.95	18.00	21.69	25.66	26.22
	Plant sturdiness	29.80	70.93	54.45	46.90	38.04

* at the time of transplanting
T_3= *Gmelina arborea*, C_1= *Zingiber officinales,* C_2= *Curcuma longa*, C_3= *Zea mays*
AGB = Above ground biomass, BGB = Below ground biomass

Table 4.16. Characteristics rooting ratio and biomass (dry weight) of different plant parts in three tree species after a 2-year of transplanting under different treatments.

Parameters	*Alnus nepalensis*				*Melia azadirachta*				*Gmelina arborea*			
	Control	T_1C_1	T_1C_2	T_1C_3	Control	T_2C_1	T_2C_2	T_2C_3	Control	T_3C_1	T_3C_2	T_3C_3
Vertical root spreading (cm)	18.44	21.20	22.19	23.85	25.42	27.23	28.49	30.90	23.08	25.28	25.57	28.24
Horizontal root spreading (cm)	10.10	11.14	11.74	13.44	17.23	18.47	19.79	19.96	15.47	16.23	17.16	18.03
Shoot biomass (g/plant)	7.47	7.82	7.90	7.95	7.64	8.18	8.21	8.52	7.60	8.14	8.16	8.47
Leaf biomass (g/plant)	3.23	4.18	4.21	4.23	4.22	5.77	5.82	5.88	4.21	5.74	5.81	5.82
Above ground biomass (AGB) (g/plant)	10.70	12.00	12.11	12.18	11.86	13.95	14.03	14.40	11.81	13.88	13.97	14.39
Tap root biomass (g/plant)	6.03	6.54	6.59	6.63	6.49	7.54	7.56	7.60	6.47	7.53	7.54	7.58
Fibrous and lateral root biomass (g/plant)	3.01	3.17	3.20	3.27	3.37	4.21	4.24	4.25	3.36	4.19	4.22	4.24
Shoot length: root length ratio	1.95	3.43	3.42	3.55	2.78	3.48	3.51	3.61	2.82	3.56	3.57	3.62
Below ground biomass (BGB) (g/plant)	9.04	9.71	9.79	9.90	9.86	11.75	11.80	11.85	9.83	11.72	11.76	11.82
AGB: BGB ratio	1.15	1.23	1.23	1.23	1.20	1.18	1.18	1.21	1.20	1.18	1.18	1.21
Total biomass (AGB+BGB) (g/plant)	19.74	21.71	21.90	22.08	21.72	25.70	25.83	26.24	21.64	25.60	25.73	26.22
Plant sturdiness	22.31	27.22	28.08	32.18	36.80	37.50	37.74	38.13	36.07	37.37	37.65	38.04

C_1= *Zingiber officinales*, C_2= *Curcuma longa*, C_3= *Zea mays*
T_1= *Alnus nepalensis* , T_2= *Melia azadirachta*, T_3= *Gmelina arborea*

Table 4.17. Analysis of variance (ANOVA, 1-way fixed effect model) due to different treatments on growth attributes of *Alnus nepalensis, Melia azadirachta* and *Gmelina arborea.*

Parameters	*Alnus nepalensis*		*Melia azadirachta*		*Gmelina arborea*	
	F- ratio	P	F- ratio	P	F- ratio	P
Height	0.03375	0.991604	0.012329	0.998109	0.016963	0.996962
Collar thickness	2.101244	0.108152	0.210889	0.888528	0.151722	0.928240
Shoot biomass	0.211468	0.888127	0.967973	0.413019	0.964300	0.414738
Leave biomass	0.619626	0.604697	3.454720*	0.021140	3.313128*	0.025052
Above ground biomass (AGB)	0.215270	0.885682	2.048772*	0.109845	1.991334	0.118067
Tap root biomass	0.437381	0.726967	3.454182	0.111577	2.176462	0.098761
Fibrous & Lateral root biomass	0.136591	0.937851	0.422577	0.737407	0.425810	0.735122
Below ground biomass (BGB)	0.286005	0.835444	1.391167	0.248062	1.449357	0.231116
Total biomass (AGB + BGB)	0.461156	0.709634	3.237500*	0.022631*	3.253633*	0.022152*

* Significant at $P \leq 0.05$,

4.4. Soil status and changes in soil characteristics during a 3-year period:

The soil texture in the study site, in general, is sandy loam, red brown in colour and acidic in nature. The soil pH ranged from 5.03 - 5.40. (Tables 4.18-4.21). The detailed physical properties of the soil in the study sites are given in Tables 4.18 - 4.21. The particle fractionations and textural classes for the surface soil revealed that the study site had sandy loam soil. At the beginning of the study (i.e. 2003), the soil pH did not vary much between the plots under species mixture; however, it was comparatively higher in the plots having species mixture than those of control treatment. The soil moisture content was somewhat higher in the plots having species mixture compared to control ones.

The pH slightly increased at the end of 3-years study period compared to the corresponding values of first two years *viz.* 2003 and 2004. The other soil parameters, however, slightly got decreased in 2004. A reverse trend, however, was observed in 2005. The pH value increased after harvesting in the first year. A similar case was observed in both after second and third year respectively. The N, P, K content in soil showed a sharp decline in their values in the second year. However, the nutrient level of the soil was increased in the third year. In general, the study sites showed low pH in control compared to the treatment plots. This was true throughout the study period. Among various treatments, the plots having maize and its tree components, in general, showed comparatively higher pH content. Soil pH and N, P, K increased significantly ($P<0.05$) during the third year of study. But no significant variation was observed between the various soil characteristics when compared between the treated plots with the control during the first two years.

Table 4.18. Physico-chemical properties of soil at the start of the experiment.

Treatments	Soil pH	Soil texture			N (%)	P (Kg/ha)	K (Kg/ha)
		Sand (%)	Silt (%)	Clay (%)			
BF/BN	5.03 (0.06)	51.21 (0.08)	20.69 (0.072)	28.1 (0.01)	0.61 (0.01)	38.98 (0.43)	151.01 (0.00)
Control (C_1 alone)	5.1 (0.02)	51.25 (0.18)	20.71 (0.22)	28.04 (0.18)	0.54 (0.02)	39.41 (0.06)	151.436 (0.25)
C_1T_1	5.1 (0.02)	51.24 (0.18)	20.72 (0.17)	28.04 (0.35)	0.54 (0.02)	39.41 (0.25)	150.76 (0.29)
C_1T_2	5.1 (0.02)	51.23 (0.25)	20.71 (0.08)	28.06 (0.10)	0.53 (0.02)	39.42 (0.34)	151.78 (0.10)
C_1T_3	5.1 (0.01)	51.25 (0.11)	20.71 (0.22)	28.04 (0.21)	0.54 (0.01)	39.341 (0.38)	151.76 (0.167)
Control (C_2 alone)	5.2 (0.01)	51.24 (0.18)	20.70 (0.22)	28.03 (0.18)	0.54 (0.02)	39.33 (0.04)	151.43 (0.25)
C_2T_1	5.2 (0.03)	51.23 (0.18)	20.71 (0.17)	28.03 (0.35)	0.51 (0.01)	39.40 (0.03)	152.76 (0.25)
C_2T_2	5.2 (0.01)	51.22 (0.25)	20.70 (0.08)	28.05 (0.10)	0.51 (0.01)	39.41 (0.08)	152.75 (0.11)
C_2T_3	5.2 (0.03)	51.24 (0.11)	20.70 (0.22)	28.03 (0.21)	0.51 (0.01)	39.39 (0.17)	152.74 (0.12)
Control (C_3 alone)	5.26 (0.03)	51.24 (0.18)	20.70 (0.22)	28.03 (0.18)	0.54 (0.02)	39.47 (0.21)	151.43 (0.25)
C_3T_1	5.3 (0.02)	51.23 (0.18)	20.71 (0.17)	28.03 (0.35)	0.50 (0.01)	39.49 (0.32)	152.75 (0.11)
C_3T_2	5.3 (0.02)	51.22 (0.25)	20.70 (0.08)	28.05 (0.10)	0.52 (0.02)	39.39 (0.29)	152.75 (0.11)
C_3T_3	5.3 (0.04)	51.24 (0.11)	20.70 (0.22)	28.03 (0.21)	0.52 (0.01)	39.49 (0.29)	152.75 (0.11)

Values in parentheses are ± SE,
BF/BN = before burning,
C_1= *Zingiber officinales*, C_2= *Curcuma longa*, C_3= *Zea mays*,
T_1 = *Alnus nepalensis*, T_2 = *Melia azadirachta*, T_3 = *Gmelina arborea*

Table 4.19. Physico-chemical properties of soil at the start and end of the 1st year study.

Treatments	Soil pH	Soil texture			N (%)	P (Kg/ha)	K (Kg/ha)
		Sand (%)	Silt (%)	Clay (%)			
Control (C_1 alone)	5.15 (1.32)	51.24 (0.18)	20.71 (0.22)	28.04 (0.18)	0.26 (0.01)	35.31 (0.20)	143.61 (0.05)
C_1T_1	5.2 (0.01)	51.23 (0.18)	20.72 (0.17)	28.04 (0.25)	0.26 (0.03)	35.21 (0.19)	144.22 (0.15)
C_1T_2	5.2 (0.01)	51.22 (0.25)	20.71 (0.08)	28.06 (0.10)	0.24 (0.01)	35.31 (0.30)	144.21 (0.21)
C_1T_3	5.18 (0.01)	51.24 (0.11)	20.71 (0.22)	28.04 (0.21)	0.26 (0.03)	35.22 (0.26)	144.56 (0.31)
Control (C_2 alone)	5.27 (0.03)	52.11 (0.03)	19.51 (0.22)	28.37 (0.13)	0.23 (0.01)	35.18 (0.18)	146.21 (0.01)
C_2T_1	5.30 (0.03)	52.12 (0.03)	19.52 (0.12)	28.35 (0.12)	0.23 (0.01)	35.18 (0.17)	146.22 (0.01)
C_2T_2	5.3 (0.01)	52.11 (0.11)	19.51 (0.14)	28.37 (0.10)	0.23 (0.01)	35.21 (0.18)	146.21 (0.01)
C_2T_3	5.28 (0.01)	52.12 (0.07)	19.52 (0.12)	28.35 (0.27)	0.22 (0.01)	35.21 (0.13)	146.21 (0.01)
Control (C_3 alone)	5.4 (0.02)	55.24 (0.15)	15.28 (0.12)	29.47 (0.40)	0.21 (0.01)	35.4 (0.05)	146.21 (0.01)
C_3T_1	5.38 (0.02)	55.24 (0.40)	15.27 (0.34)	29.48 (0.22)	0.22 (0.01)	35.5 (0.10)	146.21 (0.01)
C_3T_2	5.39 (0.04)	55.22 (0.25)	15.26 (0.12)	29.51 (0.23)	0.22 (0.01)	35.4 (0.06)	146.21 (0.12)
C_3T_3	5.4 (0.02)	55.23 (0.19)	15.28 (0.13)	29.48 (0.22)	0.22 (0.01)	35.5 (0.01)	146.21 (0.01)

Values in parentheses are ± SE,
C_1 = *Zingiber officinales*, C_2 = *Curcuma longa*, C_3= *Zea mays*,
T_1 = *Alnus nepalensis*, T_2 = *Melia azadirachta*, T_3 = *Gmelina arborea.*

Table 4.20. Physico-chemical properties of soil at the start and end of 2nd year study.

Treatments	Soil pH	Soil texture			N (%)	P (Kg/ha)	K (Kg/ha)
		Sand (%)	Silt (%)	Clay (%)			
Control (C_1 alone)	5.2 (0.01)	51.24 (0.18)	20.71 (0.22)	28.04 (0.18)	0.14 (0.01)	30.05 (0.20)	139.92 (0.21)
C_1T_1	5.21 (0.01)	51.23 (0.18)	20.72 (0.17)	28.04 (0.35)	0.16 (0.01)	30.42 (0.19)	140.59 (0.36)
C_1T_2	5.2 (0.01)	51.224 (0.256)	20.707 (0.087)	28.062 (0.109)	0.199 (0.015)	30.28 (0.166)	140.25 (0.333)
C_1T_3	5.2 (0.00)	51.24 (0.11)	20.71 (0.22)	28.04 (0.21)	0.75 (0.02)	29.59 (0.21)	139.92 (0.33)
Control (C_2 alone)	5.3 (0.01)	52.11 (0.03)	19.51 (0.22)	28.37 (0.13)	0.12 (0.01)	29.85 (0.33)	143.70 (0.23)
C_2T_1	5.31 (0.03)	52.12 (0.03)	19.52 (0.12)	28.35 (0.12)	0.14 (0.01)	30.82 (0.32)	144.98 (0.17)
C_2T_2	5.3 (0.03)	52.11 (0.11)	19.51 (0.14)	28.37 (0.10)	0.15 (0.01)	30.28 (0.16)	144.23 (0.12)
C_2T_3	5.3 (0.01)	52.13 (0.07)	19.52 (0.12)	28.35 (0.27)	0.13 (0.01)	30.45 (0.09)	143.84 (0.23)
Control (C_3 alone)	5.3 (0.01)	55.24 (0.15)	15.28 (0.12)	29.47 (0.40)	0.11 (0.01)	29.50 (0.23)	143.62 (0.14)
C_3T_1	4.71 (0.06)	55.24 (0.40)	15.27 (0.34)	29.48 (0.22)	0.13 (0.01)	30.23 (0.19)	144.05 (0.40)
C_3T_2	5.39 (0.03)	55.22 (0.25)	15.26 (0.12)	29.51 (0.23)	0.13 (0.01)	30.18 (0.33)	144.29 (0.72)
C_3T_3	5.34 (0.01)	55.23 (0.19)	15.28 (0.13)	29.48 (0.22)	0.12 (0.01)	29.51 (0.23)	144.34 (0.54)

Values in parentheses are ± SE,
C_1 = *Zingiber officinales*, C_2 = *Curcuma longa*, C_3= *Zea mays*,
T_1 = *Alnus nepalensis*, T_2 = *Melia azadirachta*, T_3 = *Gmelina arborea*

Table 4.21. Physico - chemical properties of soil at the start and end of 3 rd year study.

Treatments	Soil pH	Soil texture			N (%)	P (Kg/ha)	K (Kg/ha)
		Sand (%)	Silt (%)	Clay (%)			
Control (C_1 alone)	5.16 (0.03)	51.24 (0.18)	20.71 (0.22)	28.04 (0.18)	0.13 (0.01)	28.32 (0.12)	137.01 (0.15)
C_1T_1	5.3 (0.01)	51.23 (0.18)	20.72 (0.17)	28.04 (0.35)	0.74 (0.01)	41.39 (0.07)	156.54 (0.55)
C_1T_2	5.31 (0.01)	51.24 (0.11)	20.71 (0.22)	28.04 (0.21)	0.74 (0.01)	41.55 (0.17)	156.34 (0.35)
C_1T_3	5.30 (0.01)	51.23 (0.03)	20.72 (0.17)	28.04 (0.19)	0.73 (0.01)	41.17 (0.15)	155.34 (0.51)
Control (C_2 alone)	5.3 (0.01)	52.11 (0.03)	19.51 (0.22)	28.37 (0.13)	0.12 (0.01)	28.34 (0.27)	140.91 (0.10)
C_2T_1	5.4 (0.01)	52.124 (0.03)	19.52 (0.12)	28.35 (0.12)	0.73 (0.01)	41.57 (0.06)	156.55 (0.49)
C_2T_2	5.406 (0.01)	52.11 (0.11)	19.50 (0.14)	28.37 (0.10)	0.73 (0.01)	41.57 (0.06)	156.57 (0.49)
C_2T_3	5.39 (0.01)	52.13 (0.07)	19.52 (0.12)	28.34 (0.27)	0.72 (0.01)	41.55 (0.05)	156.54 (0.50)
Control (C_3 alone)	5.3 (0.01)	55.24 (0.15)	15.28 (0.12)	29.47 (0.40)	0.12 (0.01)	27.59 (0.25)	141.62 (0.18)
C_3T_1	5.4 (0.02)	55.24 (0.40)	15.27 (0.34)	29.48 (0.22)	0.74 (0.01)	41.55 (0.07)	157.53 (0.47)
C_3T_2	5.4 (0)	55.22 (0.25)	15.26 (0.12)	29.51 (0.23)	0.74 (0.01)	41.55 (0.07)	157.24 (0.40)
C_3T_3	5.4 (0.01)	55.23 (0.19)	15.28 (0.13)	29.48 (0.22)	0.72 (0.01)	41.53 (0.06)	156.52 (0.56)

Values in parentheses are ± SE,
C_1= *Zingiber officinales*, C_2= *Curcuma longa*, C_3= *Zea mays*,
T_1 = *Alnus nepalensis*, T_2 = *Melia azadirachta*, T_3 = *Gmelina arborea*

4.5. Relationship between soil parameters with growth parameters:

The coefficient of correlation (r) between various soil properties and different plant growth attributes indicated differential results (Table 4.22). In *Alnus nepalensis,* the plant height was positively correlated ($P \leq 0.05$) with various soil parameters such as soil pH ($p=0.6218$), nitrogen ($p=0.7261$), phosphorous ($p=0.7340$) and potassium ($p=0.7525$) respectively.

Similarly, the plant height of *Melia azadirachta* and *Gmelina arborea* were positively correlated ($P \leq 0.05$) with various soil parameters *viz.* soil pH, nitrogen, phosphorous and potassium (Table 4.22).

Table 4.22. Coefficient of correlation (r) between various soil parameters and growth attributes of the tree seedlings.

Species / Soil parameter	Growth attributes				
	Height	Collar thickness	AGB	BGB	Total Biomass
Alnus nepalensis					
Soil pH	0.6218* (p= 0.000)	0.0219 (p= 0.114)	-0.5015* (p=0.000)	-0.5003* (p=0.000)	-0.5015* (p=0.000)
N	0.7261* (p=0.000)	0.2061 (p=0.114)	-0.4236* (p=0.001)	-0.3920* (p=0.002)	-0.4236* (p=0.001)
P	0.7340* (p=0.000)	0.1864 (p=0.154)	-0.4133* (p=0.001)	-0.3747* (p=0.003)	-0.4133* (p=0.001)
K	0.7525* (p=0.000)	0.1713 (p=0.191)	-0.4053* (p=0.001)	-0.3801* (p=0.003)	-0.4053* (p=0.001)
Melia azadirachta					
Soil pH	0.6758* (p=0.000)	0.0912 (p=0.488)	-0.4776* (p=0.000)	-0.4999* (p=0.000)	-0.4776* (p=0.000)
N	0.6978* (p=0.000)	0.2009 (p=0.124)	-0.3664* (p=0.004)	-0.3345* (p=0.009)	-0.3664* (p=0.004)
P	0.6983* (p=0.000)	0.1902 (p=0.145)	-0.3413* (p=0.008)	-0.3213* (p=0.012)	-0.3413* (p=0.008)
K	0.6865* (p=0.000)	0.1589 (p=0.225)	-0.3163* (p=0.014)	-0.3028* (p=0.019)	-0.3163* (p=0.014)
Gmelina arborea					
Soil pH	0.6248* (p=0.000)	0.2097 (p=0.108)	-0.5279* (p=0.000)	-0.5924* (p=0.000)	-0.5279* (p=0.000)
N	0.6374* (p=0.000)	0.1755 (p=0.180)	-0.3478* (p=0.006)	-0.3137* (p=0.015)	-0.3478* (p=0.016)
P	0.6408* (p=0.000)	0.1896 (p=0.147)	-0.3423* (p=0.007)	-0.3199* (p=0.013)	-0.3423* (p=0.007)
K	0.6406* (p=0.000)	0.1613 (p=0.218)	-0.3228* (p=0.012)	-0.3056* (p=0.018)	-0.3228* (p=0.012)

AGB = above ground biomass, BGB = below ground biomass
* Significant at $P \leq 0.05$,

4.6. Discussion

The growth (height and collar diameter) of *Alnus nepalensis, Melia azadirachta indica* and *Gmelina arborea* was maximum in maize field followed by turmeric, ginger field and minimum in control (sole tree). The growth performance in tree-crop may be favoured due to addition of litter fall (Brinson *et al.,* 1980), leaf shading and root decay (Datta and Dhiman, 2001). Similar augmentation in soil fertility beneath tree was also reported (Altieri *et al.,* 1987). The higher amount of leaf fall and decay of root biomass in maize field compared to ginger and turmeric in the present study might have contributed to better growth of the trees in the former than the latter. Many authors have found that in natural forests and man made protected plantations, cycling of nutrient through litter fall is very important as considerable amount of nutrients are returned through litter fall and become available for recycling (Nair *et. al.*, 1984).

Both the plant height and collar thickness of the trees species were in the order of Neem > Gamar > Alnus respectively. The field wise growth of tree species were in the order of maize > turmeric > ginger. Among the tree species, neem grew quite well along with all the crop species. This may be due to high organic matter content and also higher annual litter return by neem. The data also revealed that the growth performance of all the tree species was relatively slower during the first eighteen months and higher growth rate was observed under intercropping compared to control. This slower rate of plant height and diameter during the first eighteen months could be due to the fact that the species were not able to establish properly in up taking various natural resources required by them for their growth purposes. However, the species were able to utilize the resource better due to higher attainment of these parameters coupled with a favourable temperature and moisture or rainfall of the site after they got established. The slower growth in height and diameter under control condition obviously was due to less availability of nutrients to the plant and also was due to lower soil moisture regimes and higher evaporation from the soil surface. A relatively higher growth rate under species mixture could also be due to the possibility of their beneficial compatibility, interaction and greater biological efficiency of crops grown in association (Maitra *et al.,* 2000). Better growth under species mixture are reported and attributed to increased availability of nutrients owing to increased moisture retention and to improvement of soil conditions through crops fine root systems, which helped the soil water retention capacity and increased soil water supply (Singh *et al.,* 1999).

It appears that maize complemented better than ginger and turmeric in the present study to make use of resources for the trees when grown together rather than separately. Bulson *et al.* (1997) reported that intercropping showed an advantage over sole cropping when the component densities were sufficiently higher. The advantages of intercropping have been also reported by many workers (Rana and Saran, 1988; Prasad *et al.,* 1997; Verma *et al.,* 1997; Rana *et al.,* 1999). This may be due to increase organic matter content to the soil. The increase organic matter under tree canopy is often suggested due to ameliorating effect of shade in hot dry environment and increased soil productivity (Young, 1989; Prinsley, 1992).

The analysis of variance also showed a significant ($P \leq 0.05$) variation in plant height between treatment and months (Tables 4.2, 4.4 and 4.6). This may be due to increase soil organic matter content added by tree crop species interaction through the litter fall as argued by Brinson *et al.* (1980). The effect of trees on crop and soil productivity, however, was inconsistent. Tree-crop interaction generally helps in binding of soil particles, in maintaining soil moisture, adding litter to the soil, thus contributing to soil organic matter through shedding of their leaves and decay of roots (Brewbaker and Hu, 1981; Nair *et al.,* 1984). The success of tree crop interaction depends on the choice of suitable multipurpose tree species of plant that can be grown together. Leguminous trees when planted with agricultural crops affect favourably the microclimate (Nair and Fernandes, 1984) and therefore improve the overall crop yield.

Normally, *Alnus nepalensis* is a fast growing, nitrogen fixing tree species suitable for planting on open land. However, in the present trial, it showed poor growth than the other two species. The hot climate of the experimental site was not possibly suitable for its growth which otherwise requires moist climate. No nodule formation was also seen in *Alnus nepalensis* in the first year, however, during the 2nd year onward nodule formation occurred, although not in abundant quantities. *Melia azadirachta* performed better than those of *Alnus nepalensis* and *Gmelina arborea*. Although all these three species are fast growing, *Alnus nepalensis* failed to show good growth, *Gmelina arborea* grew well but *Melia azadirachta,* had the best growth among the tree seedlings. This differential growth response of the trees could be attributed to many factors such as genetic make up, available climatic conditions, soil nutrient level, neighbouring effect and many others (Yamoah *et al.,* 1986; Atta-Krah, 1990; Singh *et al.,* 1997). This may also explain an increase tree growth in plantation mixtures than sole cropping in the present study. This finds support from the works of Haines *et al.* (1978); Van Sambeek *et al.* (1986).

A relatively higher biomass production under species mixture compared to control treatment could be due to the beneficial nutrients released by tree-crop interaction. Again the gradual increase in biomass production over the years helped to add organic matter in form of dry leaves and decayed roots. The higher values in total biomass production under *Melia azadirachta* than those of both *Gmelina arborea* and *Alnus nepalensis* might have resulted due to heavy forking and branching in the former species than the latter. The lowest shoot and leaf biomass yield for *Alnus nepalensis* might be attributed to heavy leaf shedding during that particular period of harvesting the trees for biomass estimation.

Chapter-V

Soil moisture conservation as affected by species mixture, type and quantity of mulches

5.1. Introduction

Soil moisture and nutrients are essential for successful growth and development of plants. Under moist soil conditions, tree nutrients uptake, growth and fruit yield increases (Singh *et al.,* 1998) due to availability of adequate soil moisture. Higher soil moisture regimes in trees are also reported to increase the availability of mineral nutrients in soil for plant use (Menzel *et al.,* 1986; Singh *et al.,* 1998*).* The organic matter added by trees to the soil similarly increases water-holding capacity and the shade of trees reduces the evaporation resulting in higher soil moisture near trees. Agroforestry species differ in their soil and moisture conservation ability. Some hedgerows species like *Leucaena leucocephala* and *Flemingia macrophylla* have shown tremendous effect of moisture conservation especially during dry periods (Chirwa *et al.,* 1994). Similarly, *Prosopois cineraria* tree in arid regions of India has shown high soil moisture retention (Puri *et al.,* 1994). Nevertheless higher yield of agricultural crops under trees has largely depended on the improvement of soil fertility and conservation of moisture (Puri *et al.,* 1994; Jaimini and Tikka, 1998).

Better tree-crop compatibility and use of good quality and quantities of mulches can improve soil conditioning by improving soil moisture retention which in turn can enhance crop productivity. This chapter therefore deals with the soil moisture conservation under three different tree-crop mixture, using three mulch types and three mulch doses in the field conditions

5.2. Methodology

The treatments considered in the present chapter include both (a) species mixture and (b) quantity and quality of mulches. The first part does not involve the application of mulch material, while the second part involved one tree species i.e. *Gmelina arborea* and two crop species (*viz*. *Zingiber officinales* and *Curcuma longa*), which were evaluated for their moisture conservation ability. Besides, the relative efficacy of 3 mulch types (*viz.* rice straw, weeds and subabul leaves) and 3 mulch doses (*viz.* 6 t/ha, 8 t/ha and 10 t/ha) were tried on soil moisture conservation. The detailed design for this has been discussed in chapter III under soil conservation experiment.

During the period of the experiment, three weeding were carried out. The first weeding was done in mid-May, the second weeding in mid -July and the last weeding in the first week of September, prior to harvesting of field crops. Irrigation of any sort was not provided and the crop was raised purely under rainfed condition.

Soil moisture was determined on a monthly interval from the samples collected from a depth of 0 -15 cm. The soil samples were properly tagged and sealed in plastic packets in the field before being brought to the laboratory for analysis. Soil moisture loss on drying to constant weight was determined for 100 gm of fresh soil. The soil moisture content was expressed as percent fresh weight and was calculated as moisture percentage (M%) = (Fresh weight – Dry weight) x 100 / Fresh weight. Soil moisture conservation was expressed in term of moisture gain and was calculated as moisture gain percentage (%) = Difference in moisture gain due to species mixture/mulch over control x 100 /Amount of moisture in the control.

5.3. Results

5.3(1) Effect of species mixture on soil moisture conservation(%):

Soil moisture retention differed from field to field, increased with time and was significantly ($P \leq 0.05$) higher in 3rd year. Due to species mixture, the soil conserved 14.78 to 17.49 % in turmeric field, 14.52 to 16.94 % in ginger, and 13.38 to 13.39 % in maize field over to control (Fig. 5.1) during a 3-year year period.

Under different species mixture, maximum soil moisture (%) was recorded in *Melia azadirachta* inter crop plot, followed by *Alnus nepalensis* and minimum under *Gmelina arborea.* Field crops retained soil moisture in the order of *Curcuma longa* > *Zingiber officinales* > *Zea mays* (Table 5.1).

There is no significant difference in soil moisture between treatments during the 1st year. However, Due to species mixture, soil moisture was significantly ($P \leq 0.05$) increased between trees except in the month of October and March during the last two years (Tables 5.2 – 5.4). Soil moisture also had significant ($P \leq 0.05$) variation between crops in the months of September, January and February during 2nd and 3rd year respectively (Tables 5.3 and 5.4). No positive correlation between soil moisture with other soil parameter such as soil pH, N, P and K during the study periods (Table 5.5).

In *Alnus nepalensis* plot, soil moisture retention was positively ($P \leq 0.05$) correlated with soil pH, N, P and K. during for all the years of study (Table 5.6). Similarly, in *Melia azadirachta* and *Gmelina arborea plot,* soil moisture retention was positively ($P \leq 0.05$) correlated with other soil parameter.

The average soil moisture percent at 0 -15 cm soil depth in general showed lower soil moisture content during December to April. The percent soil moisture gradually increased from May to July with the onset of rainfall and reached its peak in the months of August to September and remained steady up to September and gradually declined. Soil moisture percent was higher during winter months compared to the summer months (Fig. 5.2 – 5.4). This was true for all the treated plots.

Table 5.1. Mean soil moisture (%) under different species mixture during a 3- year period.

Species mixture	1^{st} year	2^{nd} year	3^{rd} year
Control	23.43 ± 2.02	23.66 ± 2.05	23.61 ± 2.05
C_1T_1	24.40 ± 2.04	25.24 ± 2.07	27.61 ± 2.13
C_1T_2	24.48 ± 2.03	25.38 ± 2.06	27.70 ± 2.17
C_1T_3	24.43 ± 2.02	24.76 ± 2.05	27.04 ± 2.15
CD ($P \leq 0.05$)	1.39	1.42	1.66
Control	23.64 ± 1.89	23.63 ± 2.02	24.61 ± 2.04
C_2T_1	24.64 ± 1.90	25.21 ± 2.04	27.72 ± 2.13
C_2T_2	24.69 ± 1.89	25.41 ± 2.03	27.74 ± 2.13
C_2T_3	24.63 ± 1.90	24.73 ± 2.05	27.10 ± 2.04
CD ($P \leq 0.05$)	0.98	1.69	1.68
Control	23.61 ± 1.90	23.50 ± 2.04	24.90 ± 1.92
C_3T_1	24.61 ± 1.90	24.75 ± 2.04	27.17 ± 2.02
C_3T_2	24.66 ± 1.89	25.18 ± 2.06	27.24 ± 2.01
C_3T_3	24.62 ± 1.90	24.56 ± 2.05	27.10 ± 2.04
CD at $P \leq 0.05$	1.64	1.82	2.03

± S.E. m, n=12

C_1= *Zingiber officinales*, C_2= *Curcuma longa*, C_3= *Zea mays*

T_1=*Alnus nepalensis,* T_2=*Melia azadirachta*, T_3=*Gmelina arborea*

Table 5.2. 3-way ANOVA (Analysis of variance, fixed effects model) on soil moisture conservation (%) as affected by species mixture during the 1st year of study.

Source of variation	df	F-ratio											
		12/ 5/ 03	5/ 6/ 03	14/ 7/ 03	11/ 8/ 03	15/ 9/ 03	13/ 10/ 03	10/ 11/ 03	8/ 12/ 03	12/ 1/ 04	9/ 2/ 04	8/ 3/ 04	5/ 4/ 04
Crops	2	0.016633	5.038113*	0.068610	0.011025	0.093569	0.000514	0.033630	0.078829	0.004516	0.005007	0.024850	2.048097
Trees	3	0.005794	0.124109	0.027916	0.002805	0.086460	0.003215	0.009602	0.067604	0.030004	0.041632	0.001239	0.0033
Replication	2	01.087333	0.212679	0.079267	1.021661	2.139711	0.286879	3.120369*	0.138383	2.795585	1.198242	3.069615	0.3119
Crop x Trees	6	0.003793	0.016212	0.015899	0.000914	0.088493	0.000514	0.004493	0.001135	0.005606	0.010239	0.001631	0.0009
Crops x Replication	4	0.772230	0.116997	0.185420	0.117737	0.521637	0.428847	2.284169	0.352910	0.376830	0.657123	0.375199	0.2541
Trees x Replication	6	0.352314	0.239256	0.965859	0.762343	0.234535	0.481758	0.987596	0.649003	0.794277	0.484697	1.122705	0.5016
Crops x Trees x Rep	12	0.254046	0.249483	0.135283	0.423153	0.796100	0.374383	0.285408	0.175593	0.203941	0.248338	0.575788	0.5352

* Significant at $P \leq 0.05$,

Table 5.3. 3-way ANOVA (Analysis of variance, fixed effects model) on soil moisture conservation (%) as affected by species mixture during the 2nd year of study.

Source of variation	df	F-ratio											
		10/ 5/ 04	4/ 6/ 04	12/ 7/ 04	9/ 8/ 04	6/ 9/ 04	11/ 10/ 04	8/ 11/ 04	6/ 12/ 04	10/ 1/ 05	7/ 2/ 05	8/ 3/ 05	4/ 4/ 05
Crops	2	0.057497	2.721997	2.409101	0.023156	4.154253*	0.065323	1.79654	1.040866	3.377460*	8.727995*	0.268289	1.479150
Trees	3	7.704498*	9.392718*	3.673527*	3.750678*	7.090249*	0.122071	12.76820*	6.092077*	3.095914*	9.469510*	0.648396	6.056099*
Replication	2	0.204098	1.194521	1.940118	0.756204	0.459480	0.001735	1.08292	6.068767*	2.847233	0.141520	0.995169	0.221063
Crop x Trees	6	0.470126	0.375224	0.390284	0.939117	0.847141	0.023288	0.93364	0.307730	0.661673	1.134863	0.220032	0.632029
Crops x Replication	4	0.550569	0.180895	0.915479	0.806.85	3.070170*	0.297584	0.46311	0.207271	0.795184	1.397385	0.115001	1.637285
Trees x Replication	6	0.104074	0.799777	0.946873	0.700982	0.878593	0.207521	0.22196	1.816830	0.362908	0.291929	1.103049	0.853350
Crops x Trees x Rep	12	0.428968	0.332961	0.186078	0.518691	0.918681	0.344974	0.49089	0.460261	0.491256	0.895546	1.009523	0.723463

* Significant at $P \leq 0.05$

Table 5.4. 3-way ANOVA (Analysis of variance, fixed effects model) on soil moisture conservation (%) as affected by species mixture during the 3rd year of study.

Source of variation	df	F-ratio											
		10/ 5/ 05	7/ 6/ 05	12/ 7/ 05	9/ 8/ 05	6/ 9/ 05	4/ 10/ 05	8/ 11/ 05	6/ 12/ 05	10/ 1/ 06	7/ 2/ 06	7/ 3/ 06	11/ 4/ 06
Crops	2	0.057497	2.721997	2.409101	0.023156	4.154253*	0.065323	1.79654	1.040866	3.377460*	8.727995*	0.268289	1.479150
Trees	3	7.704498*	9.392718*	3.673527*	3.750678*	7.090249*	0.122071	12.76820*	6.092077*	3.095914*	9.469510*	0.648396	6.056099*
Replication	2	0.204098	1.194521	1.940118	0.756204	0.459480	0.001735	1.08292	6.068767*	2.847233	0.141520	0.995169	0.221063
Crop x Trees	6	0.470126	0.375224	0.390284	0.939117	0.847141	0.023288	0.93364	0.307730	0.661673	1.134863	0.220032	0.632029
Crops x Replication	4	0.550569	0.180895	0.915479	0.806085	3.070170*	0.297584	0.46311	0.207271	0.795184	1.397385	0.115001	1.637285
Trees x Replication	6	0.104074	0.799777	0.946873	0.700982	0.878593	0.207521	0.22196	1.816830	0.362908	0.291929	1.103049	0.853350
Crops x Trees x Rep	12	0.428968	0.332961	0.186078	0.518691	0.918681	0.344974	0.49089	0.460261	0.491256	0.895546	1.009523	0.723463

* Significant at $P \leq 0.05$

Table 5.5. Relationship (r) between soil moisture with other soil parameters during different years of study.

Soil parameters/year	N	P	K	SMSM	SMQQ
1st year					
Soil pH	-0.1861 (p=0.012)	0.1244 (p=0.096)	0.3214 (p=0.000)	-0.1586 (p=0.033)	0.1827 (p=0.014)
N		-0.0190 (p=0.800)	-0.1200 (p=0.109)	0.0263 (p=0.726)	-0.0566 (p=0.450)
P			-0.0509 (p=0.498)	0.0142 (p=0.849)	0.1946 (p=0.009)
K				0.0637 (p=0.396)	0.1692 (p=0.023)
SMSM					0.9253 (p=0.003)
2nd year					
Soil pH	-0.1445 (p=.053)	0.0727 (p=.332)	0.5573 (p=0.000)	0.1045 (p=.163)	0.1741 (p=0.019)
N		0.1762 (p=0.018)	-0.0813 (p=0.278)	0.0532 (p=0.478)	0.0846 (p=0.259)
P			0.3799 (p=0.000)	0.1856 (p=0.013)	0.3462 (p=0.000)
K				0.2006 (p=0.007)	0.3831 (p=0.000)
SMSM					0.8401 (p=0.000)
3rd year					
Soil pH	0.3836 (p=0.000)	0.3704 (p=0.00)	0.4479 (p=0.000)	0.3388 (p=0.000)	0.2916 (p=0.000)
N		0.9817 (p=.00)	0.9485 (p=0.00)	0.6511 (p=0.000)	0.7919 (p=0.00)
P			0.9540 (p=0.000)	0.6287 (p=0.000)	0.8038 (p=0.00)
K				0.6632 (p=0.000)	0.7783 (p=0.00)
SMSM					0.8136 (p=0.00)

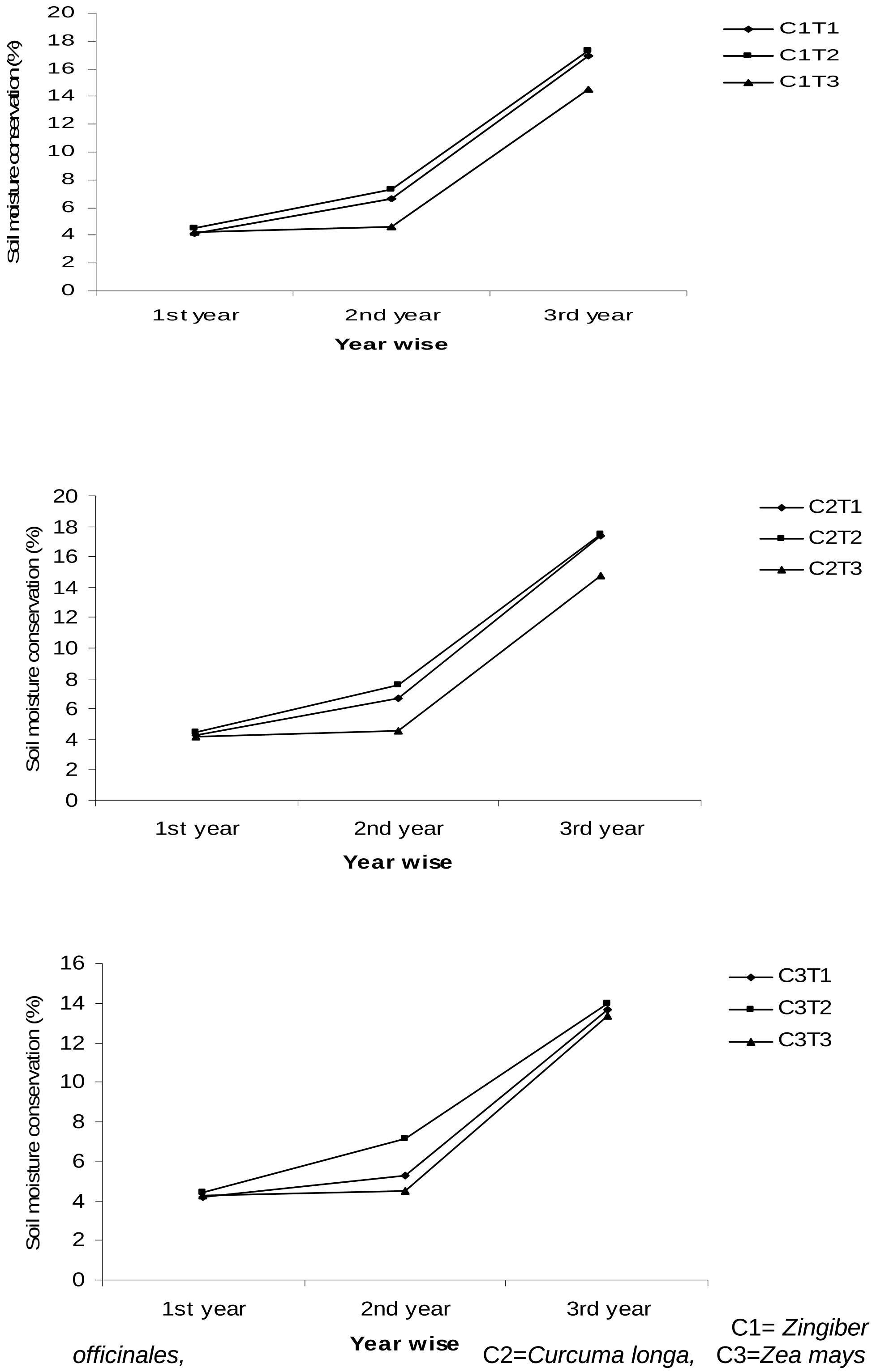
SMSM - Soil moisture in species mixture

SMQQ – Soil moisture in quantity and quality of mulches

Table 5.6. Coefficient of correlation (r) between soil moisture retention under different species mixture with various soil parameters during 3rd year period.

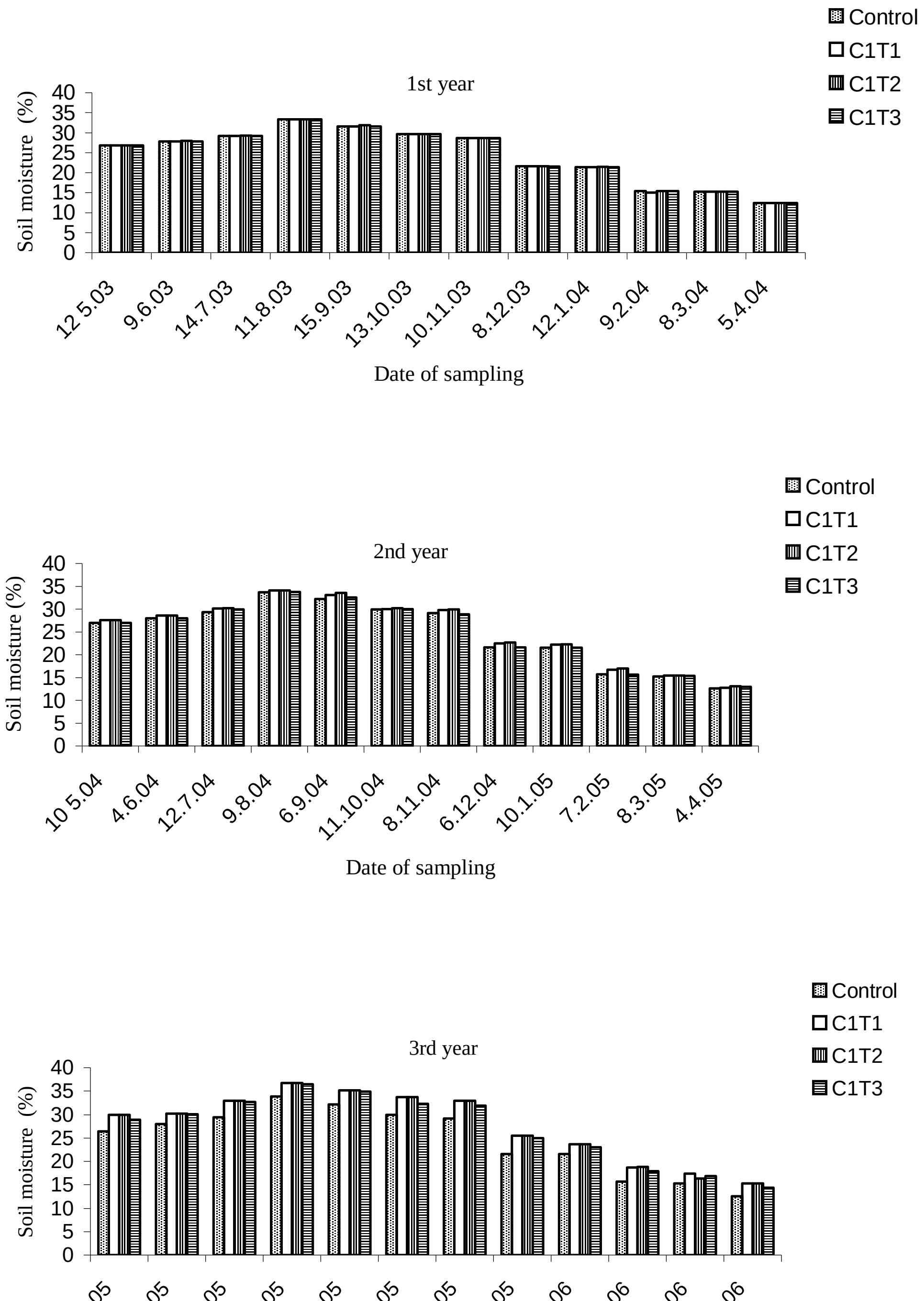
Species / Soil parameters	Soil moisture retention		
	1st year	2nd year	3rd year
Alnus nepalensis			
Soil pH	0.6186*	0.6305*	0.6428*
N	0.5379*	0.5167*	0.5839*
P	0.5402*	0.5348*	0.5928*
K	0.5687*	0.5661*	0.6212*
Melia azadirachta			
Soil pH	0.6084*	0.6073*	0.6180*
N	0.5300*	0.5133*	0.5825*
P	0.5409*	0.5366*	0.5945*
K	0.5291*	0.5334*	0.5888*
Gmelina arborea			
Soil pH	0.7508*	0.7983*	0.7884*
N	0.5383*	0.5196*	0.5870*
P	0.5410*	0.5367*	0.5947*
K	0.5341*	0.5393*	0.5943*

* Significant at $P \leq 0.05$



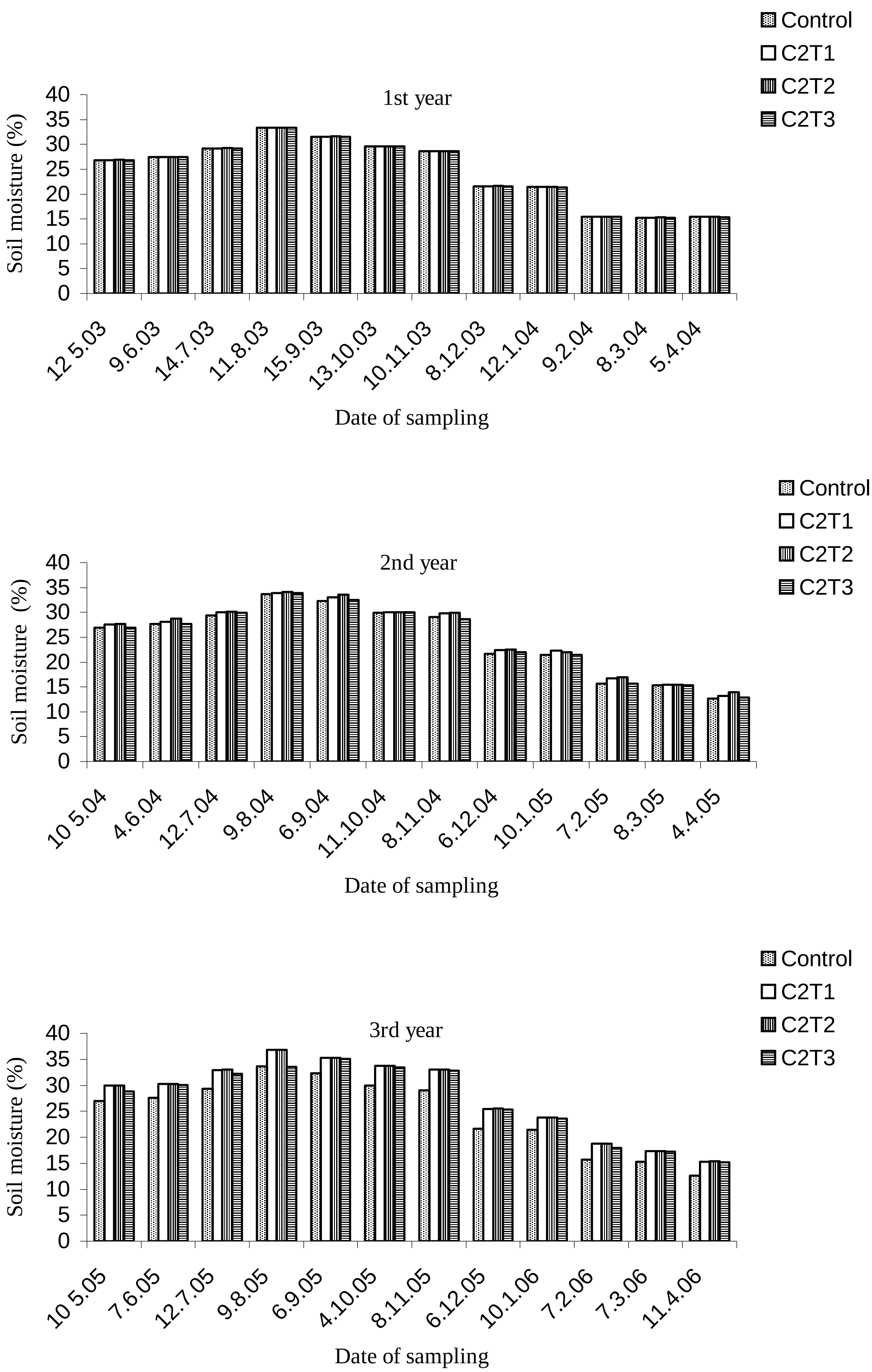
C1= *Zingiber officinales*, C2=*Curcuma longa*, C3=*Zea mays*
T1= *Alnus nepalensis* T2=*Melia azadirachta*,T3=*Gmelina arborea*

Fig. 5.1. Soil moisture conservation (%) as affected by species mixture during different years.



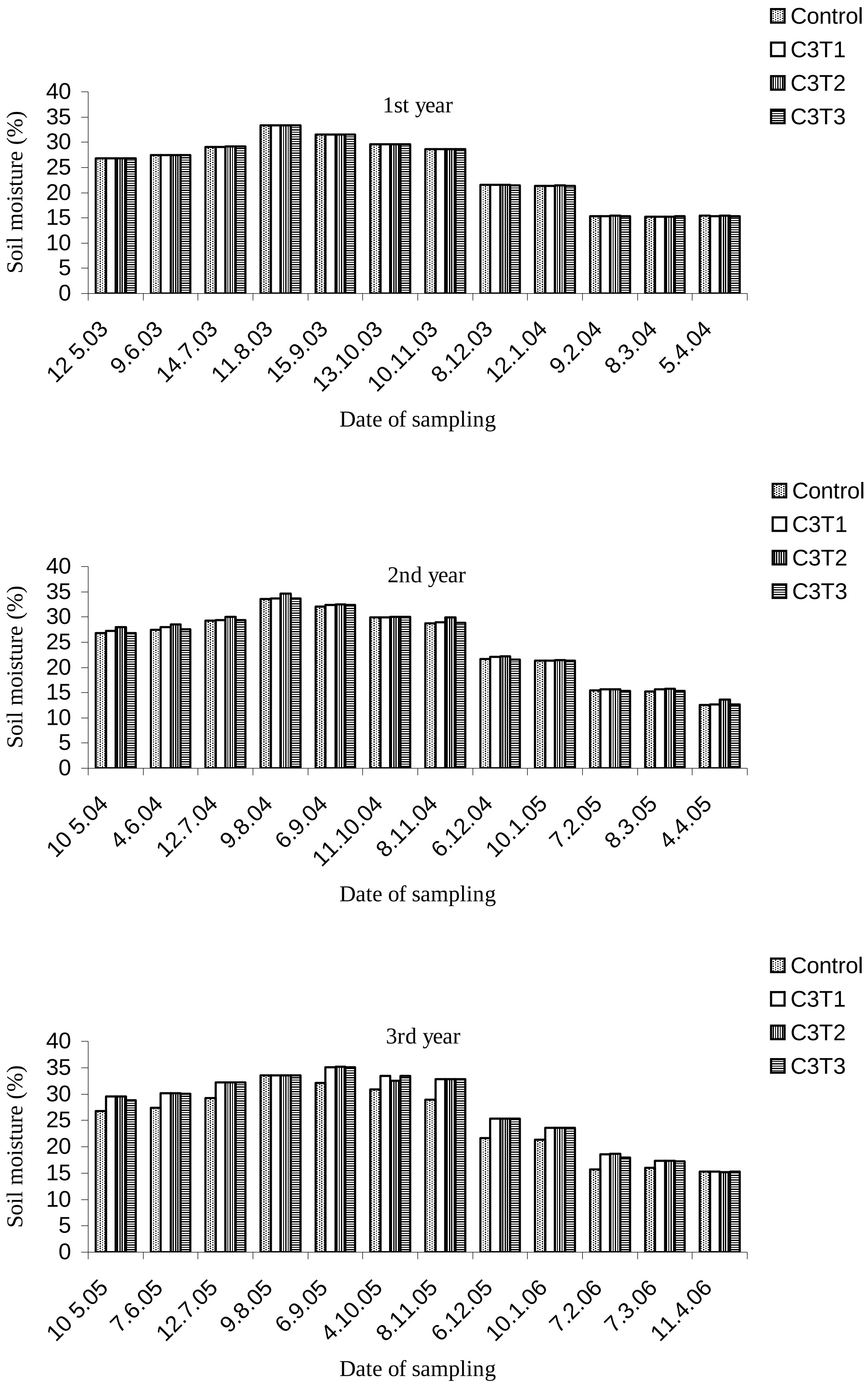
C1= *Zingiber officinales*, T1= *Alnus nepalensis*,
T2=*Melia azadirachta,* T3=*Gmelina arborea*

Fig. 5.2. Soil moisture (%) as affected by species mixture during different years in ginger based cropping system.



C2= *Curcuma longa,* T1= *Alnus nepalensis*,
T2=*Melia azadirachta,* T3=*Gmelina arborea*

Fig. 5.3. Soil moisture (%) as affected by species mixture during different years in turmeric based cropping system.



C3= *Zea mays* , T1= *Alnus nepalensis*,
T2=*Melia azadirachta,* T3=*Gmelina arborea*

Fig. 5.4. Soil moisture (%) as affected by species mixture during different years in maize based cropping system.

5.3(2) Effect of mulch type on soil moisture conservation(%):

Soil moisture conservation (%) was affected by three different mulch types *viz.* rice straw, weeds and subabul leaves in different plots differentially (Fig. 5.5). In general, the plots having mulch components had conserved more moisture than the corresponding control plots. Among the different mulches, the application of rice straw mulch conserved more moisture (59.51 %), followed by subabul leaves (49.73 %) and minimum by weeds (39.46 %) under giner-gamar inter crop plots during a 3-year period (Fig. 5.5). A similar trend was observed in turmeric-gamar inter-crop plots where the respective treatments retained 60.16 (%), 49.66 (%) and 39.43 (%) soil moisture respectively (Fig. 5.6).

The soil moisture percent was in the order of rice straw > subabul leaves > weeds > control respectively (Tables 5.7 and 5.8). The mean soil moisture (%) in general showed lower moisture content during December to April. The percent soil moisture gradually increased from May to July with the onset of rainfall and reached its peak in the months of August to September and remained steady up to September and then declined gradually (Fig. 5.7 and 5.8).

Table 5.7. Mean soil moisture (%) as affected by different mulch types and quantity under ginger - gamar inter crop plot during 3-year period.

Mulch types	1st year	2nd year	3rd year
Control	24.42 ± 2.08	23.93 ± 2.06	22.50 ± 2.04
Rice straw	28.51 ± 1.97	32.82 ± 2.15	35.89 ± 2.18
Weeds	26.36 ± 2.03	28.80 ± 2.04	31.38 ± 2.05
Subabul leaves	26.76 ± 1.99	30.89 ± 2.04	33.69 ± 2.14
CD ($P \leq 0.05$)	3.12	2.39	2.13
Mulch quantity			
Control	24.42 ± 2.08	23.93 ± 2.06	22.50 ± 2.04
6 t/ha	26.17 ± 1.99	28.78 ± 2.06	31.44 ± 2.10
8 t/ha	27.04 ± 2.00	30.80 ± 2.14	33.50 ± 2.12
10 t/ha	28.51 ± 2.00	32.86 ± 2.07	35.99 ± 2.15
CD ($P \leq 0.05$)	3.15	2.18	2.02

± S.E. m, n=12

Table 5.8. Mean soil moisture (%) as affected by different mulch types and quantity under turmeric - gamar inter crop plot during 3-year period.

Mulch types	1st year	2nd year	3rd year
Control	24.48 ± 2.07	23.98 ± 2.06	22.57 ± 2.05
Rice straw	28.58 ± 1.98	32.90 ± 2.16	36.15 ± 2.18
Weeds	26.44 ± 2.02	28.87 ± 2.04	31.47 ± 2.06
Subabul leaves	26.82 ± 1.99	30.96 ± 2.03	33.78 ± 2.13
CD ($P \leq 0.05$)	3.09	2.34	2.08
Mulch quantity			
Control	24.48 ± 2.07	24.01 ± 2.07	22.59 ± 2.03
6 t/ha	26.25 ± 1.99	28.86 ± 2.05	31.53 ± 2.12
8 t/ha	27.12 ± 2.01	30.98 ± 2.10	33.67 ± 2.12
10 t/ha	28.60 ± 2.01	32.96 ± 2.07	36.17 ± 2.17
CD ($P \leq 0.05$)	3.12	2.15	2.01

± S.E. m, n=12

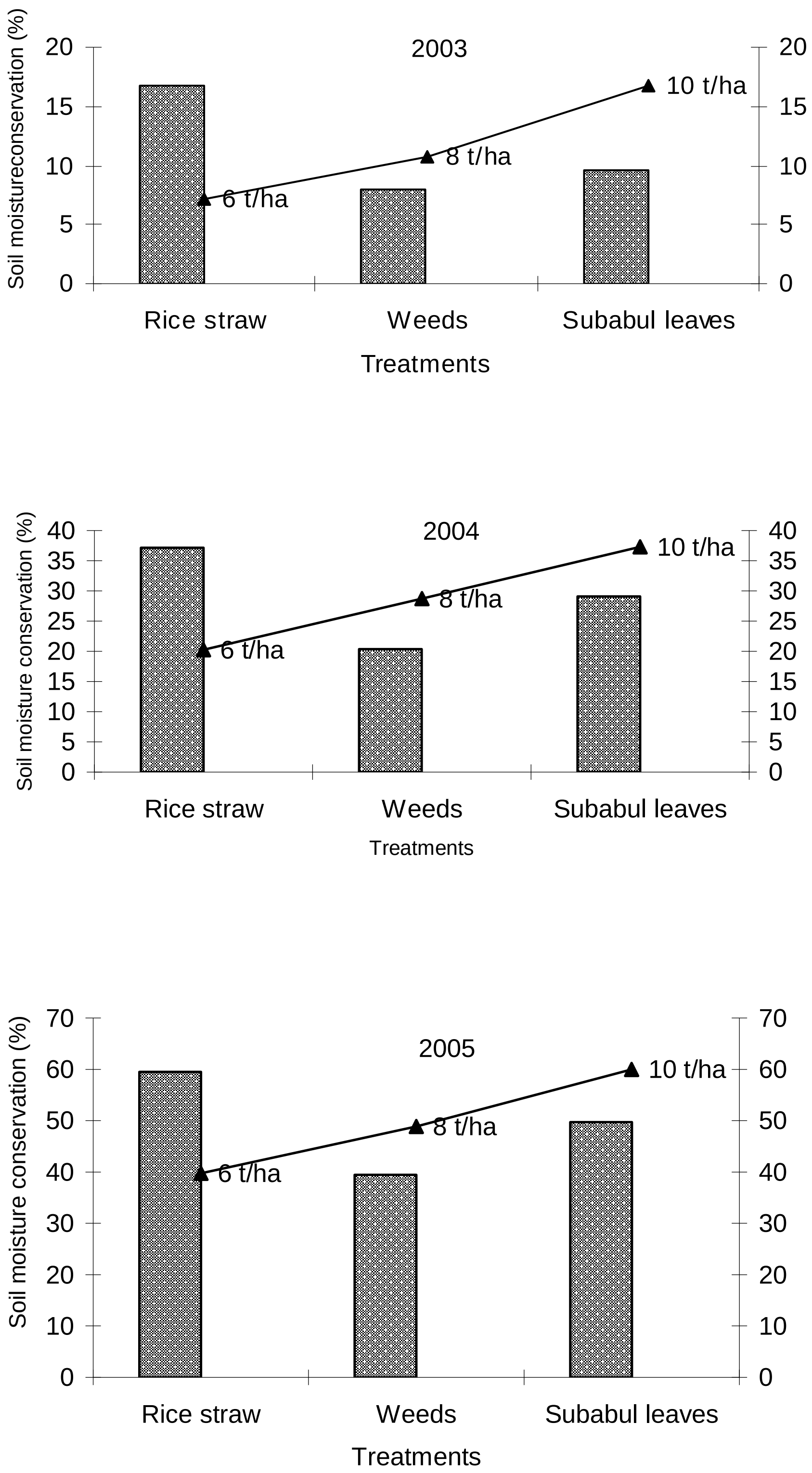
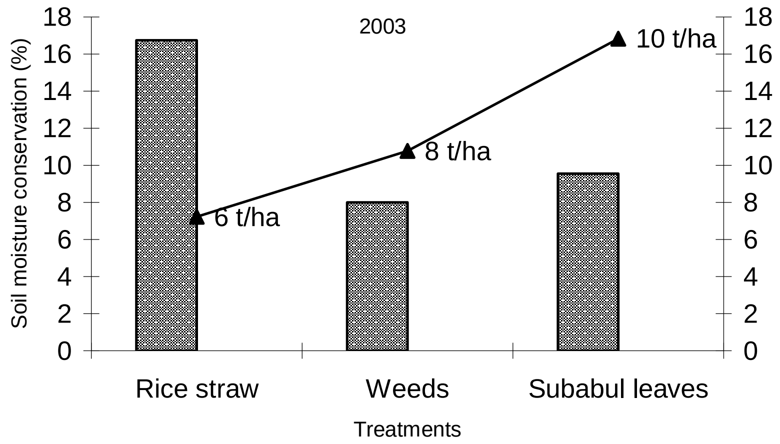
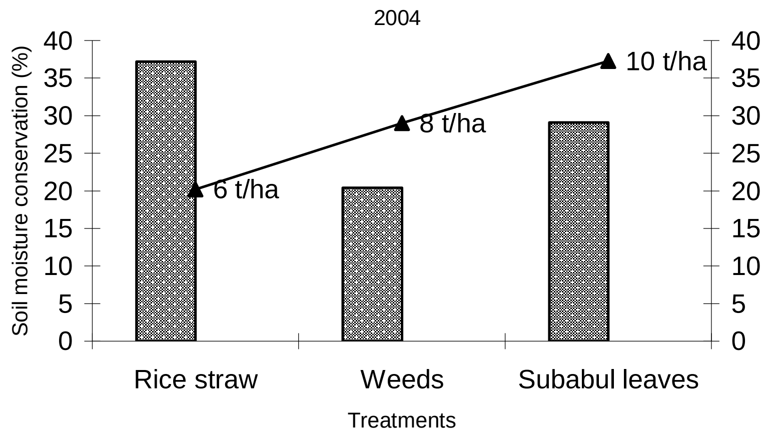


Fig. 5.5. Soil moisture conservation (%) as affected by mulch types and quantity of mulches during different years in ginger-gamar intercrop plot.





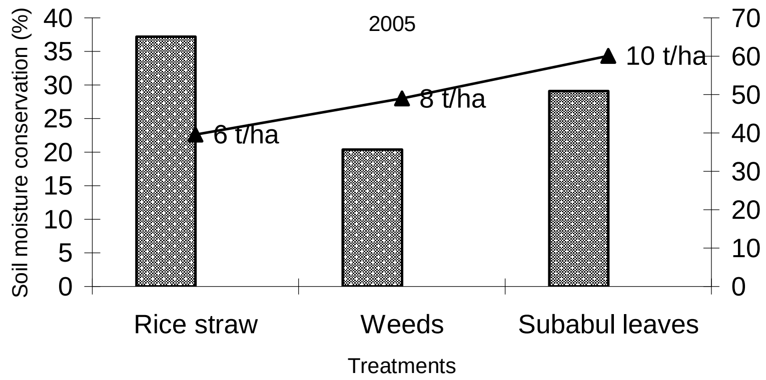
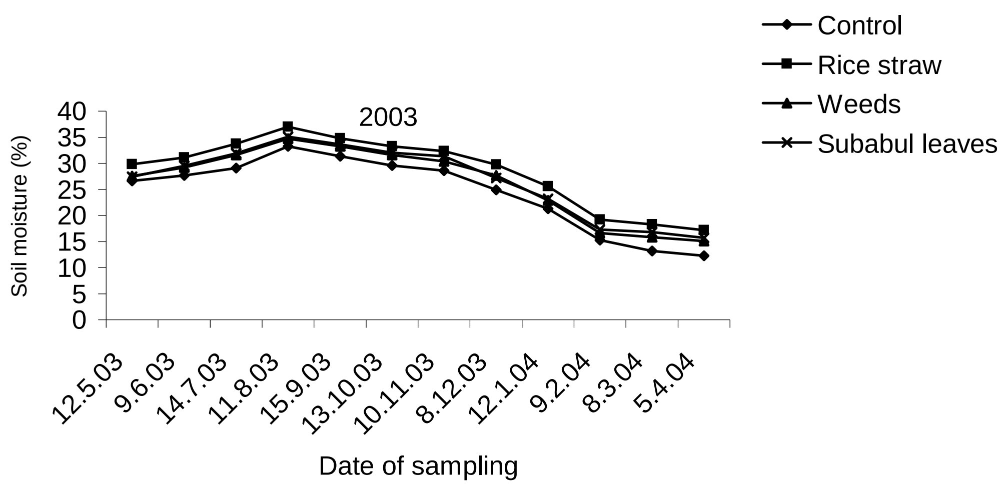
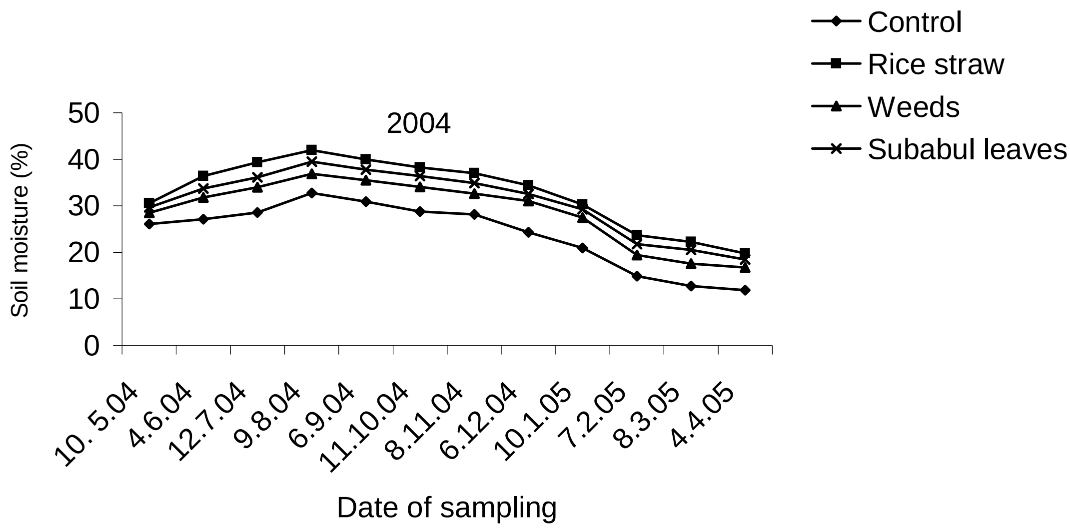


Fig. 5.6. Soil moisture conservation (%) as affected by mulch types and quantity of mulches during different years in turmeric-gamar intercrop plot.





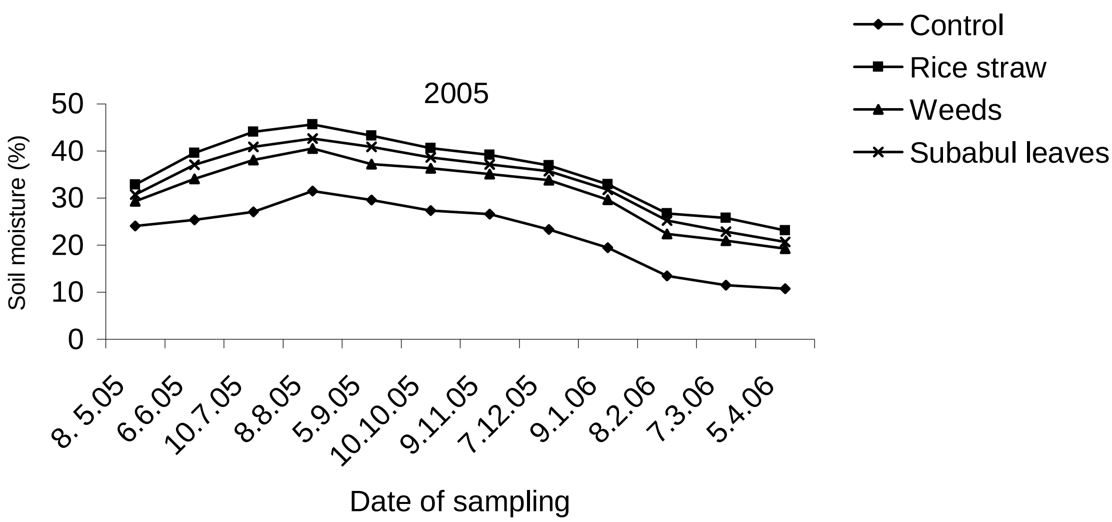
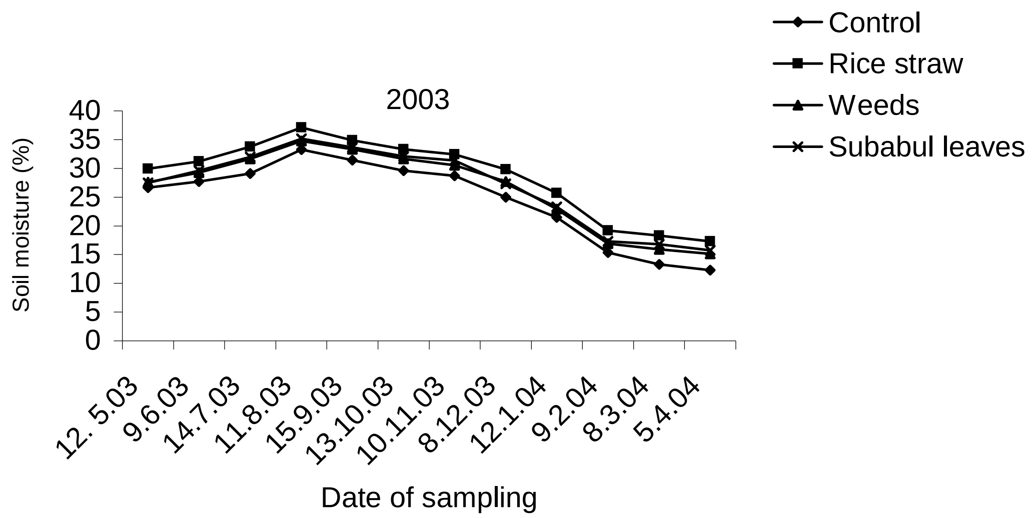
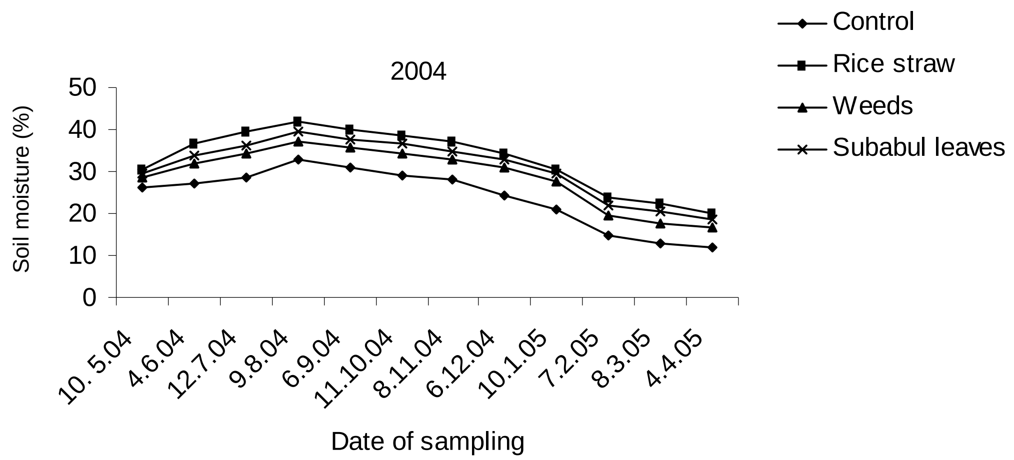


Fig. 5.7. Soil moisture (%) under different types of mulches during different years in ginger-gamar inter crop plot.





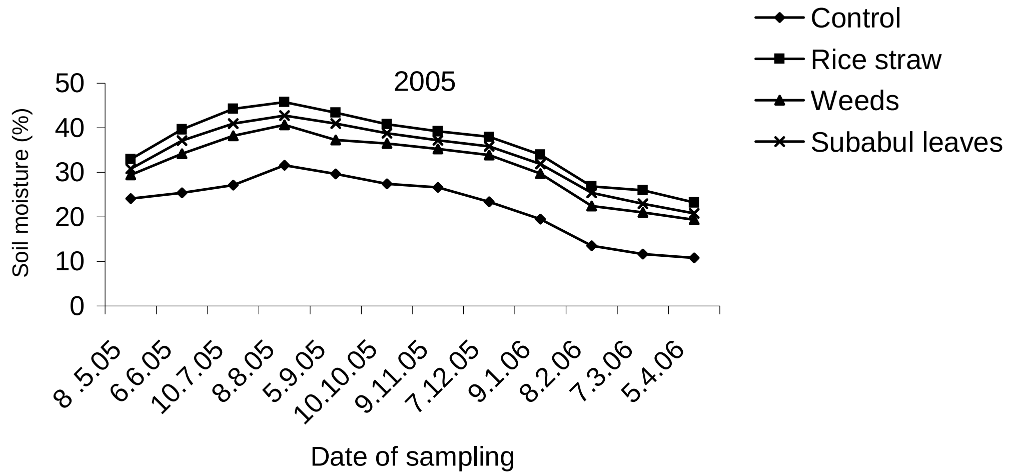


Fig. 5.8. Soil moisture (%) under different types of mulches during different years in turmeric-gamar inter crop plot.

5.3 (4) Effect of mulch quantity on soil moisture conservation (%):

Mulching had a considerable positive effect on residual soil moisture retention. The amount of conserved moisture in the soil increased with the increase in dose of mulch application. Maximum moisture conservation was recorded in those plots where mulch was applied at the rate of 10 t/ha, followed by 8 t/ha and minimum in 6 t/ha compared to the control under ginger-gamar intercrop plots (Fig. 5.5). A similar trend was observed in turmeric-gamar inter crop plot (Fig. 5.6).

Similarly, the order of soil moisture percent was 10 t/ha > 8 t/ha > 6 t/ha > control respectively (Tables 5.7 and 5.8). Soil moisture percent was maximum in the months of July to September and there was gradual decline in moisture percent till April. The lower soil moisture percent was observed during December to April. In general, soil moisture (%) was higher during winter than summer months (Fig. 5.9 and 5.10). This was the trend for all the treatments.

Analysis of variance showed that the application of mulch type and mulch dose significantly ($P \leq 0.05$) increased soil moisture percent over a 3-year period (Tables 5.9 -5.11).

Table 5.9. 3-way ANOVA (Analysis of variance, fixed effects model) on soil moisture conservation (%) as affected quality and quantity of mulches during the 1st year of study.

Source of variation	df	F-ratio											
		12/ 5/ 03	9/ 6/ 03	14/ 7/ 03	11/ 8/ 03	15/ 9/ 03	13/ 10/ 03	10/ 11/ 03	8/ 12/ 03	12/ 1/ 04	9/ 2/ 04	8/ 3/ 04	5/ 4/ 04
Mulch types	2	17.20347*	11.71376*	9.619571*	5.689545*	4.803974*	7.441934*	11.93752*	10.68512*	23.20485*	12.83779*	14.58471*	8.433534*
Mulch doses	2	1.01985	0.75294	1.795514	3.126063*	0.068898	0.453303	0.20075	0.75613	0.96689	0.18530	0.86619	0.418671
Replication	2	0.48446	3.91748*	3.237999*	0.865648	2.828984	1.780101	2.09673	0.45645	0.42691	0.42362	0.68278	0.076318
Mulch type x Mulch dose	4	1.71408	1.37973	1.206572	6.311247*	1.681535	1.884232	3.80799*	8.49616*	1.29615	1.29172	2.33192	3.363999*
Mulch type x Replication	4	1.34908	0.48528	0.129649	0.355345	0.305627	0.051748	0.24347	0.33048	0.11226	0.02367	0.26414	0.139524
Mulch doses x Replication	4	0.74615	0.35032	0.222834	1.449186	0.541222	0.797780	0.63786	0.40137	0.56078	0.53890	0.21198	0.039150
Mulch types x Mulch doses x Rep.	8	0.76270	0.31497	0.288824	3.033037*	0.377704	0.866292	0.71772	0.89010	1.06312	0.99288	0.67727	0.438490

* Significant at $P \le 0.05$

Table 5.10. 3-way ANOVA (Analysis of variance, fixed effects model) on soil moisture conservation (%) as affected quality and quantity of mulches during the 2nd year of study.

Source of variation	df	F-ratio											
		10/ 5/ 04	4/ 6/ 04	12/ 7/ 04	9/ 8/ 04	6/ 9/ 04	11/ 10/ 04	8/ 11/ 04	6/ 12/ 04	10/ 1/ 05	7/ 2/ 05	8/ 3/ 05	4/ 4/ 05
Mulch types	2	6.672396*	14.00998*	14.76163*	17.15894*	13.61221*	11.42190*	13.34582*	4.302324*	3.016151	11.71979*	14.29555*	6.371019*
Mulch doses	2	0.076588	0.50903	0.66650	0.39253	1.95836	1.44469	1.75475	0.093109	0.049883	0.65990	0.71334	0.179769
Replication	2	0.339484	0.00017	0.04766	0.00695	0.09372	0.37883	0.04436	0.017631	0.014981	0.32930	0.19463	0.096348
Mulch type x Mulch dose	4	1.210733	5.17916*	5.11950*	4.94724*	4.45435*	5.75708*	3.64491*	2.352010	3.519189*	2.33892	3.87978*	2.128491
Mulch type x Replication	4	0.139436	0.05874	0.03684	0.07043	0.11545	0.07606	0.02597	0.058867	0.007149	0.26503	0.06875	0.088090
Mulch doses x Replication	4	0.169975	0.13950	0.04188	0.16942	0.23535	0.01430	0.08964	0.031159	0.049823	0.03046	0.01440	0.046686
Mulch types x Mulch doses x Rep.	8	0.150721	0.16408	0.09376	0.22049	0.06427	0.09159	0.08615	0.078584	0.082928	0.07069	0.05768	0.060787

* Significant at $P \leq 0.05$

Table 5.11. 3-way ANOVA (Analysis of variance, fixed effects model) on soil moisture conservation (%) as affected quality and quantity of mulches during the 3rd year of study.

Source of variation	df	F-ratio											
		10/ 5/ 05	7/ 6/ 05	12/ 7/ 05	9/ 8/ 05	6/ 9/ 05	4/ 10/ 05	8/ 11/ 05	6/ 12/ 05	10/ 1/ 06	7/ 2/ 06	7/ 3/ 06	11/ 4/ 06
Mulch types	2	8.851017*	8.454285*	8.217454*	8.065997*	11.60156*	5.849072*	5.981179*	3.056316*	3.579954*	6.514182*	7.535001*	6.345737*
Mulch doses	2	0.021450	0.086799	0.644365	0.410270	0.37820	0.163317	0.227592	0.082329	0.212109	0.031006	0.181330	0.340573
Replication	2	0.122367	0.083179	0.021367	0.008046	0.03668	0.142214	0.081232	0.004243	0.009723	0.135141	0.108561	0.101012
Mulch type x Mulch dose	4	2.895356*	5.695902*	7.382406*	4.071450*	4.58939*	5.309253*	4.716558*	4.800718*	3.857665*	6.118791*	5.618608*	5.569226*
Mulch type x Replication	4	0.026636	0.014838	0.023399	0.065367	0.04249	0.007484	0.104666	0.037471	0.049953	0.019414	0.052820	0.072062
Mulch doses x Replication	4	0.095319	0.010907	0.006014	0.074735	0.04642	0.03511	0.132088	0.033875	0.049266	0.026901	0.021971	0.036674
Mulch types x Mulch doses x Rep.	8	0.055202	0.016206	0.062584	0.013598	0.04331	0.018372	0.058229	0.036766	0.047929	0.037209	0.020493	0.044898

* Significant at $P \leq 0.05$

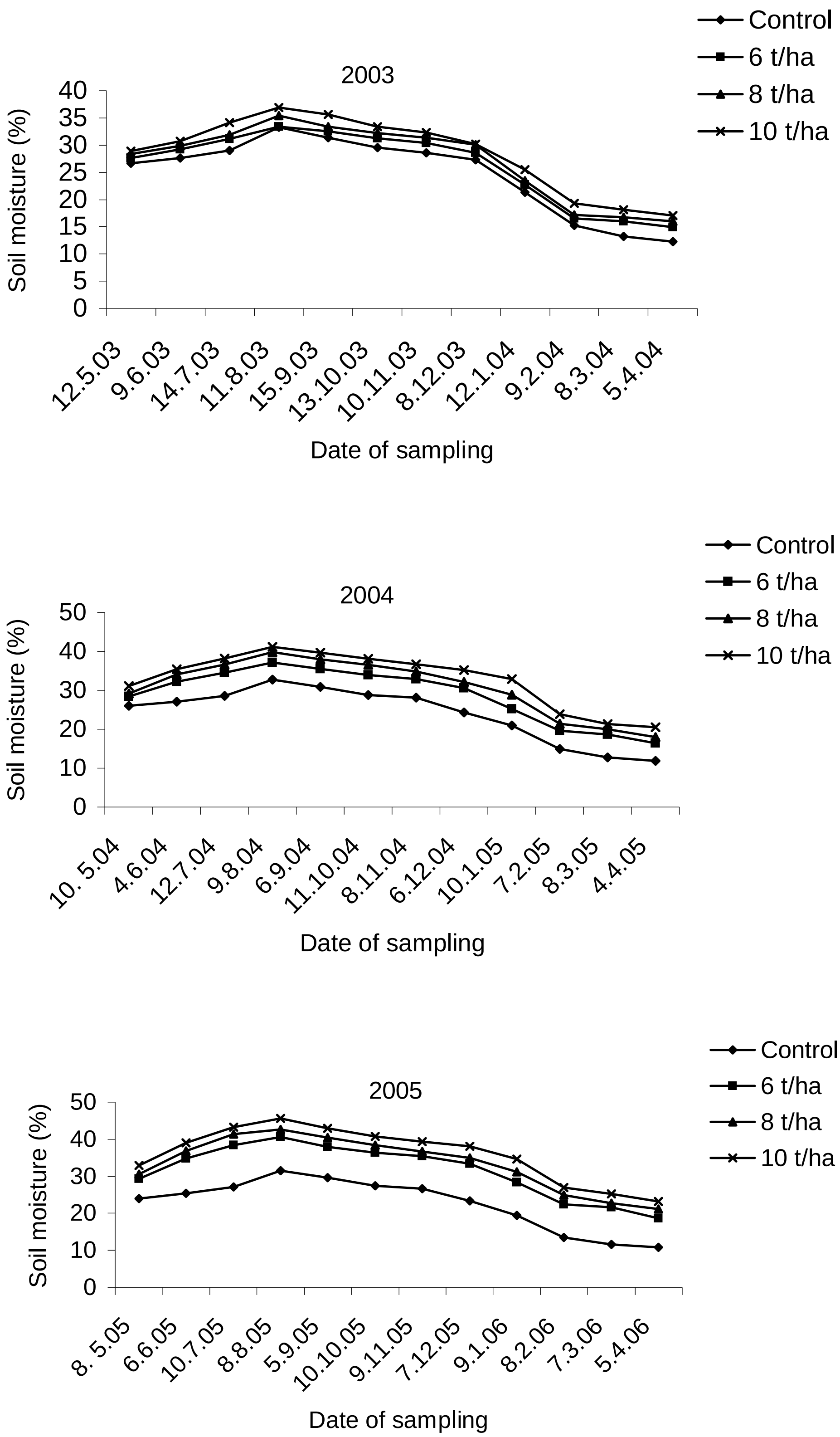


Fig. 5.9. Soil moisture (%) as affected by quantity of mulches during different years in ginger-gamar inter crop plot.

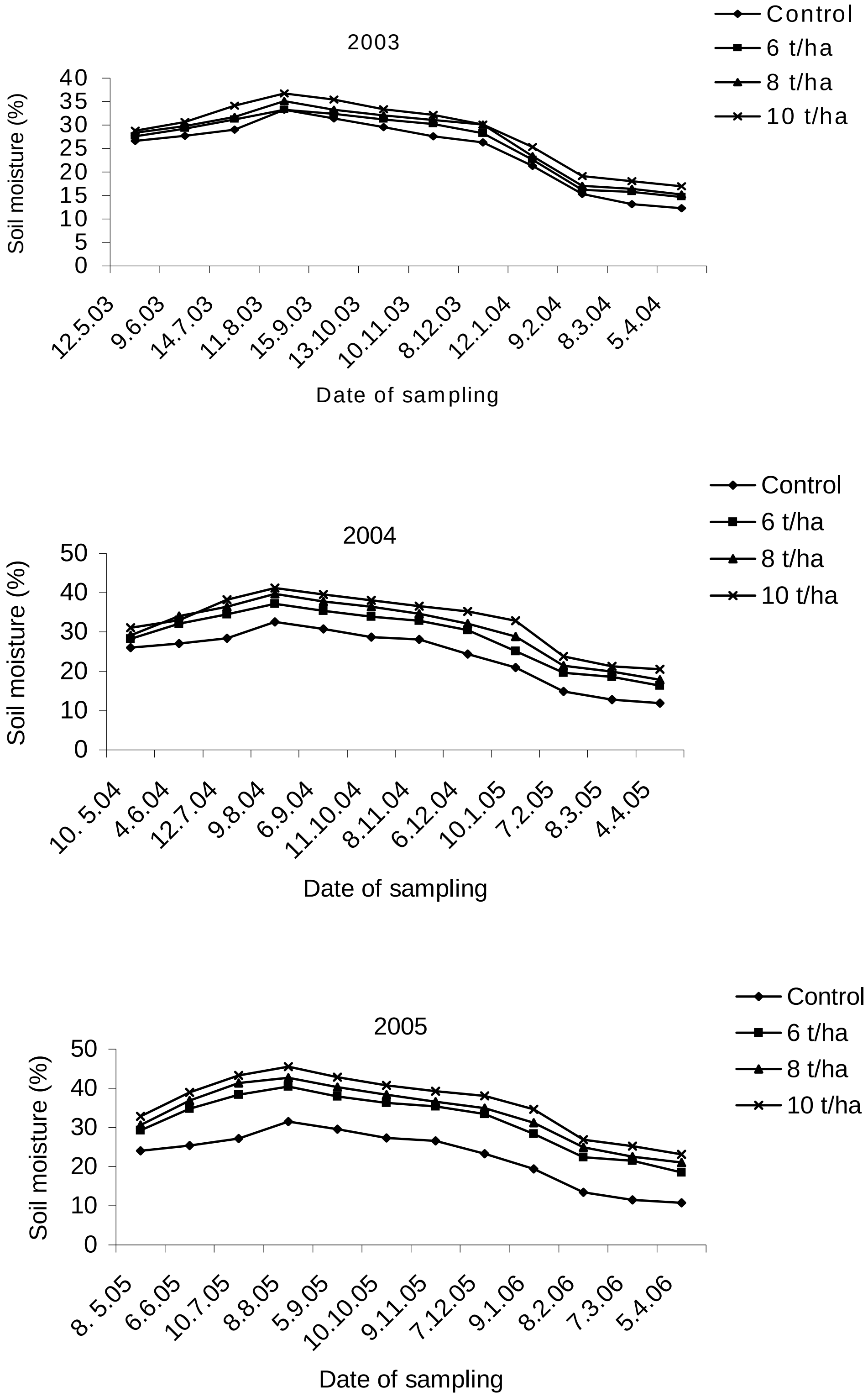


Fig. 5.10. Soil moisture (%) as affected by quantity of mulches during different years in turmeric-gamar inter crop plot.

5.4. Discussion

Soil moisture percent retention as affected by species mixture revealed no discernable influence during the first two-years study. However, soil moisture percent retention was significantly ($P \leq 0.05$) higher in the third year (Fig. 5.1). This may be due to tree-crop component rendering leaf litter to the soil, shading of tree, poor weeding and less evaporation in tree-crop intercropping. Higher soil moisture content in intercrop plots is ascribed to improvement in the soil physical environment (Lal *et al.,* 1991). Maximum soil moisture conservation was obtained under *Melia azadirachta* inter crop plot followed by *Alnus nepalensis* intercropping and minimum in *Gmelina arborea* intercrop plot. Similarly, the soil moisture percent retention showed in the order of *Curcuma longa* > *Zingiber officinales* > *Zea mays* respectively (Fig. 5.1).

In general, it was observed that soil moisture conservation percent was higher in tree-crop interaction compared to control treatment. Similar findings have been reported by Singh *et al.* (1988) and Budelman (1989) according to whom the improved hedgerow intercropping of maize with subabul improved the soil fertility level and soil moisture retention. Through agroforestry practices numerous benefits (environmental, economic and social) can be obtained of which soil and water conservation is among the important benefits that are noteworthy (Omoro and Nair, 1993; M.C Intyre *et al.,* 2000). The higher soil moisture retention under tree-crop interaction as compared to control may be due to improved microclimate owing to tree growth, poor weed growth and less evaporation in tree-crop plots than the control. Besides, better growth performance under intercropping could be owing to minimum competition for natural resources from the tree and increased availability of nutrients. Similar result were obtained by Harish and Tiwari (1993).

Soil moisture conservation as affected by quality of mulches in ginger-gamar and turmeric-gamar inter crop plots (Fig. 5.5 and 5.6) revealed that more soil moisture conservation was recorded with the plots having mulch components than those of control (without mulch). Similar results of increased soil moisture retention by different mulches were reported in guava (*Pisum quajava)* by Borathakur and Bhattacharya (1988); in grapes by Srinavas *et al.*(1990) and in Assam lemon *(Citrus limon)* by Nath and Sharma (1993), apple (Jayantkumar *et al.,* 1999), aonla (Shukla *et al.,* 2000) and Sapota (Reddy *et al.,* 1993). The effect of various rates of surface mulch on infiltration and erosion and soil conservation technique has also been discussed by Mannering and Mayer (1963). According to Sharma *et al.* (2002); Singh *et al.* (2002) and Agarwal *et al.* (2003), application of mulches result in additional benefits like soil conservation, moderation of soil temperature, suppression weeds, addition of organic matter to the soil and increase in crop production. Mulches conserved soil moisture and affected the water relations of the plant (Gregorius and Rajkumar, 1984; Srinavas *et al.,* 1990; Kotoky and Bhattacharya, 1991; Chovatia *et al.,* 1992*;* Nath and Sharma, 1993). Mulching has been argued to have a considerable positive effect on residual soil moisture conservation and the incorporation of mulch improved soil moisture conservation (Sharma *et al.,* 2001). According to Sharma and Acharya (2000) and Edwards *et al.* (2000) mulch maintains soil moisture at higher levels compared with unmulched soil.

Increased soil moisture content with different mulching treatments in the present study might have been due to increased infiltration percolation capacity of soil and owing to resistance of runoff water. The mulches might have reduced the rate of evaporation of soil moisture from the soil surface, thereby retaining the soil moisture in the soil for a longer time. According to Ossom *et al.* (2003), the mulch soils have lower temperature at the soil surface than the unmulched soil which is another reason for better moisture retention of the crop in the hilly terrains.

Various mulches have proved efficient in moisture conservation in different rainfed pockets of India as reported by many workers. For example, Chaudhary and Achaya (1993) reported that *Lantana* mulch in silty clay loam Alfisols retained 32 per cent moisture compared to 9 per cent under no mulch treatment during 50 days of study. Similarly, in red lateric silty clay loam soils, the paddy straw mulch retained 18 per cent moisture compared to 8 per cent (control) under turmeric crop during 61 days (Singh *et al.,* 1998). In the present study, the rice straw conserved soil moisture from 59.51 to 22.50 % over control. The values are somewhat comparable with those reported by Mohanty *et al*. (1990; 1991) and Dinesh Kumar *et al.* (2003).

Soil moisture conservation depends upon many factors such as soil type and climatic conditions (Prihar *et al.,* 1968), porosity and thickness of the mulch (Acharya and Prihar, 1969) and evaporation stage (Bond and Willis, 1969). Gardner (1959) and Scott and Hanks (1962) showed that in falling rate stage of drying, the rate of evaporation decreases and cumulative evaporation increases. Thus, it is advantageous to apply the mulch at the initial stage. Gupta (1989) also reported continuous crop production in dry region using water harvesting together with manuring and mulching resulted in significant increase in soil organic matter content, soil moisture retention, enhanced steady state infiltration rates and reduced bulk density. Chovatia *et al.* (1992) and Tejedor *et al.* (2002) concluded that improved soil physical and fertility conditions due to application of mulch prior to planting were the main causes of the improved yields in the test crops (wheat and rice). Soil conditioning is recommended for improved moisture retention, efficient use of water in crop production (Larson *et al.,* 1983) and higher crop yield. Therefore, tillage and residue management practices in agroforestry play an important role in soil conservation (Singh *et al.,* 2002).

Our data revealed that among the different mulches the application of rice straw mulch conserved more soil moisture followed by subabul leaves mulch and minimum in weeds (Fig. 5.5 and 5.6). The more conservation of moisture by rice straw over other mulches may be due to its slower rate of decomposition than the others. The control treatment recorded the least soil moisture percentage, which clearly signifies that mulch treatments proved efficient to conserved soil moisture, and this was found to be in consonance with the findings of Mohan *et al*. (2004). Similar results were reported in apple (*Malpighia pumila* Hill) by Mage (1982); mango (*Mangifera indica* L.) and avocado (*Persea americana* Mill.) by Gregorious and Rajkumar (1984) and in grapes (*Vitis vinifera* L.) by Srinivas *et al.* (1990).

Our data also revealed that the percent of soil moisture gradually increased from May to July with the onset of rainfall and reached its peak in the months of August to September and remained steady up to September and there was gradual decline (Fig. 5.7, 5.8, 5.9 and 5.10). This was true in all mulched plots. This could be due to the decomposition of the vegetative mulch materials under high moisture percent in the soil. Further, soil moisture retention was higher during winter months than summer months. This was true in all treatments. Similar results were obtained by Jiang Ping *et al.* (1997) who advocated mulching reduced soil temperature in summer and increased in winter.

Soil moisture conservation increased with the increasing rates of application of mulch materials in both ginger and turmeric fields (Fig. 5.5 and 5.6). Maximum moisture conservation was recorded with 10 t mulch/ha, followed by 8 t mulch/ha and 6 t mulch/ha and minimum in control treatment. The present findings are in conformity with the observations recorded by Mohanty *et al.* (1990); Sharma *et al.* (2001); Dinesh Kumar *et al*. (2003). Moisture conservation due to high quantity mulch might have caused reduction in soil surface evaporation and weed intensity. The higher moisture content under the mulch dose treatments may also be ascribed to the thermal insulating effect and the slower evaporation caused by cooling (Ross *et al.,* 1985). In control treatment, the continuity of conducting pores might have permitted more water movement to the surface aggravating the losses through evaporation (Bhusan *et al.,* 1973).

Chapter-VI

Crop productivity as affected by species mixture, type and quantity of mulches

6.1. Introduction

Crop productivity is an important determinant for site quality assessment, therefore in many of the agroforestry research studies, major emphasis is given to the sustainable land management so as to provide optimum supply of the basic requirements like food, fodder, fuel wood and green manure for agricultural crop (Sanchez, 1995), besides providing employment to local people. In rainfed hilly areas it is an usual system because it provides some insurance against the vagaries of the monsoon. Moreover the tree cover is vital for the ecological balance and for economic sustainability of food production system. Crop productivity can be increased by adopting improved package of practices, particularly *in situ* moisture conservation by mulching.

Mulch materials are well known to improve conservation of soil moisture during dry period (Luchtov *et al.,* 1989) and improve the growth and vigour of fruit trees (Haynes, 1980). Increase in moisture content in the root zone has been ascribed to application of Stover mulch resulting in improved crop growth and yield (Moitra *et al.,* 1994). Quality of mulch is more effective than quantities of mulch application in conserving soil moisture and increasing growth and yield of turmeric (Dinesh *et al.,* 2003). Use of various types of mulches has been found to delay the process of soil drying by reducing evaporation loss (Parihar *et al.,* 1977; Gupta and Gupta, 1982; 1983; Gupta, 1983). Mulches conserved the soil moisture and affected the water relations of the plant (Gregorious and Rajkumar, 1984; Srinivas *et al.,* 1990; Kotoky and Bhattacharya, 1991; Chovatia, *et al.,* 1992; Nath and Sharma, 1993) and increased fruit yield due to mulches were reported in different fruit crops mainly due to increased soil moisture status (Chattopadhyay and Patra, 1992; Mage, 1982; Syes Ismail *et al.,* 1993). Beneficial effect of organic mulches is mainly due to their efficacy to reduce evaporation by moderating the soil temperature and helps to conserve soil moisture (Rajput and Singh, 1970; Aggarwal *et al.,* 1992). Incorporation of organic matter has been reported to augment water retention capacity by improving structure and physical environment of soil (Hussain *et al.,* 1988; Tomar *et al.,* 1990).

In Mizoram, the prevailing traditional farming practice being unscientific contributes loss of soil moisture and subsequent degradation of the sites. Therefore, there is a need for conserving soil moisture to avert moisture deficit during crop growth period. Thus, the present study was undertaken to compare the relative efficacy of different mulches (both quality and quantity) for moisture augmentation and to assess the role played by different tree species in soil moisture conservation.

6.2. Methodology

The relative efficacy of three mulch types and three mulch doses as discussed in chapter III have been tried here to evaluate the growth and crop productivity of ginger and turmeric following standard methodologies. Besides, the effect of species mixture on the productivity of ginger and turmeric has been attempted. The data were subjected to ANOVA and CD at 5% level was calculated to see the variations between the treatments.

6.3. Results

6.3(1) Productivity of ginger and turmeric as affected by species mixture:

Productivity of ginger and turmeric as affected by species mixture is given in Tables 6.1 and 6.2. Ginger intercrop under *Alnus nepalensis* has maximum rhizome yield (6.22 t/ha), followed by *Melia azadirachta* inter cropped (6.20 t/ha), *Gmelina arborea* (6.19 t/ha) and minimum (5.11 t/ha) in control during a 3-year period (Table 6.1). Similarly, maximum (6.80) number of finger was recorded in *Alnus nepalensis* intercrop plot followed by *Melia azadirachta* (6.66) and *Gmelina arborea* (6.60). *Alnus nepalensis* plots also has produced maximum finger size f ginger (8.01 cm x 7.43 cm), next to *Melia azadirachta* (7.99 cm x 6.42 cm), and *Gmelina arborea* (7.98 cm x 6.41 cm).

The turmeric intercrop under *Alnus nepalensis* showed maximum rhizome yield (5.64 t/ha), followed by *Melia azadirachta* inter cropped (5.60 t/ha), *Gmelina arborea* (5.60 t/ha) and control (5.01 t/ha) during a 3-year period (Table 6.1). Maximum number of finger (6.66) under *Alnus nepalensis* was recorded, followed by *Melia azadirachta* (6.53), *Gmelina arborea* (6.46) and minimum (5.93) in control plot. Similarly, maximum finger size (6.15 x 5.97 cm) was attained in *Alnus nepalensis* intercrop plot, followed by *Melia azadirachta* (6.13 x 5.95 cm) and *Gmelina arborea* (6.11 x 5.94 cm).

During the first two-years, no discernable changes in crop productivity were obtained in treated plots compared to the control ones. However, during the third year, crop productivity was significantly ($P \leq 0.05$) increased in *Alnus nepalensis* plot inter crop plots (Tables 6.1 and 6.2).

Table 6.1. Productivity of ginger as affected by species mixture.

Treatments	Ginger yield (t/ha)			Number of finger		
	2003	2004	2005	2003	2004	2005
Control	5.22 ± 0.02	5.19 ± 0.02	5.11± 0.03	6.40 ± 0.11	6.26 ± 0.06	6.06 ± 0.17
C_1T_1	5.30 ± 0.01	5.51 ± 0.03	6.22 ± 0.08	6.46 ± 0.13	6.60 ± 0.20	6.80 ± 0.11
C_1T_2	5.29 ± 0.02	5.50 ± 0.01	6.20 ± 0.13	6.46 ± 0.17	6.53 ± 0.17	6.66 ± 0.13
C_1T_3	5.27 ± 0.03	5.49 ± 0.02	6.19 ± 0.06	6.40 ± 0.20	6.53 ± 0.17	6.60 ± 0.20
CD ($P \leq 0.05$)	0.17	1.96	0.64	1.19	1.22	0.45

± S.E.m, n=3

Treatments	Finger size (cm)		
	2003	2004	2005
Control	7.22 x 6.29	7.19 x 6.12	6.81 x 5.72
C_1T_1	7.43 x 6.34	7.89 x 6.36	8.01 x 7.43
C_1T_2	7.42 x 6.32	7.88 x 6.35	7.99 x 6.42
C_1T_3	7.42 x 6.32	7.87 x 6.35	7.98 x 6.41

C_1 = *Zingiber officinales*, T_1 = *Alnus nepalensis*,
T_2 = *Melia azadirachta* , T_3 = *Gmelina arborea*

Table 6.2. Productivity of turmeric as affected by species mixture

Treatments	Turmeric yield (t/ha)			Number of finger		
	2003	2004	2005	2003	2004	2005
Control	5.10 ± 0.01	5.07 ± 0.07	5.01 ± 0.04	6.26 ± 0.06	6.13 ± 0.06	5.93 ± 0.24
C_2T_1	5.14 ± 0.01	5.30 ± 0.03	5.64 ± 0.01	6.33 ± 0.17	6.46 ± 0.17	6.66 ± 0.06
C_2T_2	5.14 ± 0.01	5.25 ± 0.03	5.60 ± 0.05	6.33 ± 0.06	6.40 ± 0.20	6.53 ± 0.06
C_2T_3	5.13 ± 0.02	5.23 ± 0.01	5.60 ± 0.12	6.26 ± 0.13	6.33 ± 0.17	6.46 ± 0.13
CD ($P \le 0.05$)	0.09	0.34	0.52	0.99	1.06	1.09

± S.E.m, n=3

Treatments	Finger size (cm)		
	2003	2004	2005
Control	5.42 x 5.27	5.39 x 5.25	4.59 x 4.12
C_2T_1	5.43 x 5.28	5.52 x 5.37	6.15 x 5.97
C_2T_2	5.42 x 5.29	5.52 x 5.36	6.13 x 5.95
C_2T_3	5.42 x 5.27	5.51 x 5.35	6.11 x 5.94

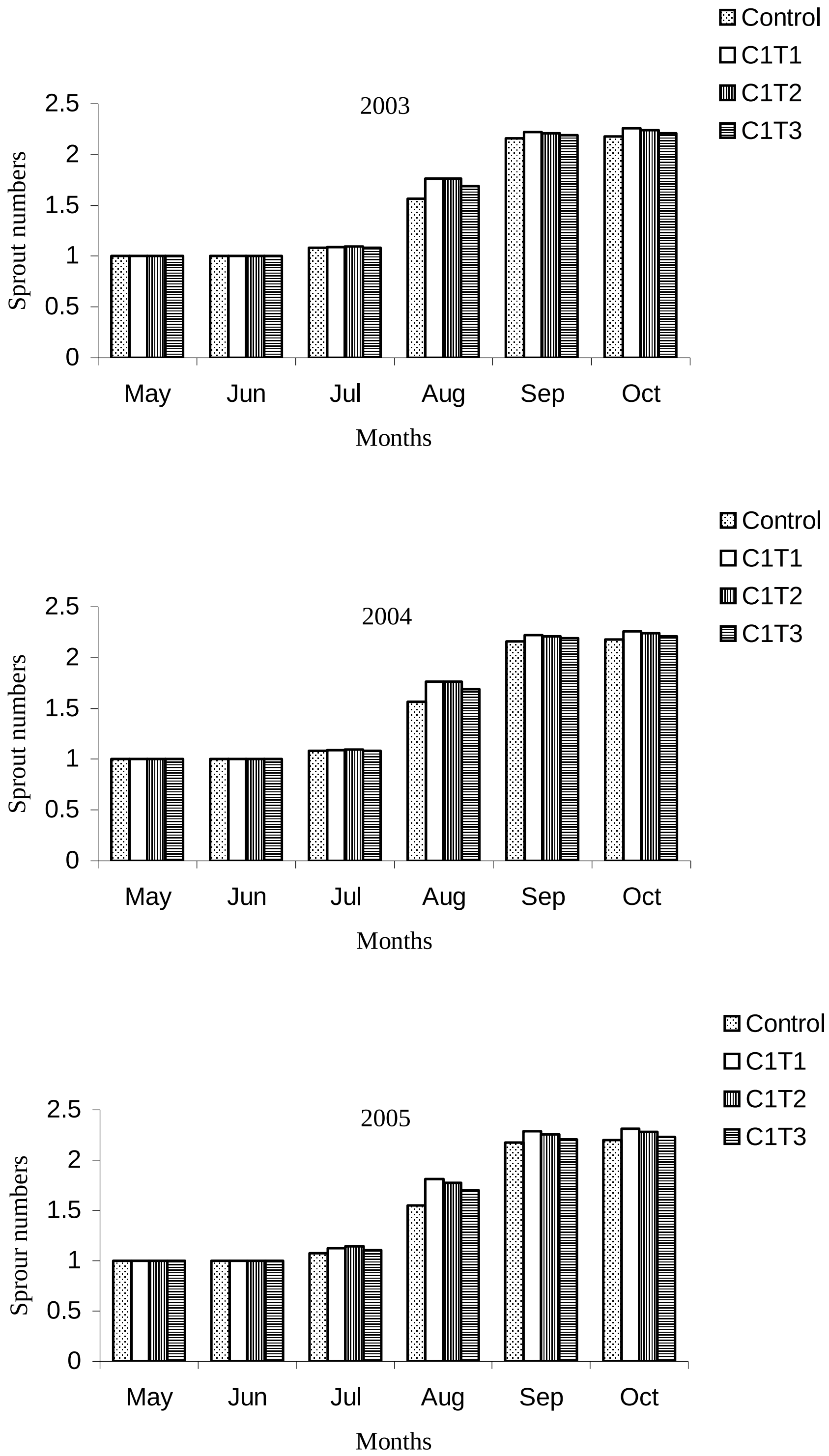
C_2 = *Curcuma longa*, T_1 = *Alnus nepalensis*,
T_2 = *Melia azadirachta,* T_3 = *Gmelina arborea*

6.3(2) Number of tillers, sprouting frequency and height of ginger and turmeric as affected by species mixture:

Sprouting number, sprouting frequency percent and average sprout height of ginger (Fig. 6.1 - 6.3) and turmeric (Fig. 6.4 - 6.6) increased with time. The rate of change in all these was related to the characteristic sigmoid growth curve. No discernable change in sprout numbers was obtained in the treated plots compared to the control ones. Sprout numbers increased gradually till October in all the plots, so was the case with sprouting height and sprouting frequency.

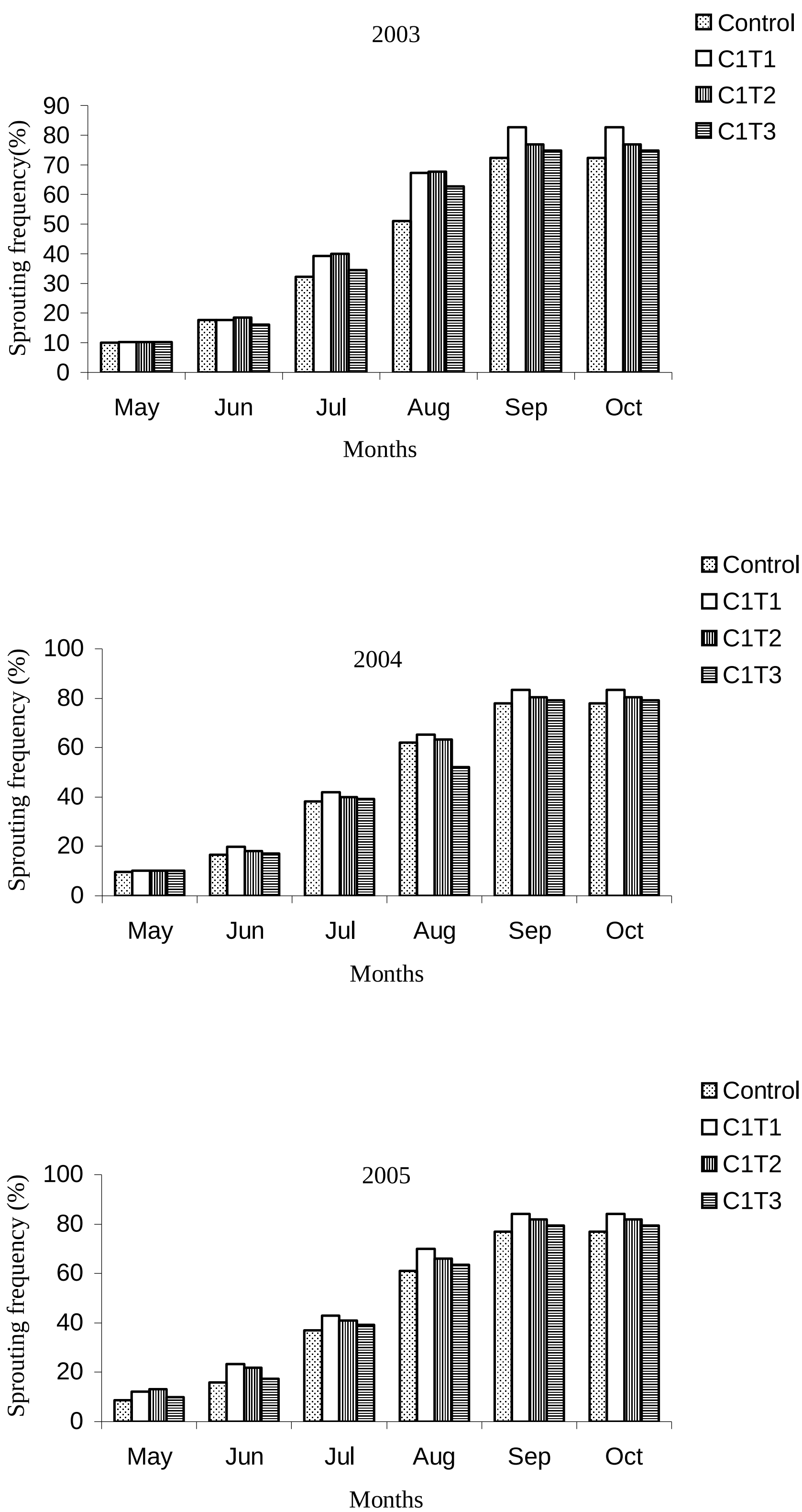
Maximum sprouting number (2.29), sprouting frequency (83.85) and average sprout height (47.28 cm) of ginger were obtained under *Alnus nepalensis* intercropped plot, followed by *Melia azadirachta* having sprouting number (2.25), sprouting frequency (82.05) and average sprout height (46.60cm), *Gmelina arborea* having sprouting number (2.23), sprouting frequency (79.28) and average sprout height (46.12cm) and minimum in control having sprouting number (2.20), sprouting frequency (76.92) and average sprout height (37.20 cm) during a 3-year period (Fig. 6.1 - 6.3).

Similarly, for turmeric, maximum sprouting number (1.33), sprouting frequency (93.08) and average sprout height (72.15 cm) were obtained under *Alnus nepalensis* intercropped plot, followed by *Melia azadirachta* having sprouting number (1.31), sprouting frequency (92.56) and average sprout height (68.94cm), *Gmelina arborea* having sprouting number (1.29), sprouting frequency (89.02) and average sprout height (68.47 cm) and minimum in control having sprouting number (1.26), sprouting frequency (79.74) and average sprout height (57.37 cm) during a 3-year period (Fig. 6.4 - 6.6).



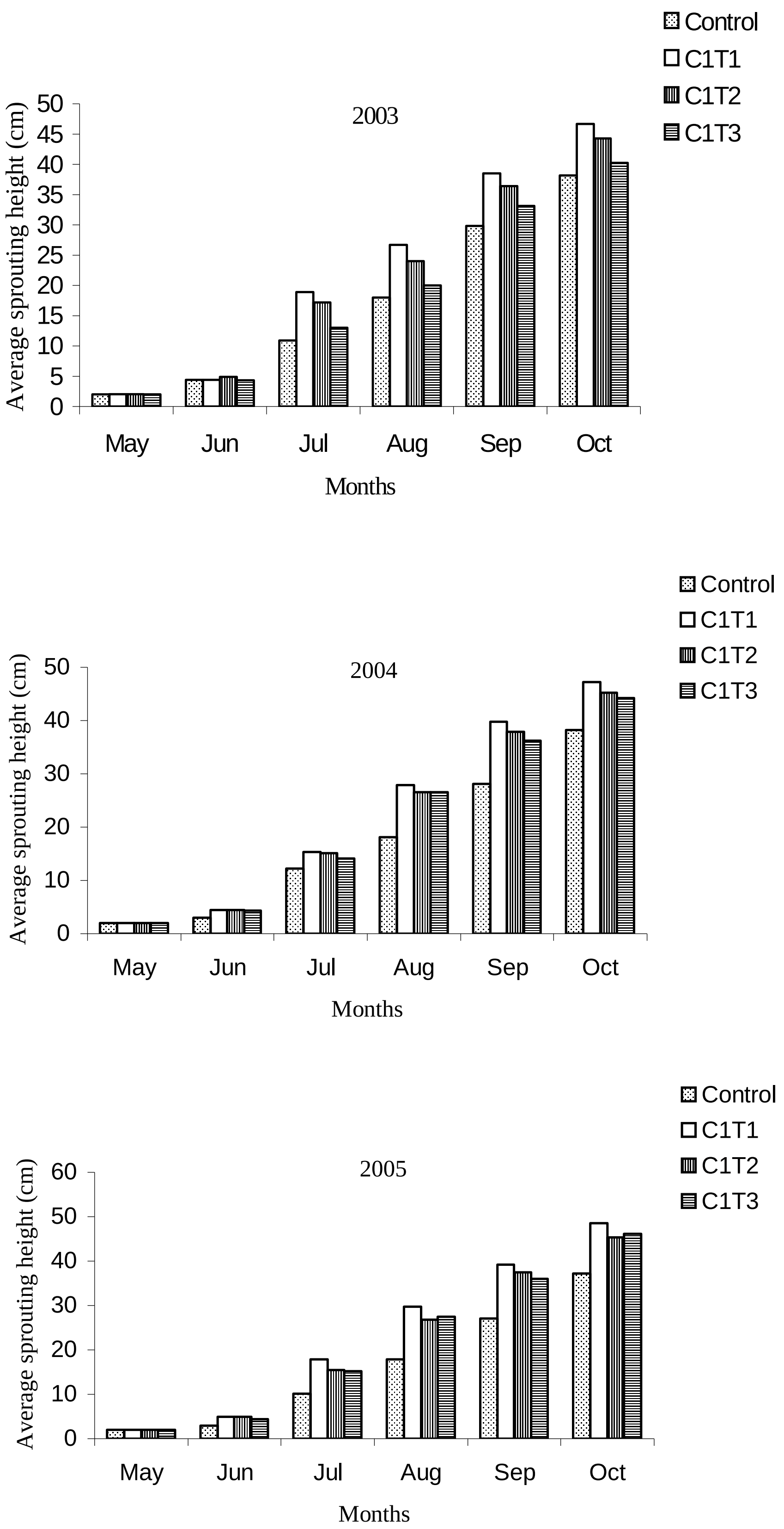
C1 = *Zingiber officinales,* T1 = *Alus nepalensis,*
T2 = *Melia azadirachta,* T3 =*Gmelina arborea*

Fig. 6.1. Sprout numbers of ginger as affected by species mixture.



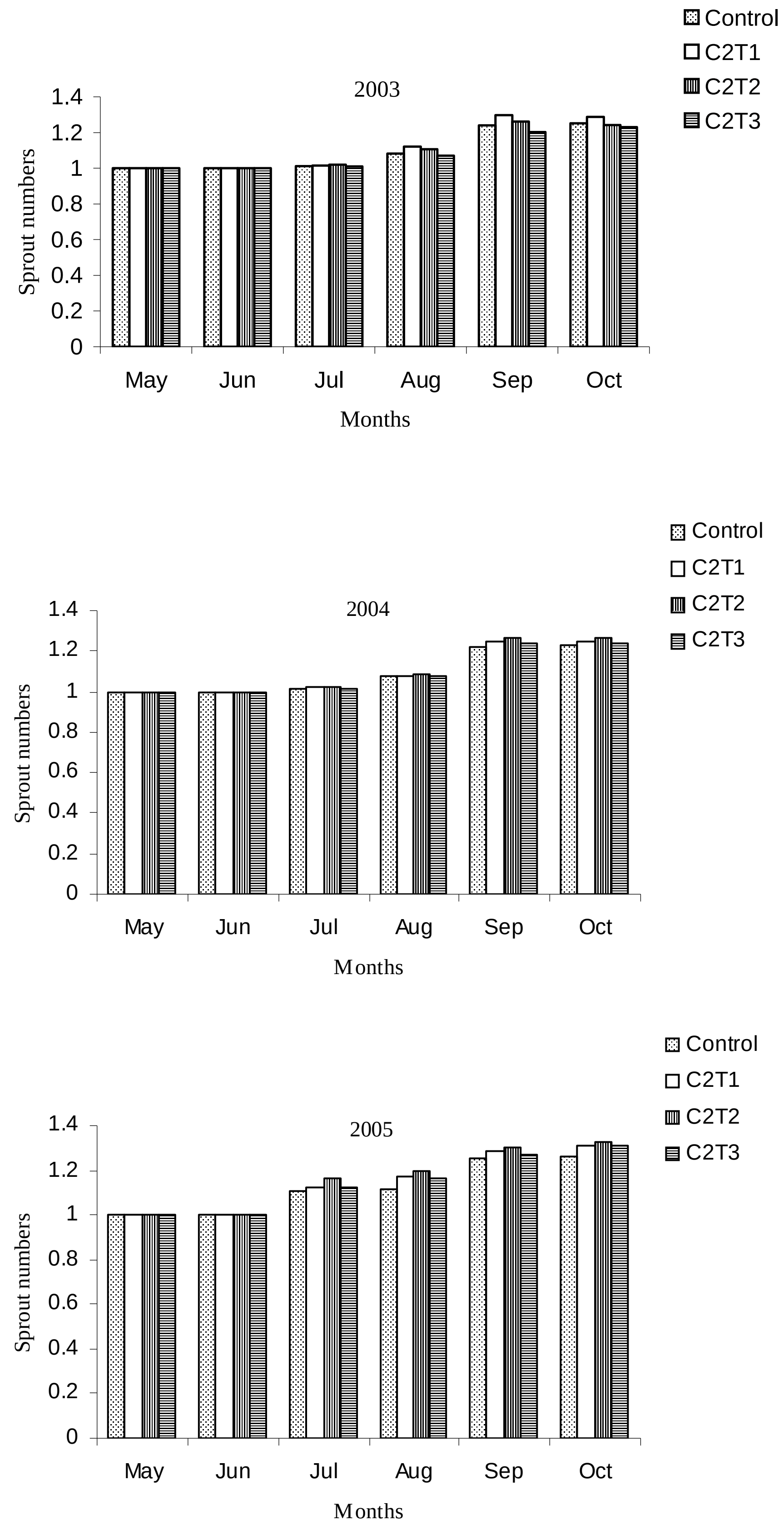
C_1 = *Zingiber officinales,* T_1 = *Alnus nepalensis,*
T_2 = *Melia azadirachta,* T_3 = *Gmelina arborea*

Fig. 6.2. Sprouting frequency (%) of ginger as affected by species mixture



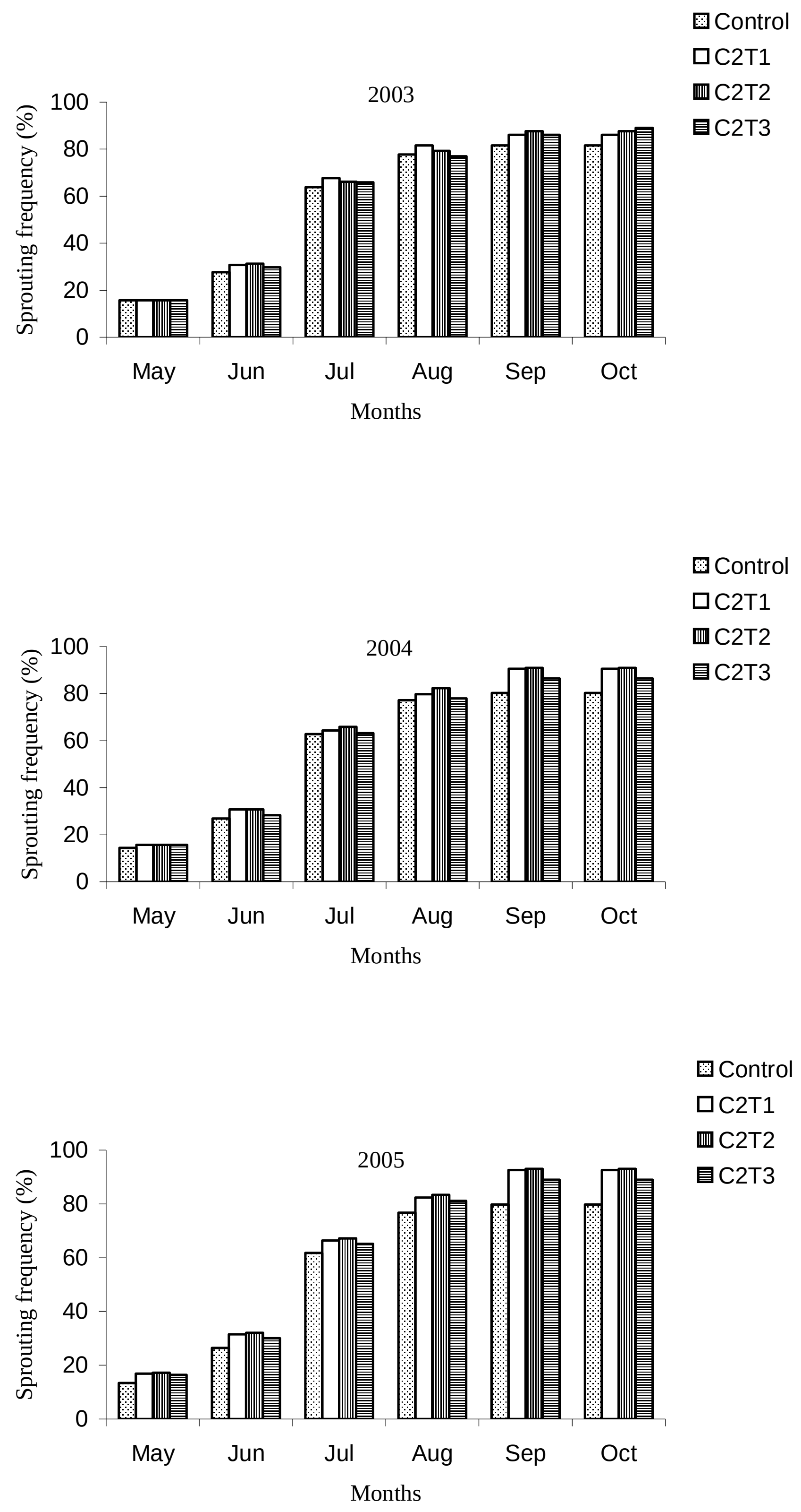
C_1 = *Zingiber officinales,* T_1 = *Alnus nepalensis,*
, T_2 = *Melia azadirachta,* T_3 = *Gmelina arborea*

Fig. 6.3. Average sprouting height (cm) of ginger as affected by species mixture.



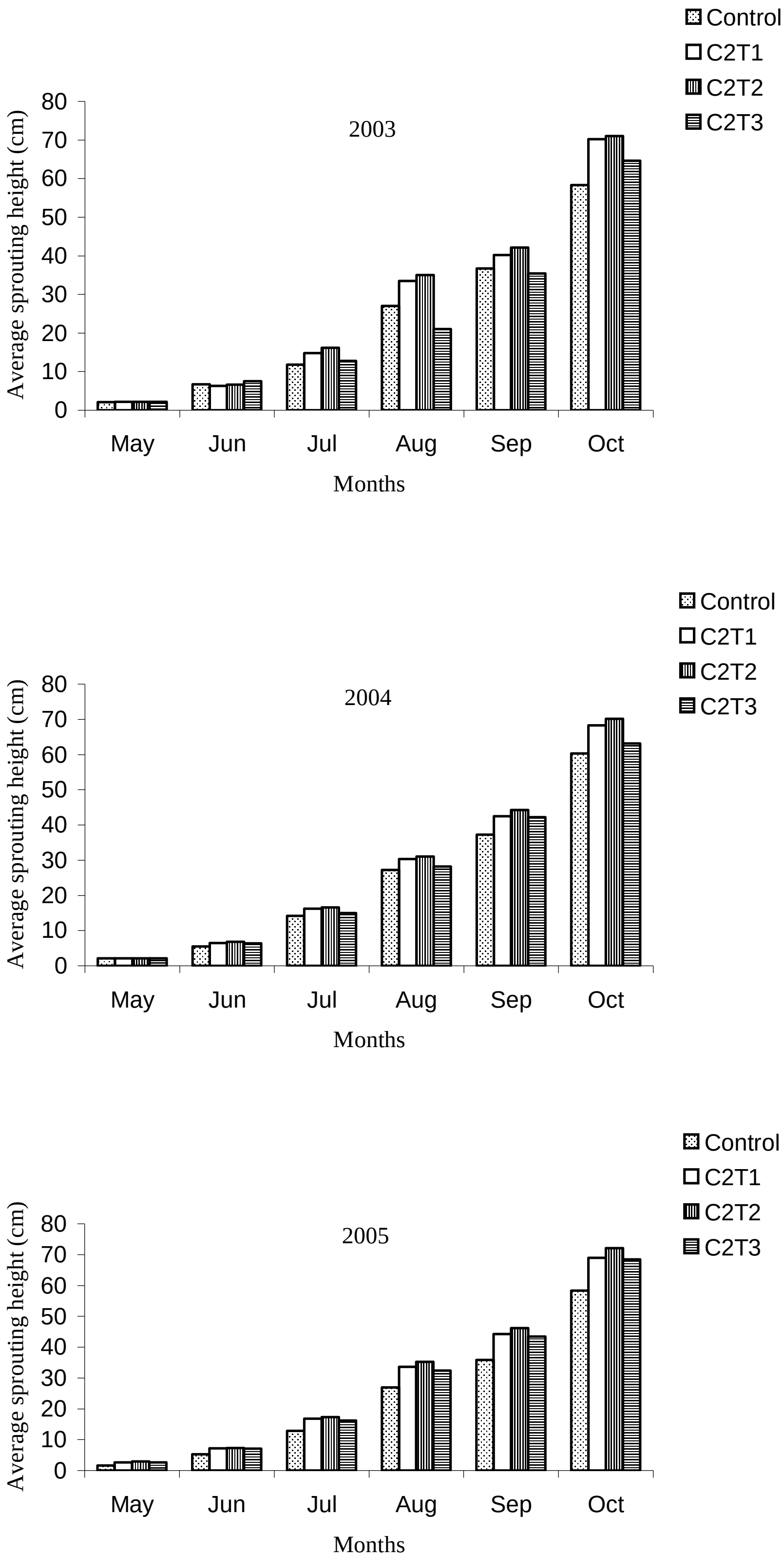
C_2 = *Curcuma longa*, T_1 = *Alnus nepalensis*,
T_2 = *Melia azadirachta*, T_3 = *Gmelina arborea*

Fig. 6.4. Sprout numbers of turmeric as affected by species mixture



C_2 = *Curcuma longa,* T_1 = *Alnus nepalensis,*
T_2 = *Melia azadirachta,* T_3 = *Gmelina arborea*

Fig. 6.5. Sprouting frequency (%) of turmeric as affected by species mixture.



C_2 = *Curcuma longa,* T_1 = *Alnus nepalensis,*
T_2 = *Melia azadirachta,* T_3 = *Gmelina arborea*

Fig. 6.6. Average sprouting height (cm) of turmeric as affected by species mixture.

6.3(3) Productivity of ginger and turmeric as affected by different mulch types in *Gmelina arborea* plot:

The crop yields, number of fingers and finger size of both ginger and turmeric gradually increased with time. The variations in these parameters were not statistically significant during the first two years, however, crops productivity showed significant ($P \leq 0.05$) increase at the end of experiment (Tables 6.3 and 6.4).

Among the mulch types, subabul leaves caused maximum (9.17 t/ha) ginger yield, higher finger number (6.71) and better finger size (8.27 x 8.18cm), followed by rice straw, weeds and minimum in control (Table 6.3). The trend was similar for all the years.

Similarly, maximum turmeric yield (9.04 t/ha), higher number of finger (6.58) and better finger size (6.71 x 6.30 cm) were obtained due to the use of subabul leaves mulch followed by rice straw (8.47 t/ha, 6.49 and 6.65 x 6.28 cm), and weeds (7.69 t/ha, 6.31 and 6.22 x 6.16 cm respectively) during a 3-year period (Table 6.4).

Table 6.3. Productivity of ginger as affected by different mulch types in *Gmelina arborea* plot.

Treatments	Ginger yield (t/ha)			Number of finger		
	2003	2004	2005	2003	2004	2005
Control	5.19 ± 0.02	5.18 ± 0.02	5.15 ± 0.02	6.14 ± 0.06	6.06 ± 0.03	5.74 ± 0.17
Rice straw	6.87 ± 0.37	7.94 ± 0.31	8.52 ± 0.26	6.44 ± 0.07	6.56 ± 0.05	6.64 ± 0.04
Weeds	5.59 ± 0.20	6.57 ± 0.30	7.70 ± 0.33	6.25 ± 0.05	6.36 ± 0.05	6.47 ± 0.07
Subabul laves	7.35 ± 0.36	8.47 ± 0.28	9.17 ± 0.31	6.55 ± 0.08	6.64 ± 0.09	6.71 ± 0.09
CD ($P \leq 0.05$)	2.10	1.96	1.99	0.54	0.48	0.83

± S.E.m, n=3

Treatments	Finger size (cm)		
	2003	2004	2005
Control	7.50 x 6.31	7.47 x 6.59	6.80 x 5.71
Rice straw	8.21 x 8.12	8.21 x 8.13	8.23 x 8.14
Weeds	8.18 x 8.09	8.19 x 8.10	8.21 x 8.10
Subabul laves	8.23 x 8.15	8.25 x 8.16	8.27 x 8.18

Table 6.4. Productivity of turmeric as affected by different mulch types in *Gmelina arborea* plot

Treatments	Turmeric yield (t/ha)			Number of finger		
	2003	2004	2005	2003	2004	2005
Control	5.18 ± 0.02	5.16 ± 0.02	5.12 ± 0.03	5.93 ± 0.06	5.76 ± 0.08	5.73 ± 0.17
Rice straw	7.06 ± 0.35	7.95 ± 0.36	8.47 ± 0.41	6.29 ± 0.09	6.38 ± 0.08	6.49 ± 0.05
Weeds	5.68 ± 0.19	6.57 ± 0.29	7.69 ± 0.31	6.11 ± 0.05	6.20 ± 0.07	6.31 ± 0.05
Subabul laves	7.29 ± 0.34	8.44 ± 0.30	9.04 ± 0.40	6.42 ± 0.08	6.51 ± 0.09	6.58 ± 0.09
CD ($P \leq 0.05$)	2.00	2.15	2.56	0.58	0.55	0.82

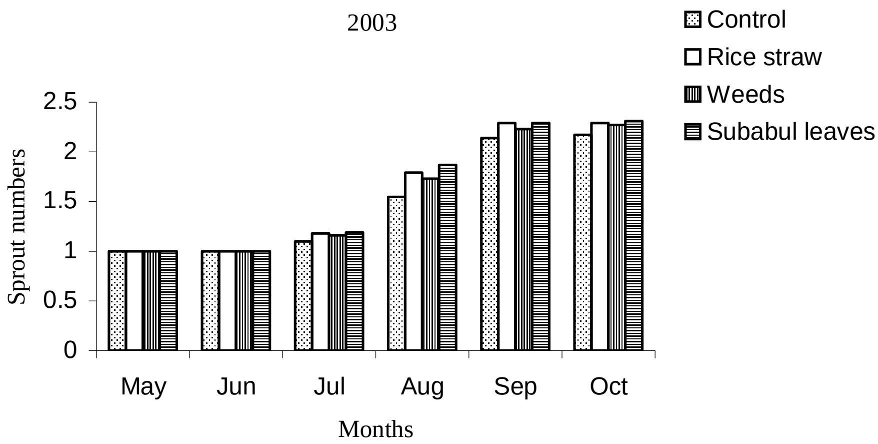
± S.E.m, n=3

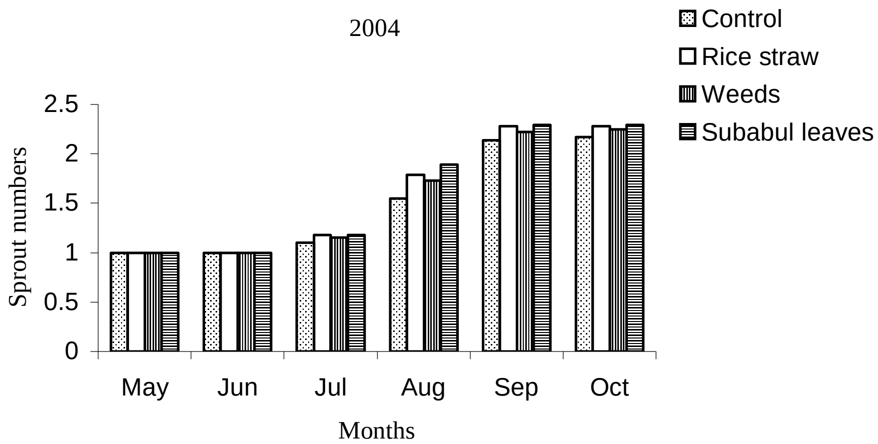
Treatments	Finger size (cm)		
	2003	2004	2005
Control	5.42 x 5.27	5.41 x 5.25	4.59 x 4.13
Rice straw	6.23 x 6.12	6.27 x 6.14	6.65x 6.28
Weeds	6.17 x 6.11	6.18 x 6.12	6.22 x 6.16
Subabul laves	6.28 x 6.19	6.30 x 6.23	6.71 x 6.30

6.3(4) Number of tillers, sprouting frequency and height of ginger and turmeric as affected by different mulch types in *Gmelina arborea* plot:

Number of tillers, sprouting frequency and sprouting height of ginger (Fig. 6.7 - 6.9) and turmeric (Fig. 6.10 – 6.12) as affected by mulch types under *Gmelina arborea* inter crop plot during different years showed that maximum sprouting number (2.33), sprouting frequency (86.87) and average sprout height (49.72 cm) of ginger were recorded in the application of subabul leaves mulch followed by rice straw mulch having sprout number (2.29), sprouting frequency (85.08) and average sprout height (49.21 cm), weeds mulch having sprout number (2.27), sprouting frequency (84.27) and average sprout height (48.21 cm), and minimum in control having sprout number (2.17), sprouting frequency (76.92) and average sprout height (37.20 cm) during a 3-year period (Fig. 6.7-6.9). There was no difference in this trend on the growth parameters of ginger in the first two years.

Similarly, maximum sprouting number (1.45), sprouting frequency (92.26) and average sprout height (78.81 cm) of turmeric were obtained under subabul leaves mulch, followed by rice straw mulch, having sprout number (1.42), sprouting frequency (90.69) and average sprout height (76.73 cm), weeds mulch having sprout number (1.38), sprouting frequency (89.21) and average sprout height (73.62 cm), and minimum in control having sprout number (1.26), sprouting frequency (79.74) and average sprout height (58.37 cm) during a 3-year period (Fig. 6.10 - 6.12). It was also observed that a gradual increase in growth parameters such as sprout number, sprouting frequency percent and average sprout height of both the ginger and turmeric obtained with time.





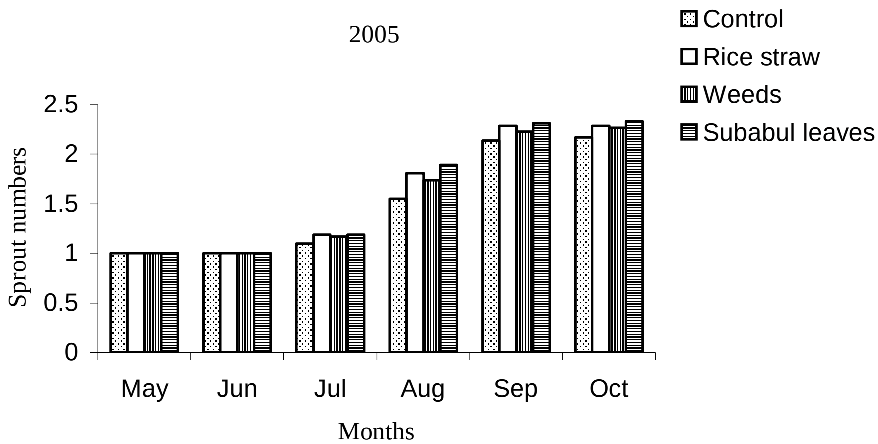


Fig. 6.7. Sprout numbers of ginger as affected by three mulch types in ginger field under *Gmelina arborea.*

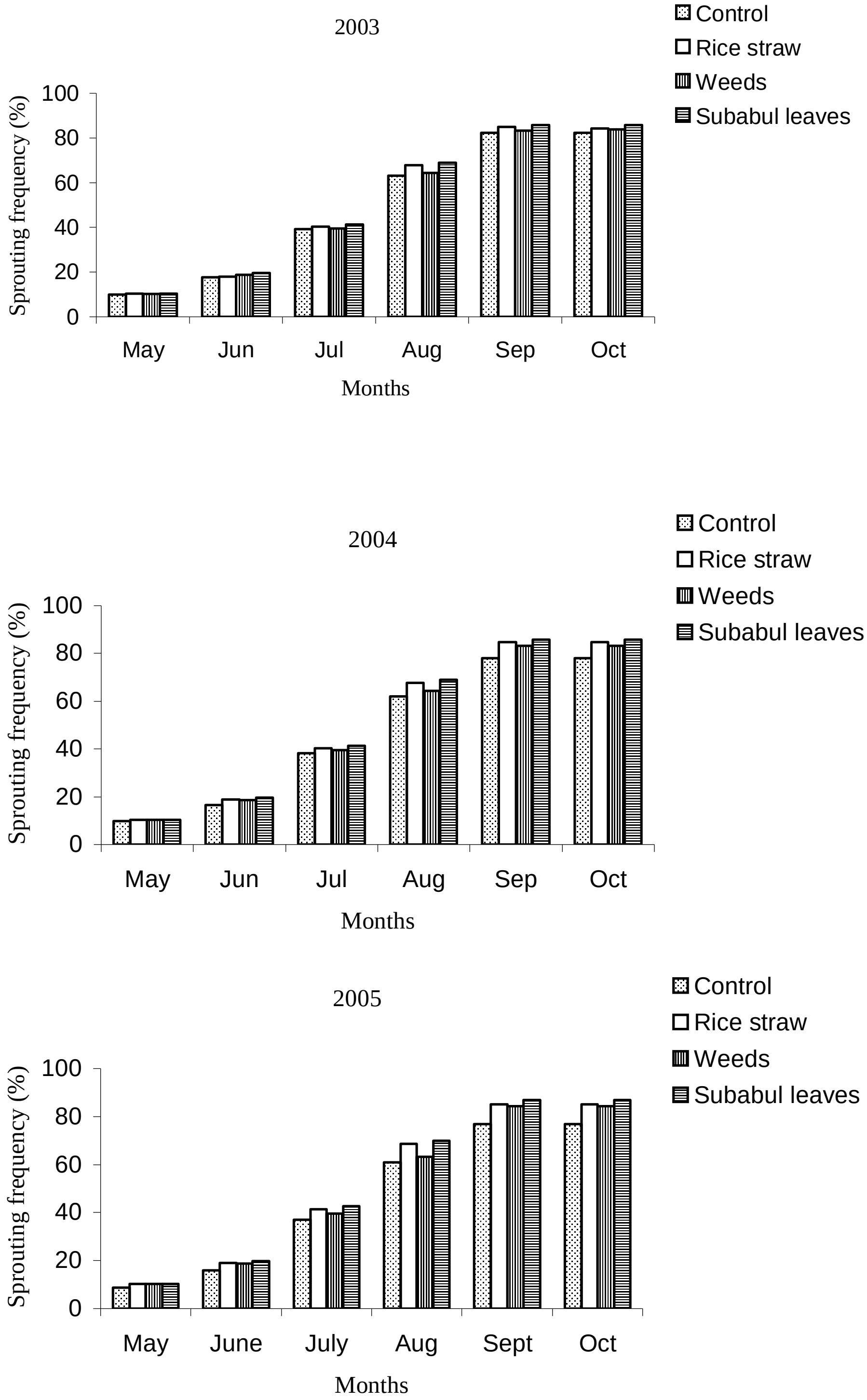


Fig. 6.8. Sprouting frequency (%) of ginger as affected by three mulch types in ginger field under *Gmelina arborea.*

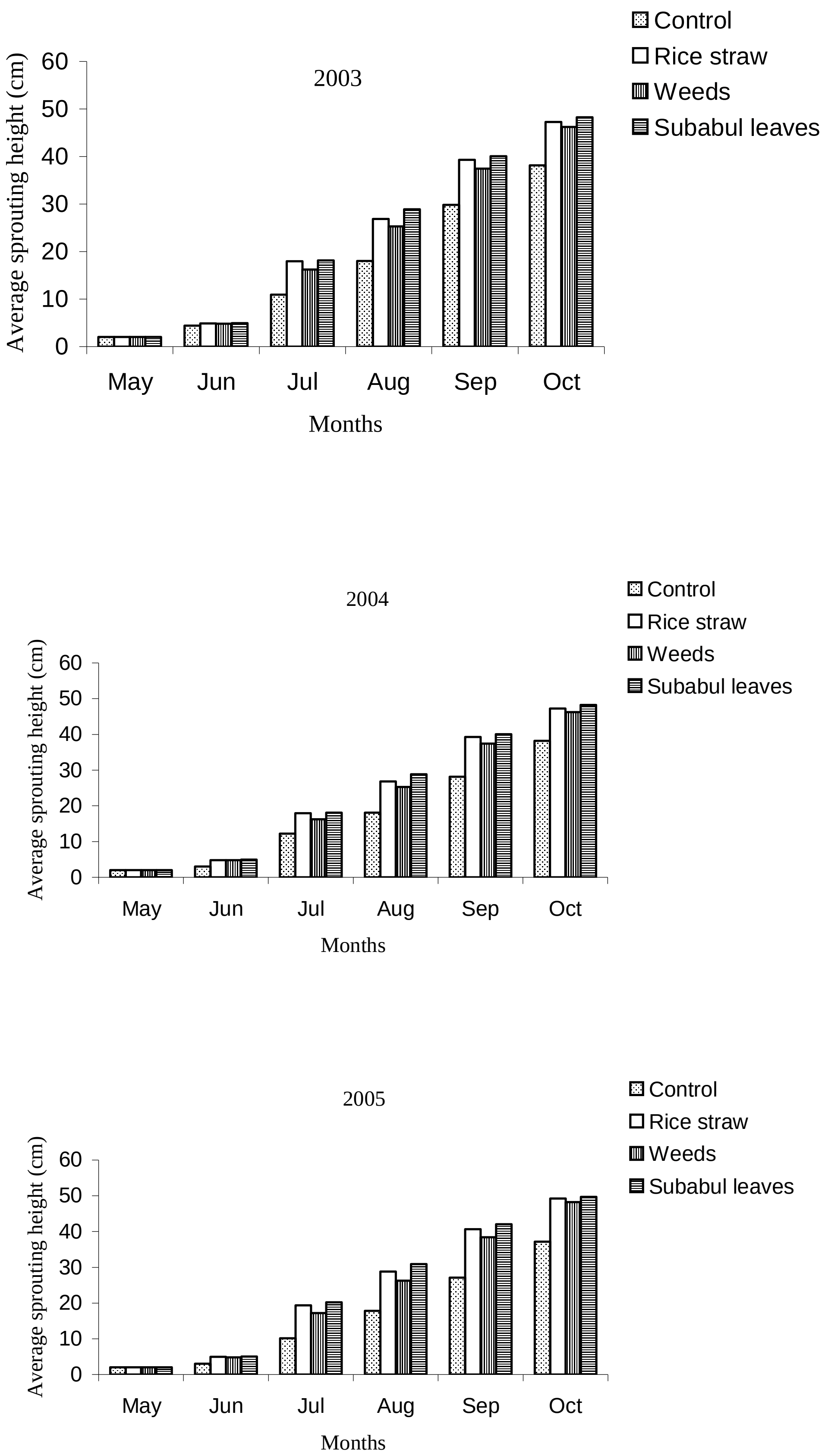


Fig.6.9. Average sprouting height (cm) of ginger as affected by three mulch types in ginger field under *Gmelina arborea*

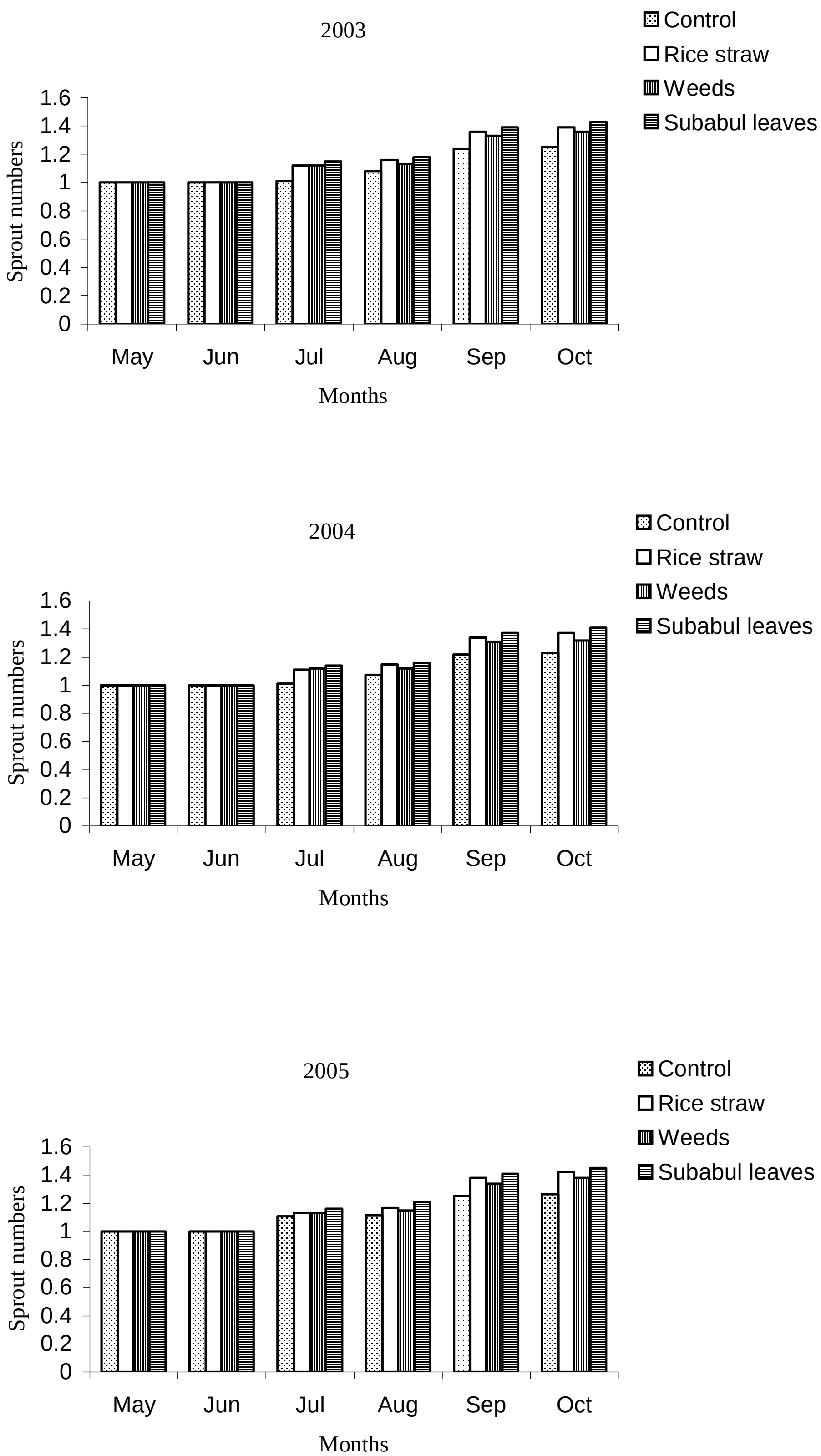


Fig.6.10. Sprout numbers of turmeric as affected by three mulch types in turmeric field under *Gmelina arborea.*

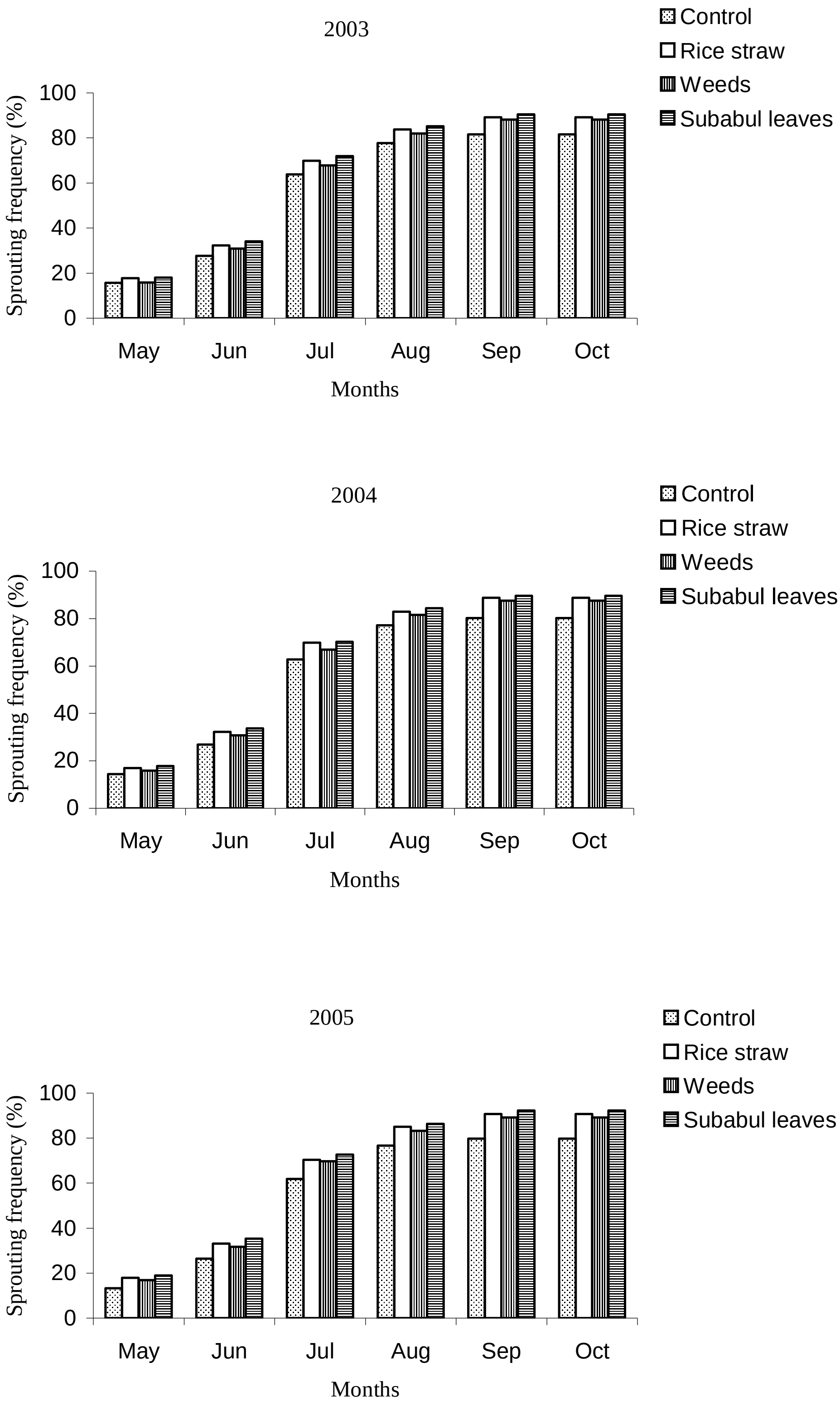


Fig.6.11. Sprouting frequency (%) of turmeric as affected by three mulch types in turmeric field under *Gmelina arborea.*

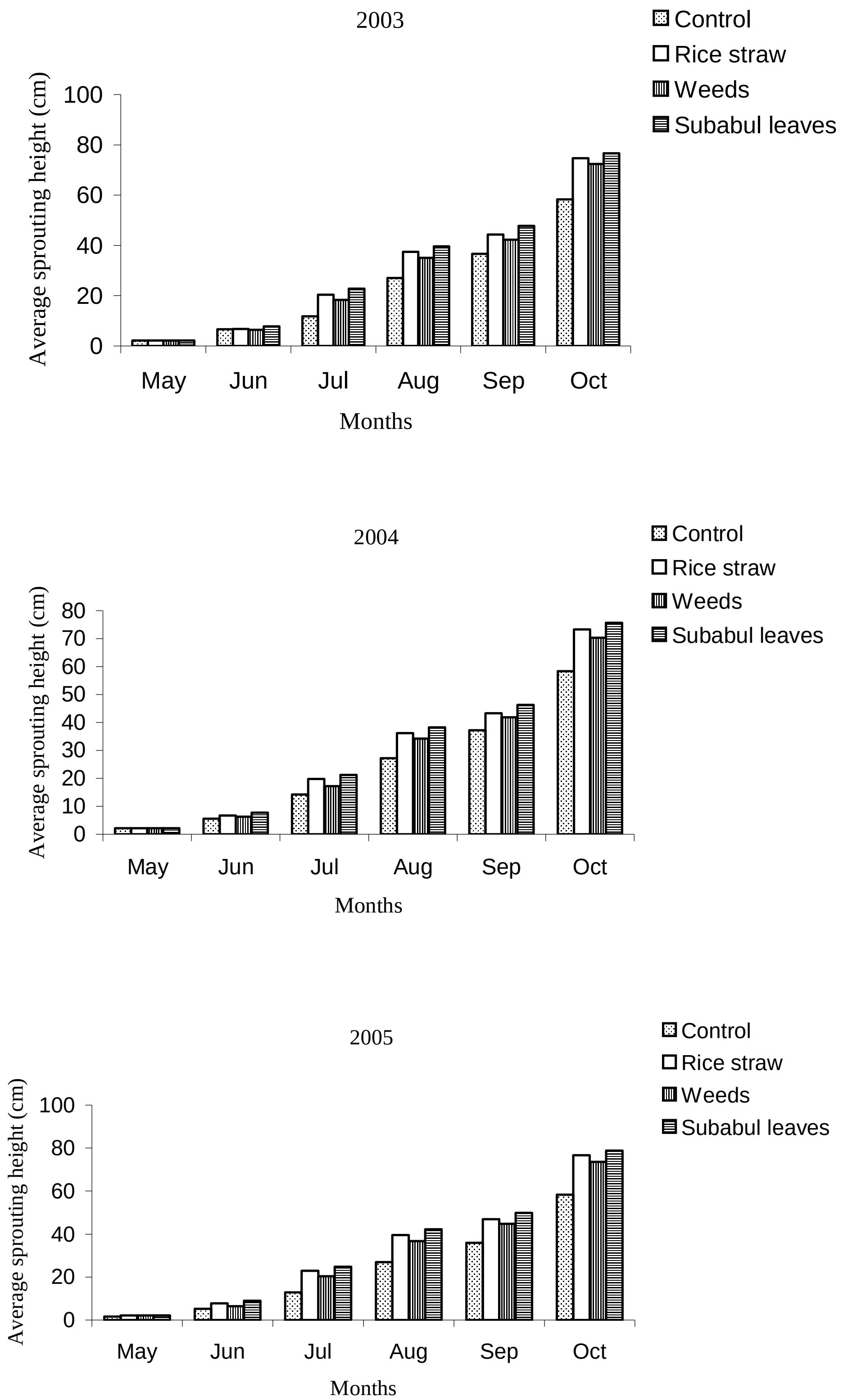
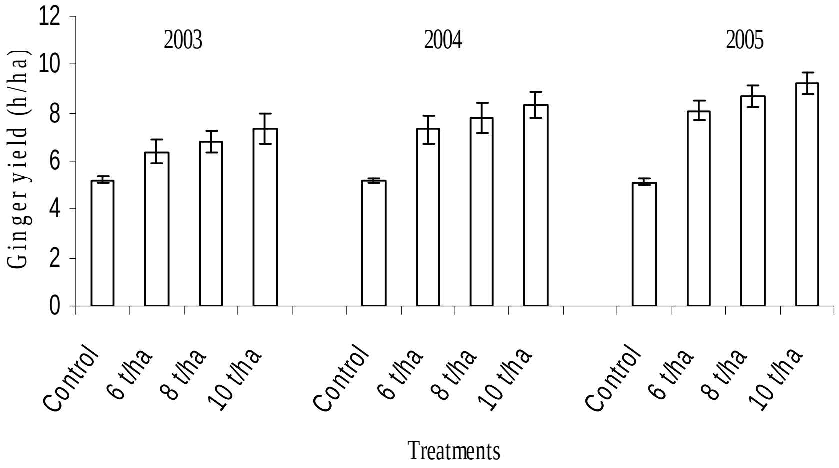


Fig.6.12. Average sprouting height (cm) of turmeric as affected by three mulch types in turmeric field under *Gmelina arborea.*

6.3(5) Productivity of ginger and turmeric as affected by quantity of mulches in *Gmelina arborea* plot:

Mulch quantity affected the productivity of ginger (Fig. 6.13) and turmeric (Figure 6.14) in *Gmelina arborea* inter crop plot during different years. Maximum ginger yield (9.25 t/ha) was obtained with 10 t mulch/ha. Similarly, maximum number of finger (6.85) and maximum finger size (8.29 x 7.99 cm) was obtained with this doze. The ginger yield was in the order of 10 t mulch/ha > 8 t/ha > 6 t/ha. Similar was the case with finger number and finger size. No significant difference in ginger yield, number of finger and finger size were observed in different mulching doses during the first two year, although a gradual increased was obtained with time. During the third year all the mulching treatments significantly ($P \leq 0.05$) increased the yield (Fig. 6.13).

Turmeric yield was directly related to quantity of mulches applied. The higher the dose of the mulch, the greater was the turmeric yields, its number of finger and finger size. The turmeric yield was in the order of 10 t/ha (9.08 t/ha) > 8 t/ha (8.53 t/ha) > 6 t/ha (7.79 t/ha). The corresponding values of number of finger for 10, 8 and 6 t/ha were 6.58, 6.47and 6.33 respectively and the finger sizes for 10, 8 and 6 t/ha were 6.52 x 6.31 cm, 6.35 x 6.20 cm and 6.65 x 6.26 cm respectively (Fig. 6.14). Crops yield; number of fingers and finger size gradually increased with time. However, the variation was not statistically significant during the first two years, although crop yield was significantly ($P \leq 0.05$) increased at the end of study period.



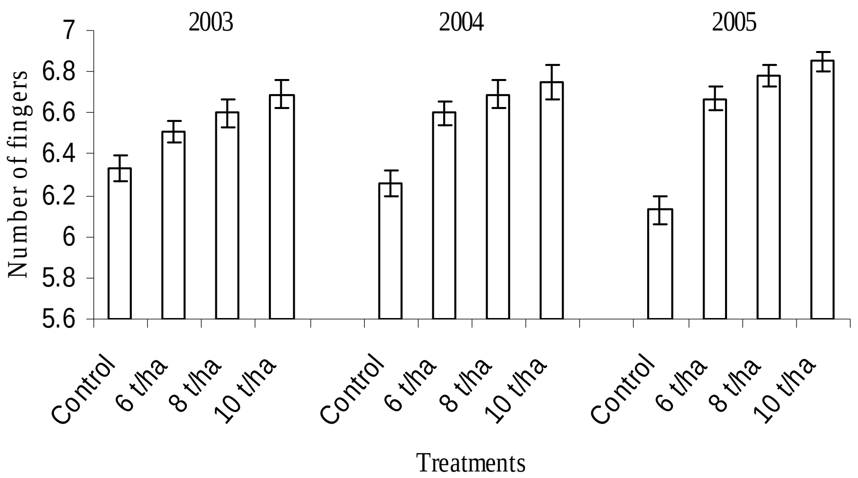
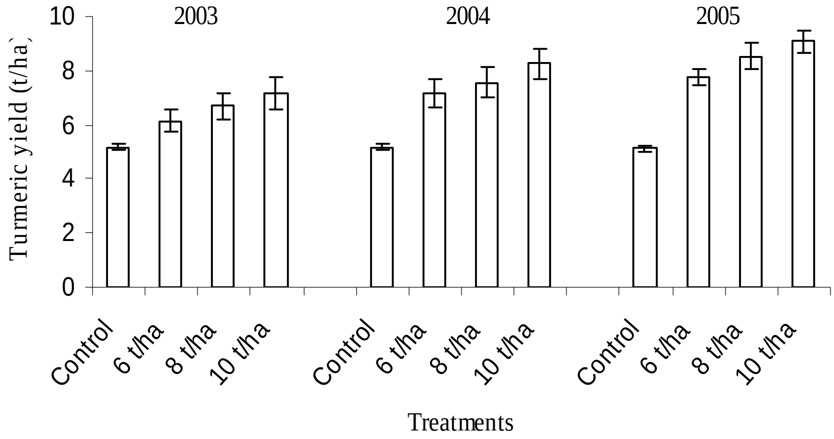


Fig.6.13. Productivity of ginger yield (t/ha) and number of fingers as affected by quantity of mulches in *Gmelina arborea* plot.



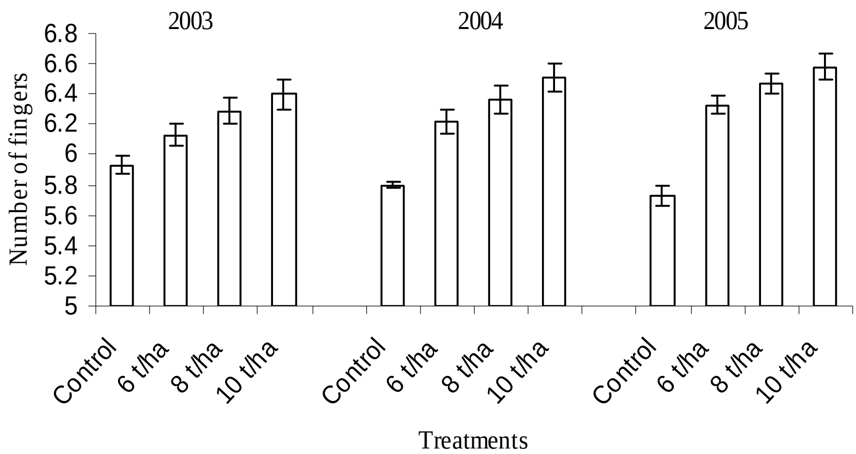


Fig. 6.14. Productivity of turmeric yield (t/ha) and number of fingers as affected by quantity of mulches in *Gmelina arborea* plot.

6.3(6) Number of tillers, sprouting frequency and height of ginger and turmeric as affected by quantity of mulches in *Gmelina arborea* plot:

The number of tillers, sprouting frequency and average sprouting height of ginger (Fig. 6.15 - 6.17) and turmeric (Fig. 6.18 - 6.20) influenced by different mulch quantity during different years revealed that mulching treatments were not effective for the variation in the number of tiller, but for sprouting frequency and average sprout height.

Maximum sprouting number of ginger (2.39) was recorded with 10 t mulch/ha followed by 8 t/ha (2.34) and 6 t/ha (2.31) respectively. Similar trend was observed for sprouting frequency, and the respective values for 10, 8 and 6 t/ha were 85.27, 84.87 and 83.55. The plant height was in the order of 10t/ha > 8 t/ha > 6 t/ha (Fig. 6.17-6.19).

Vegetative growth of turmeric increased with increasing dose of mulch application (Fig. 6.20 - 6.22). Higher sprout number was observed in 10 t/ha (1.49) followed 8 t/ha (1.42) and minimum 6t/ha (1.39). The sprouting frequency percent was in the order of 10 t/ha (89.92) > 8 t/ha (89.27) > 6 t/ha (88.11). The corresponding values of sprouting height were (76.08 cm), (74.53 cm) and (72.53 cm) respectively.

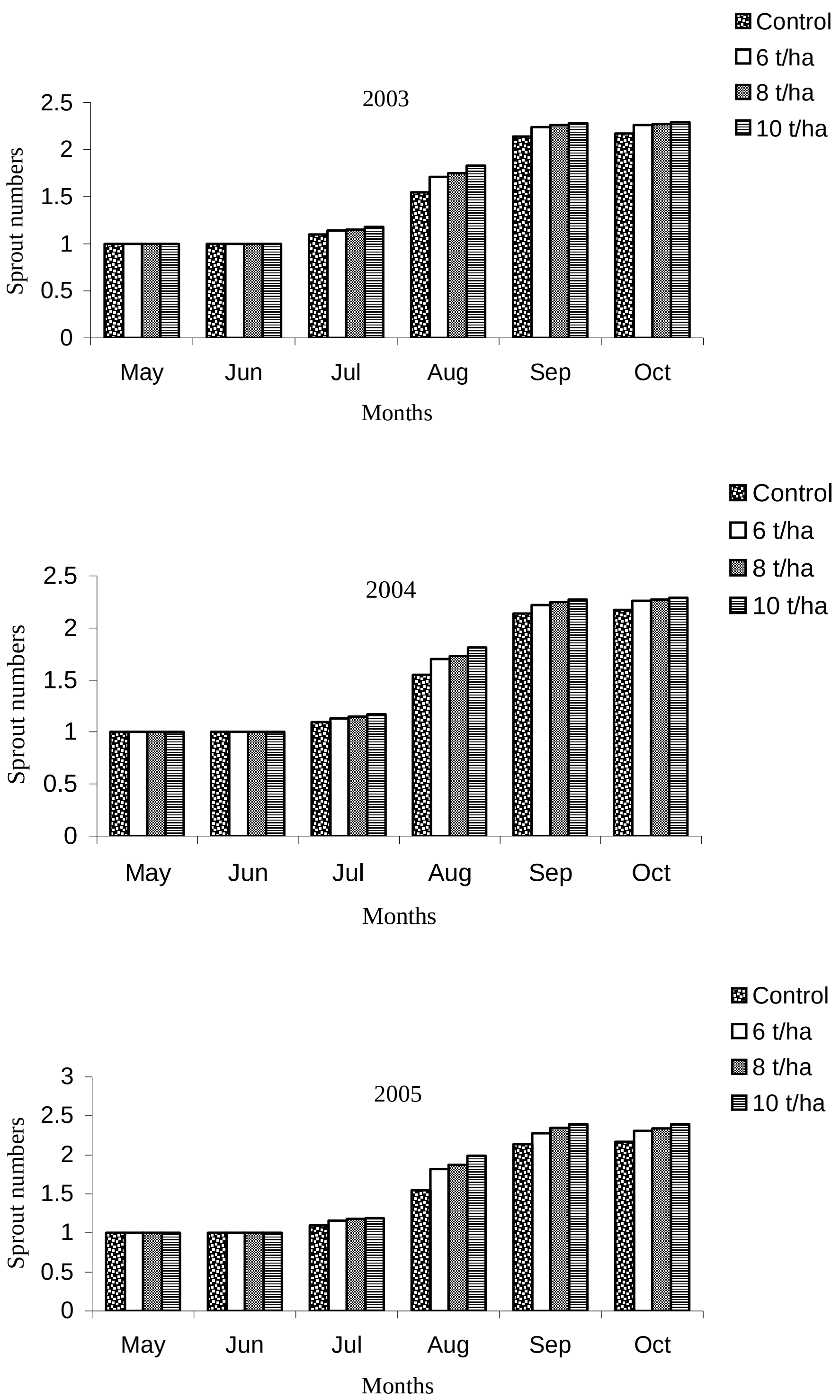


Fig. 6.15. Sprout numbers of ginger as affected by quantity of mulches in ginger field under *Gmelina arborea.*

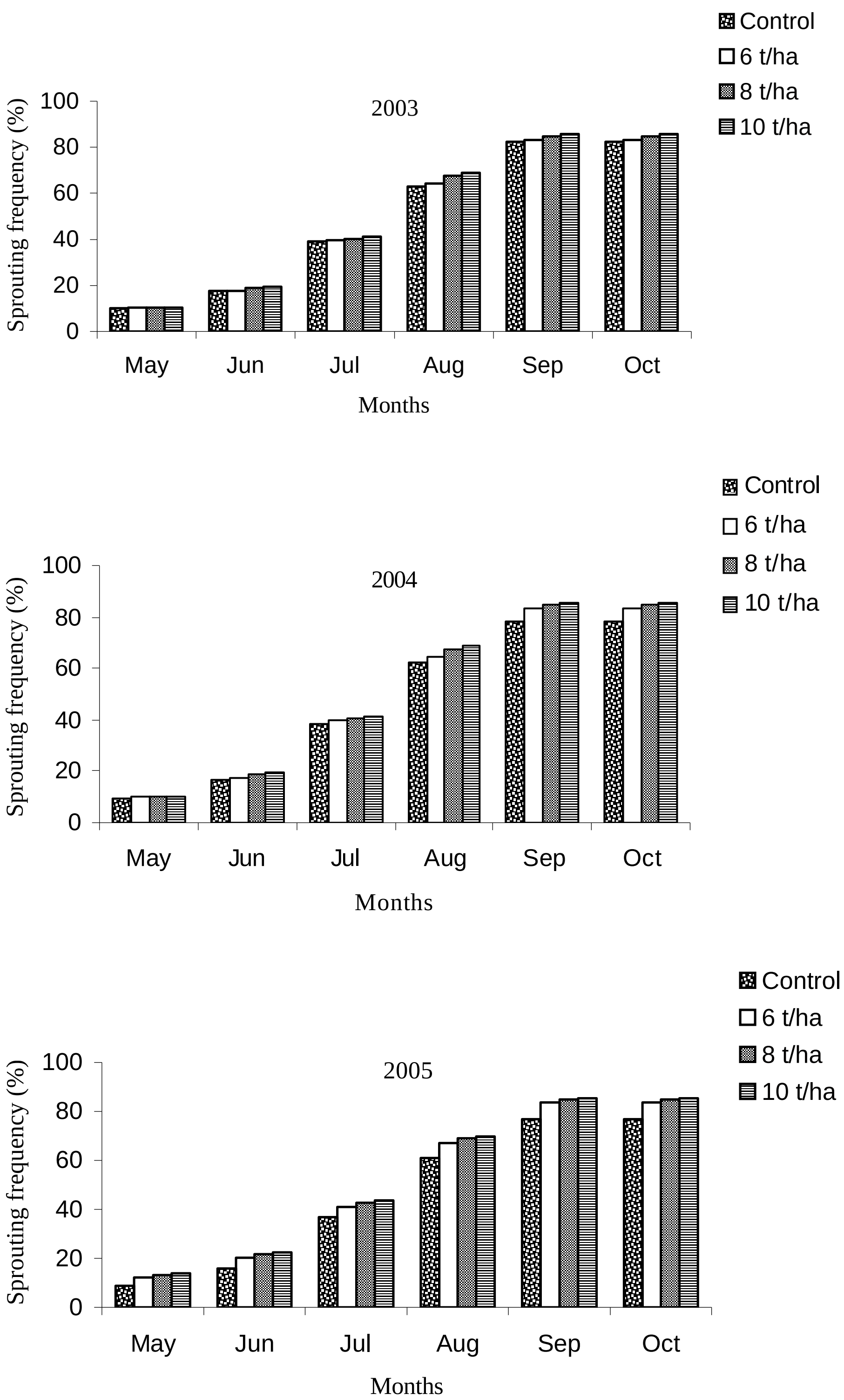


Fig. 6.16. Sprouting frequency (%) of ginger as affected by quantity of mulches in ginger field under *Gmelina arborea.*

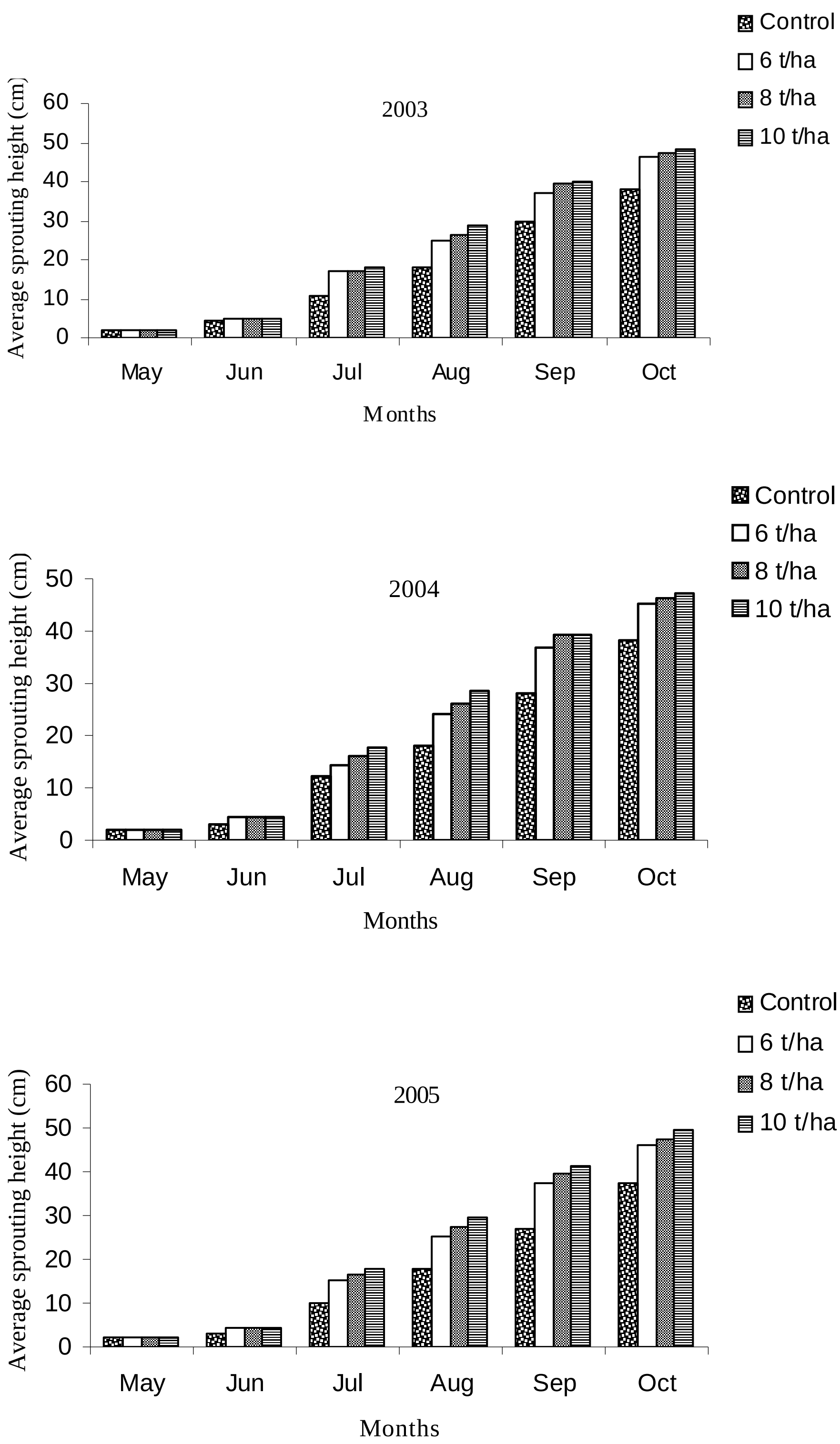


Fig. 6.17. Average sprouting height (cm) of ginger as affected by quantity of mulches in ginger field under *Gmelina arborea.*

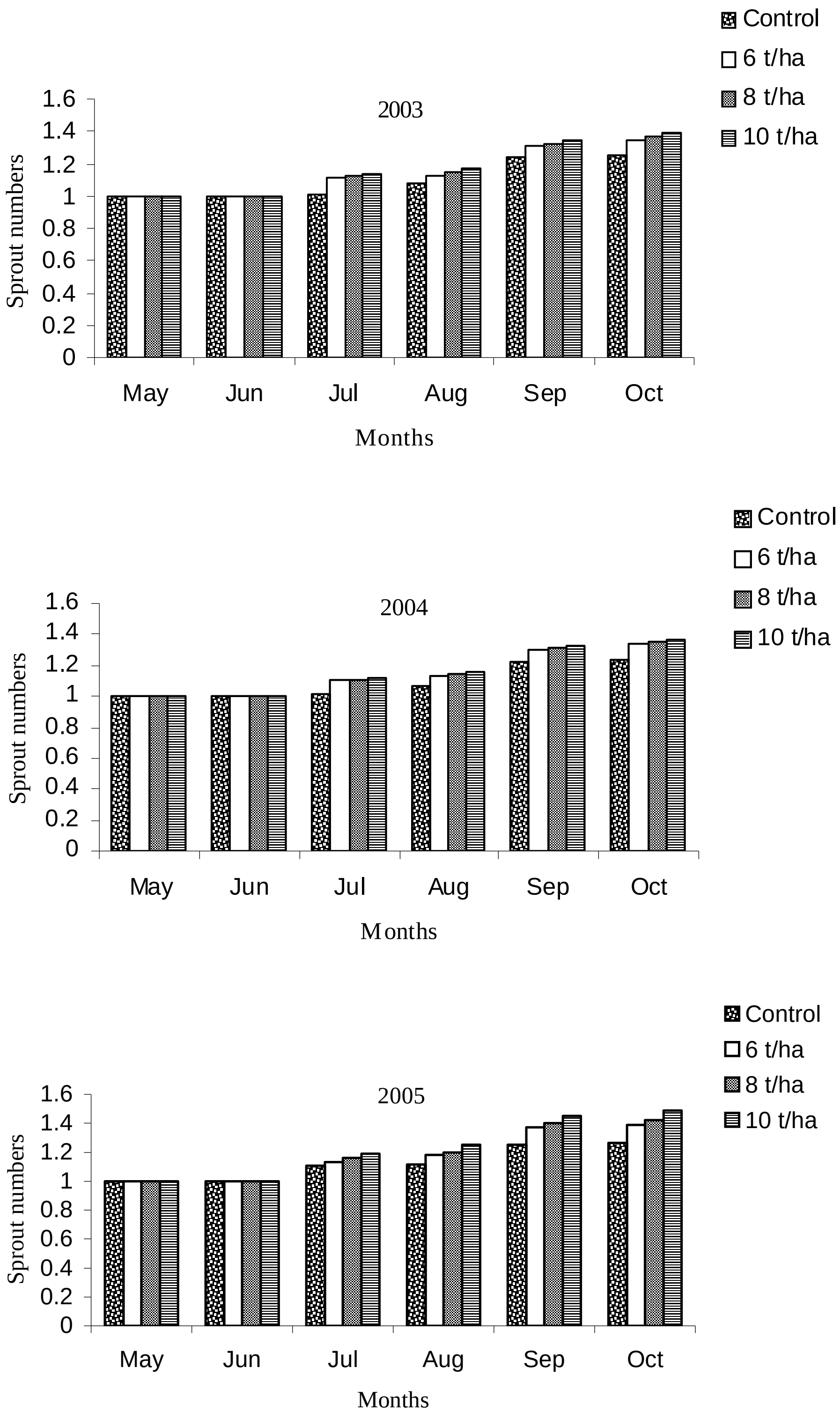


Fig. 6.18. Sprout numbers of turmeric as affected by quantity of mulches in turmeric field under *Gmelina arborea.*

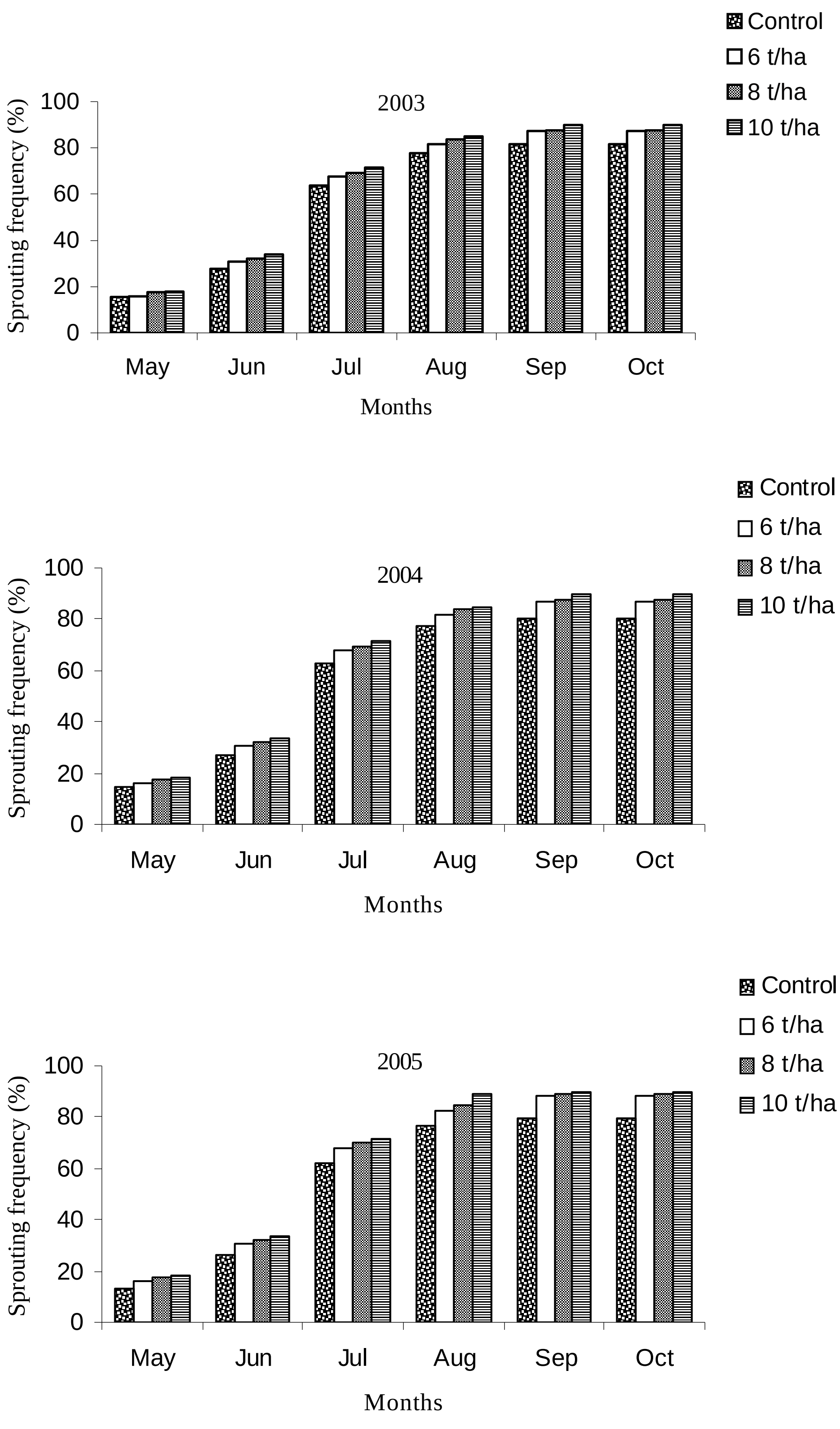


Fig. 6.19. Sprouting frequency (%) of turmeric as affected by quantity of mulches in turmeric field under *Gmelina arborea.*

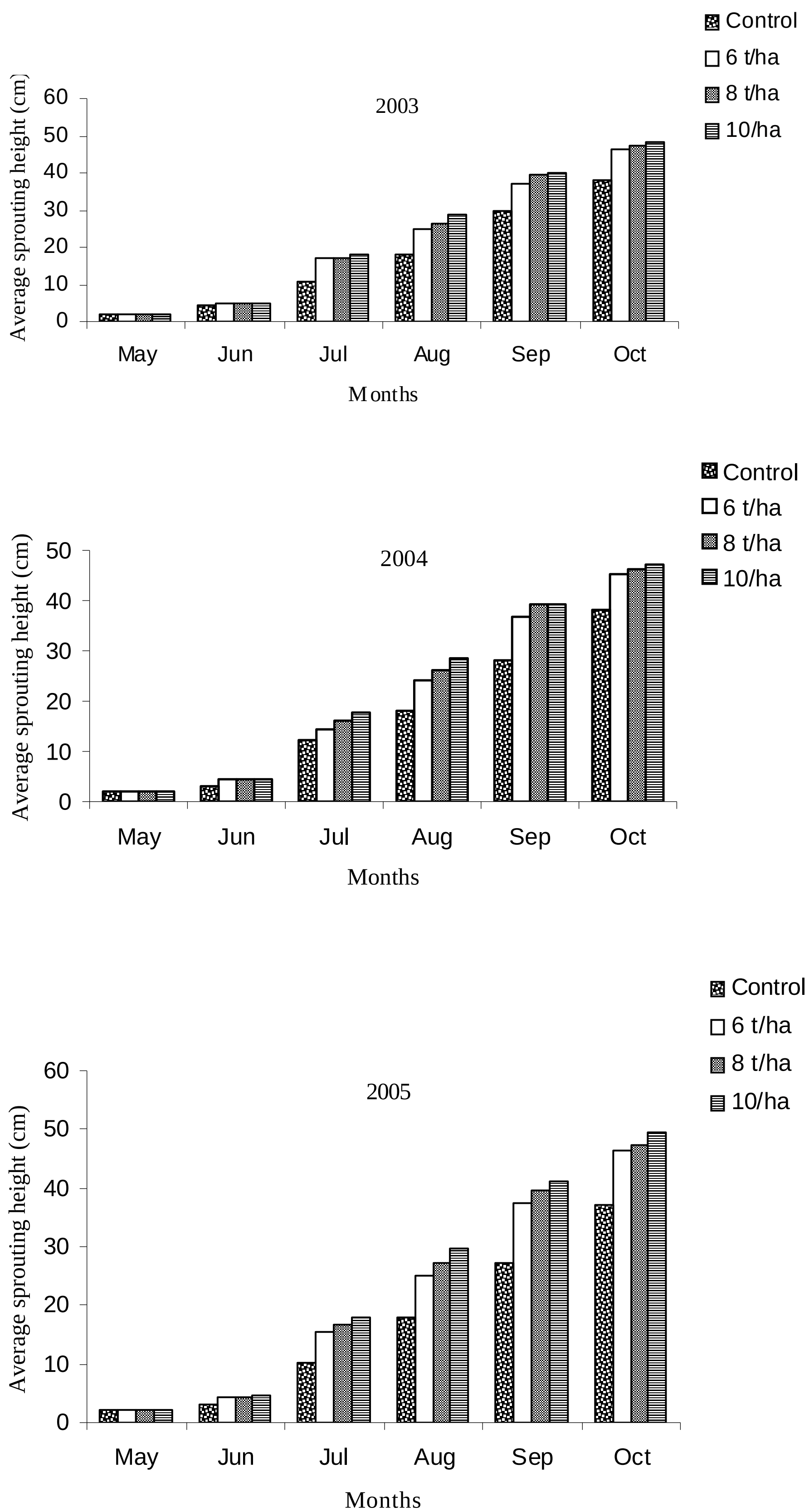


Fig. 6.20. Average sprouting height (cm) of turmeric as affected by quantity of mulches in turmeric field under *Gmelina arborea* .

6.4. Discussion

Both the tuber crops (i.e. ginger and turmeric) intercropped with *Alnus nepalensis* showed maximum rhizome yield, maximum number of finger and higher finger size, followed by *Melia azadirachta* inter-cropped, *Gmelina arborea* inter-cropped and minimum in control treatment. In general, higher yield were obtained under tree-crop intercropping than sole cropping (Tables 6.1 and 6.2). Higher yields and better growth performance along tree crop could be due to improvement of site with the addition of organic residues through leaf litter or root mass, less leaf temperature which all contributed to better photosynthetic activity and also no shading effect on intercrop resulting in higher PAR values. The results confirm the findings of Pathak (1994) and Tomar and Sharan (1987), who reported higher seed yield of arable crops under agri-horticulture system. On the contrary, Bhatt *et al.* (2005) observed that the multipurpose trees adversely influenced the crop yield of soybean, pineapple, turmeric and ginger. According to Prinsely (1992) and Young (1989) increased productivity in tuberous crops could be due to the ameliorating effect of shade in hot dry environment and increased soil productivity. Dauley *et al.* (1970) observed that intercropping of legumes with perennial grasses gives higher farage yield compared with grass alone. Rao and Willey (1990) was also of the same view that intercropping is more stable and dependable than the sole crops. Dhyani and Chauhan (1989) obtained higher yield of ginger, taro and turmeric under natural stand of pine (*Pinus insularis)* than open field in East Khasi hills (Meghalaya). Bisht *et al.* (2000) reported that association of *Quercus leucotrichophora* with turmeric and ginger was found to be the most suitable and renumerative silvi-horti combination.

Our data revealed that in the third year of study, in both the intercrops (i.e. ginger and turmeric) the yield and number of fingers were significantly ($P \leq 0.05$) increased compared to control plots (Tables 6.1 and 6.2), however, during the first two years, no significant ($P \leq 0.05$) variation was observed between the treatments. Although *Alnus nepalensis* is a nitrogen fixing species, it probably failed to fix a sizeable amount of nitrogen required to improve productivity. Besides, proper decomposition of green biomass and plant residues during this period probably did not take place (Wilson and Tilman, 1993; Inchausti, 1995). Nevertheless, the second year values on all the parameters were increased than that of first year (Tables 6.1 and 6.2). During the first year, the yield of tuber crops was very low compared to the other two years.

As expected, the various growth performance such as sprouting number, sprouting frequency per cent and average sprout height of ginger and turmeric were maximum under *Alnus nepalensis* intercropped plot followed by *Melia azadirachta* intercropped plot, *Gmelina arborea* intercropped plot and minimum in control treatment (Fig. 6.1 - 6.6). In general, the treated plots increased plant height, higher survival rate and better frequency percentage, higher yield of ginger and turmeric than corresponding control ones. This was true for all the years. The roots of tree-crop components enhancing better growth of the field crops could have easily trapped the fertile topsoil available.

Among the different mulches, the application of subabul leaf mulch, in general, showed maximum ginger and turmeric yield, higher number of finger and better finger size, followed by rice straw, weeds and minimum in control (Tables

6.3 and 6.4). This was true for all the years. Subabul leaves mulch increased the growth performance of ginger and turmeric over rice straw and weeds mulches. Quick decomposition of subabul leaves might have released some nutrients to the soil with mulch application causing better growth performance of the crop in the system.

Analysis of variance showed the rhizome yield of ginger and turmeric were significantly ($P \leq 0.05$) increased by the application of different mulches. The finger size also gradually increased with time. Similar results of increased yield due to mulches were reported by Gill *et al.* (1992); Ghosh (1985); Nath *et al.* (1993); Jayantkumar *et al.* (1999); Shukla *et al*. (2000). Various workers (Marumota *et al.,* 1991; Ducan *et al.,* 1992; Abdul-Baki and Teasdale, 1993) also mentioned that mulches influence plant growth and yield of crops. The increase in yield due to spread of mulch in the whole plot could be as high as 60.5 per cent compared to un-mulch control (Singh *et al.,* 2002). Mulches influence the soil properties, plant growth and yield of crops (Marumota *et al.,* 1991; Duncan *et al.,* 1992; Abdul-Baki and Teasadale, 1993). The beneficial effects of mulch in reducing soil loss and increasing crop yields were also reported by Hadda and Sur (1998); as well as by Khera and Singh (1995; 1998).

The various investigations on mulching in fruit crops like apple (Jayantkumar *et al.,* 1999); aonla (Shukla *et al.,* 2000) and sapota (Reddy *et al.,* 1993) improve the soil moisture status, growth and yield besides reducing the weed growth were documented. Aggarwal *et al.* (2003) also reported that mulches were useful in altering the hydrothermal regime of soil and provide favourable soil environment for rhizome development. The work done by Bhan

(1976); Singh (1989) and Uttam *et al.* (1994) demonstrate the utility of straw mulch in enhancing the productivity of rainfed mustard. Beneficial effects of jalshakti (Singh, 1989) in increasing the yield of mustard have also been reported. According to Sonia Aggarwal *et al.* (2003) mulches markedly influenced the growth and yield of ginger. Prasad *et al.* (1996) also observed that mulching treatments significantly increased the yield of opium latex, seed and husk.

The lowest yield in the present study was observed in control (no mulching), which may be due to availability of lower soil moisture regimes in the control. Besides, abundant weed growth might have caused reduction in the availability of the resources to the crops, thereby reducing the yield too. The findings of Montagini *et al.* (1993) also revealed that un-mulched control plots showed significantly inferior growth. The average dry matter yield in mulched plot was significantly higher than the un-mulched plots (Weeratana and Asghur, 1990; Gajero *et al.,* 1998).

The crop height, number of leaves and sprouting frequency percent gradually increased with time; however, the variations were not statistically significant ($P \leq 0.05$). The increased in the various growth performances in the third year, obviously was due to reduction in moisture loss. The beneficial effect of mulches on plant height was also observed by Singh *et al.* (1989).

The ginger and turmeric yield, number of finger and finger size increased with the increasing rates of application of mulch materials. Maximum yield, number of finger and finger size were obtained with 10 t mulch/ha, followed by 8 t mulch/ha, 6 t mulch/ha and minimum in control (Fig. 6.13 and 6.14). This was due to more number and size of fingers per mother rhizome with mulch application of

10 t mulch/ha of subabul compared with other treatments. These results indicated that mulches have beneficial effects on crop productivity. Similar findings are also reported by Mathews *et al.* (1992); Moitra *et al.* (1994); Dayanand (2000); Singh *et al.* (2002); Mohan *et al.* (2004); and Sonia Aggarwal *et al.* (2003).

According to Moitra *et al.* (1994), increase in moisture content in the root zone profile due to mulching cause better crop growth and yield. Similar results of increased yield due to mulches were reported in different fruits yield due to increased soil moisture status (Srinivas *et al.,* 1990; Chattopadhyay and Patra, 1992; Mage, 1982; Chovatia *et al.,* 1992; and Syed Ismail, 1993). Besides, different types of mulches have been in trial by various workers for improving crop productivity. For example, banana leaf mulch for increasing ginger yield (Mohanty, 1977) green mulches for increasing yield of sweet potato (Ossom *et al.,* 2003), subabul leaf mulch on yield of wheat (Sharma *et al.,* 2001), stover mulch increased the crop growth and yield (Moitra *et al.,* 1994), use of gliricidia, rice straw and grasses on turmeric (Kumar *et al.,* 2003) use of organic manure increase growth parameters of ginger (Maiti *et al.,* 1985). During the third year study, analysis of variance in the present study showed significant ($P \leq 0.05$) rhizome yield caused by higher mulch doses. The finger number and finger size got improved gradually with time till the harvest.

Our data revealed that sprout number, sprouting frequency and average sprouting height of ginger and turmeric were in the order of 10 t mulch/ha > 8 t mulch > 6 t mulch/ha (Fig. 6.15 - 6.20). The present findings are in conformity with the observations of Mohanty *et al*. (1990); Sharma *et al.* (2001); and Dinesh Kumar *et al.* (2003).

Chapter-VII

General Discussion

Growth performance of any tree species is influenced not only by its ability to utilize the available natural resources optimally but also to its compatibility and interaction with the neighbouring plant population. The growth performance in terms of plant height (Tables 4.1, 4.3 and 4.5) and collar thickness (Tables 4.7, 4.9 and 4.11) of all the three tree species was good under inter-crop plots compared to control (sole tree) during 3 of years study. In the first two years, however, these variations between the species mixture were minimal and became clearly distinct during the third year. This may be due to the overall beneficial effect of tree-crop interaction. The tree-crop interaction must have helped favourably in binding of soil particles, maintaining better soil moisture content and contributing more soil organic matter content through shedding of their leaves. Similar relatively higher growth rate under intercropping could have been due to the possibility beneficial compatibility, interaction and greater biological efficiency of crops grown in association. Intercropping of trees with different crops in the present study has complemented each other and made use of resources better rather than when grown separately. Similar findings were obtained elsewhere by Screevani (2001) from sunflower in association with *Hardwickia binata* Roxb. trees. The advantages of intercropping have also been reported by many workers (Brewbaker and Hu, 1981; Rana and Saran, 1988; Prasad *et al.,* 1997; Verma *et al.,* 1997; Rana *et al.,* 1999; Maitra *et al.,* 2000). The beneficial effects on tree growth intercropping have also been reported by various workers (Brinson *et al.,* 1980; Yamoah *et al.,* 1986; Atta-Krah, 1990; Singh *et al.,* 1997). Increased tree growth has also been observed in plantation mixtures of hardwood seedlings and herbaceous legumes (Haines *et al.,* 1978; Van Sambeek *et al.,* 1986). Rao and Willey (1980) observed that intercropping is more stable and dependable than sole crops. Bulson *et al.* (1997) reported that intercropping showed an advantage over sole cropping when the component densities were sufficiently higher. Tree-crop interaction in agroforestry systems is generally aimed at providing optimum land use where which trees or woody perennials are deliberately planted on the same land management unit in association with annual crops, with significant ecological interactions between the woody and non-woody components. When the tree legumes are interplant with cereals like maize, the components can be effective in soil nutrient cycling and enhancement. The numerous benefits of tree-annual crop association reported by various workers are (a) retrieval of nutrients from bellowed the rooting zone of annual crops, (b) reduction of nutrient losses from leaching, runoff and erosion, (c) legumes trees increase the supply of nutrients within the rooting zone of annual crops through N input by biological N_2 fixation.

Normally, *Alnus nepalensis* tree species are fast growing, nitrogen fixing species suitable for planting on open land. However, in the present trial experiment *Alnus nepalensis* showed much slower growth compared to the other species. This was mainly because the prevailing climate of the study area did not favour the growth of *Alnus nepalensis, which* required moist sites. The present investigation observed that *Melia azadirachta* performed better growth performance compared to the other two species and was probably due to high organic matter content and also higher annual litter return by neem to the agroforestry systems (Table 4.16).

During the first two years of study, no significant ($P \leq 0.05$) increase in plant height compared to control plot was obtained. Obviously, this may be due to no organic matter content input to the soil. However, during the 3rd year significant ($P \leq 0.05$) increase in plant height (Tables 4.1, 4.3 and 4.5) and higher biomass production could have been favoured by tree-crop intercropping through decaying of their roots and rendering leaf litter to the soil, which increased the fertility of the soil condition. This is the reason how the soil during 2nd and 3rd years got more organic matter content (Tables 4.13 – 4.15). The increase organic matter under tree canopy is due to ameliorating effect of shade in hot dry environment and increased soil productivity (Young, 1989; Prinsley, 1992). The higher total biomass production under *Melia azadirachta* may be due to its heavy forking and branching ability.

Ginger and turmeric are two of the most popular tropical tuber crops of Mizoram. Their diverse use in food, beverages, confectionary and medicines by the tribes couple with the prevailing favourable rainfall and temperature in the state make them the most widely grown species of tropical tubers, in comparison to other species like yam (*Dioscorea*) and tapioca (*Manihot esculentus*). However, their growth, development and yields are reduced significantly by soil moisture stress, and this is attributed to changes in root systems of these species due to variations in the available moisture for development.

Among species treatments, there were no significant differences in any soil moisture comparisons of either species mixture combination especially during the first two years. However, soil moisture content was significantly ($P \leq 0.05$) increased in the third year (Table 5.1). Maximum soil moisture conservation was under *Melia azadirachta* inter crop plot, followed by *Alnus nepalensis*, *Gmelina arborea* and minimum in control. In general, soil moisture percent conservation was higher under intercropping compared to control treatment. This may be due to incorporation of tree-crop intercropping residues rendering more leaf biomass, shoot biomass, higher vertical and horizontal root spreading (Table 4.16), Improved microclimate owing to tree growth, poor weeding and less evaporation under tree-crop intercrop also enhance more soil moisture conservation in tree-crop interaction. Incorporation of crop residues in the soil has been found to significantly increase the percentage of water stable aggregates, and enhance water retention and available water capacity (Bhagat *et al.,* 1994). Similar was the result of Singh *et al.* (1988) and Budelman (1989) who found an improved hedgerow intercropping of maize with subabul.

Soil moisture content of all treatments was similar at the beginning of the study and varied with time in response to mulch. At the early growing stage, soil moisture content of the plots with mulch was significantly greater than control and the order from high to low was rice straw, subabul leaves, weeds and control. Different mulch materials had different effect on soil condition. Rice straw mulch and *Leucaena* leaves mulch seems more favourable for conserving soil moisture and rice straw is the best treatment for increasing soil moisture; weeds mulch decreases the soil surface salinity level more in comparison to the other two material mulches. However, the weeds mulch decreases crop yield due to low temperature. Weeds mulch is not very fit for crops production in this area. Weeds mulch has similar effect with rice mulch on promoting crops development and growth. As a new mulch material, the weeds mulch has some advantage such as repeated use, without pollution and low cost, compared to others mulch, so we recommend that it can be used as a complementary material.

Soil moisture levels among mulch treatments were variable across seasons and species mixture. Soil moisture levels in the top 15 cm of the soil surface were significantly higher under the rice straw mulch compared with other mulches (Fig. 5.5 and 5.6). Slow rate of decomposition may be the reason for higher moisture retention with rice straw mulch. The present findings are in conformity with the observation recorded by (Mohanty *et al.,* 1990; Dinesh Kumar *et al.,* 2003; Sahoo *et al.,* 2005). Increased soil moisture content with mulch application might be due to the increased infiltration percolation capacity of soil and owing to resistance of runoff water and mulching treatments reduced the rate of evaporation of soil moisture from soil surface, thus retaining the soil moisture in the soil for a longer time. Similar results of increased soil moisture by different mulches were reported in guava (*Psidium quajava)* by Borathakur and Bhattacharya (1988); in grapes by Srinavas *et al.*(1990); and in Assam lemon *(Citrus limon)* by Nath and Sharma (1993); apple Jayantkumar *et al.* (1999); aonla (Shukla *et al.,* 2000) and Sapota (Reddy *et al.,* 1993). Many workers like (Sharma and Acharya, 2000; Edwards *et al.,* 2000; Sharma *et al.,* 2001; Ossom *et al.,* 2003) also observed that mulch soils have lower temperature at the soil surface than the un-mulched soil which is another reason for better moisture retention of the crop in hilly terrain The control treatment recorded the least soil moisture in consonance with the findings of Mohan *et al*. (2004). Similar results were reported in apple (*Malpighia pumila* Hill) by Mage (1982); mango (*Mangifera indica* L.) and avocado (*Persea americana* Mill.) by Gregorious and Rajkumar (1984) and in grapes (*Vitis vinifera* L.) by Srinivas *et al.* (1990). The environmental factors that are affected by mulch include soil temperature, soil moisture, soil salinity level, nutrients and soil texture. The initial response of application of mulch could be the change of soil temperature, which obviously varied with the type and quantity of mulch material and also with the application time and site. Our results indicated that soil moisture in rice straw and subabul leave mulch was higher than those in bare soil during most growing stages, which is consistent with results of numerous studies that showed use of mulch increases soil moisture (Unger, 1978; Li *et al.,* 2000). Excessive amount of straw may lead to low soil temperature (Edwards *et al.,* 2000; Mohan *et al.,* 2004). However, Khera and Singh (1995) argued that the soil temperature with straw mulch decreased during the day and increased at night. Edwards *et al.* (2000) and Mohan *et al.* (2004) reported that soil temperature with straw mulch increased in winter and decreased in the spring.

The soil moisture gradually increased from May to July with the onset of rainfall and reached its peak in the months of August to September and remained steady up to September and there was gradual declined (Fig. 5.7, 5.8, 5.9 and 5.10). This was true in all mulched plots. This could be due to the decomposition of the vegetative mulch materials under high moisture condition in the soil. Soil moisture retention was higher during winter months than summer months in all the three years of study. Similar result was obtained by Jiang Ping *et al.* (1997) who advocated mulching reduced soil temperature in summer and increased in winter and increased the tree growth by 17-20% and reduced fruit cracking 12.6 –16.3%. Among the vegetative mulches, the weeds mulch had poor soil conservation ability in our study. Nevertheless the weeds had the ability to hold soil water and improve crop productivity.

The amount of soil moisture increased with increasing rates of application of mulch materials (Fig. 5.5 and 5.6). Higher mulch doses (10 t/ha) retained more soil moisture than medium (8 t/ha) and low (6 t/ha) mulch doses and minimum in the control. The increase in soil moisture content with increase in mulch quantity might be due to more reduction in soil surface evaporation and weed intensity and may be ascribed to the thermal insulating effect and the slower evaporation caused by cooling (Ross *et al.,* 1985). In control treatment, the continuity of conducting pores might have permitted more water movement to the surface aggravating the losses through evaporation (Bhusan *et al.,* 1973).

Comparing between species mixture, average soil moisture levels of all treatment were always higher than the control. The difference may be attributed to root architecture and water requirements of each species. Though higher soil moisture levels were retained under all mulches compared with non-mulched (control) there was a trend toward greater soil moisture conservation in rice straw than others though quality wise differences were not statistically significant.

The soil temperature and diurnal fluctuation patterns underneath the mulch and bare soils must have caused the differential moisture retention. In the present study we did not record the soil temperature periodically and therefore cannot relate the soil temperature with the soil moisture conservation. The warmer daily average and daily maximum temperatures during summer seasons could also have differentially caused moisture retention in different mulches compared to the winter seasons. However, since we do not have recorded the data no relation could be established between soil temperatures with soil moisture conservation between treatments and between seasons or crops.

The crop productivity, number of finger and finger size of ginger (Table 6.1) and turmeric (Table 6.2) was higher under *Alnus nepalensis* followed by *Melia azadirachta, Gmelina arborea* and minimum in control. Higher crop productivity under *Alnus nepalensis* obviously may be due to the ability of this tree to release more amount of nitrogen to the soil, helping the crops to perform better. Besides, improved crop performance could be due to reduced N-leaching under *Alnus* as opposed to other species and single crop system (Singh and Prasad, 1981; Yadav, 1981).

Higher crop yield was always recorded under tree-crop intercropping compared with sole cropping in all the three years. Higher yields and better growth performance under tree-crop intercropping could be due to improvement of site with addition of organic residues through leaf litter or root biomass (Table 4.16). The results confirm the findings of Pathak (1994); Tomar and Sharan (1987) who reported higher seed yield of arable crops under agrihorticulture system. Bhatt *et al.* (2005) observed that the multipurpose trees adversely influenced the crop yield of soybean, pineapple, turmeric and ginger. Prinsley (1992) and Young (1989) mentioned that the increased in crop productivity in mixed cropping is due to the ameliorating effect of shade in hot dry environment and increased soil productivity. Rao and Willey (1990) also observed that intercropping is more stable and dependable than sole crops. Dhyani and Chauhan (1989) obtained higher yield of ginger, taro and turmeric under natural stand of pine (*Pinus insularis)* than open field in east Khasi hills (Meghalaya). Bisht *et al.* (2000) reported that association of *Quercus leucotrichophora* with turmeric and ginger was found to be the most suitable and remunerative silvi-horti combination. Better growth performance under intercropping may also be due to the fact that the fertile topsoil available was trapped by the roots of tree-crop components better than the sole cropping thereby enhancing the growth performance of the field crops. Muller (1887) and Ebermayer (1876) stated that litter fall has its importance in regulating the nutrient cycling and soil development.

The rhizome yield of ginger (Tables 6.3) and turmeric (Tables 6.4) were significantly ($P \leq 0.05$) increased by the application of different mulches. This may be due to the beneficial effects of the mulches. The mulches when spread on the ground must have suppressed the weed growth around the base of the crop while retaining soil moisture and could have added some nutrients through decomposition resulting in better growth yield under mulches. Yields of tuber crops thus are increased by early tuber initiation in the present study thereby increasing the yield components. The mean increases in tuber numbers of ginger and turmeric due to mulching were 34% and 27% respectively, highlighting the greater impact in ginger due to mulching. The impact of the legume (*Leucaena*) mulch was also greater in ginger (17%) than in turmeric (13%). Mulches nevertheless increased the strategies not only upon environmentally suitable crops like ginger and turmeric, but also upon available resources, which can be made used at the farm. Mulches of crop residues, minimum tillage and leguminous covers crops are thus promising technologies for improving nutrient and water use efficiency and sustaining high yields of maize, ginger and turmeric in the sub-humid and humid transition zones. The concentration of C and N in the soil surface (0 -15 cm depth) increased with increasing C input by incorporating crop residue in to the soil as mulch. According to the findings of Mohanty *et al.* (2000) and Dinesh Kumar *et al.* (2001) growth of turmeric was highest under mulch treatments, while un-mulched control plots showed significantly inferior growth. Our results are also inconformity with the above workers. The average dry matter yield in mulched plot is therefore significantly higher than the un-mulched plots (Weeratana and Asghur, 1990; Gajera *et al.,* 1998). Mulches increased the number of tiller, tiller frequency and crop growth rates, and reduced the time for tuber initiation significantly in both ginger and turmeric irrespective of quality. This implied the benefits of using some type of plant materials as mulch for promoting the vegetative growth and tuber initiation of these tuber crops. Mulching enhanced mean time for tuber initiation significantly in both species. The legume mulch (subabul) enhanced tuber initiation to a greater extent in both species, while the weed mulch reduced the time for tuber initiation than rice straw. This impact could be related to growth rates, as greater photosynthetic efficiency and crop growth leads to earlier tuber initiation in tuber crops. The better growth of the tillers could again be related to the nitrogen supply of the rapidly decaying legume leaves in contrast to the slower decomposition of grass and straw although the former retained lower moisture than straw mulch.

Soil and water erosion continues to be a threat to the agricultural productivity in hilly terrains. Tree-crops temporal and spatial arrangements play a vital role in filling open gaps in the system and in providing protective mulches in no-till and conservation tillage systems. Mulches can affect crop yields by conserving soil moisture, which allows crops to grow better in rainfed condition.

Mulching is considered essential in rainfed smallholder farming due to the many benefits they impact to the rhizosphere. However, most farmers do not adopt this practice. In tuber crops, mulches could play a significant role, as they also lower soil temperatures in addition to conserving soil moisture retention. Thus farmers need to be advised on the different types of mulches for different tuber crops, especially if they do apply some fertilizers to the crop. The mulch should be capable of retaining soil moisture, which is a scarce resource in rainfed farming and also lower soil temperatures for longer period of time to provide a more conducive rhizosphere for tuber development in ginger and turmeric, which last for over 6-7 months.

Maximum yield of yield of ginger (Tables 6.3) and turmeric (Tables 6.4) were obtained under treatment with *Leucaena* leaves mulch followed by rice straw mulch, minimum in weeds mulch. The higher grain yield in *Leucaena* leaves mulch and rice straw mulch may be caused by promoting developmental stage, increasing dry matter accumulation in the early stage and optimizing dry matter distribution in the reproduction in the late stage. In the early stage, the plant height, and leaf area and dry matter accumulation was definitely higher in *Leucaena* leaves mulch and rice straw mulch than in weeds mulch and control. But in the late season, the differences of dry matter among the three mulch treatments were not significant and the leaf area index and leaf chlorophyll content of *Leucaena* leaves and rice straw lower in comparison to straw mulch and control. The reason for reduced yield in weeds mulch treatment was likely to be due to low N fertility that occurred when the soil was covered with mulch residue.

The finger size, its frequency and number in *Leucaena* leaves and rice straw mulch treatments were significantly higher than those in control and weed mulch treatments especially in the 2nd and 3rd years. The basic seedling was similar in all the treatment before tiller initiation. However, the tillers varied due to different mulch materials and the *Leucaena* leaves mulch was the most favourable for the ginger and turmeric tillers development, and the next was rice straw mulch compared to the control, which was similar to weed mulch. Similar findings are also reported by (Gill *et al.,* 1992; Mathews *et al.,* 1992; Nath *et al.,* 1993; Reddy *et al.,* 1993; Moitra *et al.,* 1994; Ghosh, 1985; Jayantkumar *et al.,* 1999; Shukla *et al*., 2000; Dayanand, 2000; Singh *et al.,* 2002; Mohan *et al.,* 2004). According to Moitra *et al.* (1994), increase in moisture content in the root zone profile due to mulching cause better crop growth and yield. The increase in crop yield due to spread of mulch in the whole plot could be as high as 60.5 per cent compared to un-mulch control (Singh *et al.,* 2002). The beneficial effects of mulch in reducing soil loss and increase crop yield were also reported by (Hadda and Sur, 1989; Marumota *et al.,* 1991; Ducan *et al.,* 1992; Abdul-Baki and Teasdale, 1993; Khera and Singh, 1995; 1998). Similar findings were also reported by Gill *et al.* (1992) in a field experiment in which maize yield increased significantly with crop residue mulch application. Sonia Aggarwal *et al.* (2003) also observed that mulches markedly influenced the growth and yield of ginger. The mulches in agroforestry systems offer the possibility for multiple benefits of enhancing soil quality, nutrient cycling, as well as improving soil and water conservation. The selection and management of specific mulch therefore involve a broad knowledge of both beneficial as well as detrimental effects, and must be tailored to specific cropping systems.

The study clearly presented the benefits of mulching for tuber crops under rainfed field conditions in Mizoram. The legume mulch (subabul) promoted vegetative growth due to faster decomposition and release of nutrients to the crop. The study clearly showed the benefits of mulches such as rice straw having a slower decomposition rate than legume in increasing yields to a greater extent in ginger and turmeric. The lowest yield in the present investigation in control (no-mulching) may be due to lower soil moisture regimes, more weeds and higher evaporation from soil surface. The findings of Montagini *et al.* (1993) also revealed that un-mulch control plots showed significantly inferior growth. The average dry matter yield in mulched plot is significantly higher than the un-mulched plots (Weeratana and Asghur, 1990; Gajero *et al.,* 1998).

Tuberous rhizome yield was significantly ($P \leq 0.05$) increased by the application of different quantity of mulch materials. In general, higher production of ginger (Fig. 6.13) and turmeric (Fig. 6.14) was obtained with the application of high dose of mulches. Significant difference in number of maximum yield occurred among different dose of mulch treatments and the maximum number was achieved in mulch used at the rate of 10t/ha followed by 8t/ha and 6t/ha and lowest in control. Maximum yield, number of finger and finger size were also obtained with 10 t mulch/ha, followed by 8 t mulch/ha, 6 t mulch/ha and minimum in control. This was due to more number and size of fingers per mother rhizome with mulch application of 10 t mulch/ha of subabul compared with other treatments. These results indicated that mulches have beneficial effect on crop productivity. The results also inconformity with the finding of (Budelman, 1989; Duguma *et al*., 1988; Gutteridge, 1990; Onim *et al.,* 1990; Tiraa and Asghar, 1990; Yamoha and Burleigh, 1990) who reported mulch improves site micro environmental conditions and increase the productivity of agricultural crops. Similar increase yield due to mulches were reported in different citrus as well as others crops by various workers elsewhere (Ghosh 1985; Nath *et al.,* 1993; Jayantkumar *et al.* 1999; Shukla *et al.,* 2000; Reddy *et al.,* 1998). Increased yield due to mulches were also reported in different fruits yield due to increased soil moisture status (Srinivas *et al.,* 1990; Chattopadhyay and Patra, 1992; Mage, 1982; Chovatia *et al.,* 1992; Syed Ismail, 1993). Besides, different types of mulches have been in trial by various workers for improving crop productivity. For example, banana leaf mulch for increasing ginger yield (Mohanty, 1977) green mulches for increasing yield of sweet potato (Ossom *et al.,* 2003), subabul leaf mulch on yield of wheat (Sharma *et al.,* 2001), stover mulch increased the crop growth and yield (Moitra *et al.,* 1994), use of gliricidia, rice straw and grasses on turmeric (Kumar *et al.,* 2003) use of organic manure increase growth parameters of ginger (Maiti *et al.,* 1985).

Mulching is an easy and useful method, which can bring great benefit to most tropical crops in hilly areas. However, the practice of mulching is not very popular among the farmers. Since the vegetative organic mulches in the present study have proved to increase yield, it is recommended to use mulches in the marginal and sub-marginal farming systems, due to their ability to conserve soil and moisture and also suppress weeds. Some mulch with low C:N ratio like subabul leaves provide nutrients for crop growth through rapid decomposition therefore is found to be most beneficial to ginger and turmeric to stabilize yields.

The farmers cultivating ginger and turmeric obviously expect high yields. Through this study, we have found that mulching helped in enhancing mean tubers yields of ginger and turmeric. This implied the greater economics benefits from the mulch and better ecosystem management of the technique. Since our experiments on tree-crop compatibility and relative efficacy of quality and quantity of mulches on crop production was for a shorter duration, no discernable impact could be established although subabul leaf mulch tended to increase tuber yields appreciably.

In Mizoram, crop yield are generally low because of faulty cultivation practices. Besides, the decline crop yield in upland farming systems in Mizoram has often been attributed to the lack of adoption of modern farming technologies. The limitation seems to be the farmer’s inability to replenish nutrients lost in the continuous cultivation, which has replaced the traditional bush fallow system. Shifting cultivation (locally known as ‘jhum’) is the traditional farming system, which majority of farmers is still practicing The primitive method of slash and burn cultivation results in more soil and water erosion and ultimate poor soil productivity affecting adversely crop yield. In order to compensate the nutrients erosion in jhum land, farmers can use fertilizers, but most of the farmers cannot afford to buy fertilizers, and hence jhum cultivation has become economically non-viable (Szott and Kass, 1993). The Government of Mizoram has launched different programmes to wean away the jhum cultivators but the success was only nominal. There has been no single suitable, sustainable, economically viable and socially acceptable land use systems for the region in general, and the state in particular to solve the farmers problems in one hand and the ecology on the other hand (Sharma, 1980). It is further envisaged that if no scientific manipulation is made to jhum, then not only ginger and turmeric but also the other agricultural crops production in the state may decline beyond their expectation (Garbyal, 1999). To solve these problems and replace them with a better and improved method of cultivation, the findings of the present study offer an alternative means of introducing crops along with trees and mulches with a positive impact on the environment and enhancing the basic natural resources leading to higher and suitable production. The applications of organic materials can not only replenish soil nutrients but also can improve the physical, chemical, and biological properties of soil. To a large extent, this may be achieved by managing crop mixture, incorporating different quality and quantity of mulches in the agro ecosystem in such a way that nutrient sources are sufficiently generated, recycled and maintained. Our research was conducted under specific context to determine the tree-crop compatibility, role of species mixture and usefulness of mulches on soil moisture conservation. The cost-benefit analysis is an important issue, which could determine the effectiveness of a system while recommending the farmers, however, this study can be carried out in future.

Nitrogen and phosphorus are the most serious limiting factors for cereals and food legumes respectively in the agroforestry systems of Mizoram. Deficiencies of potassium in root crops like ginger and turmeric, sulfur and zinc in maize have been reported in continuously cultivated fields which have few or no inputs of crop residues or animal manure (Roskoski *et al.,* 1982; Patterson and La Rue, 1983; Onim *et al.,* 1990). Therefore, external nutrients inputs are essential to improved and sustained maize, ginger and turmeric crop production. Nutrient inputs may either be from organic sources (i.e. crop residues, green manure, and animal manure) or from inorganic sources (i.e. chemical fertilizers and lime). Published results have shown that chemical fertilizers alone cannot sustain crop yields on poorly buffered soils, at the same time the marginal and poor farmers can not afford to invest costly chemicals on the crops, thus the available organic mulches come as hardy for the farmers to provide the necessary supplements. The results of our finding are important particularly for the indigenous agroforestry systems of Mizoram where various crops species such as maize, ginger and turmeric were intercropped with *Alnus nepalensis, Melia azadirachta* and *Gmelina arborea* . Besides, *Leucaena* leaf, rice straw and weeds are being used as mulch for soil conservation. Applications of weeds that are generally removed from the field as because they are unwanted and nuisance have also been very useful in not only conserving soil moisture but also enhancing crop productivity. Further, *Alnus nepalensis, Melia azadirachta* and *Gmelina arborea* have been proved to be suitable agroforestry tree component for maize, ginger and turmeric production in rainfed condition and mulching can be an effective tool to conserve moisture and improve crop productivity under agroforestry system in Mizoram.

Chapter-VIII

Summary

The present investigation entitled "*Studies on tree-crop compatibility and growth performance of field crops and soil moisture conservation as affected by different mulches under hilly terrain of Mizoram* " was conducted during 2003-2006. The study covered the growth performance of three field crops *viz*. ginger, turmeric, and maize under three different trees *viz*. alder, neem and gamar. Besides, the relative efficacy of different types of mulches (*viz*. rice straw, subabul leaves, weeds) and three different mulch doses (*viz.* 6 t/ha, 8 t/ha and 10 t/ha) on soil moisture conservation and productivity of crops especially the tuberous crops like ginger and turmeric was assessed. The present study has been designed to cover the following objectives:

(a) To find out compatibility in tree - field crop combination from crop and soil productivity view points.

(b) To estimate nutrient status of the soil and crop productivity under different tree-crop combinations.

(c) To study the relative efficacy of different mulch materials such as rice straw, weeds and subabul leaves on the soil moisture retention ability and crop yield of ginger and turmeric.

(d) To estimate the relative efficacy of different doses (6, 8, 10 tonnes/ha) of mulch materials on the soil moisture retention ability and crop yield of ginger and turmeric.

The major findings of the project are as follows:

(a) During the 3rd year experiment, no significant change was observed in various physico-chemical properties of the soil. The soil texture remained sandy loam. The soil pH ranged from 5.03 - 5.40. In general, the study sites showed low pH in control compared to the treatment plots. This was true throughout the study period. Among various treatments, maize and its tree components in general showed comparatively higher pH content. At the end of 3rd year, however, soil pH slightly increased. The N, P, K, contents in the soil did not show any clear trend. However, application of subabul mulch in the treated plots brought significant variations in N, P and K levels. The soil moisture content was higher in plot having species mixture than those of control treatment.

(b) Among the tree species, neem grew very well along with all the crop species while the growth of *Alnus* was very slow. The field wise growth of tree species were in the order of maize > turmeric > ginger > control. However, no significant change in the growth of tree species observed between the treatments in the first 18 months after transplantation, and in the next eighteen months, its height increased at a faster rate. Similar was the case with the collar thickness of the tree species during the 3-years period. The analysis of variance showed significant ($P \leq 0.05$) variation of growth behaviour (plant height) between treatments. It is also observed that the parameters significantly ($P \leq 0.05$) varied between the months. The collar thickness however, in all the tree species was not affected by any treatment. It was observed that the parameters significantly ($P \leq 0.05$) varied between the months.

(c) Among the tree species, *Melia azadirachta* has maximum (25.42 cm to 30.90 cm) vertical root spreading, followed by *Gmelina arborea* it ranged between 23.08 cm to 28.24 cm and minimum in *Alnus nepalensis* (18.44 cm to 23.85 cm). The field wise biomass production, all the root characteristics parameters i.e. ratio of shoot length: root length, AGB: BGB ratio, plant sturdiness and the root spreading whether vertical or horizontal of tree species were in the order of maize > turmeric > ginger > control. However, the values were somewhat higher in *Melia azadirachta* compared to *Gmelina arborea* and *Alnus nepalensis*. The shoot biomass contributed substantially to the above ground biomass in all the species. The production of leaf biomass was somewhat higher in *Melia azadirachta* compared to *Gmelina arborea* and *Alnus nepalensis*. The biomass production in respect of leaves biomass, above ground varied significantly ($P \leq 0.05$) between the treatments (Table 4.17). The analysis of variance showed significant ($P \leq 0.05$) variation of total biomass production (AGB + BGB) between treatments.

(d) Soil moisture retention (%) was maximum under rice straw mulch and minimum under control. The order of soil moisture conservation was in the order of rice straw > subabul leaves > weeds in all the three years study. Analysis of variance showed the application of different mulch types significantly ($P \leq 0.05$) affected soil moisture conservation. Among the different mulches, rice straw mulch showed significantly ($P \leq 0.05$) higher soil moisture content during the study periods. Higher mulch doses (10 t/ha) retained more soil moisture than medium (8 t/ha) and low (6 t/ha) mulch dose. This was true irrespective of the crop type and tree species.

Analysis of variance showed that mulch type and mulch dose significantly ($P \leq 0.05$) increase soil moisture content. The tree species had no discernable influence in retaining soil moisture, although neem and a *Alnus* had higher tendency towards more soil moisture conservation. In general, soil moisture retention was higher during winter than the summer months and there was increased soil moisture retention in the third year compared to the corresponding values of 1^{st} and 2^{nd} years. The analysis of variance showed no significant ($P \leq 0.05$) variation of soil moisture conservation between treatment and the months during the 1^{st} year. However, during 2^{nd} and 3^{rd} year soil moisture conservation was significant ($P \leq 0.05$) between treatments. The field wise soil moisture conservation of tree species were in the order of turmeric > ginger > maize > control respectively.

(e) Maximum rhizome yield (crop productivity), maximum number of finger and higher finger size of ginger and turmeric was higher under *Alnus nepalensis* followed by *Melia azadirachta* and *Gmelina arborea* during the 3^{rd} year study. Similarly, maximum sprouting number, sprouting frequency and average sprout height of ginger and turmeric was obtained under *Alnus nepalensis* followed by *Melia azadirachta* and *Gmelina arborea* during this time. During the third year study, crops productivity in general was significantly ($P \leq 0.05$) higher in all the plots when compared with the respective control plots. Similar was the case in turmeric. During all the years of study, the data revealed that higher crops yield was recorded under tree-crop intercropping compared to sole cropping. Maximum sprouting number, sprouting frequency and average sprout height of both the crops were recorded in plots applied with subabul leaf mulch, followed by rice straw and weeds mulch. The reduction in soil moisture couple with release of nutrients by subabul mulch could have facilitated better growth of the tuberous crops in the present study. Higher production of ginger and turmeric was also obtained with the application of high dose of mulches in general and in *Alnus nepalensis* and *Melia azadirachta* plots, in particular.

From our present investigation, it can be depicted that multipurpose tree species like *Alnus nepalensis, Melia azadirachta* and *Gmelina arborea* could be better species for widely grown crops such as maize, ginger and turmeric in humid sub-tropics of Mizoram. It has also been found that using subabul leaf mulch, weeds and rice straw mulch, which in turn can provide better crop productivity, can enhance the soil moisture retention in the hilly terrain. So, introduction of species trial experiment like Neem-based agroforestry, *Alnus* and *Gmelina* based-agroforestry system with maize, ginger and turmeric in the hilly terrain of Mizoram will boost up the crop productivity and uplifting the economy of the state in long run. The relative efficacy of different mulch quality and quantity can be an effective tool to conserve moisture and improve crop productivity in the hilly terrain of Mizoram.

Photo 1. Growth of Neem intercropped turmeric plot.

Photo 2. Growth of Neem intercropped ginger plot.

Photo 3. Growth of Gamar intercropped ginger plot.

Photo 4. Growth of Gamar intercropped turmeric plot.

Photo 5. Growth of *Alnus* intercropped turmeric plot.

Photo 6. Growth of *Alnus* intercropped ginger plot.


Photo 7. Growth of turmeric in control plot.

Photo 8. Growth of maize in control plot.

Photo 9. Growth of ginger in control plot.


Photo 10. Growth of Neem in control plot.


Photo 11. Growth of Gamar in control plot.


Photo 12. Growth of *Alnus* in control plot.

Photo 13. Application of rice straw mulch in ginger plot.

Photo 14. Application of subabul mulch in ginger plot.

Photo 15. Application of weeds mulch in ginger plot.

Photo 16. Application of rice straw mulch in turmeric plot.

Photo 17. Application of subabul mulch in turmeric plot.

Photo 18. Application of weeds mulch in turmeric plot.

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Sahoo, U.K**., Vanlalhluna, P.C.** and Mohan, R. (2005). Effect of different levels of N.P.K. on the growth behaviour of *Leucaena leucocephala* (Lam.) de Wit and yield of *Zea mays* L. in Mizoram. *Journal of Current Science*, **7**(2): 433-436.

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Vanlalhluna, P.C, Sahoo, U.K. and Upadhyaya, K. (2007). Effect of different mulches on soil moisture conservation and productivity of ginger in Mizoram. *Indian Journal of Soil conservation*, Dehradun. Comm.

Vanlalhluna, P.C. and Sahoo, U.K (2006). Growth and productivity of some multipurpose tree species in Agroforestry systems of Mizoram. *Journal of Current Science*, Dumka.-Comm.

Bio-data

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2. Educational Qualifications: **M.Sc. (Bot.)**

Exam Passed	Board/ Univ.	Year	% mark	Div.	Rank (if any)	Special paper
H.S.L.C.	MBSE	1991	62.2	I	-	-
P.U. (Sc.)	NEHU	1994	52.0	II	-	-
B.Sc. (Bot.)	NEHU	1998	60.0	I	10 th position	-
M.Sc. (Bot.)	NEHU	2000	61.94	I	-	Microbiology

Research Experience

Working as Senior Research Fellow in the Indian Council of Agriculture Research (ICAR), New Delhi Project (Sanction No. 5(29)/97-SW & DF dt. 12/09/2002) during 1st April, 2003 – 31st March, 2006.

Participated in seminar/workshop

Participated and presented a paper entitled "Analyzing shifting agriculture as a component of village landscape and local livelihoods: A case study in Ailawng village of Mizoram, India" in the JNU-UNU-NIRD Collaborative International Synthesis Workshop on "*Shifting Agriculture, Environmental Conservation and Sustainable Livelihoods in the Marginal Mountain Environment*" held during September 23-25, 2006 at NIRD-NERC, Guwahati, Assam, India.