SOCIO-ECONOMIC AND ECOLOGICAL STUDIES IN HOME GARDENS OF UNDIVIDED AIZAWL DISTRICT OF MIZORAM, INDIA.

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Certificate

This is to certify that the thesis entitled ***"Socio-economic and ecological studies in home gardens of undivided Aizawl district of Mizoram, India"*** submitted by Shri. Pebam Rocky, for the **Degree of Doctor of Philosophy** in **Forestry** 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 another University.

AIZAWL

THE 27th NOVEMBER 2013

(U.K. SAHOO)

Supervisor

Declaration

I hereby declare that this Ph.D. thesis entitled "**Socio economic and ecological studies in home gardens of undivided Aizawl district, Mizoram, India**" is an independent work carried out by me for the degree of Doctor of Philosophy in Forestry under the guidance and supervision of Dr. U.K. Sahoo.

This thesis has not been submitted for any other degree, diploma or title to any other University or Institution.

Aizawl **(Pebam Rocky)**

27th November 2013

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Chapter 1

Introduction

Tropical ecosystems are renowned for their rich biological diversity. However, population growth and the resulting expansion of cultivated land are threatening the sustainable management and use of the rich biological resources in the tropics. Small-holder farming systems in the tropics are faced with constant pressure of change brought about by demographic, economic, technological and social pressures. In most of the tropical countries converting primary forests to frequently unsustainable agriculture lands has increased. With the modernization in agriculture and intensification for higher outputs to meet the increasing per capita food supply most of the traditional farming system has changed to market oriented mono-cropping system which is characterized by high input with low species diversity for profit maximization.

Although agricultural expansion is often alleged to be the major driver of biodiversity losses, there are variations among farming practices with respect to their impacts (Hamito and Abate, 1994; Harvey and Haber, 1999). For instance, intensive commercial monocropping is likely to result in low species diversity, while some of the traditional farming practices common to the tropics are known to support a high level of diversity (Harvey and Haber, 1999; Abebe, 2005). For long-term sustainability and environmental consequences due to intensification of agricultural systems to meet the demand of the ever increasing population and the pressure on the tropical forests, attention is being drawn to achieving long term stability in land utilization while fulfilling the needs of the local population (Reijntjes et al., 1992; Swift and Ingram, 1996; Matson et al., 2002; Tilman et al., 2002).

Traditional homegardens are intermediary farming system with high diversity and complexity with easy management existing in between the highly commercialized farming system and the primary forests. They are the oldest forms of managed land use systems, now called agroforestry, and are considered to be the epitome of sustainability (Kang and Akinnifesi, 2000; Kumar and Nair, 2004). A homegarden is a mixture of deliberately planted vegetation, usually with a complex structure and designed to produce natural products for the household or market. Homegardens around the world often exhibit remarkable variability in composition and structure (Nair and Kumar, 2006). It mimics the natural, multilayered ecosystem. Homegardens appear to have developed independently in the Indian subcontinent, Indonesia and other parts of Southeast Asia, the tropical Pacific islands, the Caribbean, and various parts of tropical Latin America and Africa (Brownrigg 1985, Landauer and Brazil 1990), and usually found in almost all tropical and subtropical ecozones where subsistence landuse systems predominate (Nair, 1993).

Four identifying characteristics have been recognised from published analyses of homegardens (Brownrigg 1985). First, the garden is located near the residence. Second, the garden contains a high diversity of plants. To this criterion some add that the garden recycles nutrients in a sustainable manner, that plants are planted densely, and that plants are layered to mimic natural forest. Third, garden production is a supplemental rather than a main source of family consumption or income. Fourth, the garden occupies a ‘small’ area. Although most workers identify homegardens as occupying ‘small’ plots, this criterion is applied to a wide range of plot sizes, varying from a few square meters to more than one hectare.

Another distinguishing characteristic of homegardens, offered by Marsh (1998), is that homegardens are a production system that the poor can easily enter at some level since it may be done with virtually no economic resources, using locally available planting materials, natural manures and indigenous methods of pest control. To the extent a poor family can afford to make beneficial use of homegarden plots, the plots are more likely to make a sustainable contribution to the family's livelihood objectives.

Species diversity is one of the common factor in all the homegardens reported from all over the globe and most of the literatures on homegarden around the tropics are always associated with a list of various plants that were recorded from their studies. And this species complexity is not a natural phenomenon but a result of deliberate attempts and meticulous selection and management by farmers to provide the products they consider are important for their subsistence and livelihood (Nair and Kumar 2006).

Traditional homegardens often have complicated vertical structure, varying spatial pattern and management zones according to their location, composition, size, age, etc. (Kehlenbeck and Mass 2004). Ecological and socio economic factors influence the species diversity of traditional homegardens, including the utilization of the products (Gajaseni and Gajaseni, 1999). Species diversity is higher in tropical and humid regions than in temperate and arid areas (Ninez 1987, Blanckaert et al., 2004). Species diversity in a homegarden can range from less than 5 to more than 100 (e.g., Vogl and Vogl-Lukasser 2003; Kabir and Webb 2008a, b). Stem density in a homegarden can vary from less than one hundred to more than several thousands per hectare (Kabir and Webb 2008a, b).

Homegardens can be managed for commercial or subsistence purposes, and can provide from only a few to more than 100 products.

Most of the studies on sustainability of homegarden had focused on ecological sustainability while social sustainability has not been given enough attention (Torquebiau, 1992; Kumar and Nair, 2004). Social sustainability may relate either to the social acceptability of homegardens within the livelihood systems of rural producers or to the ability of homegardens to adjust to the socio-economic changes. The structure and composition of homegardens can well be adjusted to various livelihood conditions and they are not static but have evolved through centuries (Peyre et al., 2006).

In rural areas as the function of the homegarden is subsistence production, high plant species diversity exists in the garden and a wide spectrum of multiple-use products can be generated with relatively low labour cash or other external inputs (Christanty 1990, Soemarwoto and Conway 1992).

Agricultural sustainability is often enhanced through system diversity. Diversity of species of crops and trees in agroecosystems fosters recycling of nutrients, increases efficiency in the use of moisture, nutrients, and sunlight, and reduces incidence of weeds, pests, and diseases (Altieri, 1995). The maintenance of soil fertility through decomposition of litter and manuring (Wiersum, 1982; Ninez, 1987; Hoogerbrugge and Fresco, 1993) and the low export of harvested products (Nair, 2001), which are all associated with the diversity and density of species, contribute towards productivity and sustainability (Wojkowski, 1993).

Studies on tree-crop interactions in agroforestry systems as well as homegardens are important in providing better understanding to the complex mechanism in which they interact and influence upon each other. The results would also provide scientific basis for designing a proper system in order to attain maximum productivity and sustainability.

The crop combinations found in the homegardens of a region, however, are strongly influenced by the biophysical and socio-cultural factors besides the specific needs of the household and nutritional complementarities with other major food sources (Vogl et al., 2002; Kumar and Nair, 2004). As a consequence, homegardens vary greatly in species richness, structural complexity and size, but general principles are broadly similar (Gillespie et al., 1993).

The structure and composition of homegarden can well adjusted to various livelihood conditions such as size of land holdings, role of homegardens within the overall farming system and degree of commercialization (Wiersum, 1982; Christanty et al., 1986; Soemarwoto, 1987). Traditionally, the homegardens mainly served to produce vegetables, fruits and other crops which supplemented the staple food crops produced on open croplands (Soemarwoto, 1987; Kumar and Nair, 2004). With the advent of commercialization, often and increase in selected cash crops such as coconut or rubber has been observed. The shift from subsistence – oriented agriculture to market economy often implies drastic structural and functional modifications, including a homogenization of the homegardens, structure and use of external inputs (Soemarwoto, 1987; Kumar and Nair, 2004).

Homegardens are believed to provide a number of benefits to families, ranging from improving nutrition and providing a source for additional household income, to improving the status of women in the household. Furthermore, a homegarden can act as a safety net in providing alternative livelihood opportunities for the people during periods of stress, such as a bad crop year. Potential environmental benefits of homegardens may be important not only for homegardening households, but for the broader society as well.

Understanding the link between household contexts and homegarden biophysical attributes could lead to important recommendations to further promote homegardens for commercial or biodiversity conservation purposes, perhaps improving rural livelihoods in the face of disappearing forests.

A wide variety of factors may be associated with homegarden diversity and structure, including biophysical features (e.g., biogeography, proximity to forest, elevation: Soemarwoto, 1987; Kumar et al., 1994; Hocking et al., 1996; Trinh et al., 2003; Ali, 2005; Das and Das, 2005), economic requirements (e.g., subsistence or commercial orientation of the farmers: Jose and Shanmugaratnam, 1993; Michon and Mary, 1994; Salafsky, 1994; Dury, et al., 1996; Arnold and Dewees, 1998; Trinh et al., 2003; Ali, 2005; Abdoellah et al., 2006), and social responses (e.g., tradition, culture, ethnicity, previous experience, education: Alavalapati et al., 1995; Millat-e- Mustafa et al., 2000; Salam et al., 2000; Shastri et al., 2002; Trinh et al., 2003; Simons and Leakey, 2004). Understanding the forces shaping farmers' decisions about homegarden investment is important not only for exploring the human–environment linkage, but also to potentially improve livelihoods through improved management strategies.

The role of homegardens to household economy may vary depending on the component products and nature of the products utilization. Studies have documented varied levels of homegarden's contribution to the household economy. In South and Southeast Asia, from 6 to 54% (Soemarwoto, 1987; Trinh et al., 2003; Ali, 2005; Kabir and Webb, 2008) of the total household income come from homegardens.

Household food security is defined as the ability of a household to secure, either from its own production or through purchase, adequate food to meet the dietary needs of its members for a healthy and active life (Egal and Valstar, 1999). Homegardens are one strategy for addressing malnutrition and micronutrient deficiencies. Even though animal products are the best sources of micronutrients, vegetables and fruits may be the only source of micronutrients that are reliably available to poor households (Talukder et al., 2000, Bloem et al., 1998, Reddy, 1995). A number of studies have reported that homegardens produce a high percentage of fruits and vegetables consumed by homegardening families.

Homegardens are an integral part in a typical mizo homestead and have been playing a crucial role in supplying household members with a diversity of different food crops. These homegardens are important source of food supply and are also important for their economical and social values. The composition of species in a homegarden is governed by many factors that make homegarden a dynamic system. Ecology, local food culture, the socio-economic conditions, the farmers interest and prevailing market forces are some of the important factors that determine the species composition present in homegardens (Jacob and Alles, 1987; Soemarwoto and Conway, 1992; Hoogerbrugge and Fresco, 1993; Gajaseni and Gajaseni, 1999).

The developmental interventions of government and non-governmental organizations are primarily concentrated on introducing exotic species of vegetables and fruit species rather than conducting systematic studies of homegardens and improvement of this system. Hence there is also a lack of in-depth knowledge and information on species composition in mizo homegardens. Therefore, the main aim of this study was to understand the structure and functions of the mizo homegarden in relation to livelihood support in undivided Aizawl district of Mizoram. The thesis has been chapterised into the following main chapters:

- Species composition and plant diversity in traditional homegardens of Mizoramt,
- Socio-economic analysis of traditional homegardens of Mizoram,
- Ecological studies in the traditional homegarden
- Traditional homegardens for food security and nutritional needs in rural Mizoram.

Chapter 2

Review of literature

Homegardens are centuries-old components of the rural ecosystem and, especially in rural areas, are usually cultivated with a mixture of annual and perennial plants that can be harvested on a daily or seasonal basis. Soemarwoto and Christanty (1985) defined homegardens as a land surrounding houses in which the structure resembles that of a forest, combining the natural aspects of a forest with solutions to the socioeconomic and cultural needs of the people. Traditional agroecosystems all over the world often contain a high diversity of crop varieties. Traditional agroecosystems play an important role in the conservation of biodiversity and in sustainable development. As a typical type of traditional agroecosystem, traditional homegardens have been receiving increasing attention from scientists, especially ecologist, conservationist and ethnobotanists. They are considered as germplasm banks for many crops and other economic plants. They are also a key site for domestication of wild plants (Huai and Hamilton, 2009). Traditional homegardens often show complicated structures, diverse floristic compositions, multiple functions, low input (including labour and money), and ecological and socioeconomic sustainability. Further, they are often considered to be spontaneous and disorganized. The characteristics and functions of traditional homegardens are closely related to many factors, such as their geographic location and the cultural backgrounds and socioeconomic conditions of their owners (Huai and Hamilton, 2009).

Home-gardens are the oldest forms of managed land use systems, now called agroforestry, and are considered to be the epitome of sustainability (Kang and Akinnifesi, 2000; Kumar and Nair, 2004). However, along with the loss of traditional life-styles and changes in the socioeconomy, the continuing existence of traditional agroecosystems has now become questionable. The characteristics and functions of traditional agroecosystems all over the world are under great change (Dash and Misra, 2001; Trinh et al., 2003; Soini, 2005; Peyre et al., 2006). In some parts of the world, many species once commonly cultivated in traditional agroecosystems are becoming lost and along with this, related knowledge about their management is also being lost (Lamont et al., 1999; Kumar and Nair, 2004).

There are many types of traditional homegardens, varying in their layouts and types of species grown, and associated with different geographical areas or ethnic groups (Hamilton and Hamilton, 2006). Size, structure, socioeconomic value, or dominant species have all been used as criteria in classifying homegardens (Kehlenbeck and Mass, 2004). In Vietnam, Trinh et al. (2003) classified traditional homegardens into four types according to their main functions and main species, that is, "homegardens with fruit trees", "homegardens with pond and covered livestock area", "homegardens with vegetables" and "homegardens with forest trees". There are many systems of classification, but no universally accepted current scheme, especially for tropical homegardens for which many types are reported (Kehlenbeck and Mass, 2004). Niñez (1987) classified traditional homegardens into two ecological types, tropical and temperate, each marked by particular features in terms of structure and species composition. Tropical homegardens tend to have complex vertical structures and many species with many life-forms. In contrast, temperate homegardens have simple vertical structures with all the plants unshaded and dominated by annual species.

Traditional homegardens have been shown to be ecologically sustainable (Torquebiau, 1992; Jose and Shanmugaratnam, 1993; Kehlenbeck and Maass, 2004). Their benefits include maintenance of soil fertility and soil structure and maintaining nutrient cycling (Schroth et al., 2001). The complex vertical structures and high floristic diversity of tropical homegardens ensures an efficient use of sunlight, water, and nutrients. Even in tropical areas of low rainfall, shallow soils and low agricultural potential, homegardens have been shown to be agriculturally productive (Benjamin et al., 2001).

Home gardens in the tropics vary greatly in species, species richness, structural complexity and size, but general principles can be identified. Most gardens tend to have multiple canopies, with taller trees providing shade for smaller trees and shrubs (Gillespie et al., 1993). Genetic diversity is a fundamental component of biodiversity, forming the basis for species and ecosystem diversity (Atta-Krah et al., 2004). Homegardens are species-rich agroforestry systems maintained on the basis of choice, needs and importance of plants. Further, the selection of principal crop species and subsequent overall species diversity is apparently influenced by individual site conditions. The crop diversity found in the home-gardens probably reflected the specific needs (including food requirements and household dietary priorities and preferences), nutritional complementarities with major food sources, as opposed to economic, ecological and social factors (Kumar and Nair, 2004).

In all regions, most of the homegarden owners appeared to constantly introduce new plant species. Introduction of new species often depend on their uses, characteristics and values while these are mostly based on personal instincts and preference. The size of the gardens and available planting area may also contribute to choice of planting or species to be retained. This is indicated by the occurrence of plants of different stages, such as seedlings, saplings and juveniles, mature and old trees (Akinnifesi et al., 2009). It has also been known that religious and cultural beliefs may influence the diversity and composition of tropical homegardens.

Traditional homegardens contribute greatly to agrobiodiversity conservation (Trinh et al., 2003), including helping to maintain or increase both the phenotypic and genotypic diversities of cultivated plants (Casas et al., 2005; Carmona and Casas, 2005). They can also play an important role in the conservation of indigenous and endemic plants, since such plants can be major components of homegardens in some cases (Albuquerque et al., 2005; Hemp, 2005).

Northeast India, having rich ethnic and cultural diversity, gave rise to diverse homegarden structures where important plant species are maintained to fulfil various needs. A study of different ethnic groups in Brahmaputra Valley, Assam, India indicated that production from homegardens maintained by immigrant people was over four times higher and their economic returns were greater than those maintained by the native people (Shrivastava and Heinen, 2005). A study on village homesteads in Barak Valley (Das and Das, 2005) showed rich biodiversity, livelihood dependency as well as conservation of rare and endangered species. Borthakur et al. (1998) stressed the role of homegardens, a traditional Indian experience, in the management and conservation of biodiversity in Assam. Traditional homegardens often have complicated vertical structures. They vary in their vertical structure according to their location (e.g. more complex in the tropics), floristic composition, age and size (Kehlenbeck and Maass, 2004). De

Clerck and Negrreos-Castillo (2000) reported five vertical layers for one type of homegarden in Mexico

The significance of homegardens to rural livelihoods is well appreciated throughout the world (Fernandes and Nair, 1986; Soemarwoto, 1987; Torquebiau, 1992; Jose and Shanmugaratnam, 1993; Nair 2006), including India. The homegarden has been described as an important social and economic unit of rural households, from which a diverse and stable supply of economic products and benefits are derived (Christanty, 1990; Campbell et al., 1991; Shackleton et al., 2008). The diversity of crop species and production cycles in homegardens enables year-round production of different products, reducing the risk of production failure (Abebe et al., 2006). Similarly, Shackleton et al. (2008) found that goods harvested from trees are consumed within the home, buffer households during times of stress, and are bartered with neighbors or sold in local and regional markets. Some of the plant products are sold in local and regional markets, thus improving the family's financial status. The marketing of homegarden products by rural households and small-scale farmers has been identified as a potential means of poverty alleviation (Garrity, 2004; Shackleton et al., 2008).

Sustainable management of homegardens must be balanced with the short-term needs of the people for social and economic development and protection of the natural resource base (Maroyi, 2009). The sale of products from homegardens significantly improves family financial status, because cash income can be used by the household to buy food, clothing, pay school fees, etc. A homegarden is, therefore, part of a household livelihood strategy and has gained prominence as a natural asset through which sustainable use of resources, particularly for the livelihoods of the poor, may be achieved. Homegarden and agroforestry systems provide an important contribution to sustainable agricultural production because of their potential to meet economic, social, ecological, and institutional conditions for sustainable livelihoods (Nair, 2006). In spite of the inherent limitations of many such traditional agroforestry systems, and the external and internal pressures to which they are subjected, traditional homegardens have remained not only viable but also active in many parts of the world (Maroyi, 2009).

Homegardens have been shown to provide a diverse and stable supply of socioeconomic products and benefits to the families that maintain them (Niñez, 1987; Christanty, 1990; Lok, 1998). The economic significance of homegardens depends on whether they are planted primarily for subsistence or for commercial production. This, in turn, depends on owner preferences, their size, the distance to the nearest market, and the demand for the particular produce being grown (Abdoellah, 1990). The introduction of commercial crops into this system to generate income is a potential source of structural and functional change. Some homegardens have become dominated by few plant species or have even become monocultures, with the dominant species comprising cash crops such as vegetables that are in high demand in urban markets (Abdoellah et al., 2006).

Soil nutrient enrichment in agroforestry is mainly a consequence of adding organic matter, nutrient cycling and protection of soil erosion and atmospheric nitrogen fixation by nitrogen fixing trees (Nair, 1993; Palm, 1995). There would be changes that may occur in soil nutrient profile and microbial activity as a result of leaf litter deposition by tree species and interaction with inter-crop, in particular agroforestry system and soil edapho-climatic conditions. Phosphorus is an important nutrient which is relatively short supply in most natural ecosystems, and one of the primary limiting nutrient for crop production in highly weathered tropical soils (Linquist et al., 1997).

Soil fertility is maintained through decomposition of roots and agricultural crops and litterfall, which in turn increase organic matter and biological activity of the soil (Szott et al., 1991) enhancing soil nutrient status. Thus agroforestry systems promote closed nutrient cycling by taking up soil nutrients through tree roots and recycling them as a litter, including root residue and helping to synchronize nutrient release with crop requirement by controlling the quality, timing and manner of addition of plant residue (Young, 1991). There are reports on litter production and nutrient cycling in agroforestry systems in Himalayan region of India (Sharma et al., 1997). Trees help to maintain soil fertility by adding litter to the soil, improving soil physical status while their roots absorb nutrients from the sub-soil and form the weathering zone of rocks below the ground and subsequently recycle such nutrients to the top soil (Young, 1997).

The year-round utilization of homegardens results in substantial nutrient losses from the soils; therefore agricultural production requires regular addition of essential nutrient-based fertilizers to maintain crop production, and farmers add various locally derived soil amendments such as cattle manure, woodland litter, or clay-rich termitaria (Chivaura-Mususa et al., 2000). It is generally regarded that the homegardens possess a closed nutrient cycling similar to the tropical forests (Soemarwoto and Conway, 1991; Nair et al., 1999; Kumar and Nair, 2004). The dynamics of litter production and decomposition are the processes that replenish the soil nutrient pools, maintain soil life and thus endow sustainability to these agroforests (Isaac and Nair, 2006). In multi-strata agroforestry system, multipurpose trees are the main component of the system and litterfall and prunings depend on the tree species, density and management activities such as fertilisation (Rao et al., 1998; Kumar, 2006). However, cases of fertility decline in multistrata agroforestry systems have also been reported especially with soil nitrogen as a limiting factor in such systems (Schroth et al., 2001; Seneviratne et al., 2006). Information on the nutrient availability especially nitrogen from the production and decomposition of litter can provide useful insights into the sustainability of the system (Nair et al., 1999; Seneviratne, 2000).

The dynamics of litter production and decomposition are the processes that replenish the soil nutrient pools, maintain soil life and thus endow sustainability to these agroforests. Nutrient accretion to soil is primarily through litterfall and decomposition (Okeke and Omaliko, 1991) and leaf litter also serve as temporary sinks. Multipurpose trees, the integral components of homegardens, contribute significantly to the closed nutrient cycling processes and sustainability of the ecosystem. Farmers have a good understanding that leaf materials decompose to release nutrients into the soil substrate without indicating knowledge of relatively advanced concepts used by the scientific community (Grossman, 2003). Farmers' knowledge of the litter quality of different species and their planting and management of multiple species with differing rates of litter production and nutrient input plays an important role in the efficient nutrient cycling of the system (Nair et al., 1999; Sinclair and Walker, 1999).

Studies have indicated that the allelochemicals are toxins which may inhibit shoot/root growth, nutrient uptake, or may attack a naturally occurring symbiotic relationship thereby destroying the usable source of plants of a nutrient. Allelochemicals which inhibit the growth of same or different species at higher concentrations may not influence the germination and growth at lower concentration of extracts and vice versa. It has been reported that *Eucalyptus* species and *Acacia* sp. have phytotoxic effects on tree crops and legumes (Velu et al., 1999; Sazada et al., 2009). The chemicals released by roots, bark and seeds of plants influences the crop productivity (Rice, 1974; Narwal, 1994). The magnitude of these chemicals' effects on the other plants, depend on their concentration and the quantity these substances released into the environment (Tripathi et al., 1996). Sahoo et al. (2007) conducted a study on allelopathic effect of *Leucaena leucocephala* and *Tectona grandis* on maize and found out that the leaf extract were more toxic than bark and seed and *Leucaena* was more inhibiting to germination than *Tectona*. In a study in the parklands of Burkino Faso (Boffa et al., 2000) plant height and grain yield of *Sorghum bicolor* were significantly lower by a factor of 16% for grain yield under the tree crowns of karité (*Vitellaria paradoxa*).

The chemicals with allelopathy activity are present in many plants and various organs including leaves and fruits (Inderjit, 1996; Sazada et al., 2009) and have potential inhibitory effect on crops (Seigler, 1996). Other researchers have evaluated the allelopathic effects of grasses/trees on the germination, shoot length root length, bioassay on different crop species. The root length/growth and the lateral root development were more susceptible to the increase in the concentration of aqueous extract when compared to shoot (Alam, 1990; Chaturvedi and Jha, 1992; Tripathi et al., 1996)

Homegarden system is the oldest production system known and their very persistence is proof of their intrinsic economic and nutritional merit. Home gardens help fulfil dietary, economic, and social needs for many cultures. Continued cultivation and use of homegardens over the past millennium has played a key role in successful achievement of sustainable livelihoods. One of the most important multiple potential benefits of home gardening is increased direct access to nutritious foods by the food insecure (Marsh, 1998). The dynamic role of home gardening in family nutrition and household welfare must be assessed in the context of the wider farming system and household economy. Usually, the functions and output of the home garden complement field agriculture, whereas field crops provide the bulk of energy needed by the household, the garden supplements the diet with vitamin-rich vegetables and fruits, energy-rich vegetable staples, animal sources of protein and herbs and condiments (Marsh, 1998).

Home gardening can be a sustainable strategy for improving food security and incomes when gardens are well adapted to local agronomic and resource conditions, cultural traditions and preferences (Midmore et al., 1991; IIRR, 1991). Moreover, in terms of alleviating food insecurity, advocates claim that food production controlled by households is more reliable and sustainable than nutrition interventions that rely on government goodwill and financial support (Niñez, 1984; Von Braun et al., 1993; Moskow, 1996). The most successful home gardening activities involve both the nutrition and health and the agriculture sectors in an integrated approach. Homegarden production is also an important source of supplementary income for poor rural and urban households around the world. The combined value of garden production, including sale of surplus vegetable produce and animal products combined with savings in food and medical expenses, varies seasonally but constitutes a significant proportion of total income (upwards of 20 percent) for many households (Marsh, 1998).

The diversity of plants in a traditional homegarden is beneficial from the nutritional point of view. Plant products harvested from homegardens improve the family's nutritional status, health, and food security. Homegardens provide supplementary vegetable protein and readily available sources of carbohydrates, vitamins, and minerals (Abdoellah and Marten, 1986). Further, it contributes to household food security by providing direct access to food that can be harvested, prepared and fed to family members, often on a daily basis (Marsh, 1998). Even very poor, landless or near landless people practise gardening on small patches of homestead land, vacant lots, roadsides or edges of a field, or in containers. Homegardening provides a diversity of fresh foods that improve the quantity and quality of nutrients available to the family. Sri Lankan homegardens have been reported to produce 60 percent of leaf vegetables and 20 percent of all vegetables consumed by the household (Hoogerbrugge and Fresco, 1993; Ensing et al., 1985). Others have reported that homegardens typically produce more than 50 percent of vegetables, fruits, medicinal plants and herbs consumed by the household (Marsh, 1998).

Households with gardens typically obtain from them more than 50 percent of their supply of vegetables and fruits (including such secondary staples as plantains, cassava, taro and sweet potato), medicinal plants and herbs; those households having garden systems that include animal-raising also obtain their primary and often only source of animal protein (Soleri et al., 1991; Marsh and Talukder, 1994; UNDP, 1996). It is well known that several tree fruits in homegardens are nutritionally rich, and carbohydrate-rich grain crops are also a main source of vitamins and minerals for the family (Nair, 2006). Very small mixed vegetable gardens can provide a significant percentage of the recommended dietary allowance for protein (10 to 20 percent), iron (20 percent), calcium (20 percent), vitamin A (80 percent) and vitamin C (100 percent) (Marsh and Talukder, 1994; AVRDC, 1983-1989). Furthermore, home gardening is only one of the possible interventions for enhancing food security for the poor, and it should be considered in the context of a broader national food security strategy (Marsh, 1998). Thus, home gardening at some level is a production system that the poor can easily enter.

A brief review of literature presented above in the foregoing pages clearly indicates that the socio economic aspects and ecological investigation on traditional homegardens has not been well documented in this part of north east India and the present study was undertaken to analyse the socio-economic and ecological dimensions of traditional homegardens in relation to livelihood and food security in Mizoram.

Chapter 3

Study Area

Introduction

Mizoram the "land of highlanders", is one of the eight states of northeast India lies in the charming and gentle hill folds in the southernmost tip of the north eastern part of the country, projecting downwards between Burma and Bangladesh. It is flanked by Bangladesh on the west and Myanmar on the east and south. It is a land of rolling hills, valleys, rivers and lakes where more than 98 percent of the 21,087 km^2 area of the state is hilly and mountainous.. As many as 21 major hill ranges or peaks of different heights run through the length and breadth of the state. The average height of the hills to the west of the state is about 1000 m which gradually rise up to 1300 m to the east. Phawngpui Tlang also known as the *Blue Mountain*, situated in the south-eastern part of the state, is the highest peak in Mizoram at 2210 m.

The people of Mizoram are known as the "Mizos", a Mongoloid race that had migrated from Myanmar and settled in the area since the 7^{th} century. The Mizos live in villages that used to be governed by village chiefs (or "*lal*"), but are now replaced by elected village councils. The Mizos number approximately 1.1 million and are a close-knit society. The Mizo code of ethics, or "tlawmngaihna", espouses a moral of self-sacrifice for the common good. Agriculture is the main occupation and shifting cultivation continues to be the predominant practice, affecting as much as 2618 km^2 or about 12 percent of the state (NRSC, 2010).

Geology

The hills of Mizoram consist of sandstones and shales of tertiary age, thrown into long folds. The rocks are the continuation of those rocks forming Patkai range and Cachar hills of Assam (Pachuau, 1994). The geology of Mizoram is represented in general by repetitive succession of arenaceous and argillaceous sediments which were latter thrown into approximately NNW-SSE trending longitudinal plunging anticlines and synclines.

Climate

Mizoram has a mild climate, comfortable in summer 20° to 29 °C and never freezing during winter, with temperatures from 7° to 21°C. The region is influenced by monsoons, raining heavily from May to September with little rain in the dry (cold) season. The average state rainfall is 254 cm per annum. In the capital Aizawl, rainfall is about 208 cm and in Lunglei, another major centre, about 350 cm. Depending on the variation in temperature and other weather conditions, three seasons (*viz*., cold or winter season; warm season or spring; rainy season or summer season) are observed in the area as in other parts of the state. The climatogram of the study area is shown in **figure 3.1**.

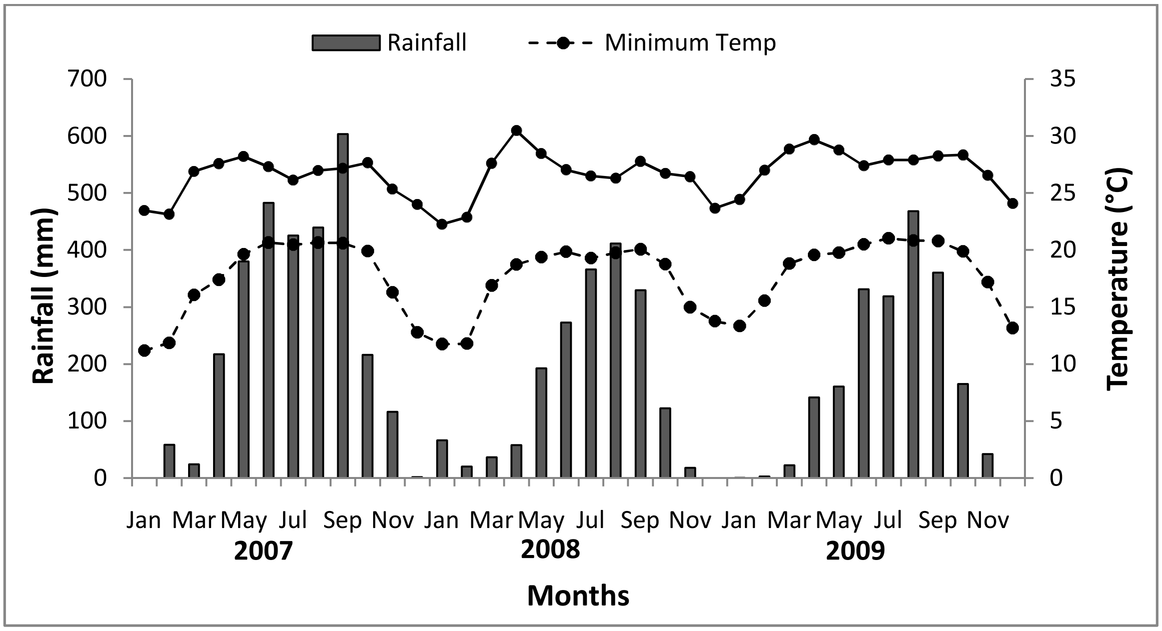
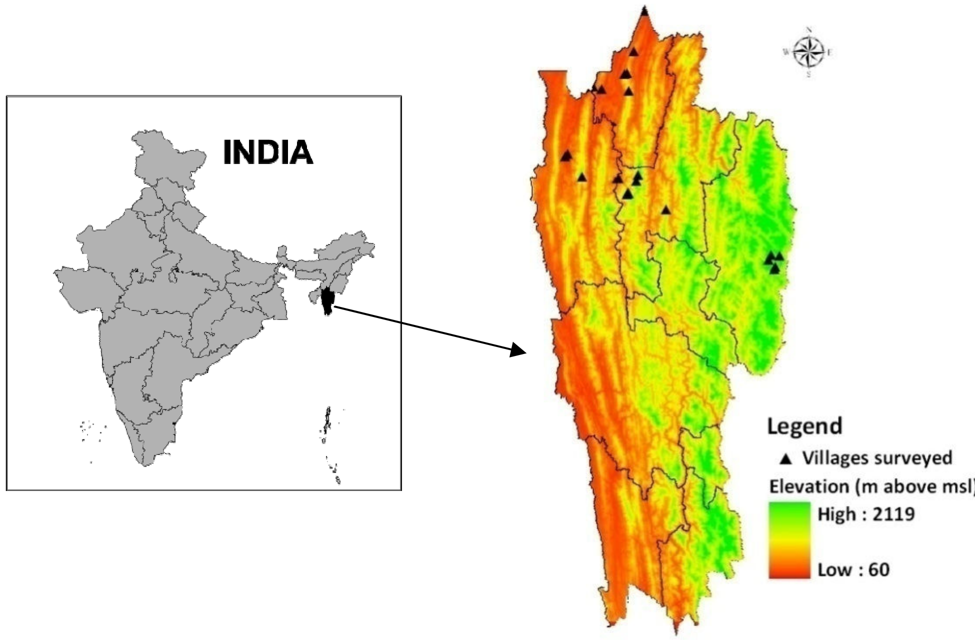


Figure 3.1: Climatogram showing total monthly rainfall and mean monthly minimum and maximum temperature of Mizoram

Study villages

The present study was conducted in sample villages located in the undivided Aizawl district (northern Mizoram) located at different altitudinal zones ranging from about 40 m above msl to the higher altitudes in eastern ranges bordering Myanmar. The location of the study villages are shown in **figure 3.2**. The field sampling was done in homegardens located in the study villages of Zote, Zotlang, Ruantlang, Hmunhmeltha, Vengsang in Champhai; Vairengte, Bilkhawthlir, Rengtekawn, Meidum, Bairabi, Kolasib, Thingdawl in Kolasib; Selesih, Siphir, Thingsulthlia, Sairang, Phungchawn, Rangvamawl, Chawlhhmun in Aizawl; Dampui, Darlak, Bawngva in Mamit.



Map of Northern Mizoram showing the study villages

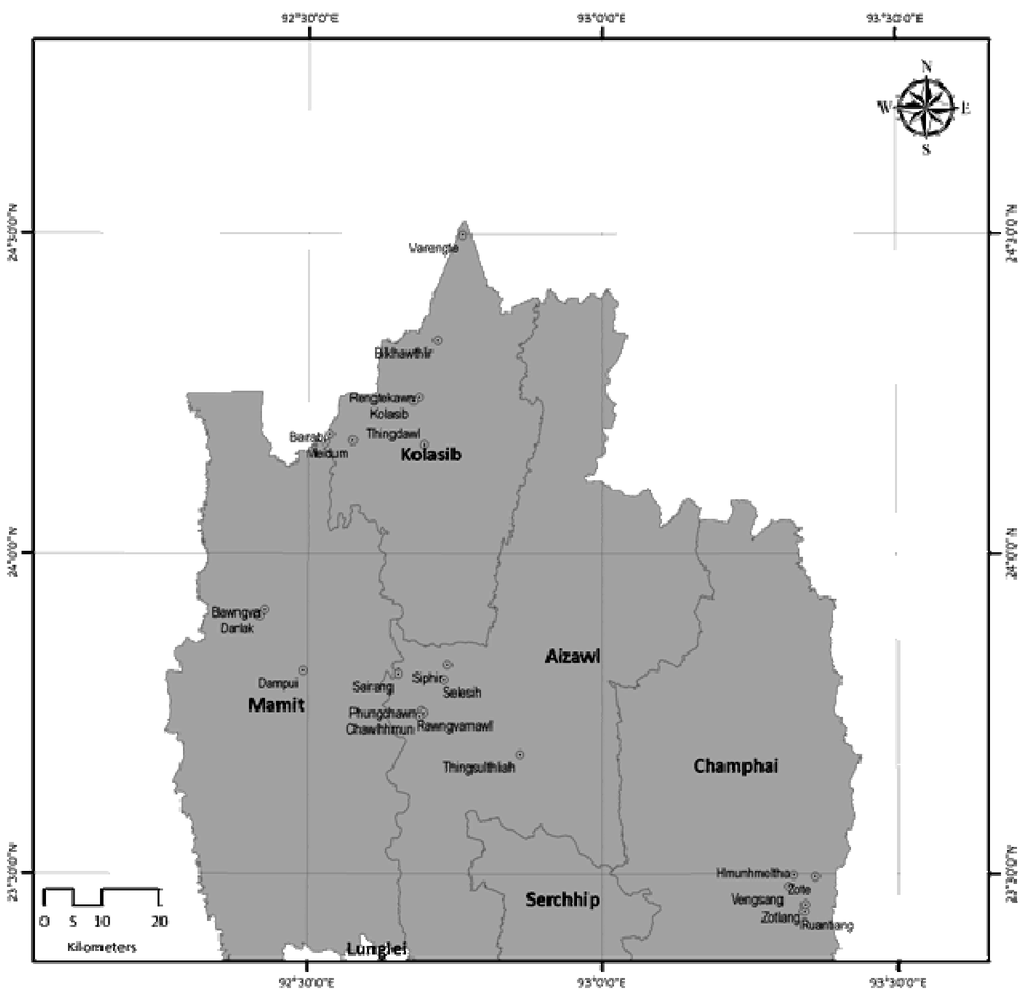


Figure 3.2: Map showing the location of study sites

Chapter 4

Species composition and plant diversity in homegardens of Mizoram

4.1 Introduction

Homegarden agroforestry systems in the tropics are known for their structural complexity and diversity in crop and other plant species (Michon et al., 1983; Fernandes and Nair 1986). They are frequently identified as traditional agroforestry system with complex structure and multiple functions. Species diversity that is of immediate homestead use is the most prominent features of home garden (Hoggerbrugge and Fresco, 1993; Soemarwoto, 1987). The high and maintained diversity of both cultivated and wild plant species makes homegardens suitable for *in situ* conservation of plant genetic resources (Maxted et.al., 1997; Watson and Eyzaguirre, 2002).

The cultivation of different crops is regarded as a strategy of farmers to diversify their subsistence and cash needs. Diversification also helps to stabilise yield or income in cases of incidences of disease and pests, and market price fluctuations. They may also help in conserving plants, both wild and domesticated, because of their use to the households (Abdoellah et al., 2006). They are also an attractive model for research and the design of sustainable agroecosystem (Das and Das, 2005). Moreover, the intimate association between the different herbaceous and woody components in these gardens is believed to enhance nutrient recycling and reduce hazards of leaching and soil erosion (Wiersum 1982; Fernandes and Nair, 1992).

It is not just humans that benefit from the carefully managed, complex structure of home gardens. By imitating the form of the surrounding forest, these areas also provide habitat for wild animals, especially birds, in an area where few primary forests still stand (Steinberg, 1998). The multi layered, forest like vegetation structure of homegardens contributes substantially to the ecological sustainability of the village ecosystem (Kehlenbeck and Maass, 2004). The species composition of homegardens varies according to climatic, topographic and edaphic factors and socio-economic conditions of the farmers.

These homegarden agroforestry systems also ensure food security, play a significant role in the regional and national economies, and also contribute to environmental resilience. Despite these contributions, only few studies have been undertaken on the systems in north eastern region of India and little is known about these homegardens in the state of Mizoram. The species richness and heterogeneity of crops in the systems as a whole, and at farm and plot levels is not known.

The study presented in this chapter aims to characterize the diversity of plant species in the traditional homegardens of Mizoram in north east India. More specifically, it attempts to understand a) the plant species richness and the diversity of the homegardens, b) the share of major plants, c) the diversity of plant species distributed at plot level, and d) structural pattern of the homegardens.

4.2 Methods

Individual households having homegarden gardens were considered as a unit of analysis and treated as a system. Ninety two households were randomly sampled in three altitudinal zones namely high altitudes (>1200 m above msl), mid altitudes (300-1200 m above msl) and low altitudes (<300 m above msl).

4.2.1 Data collection

In each sampled homegarden the area of the garden was measured using a tape along the boundary and a sketch of the garden plot was drawn along with the measurements. Vegetation enumeration of the homegardens was done in different seasons of the year. All species present in each sampled homegarden were identified and recorded by their botanical name, or by local name and later confirmed from published books. All individuals of trees and shrubs were counted and their height and GBH recorded following (Kabir and Webb, 2008). No herbs or climbers were counted. The location and altitude of each sample household was recorded using a Garmin global positioning system (GPS).

4.2.2 Data analysis

Each species recorded in the homegarden was classified by family, habit based on morphology of the plant when it was full grown (tree, shrub, herb or climber) and plant use. Frequency – the fraction of homegarden containing the species (Cox, 1990) – was calculated for all recorded species. Abundance – number of individuals per species – was calculated for trees and shrub species. The sum of the relative values of frequency, abundance and dominance for each species of trees and shrub was used for deriving the importance value index of individual species (Curtis, 1959). For trees and shrubs relative importance value was used to rank species per life form and only relative frequency for herbs and climbers. Shannon-Weiner index as used to determine the species richness, $H' = \Sigma p_i \ln p_i$ (Magurran 1988), where pi is the proportional abundance of species i (i.e., number of species divided by total number in the community). The dominance index (Simpson, 1949) of the community was calculated as $C = \Sigma pi^2$, where C is the dominance index and pi is same for Shannon's index. Floristic similarity gardens of different altitudes were calculated with Jaccard's similarity index using the formula $Cj=j/(a+b-j)$ where Cj is Jaccard's similarity index, j is the number of species shared by the two sites, a is number of species in site a, and b is the number of species in site b (Magurran, 1988). The values obtained were then statistically compared across the different altitudes.

4.3 Results

4.3.1 Floristic assemblage in the homegarden

During the survey a total of 351 plants belonging to 101 families were recorded from the survey of 92 gardens across the study area. Complete list of the plants, their occurrence and information on their utilization are given in **Appendix 3**. Euphorbiaceae was represented by maximum number of species (27) followed by Moraceae and Pappillonaceae (15 each) while 52 families were represented by only 1 species. Of the 351 species 170 were trees, 42 were shrubs, 94 herbs, 5 epiphytes, 34 climbers and 6 bamboo species.

The frequency of occurrence of the species across homegardens was rather variable (**Figure 4.1**). Five of the plant species (fruit trees like *Mangifera indica*, *Psidium guajava*, medicinal traditional vegetable *Clerodendrum colebrookianum*, *Musa paradisiaca* and nutritious pod bearing *Parkia tomoriana*) were grown in more than 60 % of the garden. Crops like ginger, fruits like *prunus*, passion fruit, *Ipomea* *batatas*, *hibiscus sabdarifa*, *Dysoxylum*, *Citrus grandis*, *Colocasia esculenta*, capsicum, areca nut tree, papaya, *Brassica juncea* were present in more than 30% of the garden while 155 plants were recorded very rarely, in less than 3% of the gardens. *Mangifera indica* was the most frequent species recorded in 83% of the gardens followed by *Psidium guajava* (79 %).

An average of 34 plant species (sd, ±14) per garden were recorded in the 92 gardens. More than fifty percent of the gardens contain 21-40 plant species while very few gardens have less than 10 species or more than 60 species per garden (**Figure 4.2**).

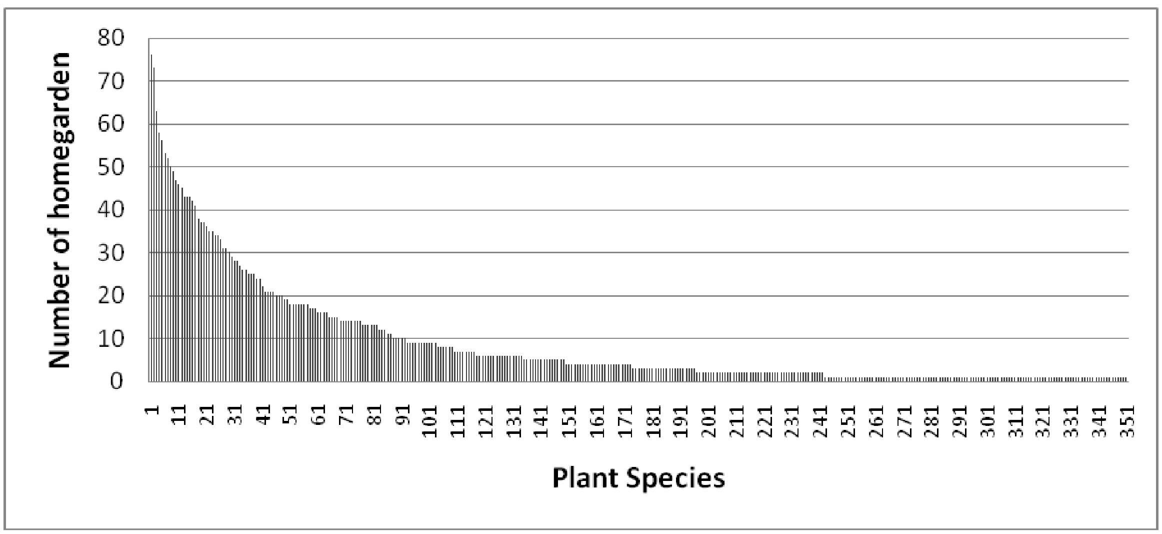


Figure 4.1: Frequency distribution of the plant species in the homegardens (n=92)

4.3.2 Variation in plant diversity across altitudinal gradient

4.3.2.1 Spectrum of plant species diversity in the homegardens across the altitudes

Plant species was recorded highest in the low altitude gardens (227, 65%) and lesser (206, 59%) in the high and mid altitude gardens (**Table 4.1**). Tree species was also recorded higher in the low altitudes (109) than mid (106) and high altitude gardens (82) while herbs and climbers were recorded more in high altitudes. Bamboo and cane were also recorded more in mid and low altitude.

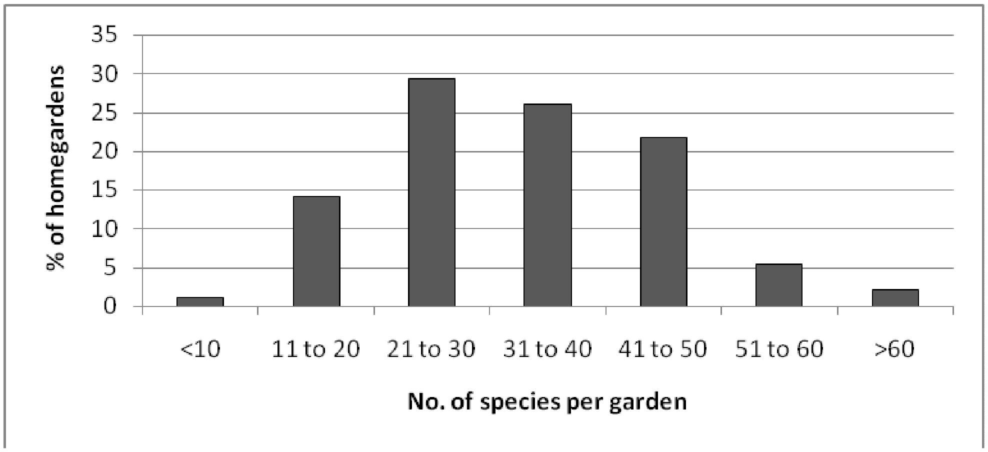


Figure 4.2: Plant species encountered per homegarden.

Table 4.1: Species richness in the homegardens of 3 different altitudes

Parameters	High altitude	Mid altitude	Low altitude
Species	206	206	227
Families	57	69	80
Trees	82	106	109
Shrubs	27	21	31
Herbs, climbers, epiphytes	95	76	82
Canes	0	4	2
Bamboos	4	3	5
Median garden area (m^2)	1990	1330	2000

4.3.2.2 Diversity of plants in homegardens across different altitudes

The diversity of plant species per garden was slightly higher in the high altitudes than mid altitudes but significantly ($p<0.01$) less in the low altitudes (**Table 4.2**). The diversity of trees and shrubs per garden was higher in the mid altitudes than low and high altitudes (**Figure 4.3**) but was not significant. Basal area of trees and woody shrubs per unit area in the garden was significantly higher ($p<0.05$) in the mid altitude gardens and lesser in the low and high altitudes. Density of trees per unit area was significantly ($p<0.01$) more in low altitudes and least in the high altitude gardens and it ranged from 15 trees in a garden in mid altitude to 720 trees in low altitude. Shannon Weiner diversity index of trees and shrubs varied significantly ($p<0.01$) across the altitudes and was higher (H'=3.89) in the mid altitudes and minimum (H' =2.73) in the low altitudes.

Although species diversity were high, the majority of species were rare. Abundance of trees and shrubs showed that many of the species were represented only by very few individuals especially in mid and low altitudes and (**Figure 4.4**) and majority of the individuals belongs to a single species (areca nut) in case of low altitude and thus dominance index of trees and shrubs was higher in the low altitude gardens (**Table 4.2**). In more detail, 19 species in high altitude, 30 species in mid altitude and 47 species in low altitude were represented by only one single individual each. Also tree and shrub species which were represented by less than 10 individuals were more in low (74%) and mid altitude (79%) and comparatively lesser (55%) in high altitude gardens.

Table 4.2: Diversity and dominance of plant in homegarden at different altitudes

Parameters	**High altitude**	**Mid altitude**	**Low altitude**	**F-test**
No of species/garden (Trees, shrubs & herbs)	37.91±1.51 (22-71)	36.19±5.91 (7-100)	27.82±1.95 (13-55)	5.63**
No of trees & shrubs/garden	17.98±1.23 (7-52)	23.06±3.52 (5-57)	17.55±1.275 (9-40)	2.32^{ns}
Basal area (m^2/ha) (Trees & shrubs)	4.99±0.66 (0.54-18.75)	9.15±2.09 (1.09-27.63)	5.67±0.89 (1.27-24.28)	3.57*
Density of trees (ha^{-1})	143.02±10.39 (27-292)	191.99±28.76 (15-310)	262.86±33.73 (52-720)	7.78**
Diversity (*H'*) (Trees & shrubs)	3.64 (0.93-3.56)	3.89 (1.48-3.55)	2.73 (0.43-3.08)	4.23*
Dominance (*C*) (Trees and shrubs)	0.048	0.035	0.24	-

±SE mean, *-P<0.01, **P<0.01

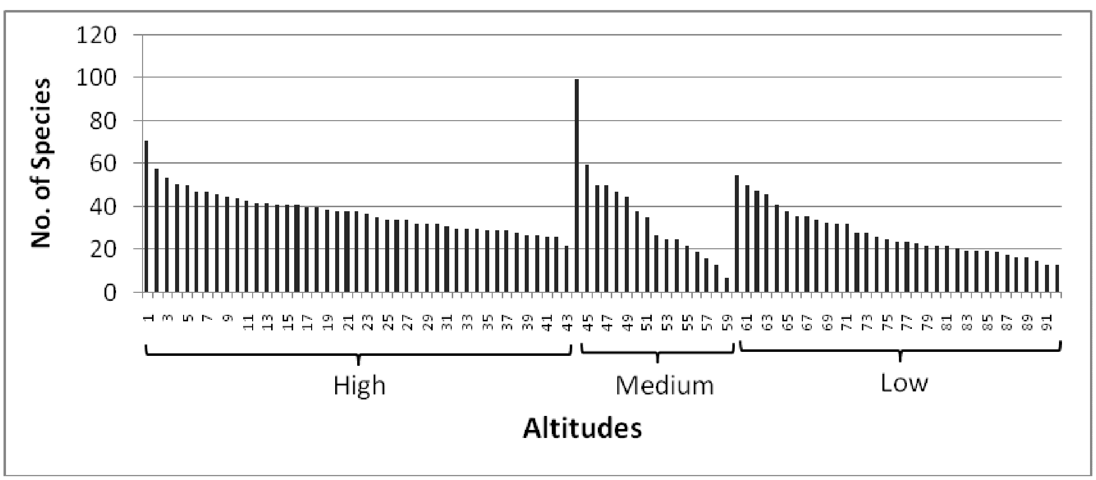


Figure 4.3: Number of plant species per garden across the altitudes.

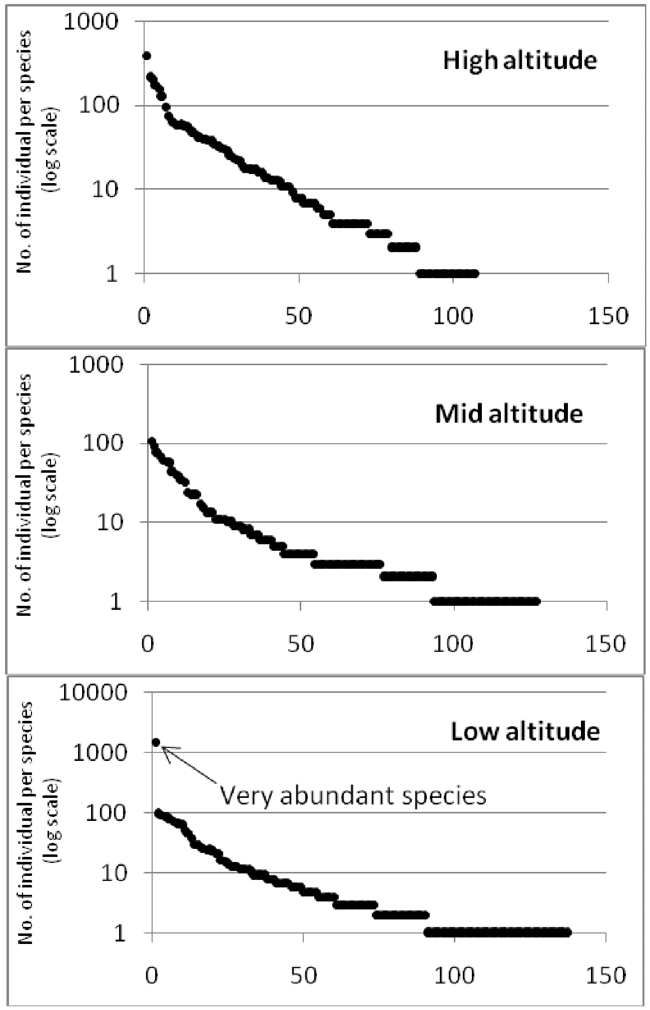


Figure 4.4: Abundance of tree and shrub species in homegardens of the three altitudes

4.3.3 Variation in frequency, density and IVI of plants across altitudes

In the high altitude gardens *Psidium guajava, Clerodendrum colebrookianum, Parkia timoriana* were the most frequently found trees and in mid altitude *Mangifera indica, Trevesia palmata* and *Psidium guajava* were more commonly found while *Areca catechu, Mangifera indica* and *Artocarpus heterophyllus* were frequently found trees in low altitude (**Table 4.3**). *Colocasia esculenta* was common across the altitudes, passion fruit was more common in the high altitude and *Acacia pennata* was more common in mid and low altitude.

The density of trees and shrubs per garden varied across the altitudes. Density of areca nut per garden was very high in the low altitudes (average of 43.61 per garden) while coffee plant (6.75) followed by *Citrus reticulata* (5.75) dominated the mid altitude gardens and Phuinam (*Clerodendrum colebrookanum*) density per garden was high (9.21) in the high altitudes followed by guava (**Table 4.4**).

The importance value index (IVI) of plants (detail list shown in **Appendix 2**) showed that *Parkia timoriana* was more ecologically important in the high altitude (19.76) and mid altitude gardens (5.61) while it was Areca nut (16.61) in the low altitude (**Table 4.5**). *Artocarpus heterophyllus* was the second most ecologically important plant in the mid altitude (4.97) and low altitude (7.19) gardens.

4.3.4 Comparison of similarity index between gardens at different altitudes

Species similarity among the trees and shrubs showed that similarity was higher in between mid altitude and low altitude (85 species) and Jaccards' similarity index also showed the same pattern (**Table 4.6** and **Table 4.7**).

4.3.4.1 Floristic variation among trees in the homegardens at different altitudes

Table 4.8 shows the different plant species with their comparative occurrence at different altitudes. In the high altitudes trees which are favourable to colder climates

Table 4.3: Prominent plant species based on % frequency in the three altitudes

High altitude	% Freq
Trees	
Psidium guajava	88.37
Clerodendrum colebrookianum	86.05
Parkia timoriana	79.07
Mangifera indica	74.42
Prunus domestica	67.44
Shrubs	
Citrus sp.	55.81
Elaeagnus caudate	53.49
Camellia sinensis	46.51
Herbs	
Colocasia esculenta	83.72
Cucurbita maxima	79.07
Hibiscus sabdariffa	76.74
Brassica juncea	72.09
Climbers	
Passiflora edulis	74.42
Sechium edule	41.86
Phaseolus vulgaris	30.23

Mid altitude	% Freq
Trees	
Mangifera indica	93.75
Trevesia palmata	81.25
Psidium guajava	75.00
Artocarpus heterophyllus	68.75
Clerodendrum colebrookianum	62.50
Shrubs	
Citrus reticulate	81.25
Coffea arabica	50.00
Camellia sinensis	43.75
Herbs	
Colocasia eculenta	62.50
Musa paradisiaca	50.00
Colocasia affinis	50.00
Phrynium capitatum	37.50
Climbers	
Acacia pennata	56.25
Piper betle	50.00
Sechium edule	37.50

Low altitude	% Freq
Trees	
Areca catechu	90.91
Mangifera indica	87.88
Artocarpus heterophyllus	72.73
Psidium guajava	66.67
Carica papaya	66.67
Shrubs	
Citrus medica var. acidus	48.48
Garcinia lanceaefolia	24.24
Eleagnus caudata	15.15
Herbs	
Musa paradisiaca	78.79
Ananas comosus	57.58
Colocasia affinis	54.55
Colocasia esculenta	42.42
Climbers	
Acacia pennata	45.45
Piper betle	18.18
Momordica charantia	15.15

Table 4.4: Prominent trees and shrubs based on density (trees per garden) in the three altitudes

High altitude			**Mid altitude**			**Low altitude**		
Botanical Name	**Life Form**	**Density**	**Botanical Name**	**Life Form**	**Density**	**Botanical Name**	**Life Form**	**Density**
C. colebrookianum	T	9.21	*Coffea arabica*	S	6.75	*Areca catechu*	T	43.61
Psidium guajava	T	4.95	*Citrus reticulata*	S	5.75	*Mangifera indica*	T	2.88
Camellia sinensis	S	4.60	*C. colebrookianum*	T	4.69	*Psidium guajava*	T	2.76
Parkia timoriana	T	4.09	*Trevesia palmata*	T	4.25	*C. medica* var. *acidus*	S	2.64
Citrus reticulata	S	3.70	*Mangifera indica*	T	3.88	*C. macroptera* var. *anamensis*	T	2.48
Mangifera indica	T	2.91	*Areca catechu*	T	3.69	*Camellia sinensis*	S	2.42
Trevesia palmata	T	2.26	*Camellia sinensis*	S	3.50	*Cocos nucifera*	T	2.18
Quercus serrata	T	1.74	*Psidium guajava*	T	2.69	*C. colebrookianum*	T	2.12
Prunus domestica	T	1.44	*Vernicia montana*	T	2.56	*Artocarpus heterophyllus*	T	1.94
Citrus sp.	S	1.42	*Tectona grandis*	T	2.50	*Carica papaya*	T	1.85

Table 4.5: Top ten species with high IVI in the three altitudes

High Altitude	IVI
Parkia timoriana	19.76
C.colebrookianum	8.04
Psidium guajava	6.13
Quercus serrata	5.06
Artocarpus heterophyllus	4.12
Mangifera indica	3.36
Eleagnus caudata	3.08
Morus alba	2.70
Carica papaya	2.53
Leucaena leucocephala	2.48

Mid Altitudes	IVI
Parkia timoriana	5.61
Artocarpus heterophyllus	4.97
Mangifera indica	2.83
Tectona grandis	2.80
Psidium guajava	1.92
Carica papaya	1.87
C. macroptera var anamensis	1.50
C.colebrookianum	1.41
Tetrameles nudiflora	1.40
Citrus reticulata	1.32

Low Altitudes	IVI
Areca catechu	16.61
Artocarpus heterophyllus	7.19
Cocos nucifera	3.75
Parkia timoriana	3.71
Litchi sinensis	3.69
Tamarindus indica	3.67
Psidium guajava	3.25
Carica papaya	3.08
Mangifera indica	2.75
C. macroptera var anamensis	2.59

High altitude

Mid altitude

Low altitude

Plate 4.1: Homegardens at different altitudes in Mizoram

like *Alnus nepalensis, Myrica esculenta, Quercus* species were found although with lesser frequency of occurrence and in mid altitudes trees like *Albizzia chinensis, Acrocarpus fraxinifolius, Tetrameles nudiflora* were recorded while trees like *Dillenia indica* , *Artocarpus chama*, *Mallotus phillipensis, Diospyros toposia* were encountered only in the low altitude gardens. *Areca catechu, Cocos nucifera, Derris robusta, Litchi sinensis, Ziziphus mauritiana* although recorded both in the low and mid altitudes the frequency of occurrence was higher in the low altitudes.

Table 4.6: No. of species common to different altitudes

Altitudes	**No. of shared species**
High & Mid	61
Mid & Low	85
High & Low	64

Table 4.7: Plant Similarity index across different altitudes

Altitude	**High**	**Mid**	**Low**
High	-	0.35	0.36
Mid	0.35	-	0.47
Low	0.36	0.47	-

Tree species common to all the gardens across the altitudes are shown in **Table 4.9**. The eleven tree species were encountered in the homegardens of all the altitudes but the frequency of occurrence of *Artocarpus heterophyllus* and *Carica papaya* were more in the low altitudes, while *Clerodendrum colebrookianum* and *Psidium guajava* were more in the high altitudes and frequency of *Trevesia palmata* were more in mid altitudes.

Table 4.8: Floristic variations among trees in the homegarden across the three altitudes

Botanical names	**Local name**	**%Frequency**		
		High altitude	**Mid altitude**	**Low altitude**
Alnus nepalensis	Hriangpui	06.98	-	-
Citrus aurantifolium	Champara/ser te	13.95	-	-
Litsea cubeba	Sêr-nam	11.63	-	-
Myrica esculenta	Keifang	27.91	-	-
Pyrus pashia	Chalthei	09.30	-	-
Quercus leucotrichophora	Then	04.65	-	-
Quercus polystachya	Thil	09.30	-	-
Quercus serrata	Sa-sua	20.93	-	-
Rhus succedanea	Chhimhruk	09.30	-	-
Castanopsis tribuloides	Thing sia	25.58	12.50	-
Michelia oblonga	Ngiau	09.30	12.50	-
Pyrus communis	pear thei	39.53	25.00	-
Rhus semialata	khawmhma	32.56	18.75	-
Acrocarpus fraxinifolius	Nganbawn	-	18.75	-
Albizzia chinensis	Vang thing	-	31.25	-
Artocarpus nitidus ssp *griffithii*	Tat	-	18.75	-
Tetrameles nudiflora	Thingdawl	-	31.25	-
Areca catechu	Kuhva	-	31.25	90.91
Citrus macroptera var *anamensis*	Hatkora	-	56.25	48.48
Cocos nucifera	Coconut	-	18.75	63.64
Derris robusta	Thingkha	-	06.25	39.39
Lagerstroema speciosa	Thlado	-	06.25	21.21
Litchi sinensis	Vai-thei-fei-mung	-	06.25	36.36
Mesua ferrea	Herse	-	06.25	06.06
Sapindus mukorossi	Hling si	-	12.50	3.03
Tectona grandis	Teak	-	25.00	30.30
Ziziphus mauritiana	Borai	-	06.25	24.24
Artocarpus chama	Tatkawng	-	-	15.15
Dillenia indica	Kawthindeng	-	-	15.15
Diospyros toposia	Zo thing hang	-	-	06.06
Ficus hispida	Paite maien	-	-	15.15
Garuga pinnata	Bungbutuairam	-	-	06.06
Mallotus phillipensis	Thingkhei	-	-	06.06

Table 4.9: Tree species common to homegarden in all the three altitudes

Botanical names	**Local name**	**%Frequency**		
		High altitude	**Mid altitude**	**Low altitude**
Artocarpus heterophyllus	Lamkhuang	30.23	68.75	75.76
Carica papaya	Thingfanghma	44.19	50.00	69.70
Citrus grandis	Sertawk	37.21	62.50	24.24
Clerodendrum colebrookianum	Phui-hnam	86.05	62.50	48.48
Mangifera indica	Thei hai	74.42	93.75	87.88
Psidium guajava	Kawlthei	88.37	75.00	69.70
Parkia timoriana	Zawngtah	79.07	50.00	42.42
Trevesia palmata	Kawh-te-bêl	67.44	81.25	30.30
Dysoxylum gobara	Thing thu pui	46.51	50.00	3.03
Callicarpa arborea	Hnah kiah	18.60	12.50	9.09
Leucaena leucocephala	Japan Zawngtah	41.86	25.00	9.09

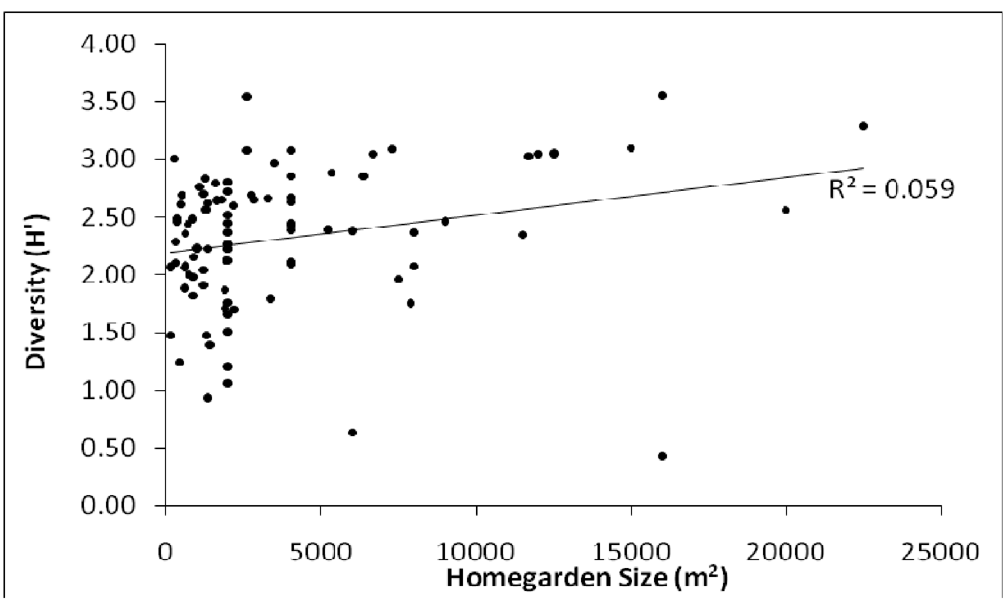


Figure 4.5: Relationship between diversity index and homegarden size.

4.3.5 Variation in plant diversity with garden size

The numbers of species encountered in the different sized homegardens varied and seems to follow an increasing trend with increase in homegarden size. The relationship between garden size and the number of species encountered at different altitudes showed an weak increasing trend (**Figure 4.6**) but was significant at the high altitude gardens ($p<0.01$). Similar pattern was observed in case of diversity index with garden size (**Figure 4.5**)

4.3.6 Vertical stratification of plants in gardens at different altitudes

The vertical distribution of plant species in the homegardens at different altitudes are detailed in **table 4.10**. *Parkia timoriana* was found to be occupying the top canopy (>14 m height) in all the altitudes but the density of stem per garden decreased with decreasing altitude. *Areca catechu* was found to dominate the top canopy in term of stem density in the low altitude followed by *Tectona grandis*, *Gmelina arborea* and *Derris robusta* was also co-dominant in the top canopy in low altitude. *Artocarpus heterophyllus* occupy the upper middle stratum (10-14m) in all the altitudes but the stem density increase with decreasing altitude. *Quercus serrata, Areca catechu* and *Cocos nucifera* were the dominant stems in the second level of stratum in high, mid and low altitudes respectively. *Mangifera indica* was common in the lower middle stratum (5-10m) across all the altitudes and *Citrus reticulata* was recorded higher stem density in high and mid altitudes. In the lowest stratum (<5m) *Camellia sinensis*

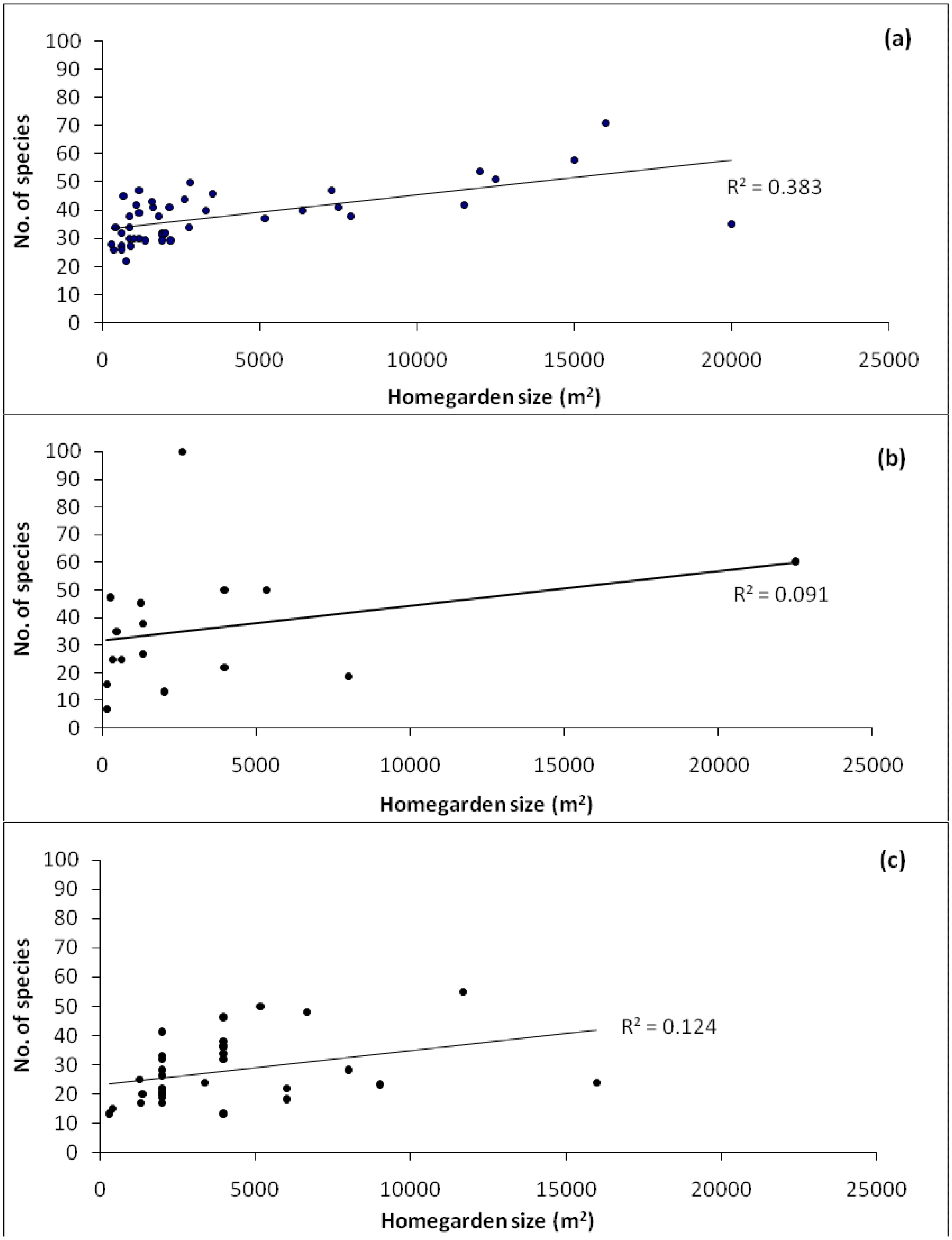


Figure 4.6: Relationship of species richness with the size of homegardens at different altitudes; (a) High, (b) Mid, (c) Low.

was common across all the altitudes but the density decreased with decrease in altitude. *Trevesia palmate* was the common species in the lowest stratum among the high and mid altitude while *C. colebrookianum* was common in the high and low altitude and *Citrus macroptera* var. *anamensis* in the mid and low altitudes. Profile diagram of typical traditional homegarden are depicted in **figure 4.7-4.9** for different altitudes.

4.4 Discussions

Farmers cultivate a diverse variety of crops and trees in homegarden for different reasons and the homegardens of Mizoram are very rich in species. The surveyed gardens were highly variable concerning size, plant species composition, richness and diversity and vertical vegetation structure. Most of the gardens resembled species rich complex agroforestry systems and some big gardens have big patch of plot for commercial cultivation but that too also in a mixture of shade trees. Compared with similar studies in Barak valley of Assam, India, Das and Das (2005) have reported 122 trees and shrubs with 87 of them trees from a survey of 50 homegardens. In the present study 170 of the 351 species were trees and 42 were shrubs which is comparatively much higher than Barak homegardens but less than the report from Bangladesh homegarden where 419species belonging to 109 families as reported by

Table 4.10: Vertical distribution of plant species (trees & shrubs) and their average density in the homegardens at different altitudes

Vertical strata	**High altitude**	**Average density per garden**	**Mid altitude**	**Average density per garden**	**Low altitude**	**Average density per garden**
Emergent layer >15 m	*Parkia timoriana*	4.09	*Parkia timoriana* *Gmelina arborea* *Vernicia montana*	1.31 0.38 2.56	*Parkia timoriana* *Derris robusta* *A. lakoocha* *Areca catechu* *Gmelina arborea* *Tectona grandis*	0.91 0.70 0.36 43.61 0.79 1.15
Canopy layer 10-15m	*Quercus serrata* *Artocarpus heterophyllus* *Myrica esculenta*	1.74 0.91 0.72	*Albizzia chinensis* *A. heterophyllus* *Areca catechu* *Tetrameles nudiflora*	0.50 1.38 3.69 0.69	*A. heterophyllus* *Cocos nucifera* *Tamarindus indica*	1.94 2.18 1.15
Understory layer 5-10m	*Mangifera indica* *Pyrus communis* *Litsea cubeba* *Citrus reticulata*	2.91 1.09 0.40 3.70	*Mangifera indica* *Citrus reticulata* *Citrus grandis*	3.88 5.75 0.94	*G. lanceaefolia* *Mangifera indica* *Litchi sinensis*	0.91 2.88 1.39
Shrub layer <5 m	*Camellia sinensis* *C. colebrookianum* *Trevesia palmate* *Carica papaya*	4.60 9.21 2.26 1.35	*Psidium guajava* *C. m. var. anamensis* *Camellia sinensis* *Dysoxylum gobara* *Trevesia palmata*	2.69 2.31 3.50 1.50 4.25	*C. m. var. anamensis* *C. colebrookianum* *C. medica var. acidus* *Camellia sinensis*	2.48 2.12 2.64 2.42

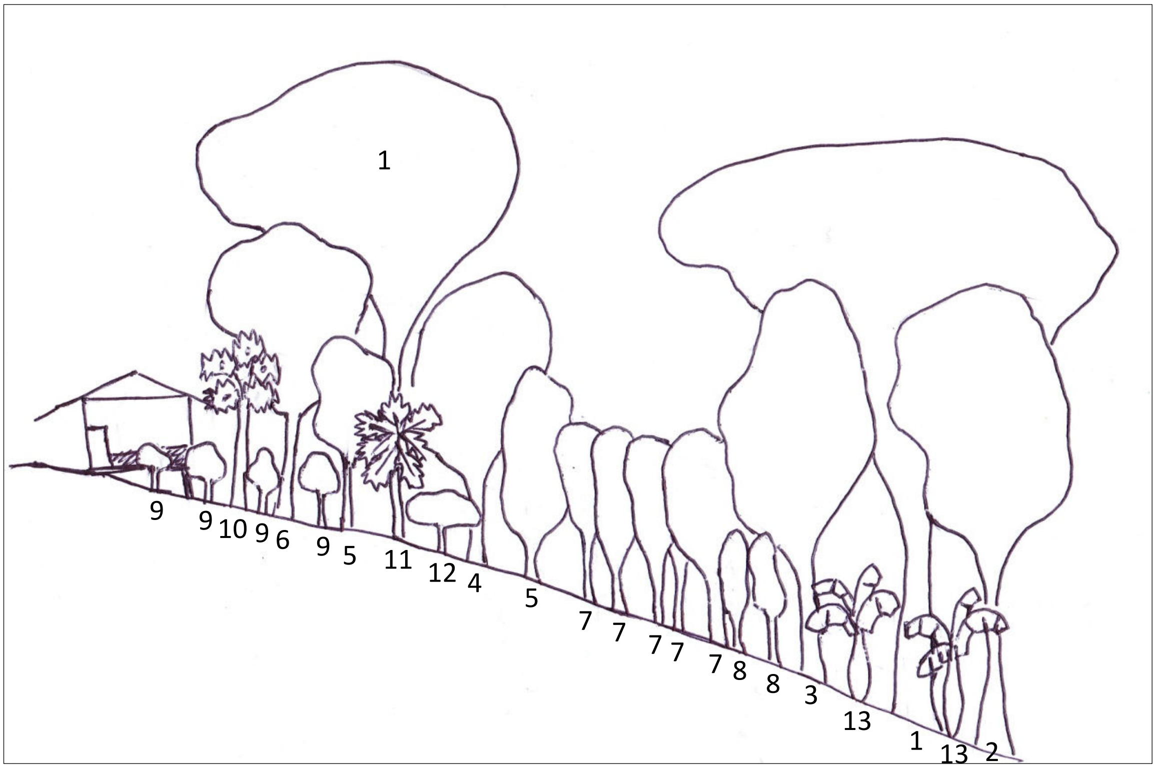


Figure 4.7: Homegarden profile depicting vertical strata in High altitude. Legend of the tree numbers corresponds to the species given below.

1. *Parkia timoriana*
2. *Quercus serrata*
3. *Artocarpus heterophyllus*
4. *Mangifera indica*
5. *Pyrus communis*
6. *Litsea cubeba*
7. *Citrus reticulate*
8. *Camellia sinensis*
9. *Clerodendron colebrookianum*
10. *Trevesia palmate*
11. *Carica papaya*
12. *Acacia pennata*
13. *Ensete superbum*

Figure 4.8: Homegarden profile depicting vertical strata in Mid altitude. Legend of the tree numbers corresponds to the species given below.

1. *Parkia timoriana*
2. *Gmelina arborea*
3. *Vernicia Montana*
4. *Albizzia chinensis*
5. *Artocarpus heterophyllus*
6. *Areca catechu*
7. *Mangifera indica*
8. *Citrus grandis*
9. *Citrus reticulate*
10. *Psidium guajava*
11. *Citrus macroptera* var *anamensis*
12. *Camellia sinensis*
13. *Dysoxylum gobara*
14. *Trevsia palmata*
15. *Clerodendron colebrookianum*

Figure 4.9: Homegarden profile depicting vertical strata in Low altitude. Legend of the tree numbers corresponds to the species given below.

1. *Tectona grandis*
2. *Derris robusta*
3. *Gmelina arborea*
4. *Artocarpus lakoocha*
5. *Areca catechu*
6. *Artocarpus heterophyllus*
7. *Cocos nucifera*
8. *Tamarindus indica*
9. *Mangifera indica*
10. *Litsea sinensis*
11. *Camellia sinensis*
12. *Clerodendron colebrookianum*
13. *Citrus macroptera* var *anamensis*
14. *Musa pardisiaca*

Kabir and Webb (2008). Still the trees species recorded in the present study (170) is higher than the Bangladesh homegarden which must be due to the wide range of topographical and climatic conditions in the present surveyed villages ranging from low lying foot hills (80m asl) to high altitudes (>1300 m asl). The higher report of plant species from the Bangladesh homegardens may be due to their large sample size (402 gardens) and larger geographical extent of the samples. In the Khasi Hills homegarden, Meghalaya, India, Tynson and Tiwari (2010) have reported 197 plants species (70 trees and 41 shrubs) belonging to 77 families from 150 homegardens while Saikia et al. (2012) have reported 294 plant species belonging to 92 families was encountered from 80 homegardens consisting of 142 trees and 56 shrubs from Upper Assam. In the Kerala homegardens, India, 127 trees and shrubs have been reported (Kumar et al., 1994) and 68 tree species in Karnataka homegardens (Sastri et al., 2002). A total of 602 species and a mean of 7 to 24 species per garden were found in small homegardens on Java, Indonesia (Karyono, 1990), 338 species in homegardens of humid Mexico (Alvarez-Buylla Roces et al., 1989) and 324 plant species in the homegardens of Nicaragua (Mendez et al., 2001). The homegardens in the tropics usually exhibit very high diversity and the average of 34 plant species in the present study is much less compared to 89 reported from Khasi Hills by Tynsong and Tiwari (2010) but in very close range with the report from Kerala homegardens (Mohan, 2004), Nepal homegarden (Sunwar, 2006) and the same as reported from Bangladesh homegarden (Kabir and Webb, 2008). The total number of species encountered in the present study may increase if more homegardens are surveyed as many of the species were recorded in single or very few homegardens and thus more rare plants may be encountered if we increase the sample size.

Many of these crops were grown as vegetable, medicine, fuel wood, fruit, or spice, few ones as staple, stimulant, or for multi-purpose- or other uses (**Appendix II**). Therefore, diverse homegarden crops provide a diverse range of valuable produce for fulfilling the daily needs (both for subsistence and cash) of gardeners and their families, as discussed in more detail in Chapter 5.

The species composition in all the homegardens within the altitudinal zone was fairly similar to each other. The number of species and trees were recorded lesser in the mid and higher altitudes. Similar observation of decrease in herbs and shrubs species with increase altitude was reported by Verma and Kapoor (2013) on a study on floristic diversity along altitudinal gradient in Himachal Pradesh, India. The lesser number of species recorded in the low altitude gardens may be due to the high dominance by few species and higher diversity index in the mid altitude may be due to presence of species of both the high altitude and low altitudes. The density of tree individuals per hectare was higher in the mid and low altitude which may be due the dense presence of small crown areca nut trees at very close spacing.

The species diversity in the homegardens is always high. Higher species diversity always promotes high soil fertility and retains soil humidity (Ninez 1985, Rico-Gray et al., 1990, Nair, 1997, Declerk and Negreros Castillo, 2000, Nair 2001). According to Nair (1997) horizontal and vertical distribution of the species brings a dynamic equilibrium with respect to organic matter and plant nutrients on the garden floor because the root systems have little or no-overlapping at this layer. The root systems help in continuous addition of leaf litter and its constant removal though decomposition and the compatible admixture of the species in homegarden offer to enrich the top soil. However, at lower soil depth, the root competition will be high, which may be in proportion to the canopy volume (Nair, 1977). Although we found species diversity to be quite similar in all gardens, the species density and species richness between the gardens was statistically significant (**Table 4.2**). Nevertheless, the species diversity indices of the homegarden in this present study are fairly comparable to those reported for natural forest ecosystem (Gajaseni and Gajaseni, 1999) and Kerala homegardens (Kumar, 1994). The plant species richness increase with increasing garden area significantly which suggests that owners maintain a diverse group of plants to fulfill their regular needs and with more available land they could opt for different variety of plants for variety of needs. The high floristic diversity is, perhaps, a reflection of the potential of homegardens to serve as repositories of genetic diversity as well. With increase in holding size, more variations in species composition were also reported by Das & Das (2005) in Barak valley, Assam and Kabir and Webb (2008) also found a strong relationship between homegarden size with species richness in Bangladesh homegardens.

The density of trees per hectare in the study homegardens are in similar range with the 238-319 ha^{-1} in Kerala homegardens (Kumar et al., 1994) and 220-409 ha^{-1} in Philippines (Snelder, 2008). Being a hilly region with steep slopes and frequent occurrence of large crown trees like *Parkia timoriana* lesser tree density might have been recorded in the surveyed gardens.

Fruit trees dominated the trees and shrubs recorded and their IVI values are also high across the altitudes. Similar observation was also reported by Zaman et al (2010) in Bangladesh, Das and Das (2005) in Barak valley, Bernholt et al. (2009) in Sulawesi, Indonesia, Akinnifesi et al. (2010) in Maranhao, Brazil. Fruit cropping systems provide valuable market benefits and services, of which some have significant objectives (Withrow-Robinson et al*.,* 1999). In general, homegarden produce contributes much more to meet the demands of protein and micronutrients (Kehlenbeck, 2007) and the homegarden owners in Mizoram usually prefer to plant more fruit trees whenever an option is given and may be the farmers also consider the importance of cash crop production of fruits in homegardens located close to market opportunities and along the major roads. The tendency to plant more fruit trees and ornamental plants for those villages close to market opportunities were also observed in many studies elsewhere (Soemarwoto and Conway 1992Karyono 2000, Mendez et al. 2001)

Parkia timoriana recorded the highest IVI value in the mid hills and high altitudes while it was areca nut in the low altitudes. And interestingly both trees are of commercial in nature apart from the household use. The fruit (pods) of *Parkia* are nutritious and a good source of protein and relished by different tribes of *Mizos, Meiteis, Ku*kis and *Nagas* in the north eastern region of India. Owing to its taste it is highly demanded winter vegetable. Rocky and Sahoo (2002) have reported that this tree contributes a good part to the farmers' family income. Kuhwa is consumed by majority of the population in this part of the north eastern region and their demand is high. Thus apart from the fruits trees for sale of the excess from the gardens these trees of economic importance are also high in the phytosociology which links the income generating tendency of the farmers from the homegarden products the details of which is discussed in Chapter 5.

Floristic similarity and dissimilarity would vary across an altitudinal gradient and in the present study it is observed that certain trees are recorded only in high altitudes and some only in the low altitudes depending on the favourable conditions. This is due to the tree physiology, its climatic requirements and related to distribution of trees in different agroclimatic zones. The similarity index indicates a low percentage of similarity between low and high altitude. Bornkamm (1981) considered low similarity to be an indicative of higher rate of species changes and *vice-versa*. These changes may be attributed to the cultural differences among the tribal communities and confounded by the needs and beliefs. The low similarity in the present study between the high altitude and low altitude might be due to the difference in climatic conditions where species which thrive well in low altitude might not be favourable to grow in high altitude.

Traditional homegardens often exhibit complex vertical and horizontal structures. The wide range of species of different heights and life forms found in traditional homegardens add to their ecological efficiency in terms of use of physical and chemical resources such as water, sunlight and nutrients (Blanckaert et al., 2004; Wiersum, 1982). Multilayered canopy configuration of the homegardens with lower plant density and species richness in the upper strata was also observed in Bangladesh homegardens (Millat-e-Mustafa et al*.,* 1996) and the neighboring forests in physiognomic terms (Barrera, 1980). However, such strata vary in numbers in different areas and may range from three to six (Fernandez and Nair, 1986; Millat-e-Mustafa et al.,1996; Das and Das, 2005). In Thailand Gajaseni and Gajaseni (1999) reported four vertical layers, in north eastern Brazil (Albuquerque et al., 2005) reported 3 strata. In the present analysis 4 vertical strata are observed with different species occupying different stratum in the homegardens at different altitudes. The ground or herbaceous layer is usually cropped with zinger, colocasia, *Phrynium capitatum,* etc., and other medicinal plants. Mustard, *Hibiscus sabdariffa*, cauliflower, etc., are cropped in slightly open area and not under the thick canopies. Climbers like *Passiflora edulis, Sechium edule* etc., are grown in open space with *Parkia timoriana* as shade trees.

4.5 Conclusion

This chapter presents the vegetation analysis of floristics and structural composition and species of different gardens at different altitudes. The present study revealed that homegardens of Mizoram are the depositories of diverse plant resources of both ecological and economic significance. The homegardens are fairly similar in structure and but different in species composition across the altitudes, indicating that the farmers purposely retained certain plant species (need not necessary be planted) that they consider important, regardless of the economic value. More plant species were recorded in the low land gardens but the diversity index was higher in the mid altitude gardens. The tree density was higher in the low altitudes with more *Areca* nut trees and it was lesser in high altitude gardens with more prevalence of *Parkia timoriana*. Species composition was slightly more similar between the low altitudes and mid altitudes than with high altitudes. Number of species and diversity of trees and shrubs increased with increasing garden size.

Chapter 5

Socio-economic analysis of traditional homegardens in Mizoram

5.1 Introduction

Homegarden although primarily used for subsistence purpose of the household in earlier days are increasingly being used to generate cash income (Christianty, 1990; Torquebiau, 1992; Mendez et al., 2001; Das and Das, 2005). They also used to generate non-market benefits such as aesthetics, ornamental, improved food quality and nutritional security to the farmers (Karyono, 1990; Jose and Shanmugaratnam, 1993; Drescher, 1996). The major reason for farmers to integrate trees, fruit trees, field crops, livestock, poultry, fishery, is for generation of employment and income. It is a common misconception that homegardens are exclusively subsistence-oriented, whereas in fact homegardens provide households with cash crops as well as food crops (Hoogerbrugge and Fresco, 1993). Kumar (2003) also stated that it has the potential to produce high value crops such as cacao, coffee, various spices and condiments. They are also suitable for resource poor situations and have economic advantage such as low capitals and labour costs, increased self sufficiency, risk avoidance and even distribution of labour (Arnold, 1987). Dury et al. (1996) reported that homegardens form an important source of cash income and wealth for many Javanese rural households. Apart from providing cash income and subsistence products to the farmers, homegardens have potential for rural employment generation. Although small gardens can meet the required labour inputs from within the household, large gardens may have the potential of employing external labour and create job opportunities in the rural areas.

The diversity of products from homegarden provides opportunity for development of small scale rural industries and creates off-farm employment and marketing opportunities (Nair and Sreedharan, 1986; Torquebiau, 1992). It was reported that in Indonesia and Nicaragua, homegardens contributed 21.1 % and 35% of the total income respectively. Studies from north-eastern Bangladesh (Motiur et al., 2005) south-west Bangladesh (Motiur et al., 2006) reported that on an average 11.8% and 15.9% of household income is derived from homegardens respectively. Livestock and tree crops produced on homegardens in southeastern Nigeria accounted for over 60 percent of family cash income in one study (Okigbo, 1990). In the Helen Keller International (HKI) pilot homegarden project in Bangladesh, 54 percent of households reported selling homegarden products and earning the cash equivalent of 14.8 percent of total average monthly income (HKI/AP, 2003).

Empirical information regarding the role of homestead forests in household economy is essential in understanding the importance of the homegarden resources. To fully understand what benefits homegardens provide their user it becomes necessary to analyse the socio-economic aspects of these system and their importance to the people who manage and conserve them. With this in view a socio-economic analysis of the homegarden system was studied.

5.2 Methodology

5.2.1 Data Collection

The sampling unit for the study was the household. Data were collected from 92 homegardens in the study villages which were categorized into three altitudinal ranges and were grouped into three farm categories according to the size. Wide ranges of information on plant diversity were collected through plant inventory and socio-economic components through structured interview in each of the households. The structured interview comprising both structured and open ended questions which were pre-tested with few households before it was finalized captured a profile of the household, and a range of variables relating to the use, traditional knowledge and management of trees, crops and livestock within the homegarden. The area and number of trees and crops grown on each farm plot were recorded with the help of the farmers and the person who managed these and the marketing of produce were interviewed. The interview was administered orally on the household's socio-economic characteristics like age of respondents, education, occupation, family size and composition, homegarden area and other land holdings under their control, past land-use and age of the garden, total family income, income from sale of their products etc.

Homegarden income was calculated by asking the respondents the amount of homegarden products they had harvested and sold and consumed and how much income was earned from the previous year's sale by recalling method. For those respondents who could not recall the total income from the sale of garden products, the garden income was also estimated from the amount of products sold and their market/on-farm values. Gross annual income of sampled households from agriculture, off-farm and other sources of income was also calculated in order to compute the contribution of the homegardens towards family gross income. Gross income was calculated by adding the amount of money earned from the products collected from homegardens including those used for self consumption and sale.

Inputs were determined as any monetary contribution to the annual economic cycle of the garden and were generally found to comprise human labour, seeds, organic manure and fertilizers, hired labour and other maintenance costs. Distance or time to market was not considered because of the high variability in the arrangements farmers had. Some sold their products in nearby market close to their house, some sold it at the farm gates on the road side and some who sold through middlemen did not spend for the transportation while few sold to far away main markets. For economic valuation of the homegardens, the household labour input and land is factored as their opportunity costs.

5.2.2. Data analysis

Descriptive statistics such as frequencies and percentages for categorical variables and mean standard deviation for continuous variables was employed. In the present study, opportunity cost of household labour is calculated as a function of time following Mohan (2004) using the expression [OC_{HL}=f (t*$labour\ rate$), where t is the time spent in the garden] and the opportunity costs of land were assigned values equivalent to the rate at which farmers were able to lease out all or parts of their lands. Basic economic methods of benefits and costs comparison were used for calculating the net financial worth of the homegardens.

5.3 Results

5.3.1 Age of the respondents, family size and income

The age of respondents ranged from 30-95 years old. Majority (78%) of the respondents were middle age and above (>45years). Average age of the respondents was high in the higher altitude and lowest in the lower altitude homegardens (**Table 5.1**). Family size ranged from 2-13 (49% male) and average member per family was highest in high altitude with 6.6 members and lowest in low altitude. Annual family income was highest among respondents in high altitudes (₹ 74,700) and minimum among low altitude garden owners (₹ 45,409). Average annual income per family was also highest in high altitude villagers and lowest in low altitude respondents.

Table 5.1: Demographic and socio-economic profile of the respondents

Parameters	High altitude	Mid altitude	Low altitude
Age of head of family (yr)	61 (30-95)	58 (32-76)	55 (30-80)
Family size	6.6 (2-12)	6.4 (3-13)	5.6 (2-10)
Annual family income (₹)	74,700 (7000-2,00,000)	55,000 (5000-4,00,000)	45,409 (2000-1,30,000)

Values in parentheses are ranges

5.3.2 Education

More than 87% of the respondents had some form of education and only 13 % had no schooling (illiterate) which confirms with the high rate of literacy for the state (**Table 5.2)**. Illiteracy was lowest and respondents attending higher education were highest in high altitude. Respondents who attended upto secondary level (VI-X) were highest in the mid altitudes and in case of lower altitudes respondents who attended upto primary level (I-V) was highest.

Table 5.2: Education level of the respondents

Education level	High altitude	Mid altitude	Low altitude
Illiterate	10	20	12
Primary level	57	27	52
Secondary level	27	53	36
Higher education	7	0	0

5.3.3 Occupation

In the rural villages of the hilly state of Mizoram majority of the population are engaged in agriculture and allied activities. Majority of the respondents were cultivators (**Table 5.3)** and maximum was observed in mid altitudes. Number of respondents in government service was highest in high altitude and wage labour was least recorded in the high altitude while it was more prevalent in low altitude.

Table 5.3: Occupation of the respondents in different altitude categories

Occupation	High altitude	Mid altitude	Low altitude
Agriculture	60 %	75 %	67 %
Government	23 %	6 %	12 %
Business	14 %	13 %	9 %
Wage Labour	3 %	6 %	12 %

5.3.4 Livestock

It was observed that rearing of cattle were more prevalent in the higher altitude while it was not recorded in the mid-hills (**Table 5.4)**. More than half of the respondent rear pigs in their homestead and more pigs per household were found to be reared in low altitude homegardens. Poultry was more prevalent in the higher altitude. Apiculture was also recorded more in the higher altitude.

Table 5.4: Average number of livestock in different farm categories

Livestock	High altitude	Mid altitude	Low altitude
Piggery	02.0 (51)	01.4 (50)	03.1 (52)
Poultry	17.5 (72)	13.9 (56)	22.9 (55)
Cattle	06.9 (19)	00.0	04.5 (6)
Apiculture	02.0 (14)	1.0 (6)	01.0 (3)

Values in parentheses are percentage

5.3.5 Land holdings and land use

Based on the topography of the villages the land holdings of the farmers varied across the altitudes. The average agricultural land own by farmers in the study villages are depicted in **table 5.5**. In the higher altitudes of Zote, Ruantlang, Hmunhmelthra villages of Champhai and lower altitudes in the foot-hill villages of Bairabi, Darlak, Bilkhawthlir, Vairengte etc., farmers own paddy fields where they practice wet rice cultivation but it was nonexistent in the mid hill villages. Larger paddy fields (locally called *Phai*) were recorded in the higher altitude villages of Champhai (mean = 5107m^2) as compared to the low altitude villages (mean = 1120 m^2).

Table 5.5: Agricultural land own by farmers other than homegarden

Land use type	**High altitude**	**Mid altitude**	**Low altitude**
Paddy fields (m^2)	5107 (0-28,098)	0	1120 (0-9,990)
Jhum lands (m^2)	1194 (0-16,056)	0714 (0-10,000)	3922 (0-12,042)
Forest gardens (m^2)	0842 (0-16,000)	6398 (0-69,567)	4400 (0-12,500)

Values in parentheses are ranges

Shifting cultivation area (*jhum* lands) coverage per household were biggest (mean = 3992m^2) in the lower altitude villages and least (714m^2) in the mid hill villages. Forest garden area per household was highest in mid altitudes (mean = 6398m^2) followed by low altitudes and smallest in high altitudes.

In the higher altitude villages 73.68% of the respondents practice wet paddy cultivation and only 11.25% of respondents in low altitude villages practice wet paddy cultivation (**Table 5.6**) while none practice it in the mid hills. *Jhum* cultivators were highest in the lowlands and least in mid hills. Forest gardening was also more prevalent in the lowlands (36.25% of respondents) and least in the highlands. Majority of the respondents across all the study sites raise some livestock in the garden. Interestingly, 4.3% of respondents practice apiculture to supplement their income and home consumption.

Table 5.6: Farmers engaged in farming practices other than homegardening

Farm practices	**High altitude**	**Mid altitude**	**Low altitude**
Wet paddy cultivation	73.68%	0	11.25%
Jhum cultivators	13.15%	07.00%	52.50%
Forest gardens	07.89%	14.29%	36.25%
Raising livestock in the garden	89.47%	92.86%	85.00%

The wet paddy cultivation is the major source of food to support the family which is cropped only during the kharif season. The surplus production is sold off for income and few of the households also own fish farms.

5.3.6 Age of homegarden

The homegardens surveyed were cultivated for periods between 5 and 47 years, however, some garden owners were uncertain about when the garden was initially planted. On an average the oldest gardens were recorded in the highlands of Champhai with mean garden age of 33.6±3.3 years (median 34). The gardens in midhills and hilly lowlands were relatively younger in age with 18.2±1.9 and 20.2±2.5 years respectively.

Table 5.7: Age of homegarden at different altitudes

Garden Category	Mean age (years)	Median age (years)
Highlands	33.6 ± 3.3	34
Midhills	18.2 ± 1.9	15
Hilly Lowlands	20.2 ± 2.5	19
Overall	21.9 ± 1.7	19

± Standard error of mean

5.3.7 Homestead garden size

The overall mean garden size across all the altitude was 3940 m^2 (median = 2000). It ranged from smallest (144m^2) in the mid altitudes to very large (20000 m^2) in the higher altitudes. On an average garden size of small homegardens ranged from 657 m^2 in mid altitudes to 1599 m^2 in the lowlands (**Table 5.8**). Medium sized gardens ranged from 3090 m^2 in the mid hills to 4366 m^2 in lowlands and large gardens from 10000 m^2 in mid altitudes to 11529 m^2 in high altitudes. Smaller gardens were more prevalent (more than 58% of the sampled gardens) followed by medium sized (28%) and large sized gardens (14%) across all the altitudes.

Table 5.8: Mean homegarden sizes (m^2) under different categories across the altitudes

Altitudes	**Small**	**Medium**	**Large**
High lands	1220	3408	11529
Mid hills	657	3090	10000
Lowlands	1599	4366	11250

5.3.8 Labour investment and garden management

The main homegarden work was carried out mostly by the household heads or their wives or daughters and sometimes sons. Women folks of the households contributed more in maintaining the homegarden as men ventured for work/wages outside the house. Sometimes in few cases where the homegarden is of commercial in nature they hire labours for some part of the year. Most of the individuals who worked in the homegarden were over 20 years of age. According to most of the respondents they prefer younger children to devote time in school and help them only during off school time

The average time spent in gardening was 8.7 hours per week across all the gardens and this was closely related to the trees and shrubs species richness (**Figure 5.1**). The summed monthly working time varies from 1.3 – 130 hour per household with a mean of 33.3 hour (median = 24.0 hour) per month. Since working hour input will vary for different garden size the average working time for different garden size was also calculated across the different altitudes. Significant variation was observed among different garden size with similar trends across the altitudes. Maximum labour input was observed in large gardens with less variation between small and medium garden (**Table 5.9**). Mean monthly working hour of 91.0 hour was recorded in large gardens of high altitude and minimum was observed in medium garden of mid altitudes.

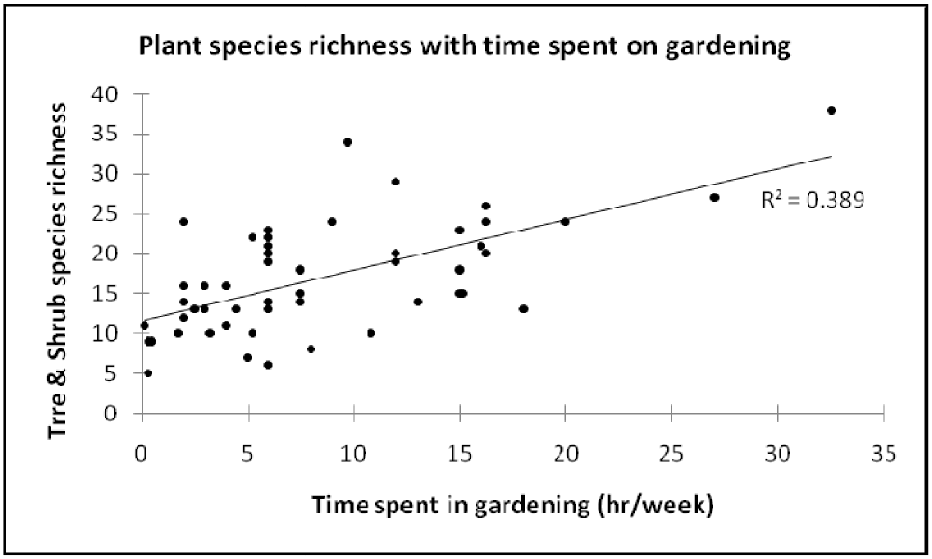


Figure 5.1: Relationship between gardening time and species richness

Table 5.9: Mean monthly working hour across altitudes and garden size.

Altitudes	**High lands**	**Mid hills**	**Lowlands**
Small	30.1 (4-80)	25.6 (1-65)	28.0 (1-104)
Medium	43.6 (8-120)	20.5 (1-39)	29.1 (1-65)
Large	89.7 (48-184)	91.0 (52-130)	51.6 (1-130)
F value	*P<0.01*	*P<0.05*	*ns*

Removing weeds and bush cutting were carried out regularly by most of the gardeners and few (5% of the respondents) engaged outside labour to clean the garden at least 3 times a year. Most of the time spent on the gardening in a year was on weeding alone. Chemical fertilization was not common as only 4.3 % of the respondents use fertilizers like Di-ammonium phosphate, urea etc., on *Passiflora edulis* and *Brassica juncea* etc. As the terrain was hilly no irrigation was done intensively, they depend only on the monsoon rains.

Table 5.10: Prevalence in homegarden maintenance.

Gender	High lands	Mid hills	Lowlands
Men	9.5	27.3	37.5
Women	76.2	18.2	43.8
Shared	14.3	54.5	18.7

Fifty four percent of the gardens surveyed were maintained only by the women and the rest were maintained by men or jointly by both. In the highlands women predominantly maintain and control the homegarden (**Table 5.10**) with very less participation and control by their male counterparts. In the lowland gardens men have more roles in the gardens maintenance as compared to the high lands while in the mid-hills both genders showed more or less equal contribution. In general, men does most of the physically harder tasks like cutting bamboos, lopping and pruning trees, and spent more time outside the household in activities like annual firewood collection during the dry seasons in bulk from their community reserves or safety forests, other agricultural works and livestock activities. Although there seems to be a marked gender specialization in some of the tasks many of the agricultural activities were reportedly shared by women and men.

5.3.9 Source of planting materials

The respondents mentioned different sources of planting material. Nearly half of the planting material was supplied by family members, friends and relatives. One fifth of them responded that the planting materials were purchased from nearby market or another district (**Figure 5.2**). Some of the materials were supplied or purchased through various schemes of the government and the remaining was collected from the wild.

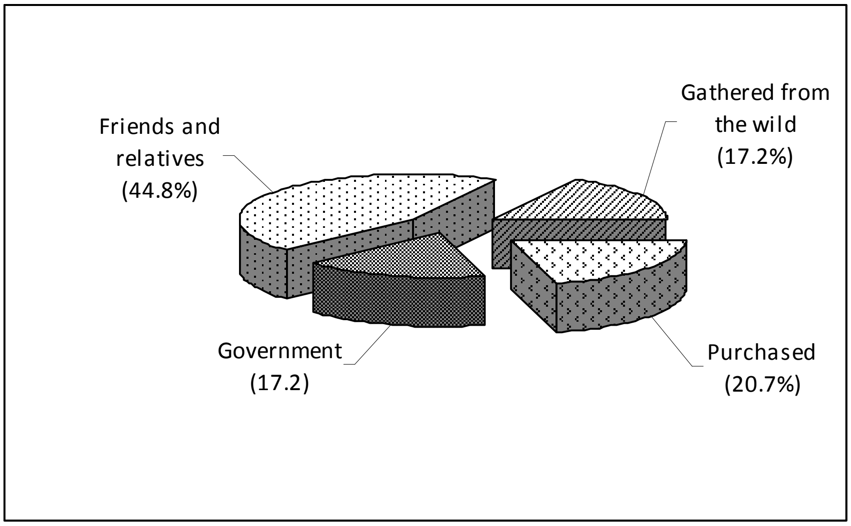


Figure 5.2. Sources of planting material as mentioned by respondents

Most of the fruits bearing trees shrubs and vegetables were self established or taken from friends and relatives. Plants like coffee, coconut and oranges were from the government whereas plants like *Dysoxylum globara*, *Musa* sp., *Artocarpus* sp. were collected from the wild. Areca nut seedlings were mostly purchased from market and even from markets of neighbouring state of Assam. In the high altitude gardens of Zotlang some of the seed sources were from Myanmar.

5.3.10 Dependence on forest resources

Almost all the respondents depend on the nearby forest resources for meeting various requirements such as small timber, fuelwood, medicinal plants, seeds and seedlings, charcoal, etc. The villagers on their way back from their *jhum* fields collect wild vegetables and non timber forest products like *Diplazium maxima*, new shoots of bamboos and canes, flowers of *Musa* sp. (*tum-bu*), mushrooms like *Agaricus campestris*, corms of *Arisaema speciosum*, crabs, prawn, and stream fishes, etc.

Those villagers who reside far away from the town depend more on forests for fuelwood. Every year during the dry winter season they collect fuelwood from the nearby community forest or safety reserve which were about 1-5 km away and store it for use throughout the year. They cut down the trees and transport them in mini trucks or tractor trolley which according to the local measure is called 1 trip or 6 feet volume which is equivalent to about 20 quintal and is the minimum a family collects for a year. Where there was no safety reserve they buy them from private forest and a trip costs about ₹4000. And if the requirement exceeds the collected volume the women of the family collect firewood from nearby forests in head loads from nearby forests on weekly or daily basis covering a distance of 1-2 km. The requirement of fuelwood in a family varies to as high as 300 quintal a year and no correlation was observed with the family size of the household and the fuelwood consumption but a strong correlation (R=0.64) was observed (**Figure 5.3**) with the number of pigs reared in the homegarden and the fuelwood consumption pattern.

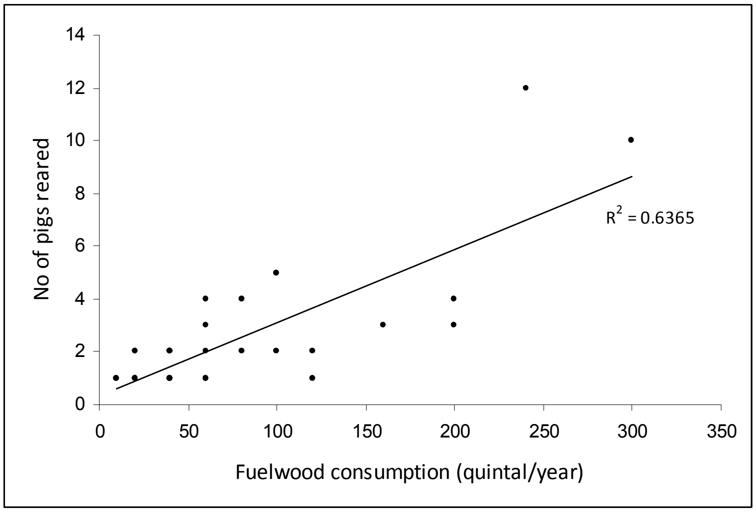


Figure 5.3: Relationship between fuelwood consumption and piggery

Some of the respondents in Ruantlang village of Champhai make charcoal to earn their livelihood during the winter season. They select sites in the nearby forests, gather trees which were good for charcoal making and prepare charcoal in pits. In a year a family could earn about ₹ 24,000 from charcoal making alone. They prefer trees like *Quercus serrata, Q. polystachya, Lithocarpus dealbata*, etc for high quality charcoal and others like *Castanopsis tribuloides, Q. helferiana, Lyonia ovalifolia* etc., for low quality charcoal. A bag of charcoal in Champhai market was sold at Rs 130 which contains about 25-30 kg charcoal.

5. 3.11 Homegarden energetic

The yield of homegarden products varied between the gardens, and was directly related to the species diversity. The total yield was higher in the larger garden than the medium and smaller ones but the yield per unit area was more in small gardens and decreased with increase in garden size

(**Table 5.11**) across the altitudes. It was observed that major energy input in were labour and in the small gardens labour inputs were only from household members whereas in the large gardens external hired labours were used for the energy requirements especially during the harvesting, weeding and sowing of crops. One man-hour human labour was assigned 1.96 MJ energy and 1 woman-hour as 1.57 MJ and total energy input inclusive of seeds and manures/fertilizers. The energy input per unit area was much higher in the highlands and it was higher in smaller gardens than the other two but the case was not so in the lowlands.

Table 5.11: Energy output input (MJ/100m^2 year^{-1}) in different homegardens

Altitudinal category	Size	Input	Output	Ratio
Highlands	Small	125.00	3728.00	27.00
	Medium	38.00	1365.00	36.00
	Large	31.00	1452.00	54.00
	F-Test			<0.04
Mid hills	Small	16.64	1903.46	102.09
	Medium	3.61	320.50	95.74
	Large	6.77	283.19	65.80
	F-test			ns
Low lands	Small	10.86	533.74	49.25
	Medium	15.46	386.81	27.07
	Large	13.72	446.42	33.45
	F-Test			ns
F-test				<0.01

The energy efficiency was found to significantly vary from 27 in smaller gardens to 54 in large gardens (p<0.04) but it was not the case in mid hills and lowlands. The energy efficiency was highest in small gardens (102.09) of mid hills, with no significant variation within the altitudes in mid hills and lowlands but there was significant variation among the garden sizes across the altitudes ($p<0.01$).

5. 3.12 Sale of homegarden products

All species in the homegarden have a multiple use. Higher number of species and individuals contributed to higher production resulting into availability of more products for sale after household consumption. Sale of surplus was more in case of large homegarden which were with commercial motives and also among the medium size gardens in the case of high altitude gardens. In all 23.9% of the respondents informed that all the products from the homegarden were for household consumption only and the remaining 76.1% sold one or more product from the garden. 35.9% of the respondents informed that more than half of their garden's product went to household consumption and the remaining 40.2% of the respondents informed that half or more of their garden's productions were sold either by self to the market, roadside or through middle men. Majority of the respondents (61.3%) sold their products by themselves while 38.7% sold through middle men directly from their garden. The markets for the destination of the products were usually 1-2 kms (nearest local market) to about 6-10 kms (major market) away while some in some of the cases the gardens were very close to the major roads (highways). **Figure 5.4** depicts the pattern and mode of sale which differed among the garden size across the altitudes in which the products were sold. All the large gardens sell their products across the altitudes while few of the gardens in lowlands didn't sell any of their products.

Figure 5.4: Sale of homegarden products from different garden categories

5.3.13 Home garden economics

The costs of monetary inputs/outputs estimated for different garden sizes under different altitudes are shown in **table 5.12.** In case of high altitude gardens monetary input/output ratio per $100m^2$ was much less in case of small gardens and higher in large gardens as the large gardens could sell more surplus products as compared to small garden that were with subsistence motives. But in the case of mid and low altitude homegardens the difference in input/output ratio between small medium and large gardens was not much.

The intensity of cultivation as indicated by the generation of profits (from sales) per unit are (mean profit/$100m^2$ homegarden) were calculated for all the homegarden categories across the altitudes and it was observed that maximum profit per unit area was highest in small homegardens of high lands and minimum in the medium sized gardens of mid-hills (**Table 5.13**). In the mid altitudes and low altitudes the mean profit per unit area was more than double the profit in medium and large sized homegardens which was not so in case of high lands.

Table 5.12: Monetary output and input (₹/100m^2) of different sized homegardens across altitudes

Altitude category	**Production measure**	**Small**	**Medium**	**Large**
High	Input	928 (54)	315 (53)	228 (58)
	Output	2597 (73)	1297 (31)	1375 (81)
	Output/input ratio	**2.6** ± 0.9	**4.4** ± 0.6	**6.6** ± 1.5
Mid	Input	164 (32)	30(64)	35 (15)
	Output	2667 (81)	652 (71)	879 (28)
	Output/input ratio	**15.0** ± 4.6	**26.9** ± 10.3	**25.8** ± 1.8
Low	Input	186 (66)	67 (15)	57 (33)
	Output	1832 (65)	686 (43)	808 (72)
	Output/input ratio	**10.1** ± 2.4	**9.9** ± 1.8	**13.9** ± 4.2

Values in parentheses are CV%, ± SEm

The mean financial values of homegarden were estimated based on the quantitative values of benefits and costs in the year of study (**Table 5.14**). The estimates revealed that net income was highest in the large gardens of high altitudes and lowest in the small sized gardens in mid and low altitudes. There was a higher economic value of homegardens in all garden sizes in the higher altitude gardens as compared to the corresponding categories in mid and low altitudes. However, since the intensity of production was greater in case of small gardens, the intensity of profit generation was also more in small gardens.

Table 5.13: Intensity of profit generation of different sized homegardens across altitudes

Altitude category	**Garden category**	**Mean profit ₹/100 m^2**	**Standard error**
High	Small	1304	369.2
	Medium	973	151.0
	Large	799	285.7
Mid	Small	1223	578.9
	Medium	413	154.2
	Large	418	137.4
Low	Small	1099	317.9
	Medium	464	127.9
	Large	530	215.3

Table 5.14: Mean financial value of homegardens for 2009-2010 (in Rs) based on the benefits and costs

Altitude category	**Garden category**	**Mean financial value (₹)**	**Mean financial value, excluding opportunity costs of land and household labour (₹)**
High	Small	28,146	19,890
	Medium	52,252	40,052
	Large	1,58,161	1,31,476
Mid	Small	14,843	13,212
	Medium	18,975	16,668
	Large	82,653	75,648
Low	Small	16,000	13,756
	Medium	28,767	24,063
	Large	61,600	53,348

5.3.14 Degree of dependence on homegardens

All the respondents depend on the homegarden irrespective of whether the garden is for income generation or household consumption or medicinal plants. For those gardeners who sell their surplus products for income, the homegarden contributed to as high as 52% of their household income in case of large gardens in the high altitude (**Table 5.15**) and the lowest was observed in small gardens in the mid hills. In general, homegarden supports about a third of the total family income in most of the cases and mean annual proceeds from the sale of homegarden products and their contribution to family income was higher in the high altitude as compared to mid altitude and low altitude gardens.

Table 5.15: Contribution to total household income from sale of homegarden products

Altitude category	Garden category	Mean annual proceeds from the sale of products (₹)	Percentage to total household income (₹)
High	Small	13,012	29.2
	Medium	33,750	32.5
	Large	78,875	52.1
Mid	Small	8,906	19.6
	Medium	14,232	26.8
	Large	55,126	33.2
Low	Small	9,600	34.1
	Medium	14,137	25.0
	Large	39,434	33.0

Among the garden products whose surplus were sold for income different crops contributed differently across the altitudes. Contributions of few prominent crops to the total homegarden income are shown in **figure 5.5,**

5.6 & 5.7. In the high lands, passion fruit (*Passiflora edulis*) and tree bean (*Parkia timoriana*) contributed maximum followed by ginger, guava, mustard, etc. In the mid altitudes maximum was contributed by *P. timoriana* followed by *Areca catechu*, *Citris reticulate, Mangifera indica*, etc., and in low altitudes largest contribution came from *A. catechu* alone

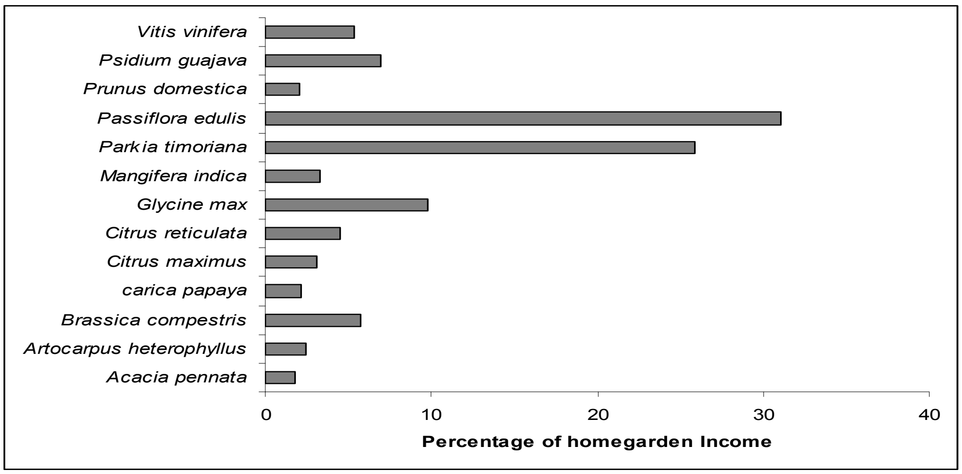


Figure 5.5: Percentage of contribution of important crops to total income in high altitude homegardens

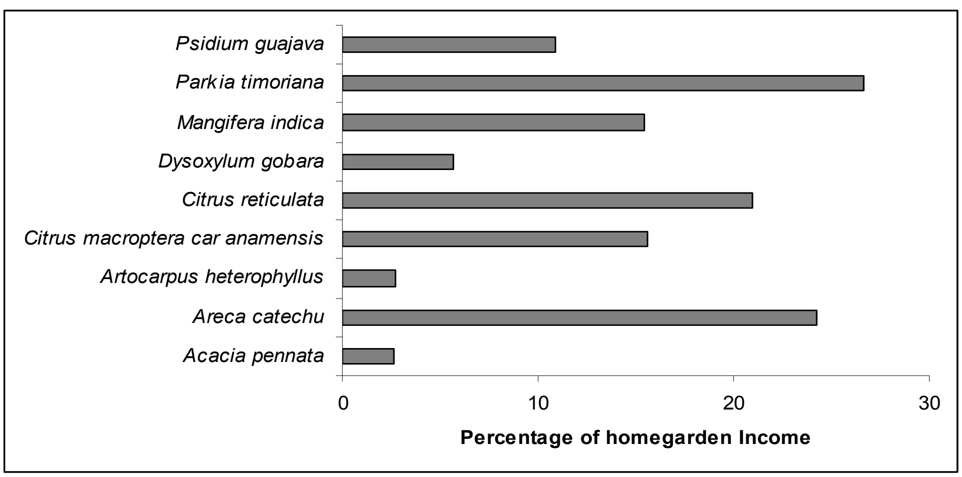


Figure 5.6: Percentage of contribution of important crops to total income in mid altitude homegardens

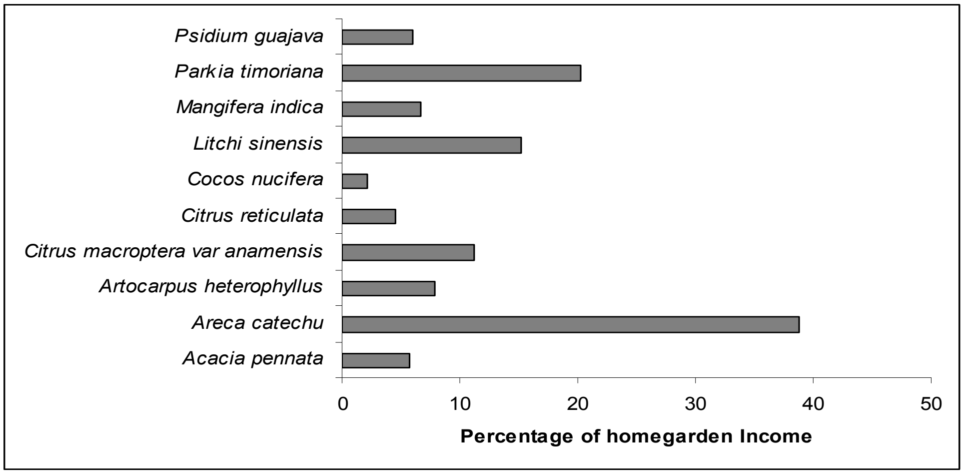


Figure 5.7: Percentage of contribution of important crops to total income in low altitude homegardens

followed halfway by *P. timoriana*. There was a marked pattern observed in the contribution of different crops to homegarden income across the three altitudinal categories. In the high altitudes varieties of trees and crops contributed to the household income as compared to the lower and mid altitudes. Most of the crops in low and mid altitudes were tree crops whereas in high altitudes many herbs, climbers and shrubs were contributing to the income. In the high and low altitude gardens the contribution was dominated differently by few trees and crops whereas in mid hills many fruit and nut trees contributed without much domination.

5.3.15 Effect of market orientation on plant diversity in the homegardens

The number of species recorded in each homegarden was plotted against the degree of market orientation on a scale of 0 to 1 depending on the percentage share of homegarden products sold to the total yield of the products in a garden. The number of species in a garden did not show any trend in the variation according to their market orientation (**Figure 5.8**) but the Simpson's index of dominance (C) showed an increasing trend with higher market orientation (**Figure 5.9**) and the correlation was significant (R^2=0.3167, p<0.01). The gardens with no sale or little sale tended to have no dominance (high evenness in species representation) while gardens with higher share of sale of products showed more dominance.

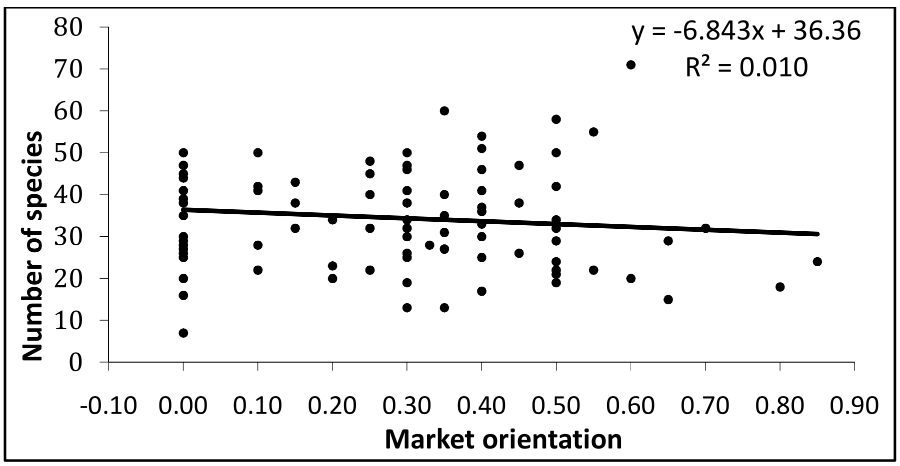


Figure 5.8: Relationship between species richness and market orientation in the gardens.

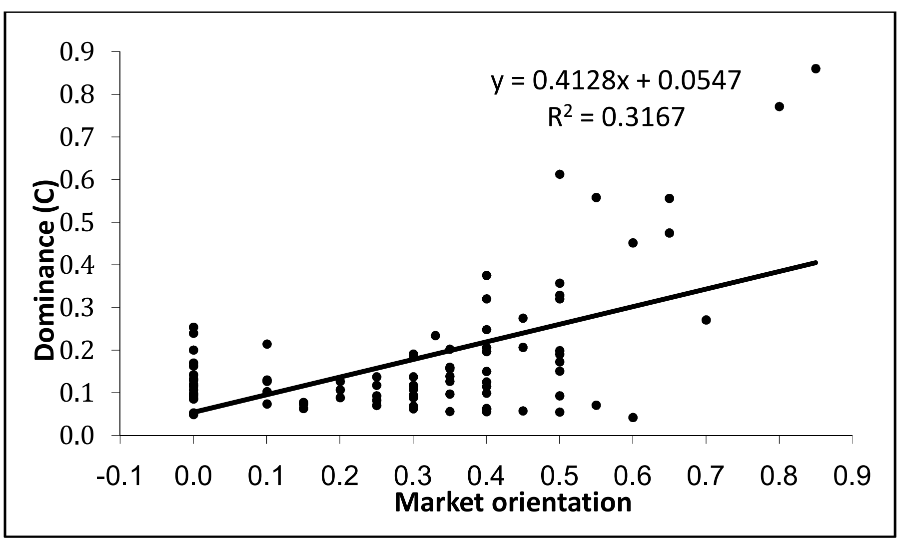


Figure 5.9: Relationship between species dominance and market orientation in the gardens.

5.3.16 Plant use in the homegarden

A total of 11 functional groups of plants were identified each represented by 1 to 104 species of plants. Each plant species was reported to have upto four use categories. A major representation was observed in food or vegetable category (44.6%) followed by timber (17.9%), ornamental (11.6%), fuelwood (8.9%), medicinal (5.9%) and other purposes (**Figure 5.10**). The composition pattern of the plant uses were following a similar trend across the altitudes but the medicinal plant use were reported highest from the lowlands compared to the highlands and mid hills.

In the highlands trees like *Parkia timoriana, Mangifera indica, Prunus domestica, Psidium guajava, Clerodendrum colebrookianum, Trevesia palmate,* etc were more prevalent as food or fruit plants while vegetables like *Colocasia esculenta, Hibiscus sabdariffa, Zingiber officinale* and climber like *Passiflora edulis* were recorded in most of the homegardens.

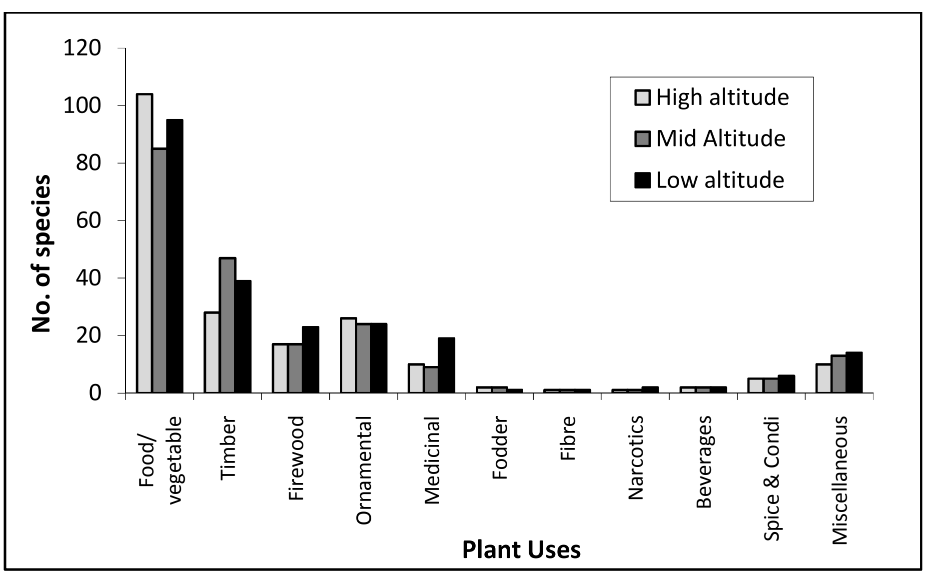


Figure 5.10: Use categories of plants across different homegardens.

Fruit trees like *Citrus grandis, Artocarpus heterophyllus, Mangifera indica, Psidium guajava,* and climbers like *Acacia pennata* as food plants were prevalent in the mid hills. In the lowlands fruits like *Ananas comosus, Artocarpus heterophyllus, Carica papaya, Musa paradisiaca,* etc. were more prevalent. Of the 351 plants recorded 236 have only one indicated use while the rest have more than one indicated utility.

5.3.17 Medicinal plants in homegardens

Various plants in the garden were used as traditional medicinal practice by the respondents. Majority of the medicinal plant uses were recorded from the informants in the low altitude gardens. The plants uses were more common among the low altitudes especially the Bru or Reang tribes. Most of the respondents in the high altitudes did not report any medicinal use of the plants in their garden. Few of the gardens in mid hills reported of some uses of the garden plants. An aged female respondent in low altitude garden of Bawngva village planted mostly medicinal plants around her homestead and many of the respondents in the that village and the neighbouring village of Darlak report of few medicinal plants uses that were grown in their garden. A list of medicinal plant uses as informed by the respondents are given in **table 5.16**.

Table 5.16: Medicinal plant uses reported from the study villages.

Botanical name	Local name	Parts use	Ailment	Methods
Citrus medica var acidus	Limbu	Juice	Headache	Juice applied to forehead
			Stomachache	Juice mix with sugar and taken orally
Kalanchoe pinnata	Zihor	Leaf	Stomach ache	Leaf extract mix with sugar and water strained & taken orally for burning stomach
Dillenia indica	Kawthrindeng	Fruit	Dysentry	Raw fruit is eaten in empty stomach
Catharanthus rosea	Kumtluang	Leaf	Headache	Leave crushed and applied on forehead
Benincasa hispida	Maipawl	Fruit	Diarrhoea	Internal flesh of fruit without seeds mix with sugar and consumed
Raphidophora decursiva	Ua makal	Stem	Bone fracture	Crushed stem and leaf applied on the fractured part
Cautleya gracilis	Pahle	Rhizome	Jaundice, flatulence	-
Cassia alata	Dak do	Leaves	Ringworms	-
Cuscuta reflexia & Chromolaena odorata	Japan hlo & Tlangsam	Leaves	Cuts	Crushed leaves together are applied for clotting blood
Ocimum americanum	Runhmui	Whole plant	Breathing problem	Whole plant mix with pineapple leaf and Acorus leaf and mix with water and taken orally
Scoparia dulcis	Bura ganja/ Perhpawngchaw	Leaf	Urinary problem	Crushed leaf and roots mix with rice water and drink
Basella alba var rubra	Nawinawk	Leaves	Burns	Crushed leaves applied on the burns
Bnettneria asper	Zawng te fian hrui	Stem	Eye pain	1 inch diameter stem cut on both ends, blow from one end and juice which ooze out from the other side is applied to the eye
Averrhoa carambola	Theiherawt	Fruit, leaves	Jaundice	-

5.4 Discussions

The demographic data of the respondents revealed that majority of the respondents in the high altitude were older in age and bigger in family size compared to the mid altitude and low altitude households and also with the state average (5.37) according to the 2003 census report (Anon, 2004). The settlements in higher altitudes of Champhai were traditional villages as compared to the relatively recent settlements in the low altitudes. This may be the reason for bigger family sizes in mid and higher altitudes. Similarly their traditional homestead gardens in higher altitude were also older. This shows that homegardens were a part and parcel of their way of life and farming practice. The average annual family income of the households were better off in higher altitude probably because more respondents and household heads were in some government service (23%) and fewer daily wage earners (2%) as compared to the low and mid altitudes (**Table 5.3**). The educational status also reflects that more respondents in higher altitudes attended up to higher education (Pre-university and colleges) while that was not the case in the other two categories (**Table 5.2**). Being a hilly agrarian state majority of the respondents were farmers. Piggery was practiced by almost half of the respondents in all the three altitudinal classes while cattle rearing and apiculture was more popular in the higher altitude which may be due to availability of more grazing lands and availability of varieties of feeds.

Larger average area of paddy fields were reported from the respondents in high altitude classes (Table 5.5) because of the availability of more flat lands in Champhai valley known as the 'Rice bowl of Mizoram' which is about 1000 ha in area and as evident from **table 5.6** majority of the respondents practiced it in high altitudes, whereas in the lower altitudes the paddy fields were along the narrow river banks and very few own them. Larger area of jhum lands were recorded in the low altitudes as many of the respondents from rural villages of Bawngva and Darlak in Mamit district own large jhum lands for growing agricultural crops as they normally don't grow vegetables in their homegarden. This is confirmed by the higher percentage of respondents who practice it (**Table 5.6**). Some of the respondents in low and mid altitudes own private teak forests as the climatic condition is favourable which is why the forest garden area was recorded more in these two categories.

The homegarden size ranged from 114 m^2 to 20000 m^2 with an average size of 3640 m^2 (median=2000 m^2) across all the categories. The homegarden size is by and large a function of population density (Das and Das, 2005) and is also govern by the topography. In **table 5.8** the mean homegarden sizes in mid hills were recorded comparatively smaller which may be attributed to the location of the study villages along the highways where population density is usually higher.

Size of homegarden also varies from region to region globally. The mean size is similar to reports from neighbouring Cachar plains where it ranged from 200 m^2 to 12000 m^2 with an average area of 3000 m^2 (Das and Das, 2005) but higher from south Khasi Hills of Meghalaya where it was reported to be from 200 m^2 to 3500 m^2 with average size of 750 m^2 (Tynsong and Tiwari, 2010). Mendez et al. (2001) also reported average size of to be 3240 m^2 (range: 200-14000 m^2) in Nicaragua whereas the area varies from 67 m^2 to 7322 m^2 in Santa Rosa, Amazon (Padoch and de Jong, 1991). In Sri Lanka the size varied from 500 m^2 to 25000 m^2 (Perera and Rajapakse, 1991) in Kyndyan homegardens while in sub urban area in Katana Division of Sri Lanka the average size was reported to be 221 m^2 (Kumari et al., 2009) and 240 m^2 to 2400 m^2 in Central Sulawesi, Indonesia (Kehlenbeck and Maass, 2004). Studies from Kerala, India reported the size of garden varying from 121 m^2 to 10000 m^2 (Mohan, 2004). Different studies in Bangladesh have reported that homegarden size ranged from 100 m^2 to 17500 m^2 with median size of 800 m^2 (Kabir and Webb, 2008) in south western Bangladesh while from Thakurgaon district in north western Bangladesh it was reported that average size ranged from 660 m^2 in small to 3300 m^2 in large gardens (Zaman et al., 2010). Smaller sized homegardens were more prevalent across all the altitudes similar to the findings by Kabir and Webb (2009) in southwestern Bangladesh which shows that the primary objective of the homegarden was for family subsistence.

Labour inputs in the homegarden will vary according to the family size and the occupation of the household heads and other members of the family. A general observation was that labour input was higher in the high altitude homegardens (**Table 5.8**) and this was also dominated by the women (**Table 5.9**). Majority of the womenfolk were busy in their garden works during the field visits engaged with planting, seeding, weeding, harvesting vegetables, preparing nursery beds, feeding poultry or watering the plants. Some were not even available at home during field visits as they had gone to the market for selling their products. The mean monthly working time of 33.3 hours is comparable with the 8 hour per week in Sri Lanka (Kumari et al., 2009) but less compared to the report from Nicaragua by Mendez et al. (2001) where men and women almost equally contributed 32.6 hr per week per family but they also observed variation in the labour inputs according to the occupation of the owner and the size and purpose of the homegarden. In large homegardens, although the labour input is higher, the division of labour is not very clear; most of the work required was done through hired labour. However, women folks look after the livestock, raising of ornamental and medicinal plants.

For long term sustainability of agricultural production system maintenance of genetic and species diversity is important. Homegardens are generally considered as suitable for *in situ* conservation of genetic resources of both wild and cultivated plant species (Bennett-Lartey et al., 2004; Fu et al., 2003; Montagnini, 2006) and women are said to play an important role in conserving both wild and cultivated traditional plant species in homegarden. The current study revealed that local seed source is important for maintenance of plant genetic resource management at community level in the homegardens. Self saved seeds and those gifted and transferred from relatives and friends are the most prevalent source followed by those seeds which were purchased, mostly the commercial plant species, and lastly by those obtained from government agencies and from the wild. Rana et al. (1998) had reported that self saved seed contributed the first source of planting material for indigenous vegetables in Kaski, Nepal whereas purchased seed is the first major source for planting material in Austria (Vogl and Vogl-Lukasser, 2003). For wood and timber species, the major source of planting material was simply self-established from the natural vegetation nearby and from the wild. Gathering from the wild was also a major source for some of the medicinal plants.

Majority of the population in rural Mizoram depend on forests for fuelwood, which is a vital source for domestic cooking as also in other hilly rural population of north east India. Apart from fuelwood rural poor traditionally collects NTFPs for their livelihood (Sahoo et al., 2010) and a major portion of the resources collected is used for consumption purpose. But the collection and consumption pattern of these resources differ according to the tribes and characteristics of the household. Maikhuri and Gangwar (1991) had also reported that in Meghalaya the consumption pattern of fuelwood varies according to ethnicity and family size. Unlike the report from Kerala homegardens (Kumar et al., 1994) where fuelwood plants from the homegarden accounts for 72% of the total fuelwood supply, the small and medium homegardens in Mizoram could not meet the requirements of the annual fuelwood demand for the households. Being a hilly tribal state in the north eastern part of India the cold winter months and the way of life demands more fuelwood. The need to warm the houses, to boil water, preparing the pig meals, etc. apart from daily cooking leads to more demand for fuelwood. As also evident from the analysis, the fuel wood consumption increase with the number of pigs reared in the sampled households (**Figure 5.3**) which indicated that a major share of the fuelwood is being utilized for preparing pig meal and similar observation was also made by Maikhuri and Gangwar (1991) that the per capita fuelwood consumption for preparing pig meal was second to cooking among Garos and Khasi tribes and per capita fuel wood consumption was higher in small families and lesser in larger family size. Apart from collection of products for household consumption other plant and animal resources life vegetables and fish and crabs and preparation of charcoal contributes to the livelihood and income generating activities of the rural poor.

The flow of energy in the homegardens was between the associated plant and animal constituents with the gardeners. In the present study we restricted our inventory to only plant resources and therefore the energy flow may not be complete without involving animals. However, the energy flow was strongly linked to the species composition, structure and function. The food plants, vegetables, tubers, rhizomes were the important homegarden outputs which directly contributed to the dietary and health requirement of the gardeners while the input to the system were brought from other parts of the system and got incorporated in the homegardens. For example, in large gardens procured animal feed and fertilizers, hired labour was used for homegarden production while the homegarden input was minimal for small and medium sized garden. The extent of production from homegarden also was dependent on biodiversity management, division of labour, integration of by-product from other agricultural systems, thus there was a visible energy exchange interaction between the household agriculture subsystems and other elements of households, more clearly in large homegardens while to a very minimal in small gardens. However, a deeper study is desired to depict the flow of energy between component systems. Nevertheless a system becomes more sustainable when there is smaller investment on non-renewable energy and external renewable energy requirements. The difference in energy efficiencies between various gardens have been observed by Shajaat Ali (2005) in Bangladesh, Pinton (1985) in Columbia and Peyre et al. (2006) in India. According to them, the efficiency diminished by increasing dependence on external inputs and greater use of non-renewable energy sources.

In the high altitude homegardens about a third of the households (30%) did not sell any of the garden products and was purely for self consumption while it was only 15% and 6% in mid hills and lowlands respectively. The small sized homegardens tended to be more of subsistence type while the medium sized and large gardens were more of commercial nature with the involvement of middlemen for the sale of the products. Larger gardens in low lands where more of areca nut trees were found the sale of the nuts were done directly from the garden. The buyer or middlemen brought young boys to climb and harvest the nuts from the trees and purchase in bulk. This was more common in the homegardens in hilly lowlands of Kolasib, Bilkhawthlir, Vairengte, etc. where Bengali traders from the Cachar valley comes and transport the product in small truckloads. Areca nuts from the smaller gardens were sold usually by the farmer themselves in the nearby markets.

Mendez et al. (2001) had reported sale of about 15% of fruit and about 22% of food (vegetable) production from homegardens of Nicaragua while in Sulawesi homegarden about 18% of the respondents did not sell any products while the rest sell one species or more from the homegarden (Kehlenback, 2007). But in the homegardens of southern Khasi Hills in Meghalaya, north east India Tynsong and Tiwari (2010) reported that about 35% of the produce were used for self consumption while 65% were sold in local markets. In the study villages different products which were in excess of home consumption were sold off but more percentage of commercial crops like coconut and oranges etc were sold than consumed as their main motive was for income while vegetables and other fruits were sold by self in nearby markets. Other garden products like *Passiflora edulis*, *Vitis vinifera*, *Sechium edule*, etc were usually sold through middlemen as the transportation of the product to the market was difficult for poor farmers.

Some products like coffee were sold back to the government agency who supplied them the seedlings.

The production from the homegardens contributes to the self sufficiency of many rural poor and the sale of the excess provides a source of income for subsistence economy. The efficiency of the output to input depends on the objective and goal of the garden as per the motives and other economic activities of the owner and family members. The monetary output: input revealed that large gardens were more efficient than the small and medium sized. Since the number of plant species use category was always higher in the large garden, obviously, garden produce were higher in the former than the latter. However, a large proportion of this monetary return in large gardens was used in buying input and labour for maintaining the garden and for long term production at a desired level, the reverse is the case with the small and medium gardens.

The intensity of profit generation was higher in the smaller gardens than medium and large gardens across the altitude. This may have attributed to the tendency of farmers to maximize its intensity of production through more cultivation within the available resources to meet their requirements and purpose of maintaining the garden. Similar trend was also observed in Kerala homegardens by Mohan (2004) and opinioned that it must be an adaptive management technique of the farmers as land being a constraint. The larger gardens usually maintain small plots of forest gardens to meet long term requirements like small timber and fuelwood, thus the intensity of monetary return per unit area may be much less. However, a comparison of the profit generation per unit area seems to be higher considering the findings from other studies. In the present study an average of Rs803 per 100 m^2 (**Table 5.13**) across all the garden categories amounts to Rs 80,300 per hectare which is much higher compared to the report from southern Khasi Hills (Tynsong and Tiwari, 2010).

The existing financial value of the different homegardens across the altitudes revealed that the homegardens in high altitudes of Champhai was worth much more than their counterparts in mid hills and lowlands. Although the financial worth is much less as compared to the different homegarden categories reported by Mohan (2004) from Kerala which might owe to high profit from areca nut and coconut trees that require less maintenance input.

The role of home gardening in rural economy has been reported from many studies in tropical countries around the world. Kabir and Webb (2008) reported it to vary between 6-54% in south-east Asia. The present study revealed that income from homegardens contributed between 19.6% to 52.1% share of the household income. Varying results in this regard has been reported from many other studies elsewhere. Zaman et al. (2010) reported that homegardens in half of the sampled households had a percent share of 10-20% of the total income with least in above 30% share in Thakurgaon district, Bangladesh while in southwestern Bangladesh it was reported to contribute be 15.9% (Motiur et al., 2006). Interestingly a study from Bieha district in Burkina Faso reported upto 75% share from homegardens income based on the yield of the products which was actually reported by the respondents to be much lesser in percent share from small and medium sized homegardens (Tang, 2011). In the neighbouring state of Meghalaya, India, Tynsong and Tiwari (2010) have reported that about only 7% was the contribution of homegarden towards people's average annual gross income. Usually there is a general trend that incomes from smaller homegardens have a lesser share to total household income compared to the bigger homegarden as also evident from the present study owing to the fact that larger garden have a more profit motive with higher composition of commercial plant species with higher input investments while in smaller gardens land is a constraint and composition of commercial crops is less but with more food crops. In the Mid hills and lowlands the difference in contribution to total household income between small, medium and large gardens were not large unlike in the highlands (**Table 5.15**). This may be due to more composition of commercial plants like areca nut trees, even in small gardens, which require less space and climatic suitability of the crop in lower altitudes. This is also evident from **figures 5.5** to **5.7,** where in lower altitudes contribution to garden income was dominated by areca nut.

The market orientation affects the species dominance in the homegardens but didn't impact much on the species composition. This implies that the homegardens in Mizoram maintains the species diversity to some extent and didn't adapt solely to commercial crops only for profits. Major et al. (2005)

have also reported of high positive correlation with species dominance and higher market orientation but the native species was not affected by market orientations. Similarly in the present study although higher species dominance was observed in homegardens with more market orientation the indigenous species was not neglected and the high dominance may be due to incorporation of commercial crops like areca nut, citrus, coconut, litchi, passion fruit, etc., mostly in the lowlands but not at the cost of traditional plants. But of late the introduction of red oil palm (*Elaeis guineensis*) in the some of the districts by private firms with the assurance of buy back of the produce with high returns in a short span has attracted lot of farmers. Although the governments' primary aim of the scheme was to reduce jhum cultivation and rehabilitate bamboo flowered area, farmers have also started introducing them in the homegardens with the hope of earning better return from their land but the ecological implications are vital for sustainability of the systems.

The number of plants species grown in a garden is an important indicator of diversity but from the utility point of view, it's not only the number that matters, but also the diversity in functions of the plants. To meets the requirements of dietary and cash requirements of the households, food crops composed of carbohydrates and protein and other medicinal uses should be fairly represented in the system. In the Cachar homegardens eight use categories were reported by Das and Das (2005) while in Bangladesh seven use categories were reported by Millat-e-Mustafa et al. (2002). In the present study plants were categorised into eleven groups and prevalence of variety of plant uses indicate the reliance on homegarden for nutritional requirements. Fruit trees have been reported as a major component of the home gardens in studies done in other tropical countries (Clerck et al., 2000; Mendez et al., 2001; Gajaseni and Gajaseni, 1999). In the present study also fruit trees have a major component in the plant use which ultimately contributes to the nutrition requirements of the households. In some of the remote villages medicinal plants in the homegarden seem to be an important component but they were not used for direct cash income but more for social cohesion and were shared freely with the villagers who had ailments which was in contrast to the observation by Kumari et al. (2009) where cash income was generated by majority of the households from the medicinal plants in Sri Lanka.

The sustainability of the homegardens lies not only on the species composition, diversity, species richness and intrinsic structure of the homegardens but also on the disturbing forces that emanate from the surrounding biophysical and socio-economic environments. Although it is premature to conclude that the small gardens are more sustainable than medium and large sized homegardens within our limited study but there are enough indication supplying our arguments due to higher species density, low risk management, higher homegarden return per unit area in the former than the latter.

5.5 Conclusion

This chapter tried to understand the socio economic aspect of traditional homegardens in Mizoram where tropical homegardens have not received enough attention although they continue to play a vital role in the livelihoods of many rural poor. The study revealed that the homegardens in the higher altitudes were comparatively older than the mid hills and lowlands; and smaller homegardens were more prevalent than the medium and large sized homegardens. Although the main purpose of maintaining a homegarden is for subsistence for many of the farmers, majority of them sold their surplus products for income generation while larger gardens tended towards commercialization for higher economic benefits and as a choice of employment opportunity. Women play an important role in maintaining and controlling the gardens than their male counterparts in the family. There is a good exchange of seeds and other planting materials. Livestock especially piggery is an important component of the households. As pork is the favourite meat in the area, piggery is an important factor in the annual fuelwood consumption in the households. From the sale of surplus products about 19.6% in small to 52.1% in large gardens were contributed by the homegardens to the total household income.

Smaller gardens contribute maximum resiliency with the objective of household food security where the elder female members of the household take the major role of managing the garden whereas the large homegarden are managed by the male member of the family with use of external labour.

Smaller homegarden with lesser monetary benefits were found to be more sustainable from ecological point of view as compared to large gardens. The homegardens' multipurpose use makes them an ideal space for *in situ* conservation of medicinal plants.

Chapter 6

Ecological studies in the traditional homegarden

6.1 Introduction

Soil properties are one of the agro-ecological factors that play an important role in determining species composition and productivity in terrestrial ecosystems. The influence of soil factors on crop diversity has not yet been studied in detail but in general low crop diversity is said to occur on rather marginal harsh environments having only poor soil quality (Millat-e-Mustafa et al., 1996; Okubo et al., 2003; Wiersum, 2006). The integration of trees into farmland has been suggested to combat soil nutrient depletion in tropical cropping systems (Sanchez, 1995). Trees are able to mobilize nutrients from the subsoil and then return these nutrients to the topsoil making them available for an annual crop (Buresh and Tian, 1998). Changes in physical and chemical properties affect soil fertility and therefore, focus on ongoing soil quality efforts must be made on protecting or restoring critical soil functions (Hoper, 2000) and using good agricultural management practices. However, protection and prevention of further soil degradation requires an integrated approach based on existing and new knowledge (Karlen et al., 2003).

Decomposition is an important part of all life cycles both in the terrestrial and aquatic environment. Litter fall and litter decomposition are two essential process by which the nutrient pool in terrestrial ecosystems is maintained (Karmas, 1970). After leaves fall they build up on the forest floor creating a layer of nutrients and litter on top of the soil. This layer is not only important for food chain as it acts as food for many microscopic beings, but more importantly it acts as a way for recycling the nutrients back into the soil. As the leaves decompose, the nutrients are released back to the ground where it helps to feed vegetation in the surrounding area. The tree species differ in leaf litterthe decay rates and in the rate and pattern of nutrient release. The rates at which litter fall decay occurs is important in understanding the productivity and nutrient budgeting of homegarden systems (Isaac and Nair, 2006). Therefore, research needs to be carried out on the nutrient flux of traditional homegardens to understand the functional efficiency of such systems. There have been relatively few studies on litter dynamics and nutrient release pattern from tropical homegardens (e.g. Jensen, 1993; Benjamin et al., 2001; Isaac and Nair, 2006; Seneviratne et al., 2006; Das and Das, 2010).

Allelopathy is yet another interference mechanism, in which live or dead plant materials release chemical substances, which inhibit or stimulate the associated plant growth (May and Ash, 1990). Allelopathy may also play an eminent role in the intraspecific and interspecific competition and may determine the type of interspecific association. Several studies have indicated that the allelochemicals are toxics which may inhibit shoot/root growth, nutrient uptake, or may attack a naturally occurring symbiotic relationship thereby destroying the usable source of plants of a nutrient. The reduction in germination (Rice, 1974) and growth from the allelochemicals are attributable to restrain cell division, reduction in mineral uptake, hinder or augment respiration, hamper the production of protein and leghemoglobin in certain crops and thereby affecting the vegetation composition (Muller, 1966 and Tukey, 1969). Allelochemicals which inhibit the growth of same or different species at higher concentrations may not influence the germination and growth at lower concentration of extracts and vice versa.

The inclination of leaves has also been recognized as an important factor influencing the efficiency of solar radiation utilization in plant canopy (Saeki, 1960; Monsi and Saeki, 1978). The leaf area index (LAI) and leaf area density (LAD) are identified as two important determinants in canopy manipulation studies in agro forestry and home gardens. The tree leaves often tend to form dense clusters on twigs which in turn assemble to make up tree crown and the whole vegetation canopy. According to Kira et al. (1969), Shinozaki and Kira (1977), such a cluster structure could increase the total LAI to a considerable extent and thereby bringing significant productivity. Studies on tree-crop interactions in agroforestry systems as well as home gardens are important in providing better understanding to the complex mechanism in which they interact and influence upon each other. The results would also provide scientific basis for designing a proper system in order to attain maximum productivity and sustainability. In this study an attempt has been made to find out the soil nutrient status in homegardens of Mizoram and to understand the litter decomposition and nutrient release pattern, the allelopathic effect of trees on crops and influence of tree canopies on the crops underneath in the homegarden.

6.2 Methodology

6.2.1 Homegarden Soil sampling and analyses

Five cores (6.5 cm inner diameter) from 0-15 cm and 15-30 cm depth were collected from each selected homegarden in different altitudes in the month of March- April. All the soils collected were pooled depth-wise and altitude wise and sieved through 2mm mesh screen. The soil moisture content (SMC), pH, ammonium-N and nitrate-N were determined within 36 hours of sampling following standard procedures given in Anderson and Ingram (1993). Rest of the soil samples were air-dried and analyzed for total kjeldahl nitrogen (TKN) using Kel Plus (Pelican model), while available phosphorous and soil organic carbon (SOC) was estimated by molybdenum blue method and rapid titration method respectively as given in Allen et al. (1974). Water holding capacity (WHC) was determined using Keen's box and the SOC values were multiplied by a constant (1.724) to obtain the soil organic matter (SOM) values (Allen et al., 1974). Soil texture was determined by Boucous hydrometer method (Anderson and Ingram, 1993).

6.2.2 Litter decomposition studies in the homegarden

The freshly fallen leaf litters of some common home garden tree species *viz. Artocarpus heterophyllus, Mangifera indica, Areca catechu, Tamarindus indica, Citrus indica* were collected during the peak litter-fall period (winter). A sub sample of the litter samples were air-dried and kept in hot air oven at 80°C for 48 hours for the determination of dry mass. The oven-dried samples were powdered in Wiley mill for chemical analysis.

Litter decomposition study was conducted using nylon-bag technique (Gilbert and Bocock, 1960). Ten grams of air-dried litter samples were kept in 20 x 20 cm nylon bag having 1x1mm mesh size. The bags were placed in the study site at the homegarden in Aizawl (92°41' E and 23°44' N 950 m above msl) following complete randomized experimental design. Three bags were recovered at monthly intervals. The adhering residual materials were separated carefully from the samples and then oven-dried at 80°C for 48 hours, weighed and powdered for chemical analysis. Nitrogen was estimated by Kjeldahl method in pelican semi-automatic N analyzer (Kel plus). Total P was estimated colorimetrically using the Olsen's molybdenum blue method (Anderson and Ingram, 1993). For estimation of lignin content 0.5 g of powdered plant sample (air-dried) was taken in a test tube, 20 ml of 72 % H_2SO_4 added and kept in deep freeze for 24 hours. This is followed by centrifugation at 3000 rpm. for 15 minutes. Residue was collected and washed to remove traces of H_2SO_4 and then oven dried and the weight was recorded. The amount weighed is the total lignin content. The result was calculated in percentage of lignin content with respect to total weight of the sample. Similarly for the estimation of cellulose content, 0.5 g of powdered plant sample (air-dried) was taken in a test tube and 25% aqueous KOH (w/v) was added. The mixture was then centrifuged at 3000 rpm for 15 minutes. The residue was washed with distilled water till trace of KOH was remained. The residue was then oven-dried at 105 ^{o}C for 24 hours and dry weight of the same was recorded. The result was calculated as in case of lignin.

Organic matter decay constants for the leaf litters were computed using negative exponential decay model of Olson (1963): X/X_0=exp (-kt), where X is the weight remaining at time t, X_0 is the initial weight, exp the base of natural logarithm, k the decay rate coefficient and t is the time Further, the time required for 50% (t_{50}) and 95% (t_{95}) decay were calculated as t_{50}=0.693/k and t_{95}=3/k (Bockheim et al. 1991). Nutrient content of decomposing leaf litter was derived as: % Nutrient remaining = (C/C_0) x (DM/DM_0) x 100, where C is the concentration of nutrient in litter at the time of sampling, C_0 is the concentration of nutrient in the linitial litter samples, DM is the mass of litter at the time of sampling, DM_0 is the mass of initial litter samples kept for decomposition (Bockheim et al. 1991). Tukey test was employed to compare the means. The effect of initial litter chemistry on the decay rate was tested using the linear regression function, Y = a+bX.

6.2.3 Allelopathic tree-crop interactions in the homegarden

Leaves of mature trees (approx. 20 years old) were collected from the homegarden in Aizawl (92°41' E and 23°44' N 950 m above msl). The leaves from the top, middle and bottom of selected tree canopy were plucked, mixed in equal proportions and air-dried for seven days. The 5 home garden trees *viz.* Jackfruit (*Artocarpus heterophyllus* L.), Lemon (*Citrus indica* Tanaka), Mango (*Mangifera indica* L.), Tamarind (*Tamarindus indica* L.) and *Areca* nut (*Areca catechu* L.) were regarded as donor plants, while the 5 food crops [chilli (*Capsicum annum*), soybean (*Glycine max* (L.) Merr.), maize (*Zea mays* L.), paddy (*Oryza sativa* L.) and lady's finger (*Abelmoschus esculentus* (L.) Moench)] were treated as receptor plants. The aqueous extracts were prepared by adding 100 g crushed fresh mature leaves in 500 ml distilled water (1:5 w/v), mixed thoroughly and soaked for 24 h at room temperature. This preparation was considered as 20% for further dilution. Thereafter, the mixtures were filtered through ordinary filter paper and the stock solution was stored in dark. Then final concentrations (w/v) 4, 8 and 16% of the extract were prepared by dilution with distilled water.

The experimental treatments consisted of 3 factors: (i) Donor tree extracts: 5 (Areca nut, Jack, Lemon, Mango, Tamarind), (ii) Recipient crops: 5 (Chilli, Lady's finger, Maize, Paddy, Soybean) and (iii) Extract concentrations: 5 (0, 4, 8, 16, 20%). The treatments were replicated thrice in completely randomised design.

Ten seeds of each test crop were placed in sterilized Petri plates (12 cm dia.) containing evenly spread absorbent cotton and saturated with respective extracts concentration. Initially 10 ml extract was added to each Petri plate followed by 5 ml at every alternate day. The control was treated with 10 ml distilled water. The number of germinated seed were recorded daily, while the seedlings root and shoot length were recorded on 10^{th} day. Five ml extract/distilled water was added to keep the medium moist. The Petri plates were kept under natural light dark cycle (24) at 25-30°C. The following nomenclatures were used as T_0: Control (distilled water) 0%; T_1: 4% extract solution; T_2: 8% extract solution; T_3: 16% extract solution and T_4: 20% extract solution

The emergence of the radicle from the seeds was regarded as germinated and germination was recorded daily till 5^{th} day. The magnitude of inhibition versus stimulation was compared by Response Index (RI) as under:

If T > C the RI = 1 - (C/T)
If T = C then RI = 0
If T < C then RI = (T/C) – 1

Where, T: Treatment mean (number of seeds germinated or mean plumule/radicle length of germinated seeds), C: control mean. A positive RI indicates stimulation, while negative denotes inhibition (Richardson and Williamson, 1988).

Relative Elongation Ratio (RER) of shoots and roots of crops was also calculated as per Rho and Kil (1986) as under:

R = (T/Tr) x 100; where, R : Relative Elongation Ratio, T : Response of treatment crop and T_r : Response of control.

The air-dried fresh leaf samples were grinded and the extracts were prepared as per laboratory bioassay by fully mixing the powdered samples in distilled water in ratio of 1:5 (w/v) (200 g powder in 1000 ml distilled water). The mixtures were kept in dark at room temperature for 24 h and then filtered through Whatman no. 1 paper. These filtrates were considered 20% extract for further dilution. Four different concentrations of the extract from each tree species were prepared by diluting the initial extract (20%) with distilled water. The following concentrations of the extracts were used for the study: 4% (T_1), 8% (T_2), 16% (T_3), 20% (T_4) and a control with only distilled water (0%; T0). Five seeds of each test crop were sown in polypots (5 kg soil mixture with garden soil, FYM and sand mixture in 3:1:1 ratio per pot) and irrigated initially with 500 ml respective extract solutions. Ten polypots were prepared per treatment. Three seeds of each test crop were sown per pot. The polypots were then kept in green house (with temperature ranging from 25-30^{0}C and 70-75% varying relative humidity) and immediately irrigated with 100 ml of respective leaf extracts and irrigated twice weekly for 30 days. Separate set of control were maintained for each crop with distilled water. Germination was recorded after the emergence of seedlings, which were thinned out to one per pot. Shoot length and root length and dry matter of seedlings were recorded on 30th day. Percentage growth inhibition was calculated using the following equation: Percentage inhibition (%) = [(Control value - treatment value)/Control value] x 100.

6.2.4 Effects of tree canopy on the germination and growth of some agriculture crops

Field experiment was conducted in the homegarden in Aizawl (92°41' E and 23°44' N 950 m above msl). Non-dormant fertilized seeds of 5 important agricultural crops were used to determine the influence of canopy on 3 parameters namely, germination, root length and shoot length sown under 3 different canopies. The experiment consisted of three levels of treatments namely: full canopy (canopy I), semi-canopy (canopy II), and exposed area (canopy III), which included three plots, in which 10 seeds each were planted in the three different plots, 5 agricultural crops viz. maize, chilli, french bean, lady's finger and mustard seeds were planted within each subplot (row) in all the experimental setup. Each seeds were planted in such a manner that each has ample space for growing up (20 cm apart). Each individual plant was planted separately and the plots were spaced with at least 3 meter away from each other. The experiment was replicated 3 times, altogether 30 seeds for each crops (10 seeds each × 3 plots × 3 treatments × 5 species). The plots were examined every day both in the morning and evening to check for germination. The emergence of the radical from the seed was regarded as germinated and germination profile was recorded every day. After the emergence of the seedling, the germinated plants were allowed to grow for >15 days, afterward, the seedlings were uprooted meticulously in such a manner that not a single root was broken in the process. The uprooted seedlings were washed thoroughly under running water till all the soil was removed completely and the length and shoot length of the seedlings were measured. The ambient prevailing light intensities (TES 1332A, Digital Lux Meter, No. 051106796) and temperatures were also recorded.

6.3. Results

6.3.1 Physico-chemical properties of soil in the homegarden

Among the physical properties of soil moisture content differed significantly ($p<0.01$) between gardens across the altitudes **(Table 6.1)** whereas water holding capacity did not vary significantly in the top layer. Greater soil moisture content and water holding capacity was recorded in the low altitude gardens.

Table 6.1**:** Physical and chemical properties of homegarden soils at different altitudinal locations.

Parameters		High Lands		Mid Hills		Low lands		*F test*	
		0-15cm	15-30cm	0-15 cm	15-30cm	0-15cm	15-30cm	0-15 cm	15-30 cm
Moisture content (%)		21.31±1.7	18.81±0.65	23.03±0.37	22.770.20	26.82±0.38	23.37±0.71	11.28 **	28.59**
WHC (%)		44.15±3.23	41.32±1.70	50.4±2.21	47.67±1.78	51.06±0.95	45.21±1.27	4.03 ^{ns}	6.01*
Soil texture	Sand (%)	63.92±3.33	63.43±1.16	68.18±1.46	63.08±1.86	62.29±3.56	59.51±2.41	1.61 ^{ns}	1.99 ^{ns}
	Silt (%)	26.65±2.00	24.01±1.98	20.25±0.75	19.16±1.13	29.57±2.52	32.77±1.65	9.37*	27.04**
	Clay (%)	9.42±1.33	12.57±1.53	11.56±1.06	17.75±0.84	8.14±0.67	7.72±0.41	4.02*	35.23**
Textural class		Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Loamy sand	-	-
pH		5.65±0.17	5.35±0.22	5.27±0.07	5.33±0.12	5.68±0.05	6.04±0.04	6.48*	11.42**
SOC (%)		1.22±0.09	1.07±0.04	2.66±0.12	2.57±0.08	1.26±0.15	1.05±0.03	67.27**	384.45**
SOM (%)		2.11±0.06	1.85±0.06	4.59±0.21	4.44±0.14	2.17±0.25	1.81±0.05	81.76**	397.78**
TKN (%)		0.16±0.01	0.14±0.01	0.49±0.04	0.47±0.05	0.22±0.02	0.20±0.03	66.23 **	39.7**
C/N ratio		7.81±1.14	7.94±0.78	6.15±0.56	5.66±0.35	5.73±0.27	5.25±0.43	3.23 ^{ns}	10.32**
NO^{-}_{3}-N (µg g^{-1})		4.16±0.29	3.01±0.36	6.32±0.32	5.06±0.13	6.24±0.45	5.76±0.22	17.35**	47.17**
NH^{+}_{4}-N (µg g^{-1})		3.24±0.21	2.58±0.33	4.51±0.52	3.92±0.11	5.14±0.14	4.78±0.15	12.6**	38.56**
PO^{-}_{4}-P (µg g^{-1})		6.17±0.26	5.61±0.47	4.55±0.29	3.44±0.3	6.19±0.61	5.17±0.32	7.61*	14.3**

*p<0.05, **p<0.1 (n=9)

Soil pH was acidic (5.27- 5.68) in all the stands with little variation. SOC and TKN varied significantly ($p<0.01$) across the altitudes and were recorded higher in mid altitude homegardens whereas available form of nutrients (ammonium-N, nitrate-N) registered lower values in the high altitude gardens and higher values in low land gardens while available phosphorus was recorded highest in mid altitudes. The concentration of Kjeldhal nitrogen was higher at surface soil (0-15 cm) layer and declined with increasing depth. C/N ratio was higher in high altitude gardens and lowest in low altitude gardens. The concentration of nitrate-N was greater than ammonium-N throughout the study. The available forms of nutrients (NH^{+4}-N, NO^{-3}-N and PO^{-4}-P) were recorded with greater values in the upper soil depth as compared to the subsurface soil layer. Ammonium N was significantly correlated with nitrate N ($p<0.01$) while available P was significantly correlated with pH, SOC and TKN (**Table 6.2**).

Table 6.2: Correlation matrix for the relationship between different soil chemical parameters in the homegardens

Parameters	*PH*	*SOC*	*TKN*	Nitrate-N	Ammonium- N
SOC	-0.716**				
TKN	-0.712**	0.985**			
Nitrate-N	-0.188	0.575	0.670*		
Ammonium-N	0.083	0.264	0.401	0.911**	
Available P	0.905**	-0.721**	-0.727**	-0.206	0.025

*p<0.05, **p<0.1 (n=9)

6.3.2 Decomposition dynamics of home garden tree leaf litter:

6.3.2.1 Initial Litter chemistry

Initial nutrient and structural components of leaf litter showed variation among the homegarden tree species (**Table 6.3**). The highest nitrogen concentration was estimated in *T. indica* (1.55%) while the lowest value was found in *A. heterophyllus* (1.21%). Phosphorous concentration did not show any significant difference among the species. Lignin and cellulose contents were maximum in *A. heterophyllus* (17.50% and 25.30% respectively). On the other hand, minimum lignin and cellulose contents were recorded in *T. indica* (10.40%) and *C. indica.* (20.50%) respectively. Lignin/N ratio ranged from 6.71 to 14.46 in the order of *A. heterophyllus*>*A. catechu*> *M. indica*>*C. indica*>*T. indica*.

Table 6.3: Initial litter chemistry

Parameters	*Artocarpus heterophylus*	*Mangifera indica*	*Areca catechu*	*Tamarindus indica*	*Citrus indica*
N (%)	1.21	1.37	1.4	1.55	1.45
P (%)	0.06	0.07	0.08	0.06	0.07
Lignin (%)	17.5	14.6	15.4	10.4	11.22
Cellulose (%)	25.3	23.3	22.3	21.5	20.5
Lignin/N	14.46	10.66	11	6.71	7.74

6.3.2.2 Litter decomposition

The decomposition patterns of leaf litters of the tree species studied were considerably different (**Figure 1**). The mass loss of *A. heterophyllus* leaf litter showed three phased decomposition pattern *viz.* initial slow phase followed by a faster decomposition phase and again relatively slow decomposition phase. In *M. indica* leaf litter decomposition almost followed the same patterns but the decomposition was faster than the *A. heterophyllus* litter and the difference among the decomposition phases were more prominent. The *A. catechu* leaf litter decomposition did not show any distinct phased pattern although there was variation in decomposition rate over the six month period of its decomposition (**Figure 6.1**). Initially the decomposition was rapid following a much slow decomposition rate towards the last phase of decomposition. The *T. indica* and *C. indica* leaf litter showed totally different pattern of decomposition compared to the other three types of litter considered in this study. The decomposition pattern was straight forward and these two leaf litter samples decomposed more than 80% of their initial mass in three months period and the decomposition of *C. indica* was complete in the fifth month. The decomposition of *C. indica* was fastest among all the litter type considered in this study closely followed by the *T. indica* leaf litter. The decay rate calculated ranged from 3.90 to 8.16 in the order of *C. indica>T. indica>M. indica>A. catechu>A. heterophyllus* (**Table 6.4**).

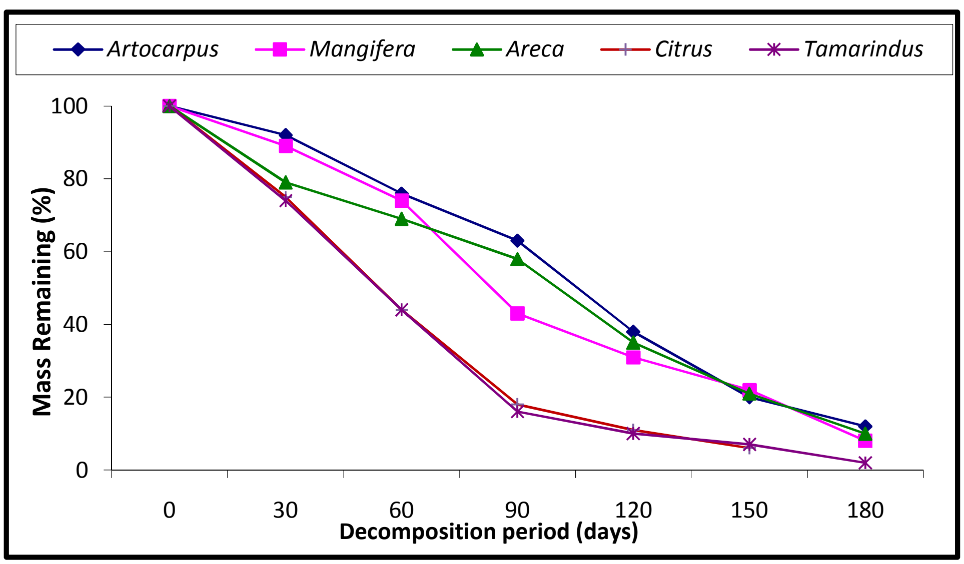


Figure 6.1: Dry mass remaining from five homegarden leaf litter during decomposition period.

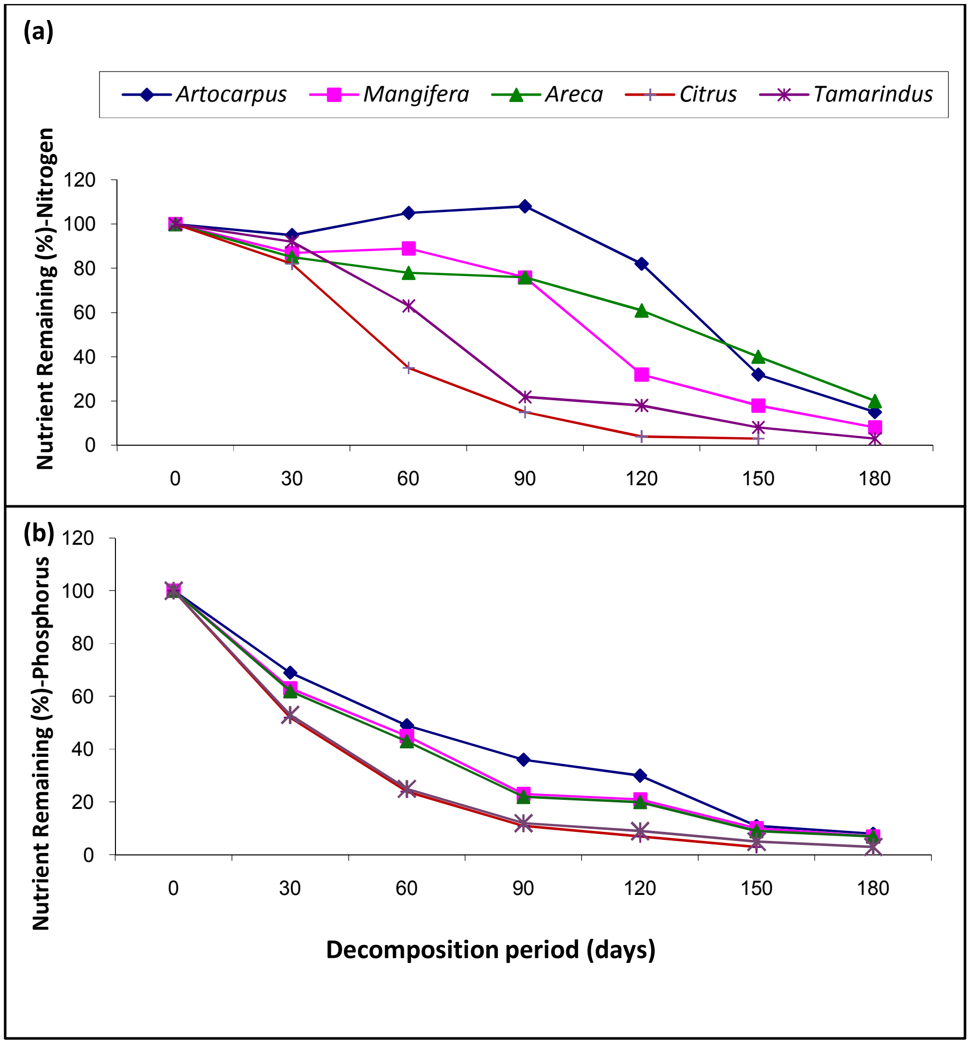


Figure 6.2**:** Nutrient remaining (%) from leaf litter of five homegarden tree species (a) N remaining, (b) P remaining.

Table 6.4. Rate of Decomposition of leaf litter from five homegarden species

Species	Decay constant (k)	t_{50} (Days)	t_{95} (Days)
Artocarpus heterophyllus	3.90	64.83	280.64
Mangifera indica	4.71	53.70	232.48
Areca catechu	4.30	58.83	254.69
Tamarindus indica	7.32	34.54	149.51
Citrus indica	8.16	31.01	134.23

The time taken for 50% decay also varied among the species where maximum time was taken by *A. heterophyllus* and minimum by *C. indica.* A significant positive correlation was found between decay rate (k) and initial nitrogen concentration in leaf litter ($p<0.01$). However, phosphorous concentration did not seem to influence the rate of decomposition as no significant correlation was observed. On the other hand, initial lignin and cellulose content and lignin/N ratio showed significant negative correlation with decay rate ($p<0.01$) of which lignin content was found to be the most influential component (R^2=0.8906) (**Table 6.5**).

Table 6.5. Relationship between initial litter chemistry (X) and decay constant (Y) from five homegarden tree species.

Litter chemistry	Regression equation	R^2	p
Nitrogen (%)	Y = -10.947 + 11.91X	0.5914	0.01
Phosphorus (%)	Y = 10.528 +75.779X	0.1029	NS
Lignin (%)	Y = 14.164 – 0.6138X	0.8906	0.01
Cellulose (%)	Y = 25.897 – 0.8954X	0.7282	0.01
Lignin/N	Y = 11.378 – 0.5635X	0.7953	0.01

6.3.2.3 Nutrient release pattern

Nutrient release from the decomposing leaf litter also varied considerably. N release was quite slow from the *A. heterophylus* leaf litter. In fact, there was no release of N in the initial phase of decomposition of this litter particularly after first month and the immobilization of N took place which increased the N concentration in the litter mass upto 90 days of incubation. After this phase of immobilization the N release was faster from the third month of decomposition (**Figure 2a**) In case of *A. catechu,* although no immobilization was observed, N release was slower till the end of third month. In *T. indica* and *C. indica* the N release was rapid from the first month onwards. The P was released gradually in all the leaf litter and was faster than the release of N although there were some variations (**Figure 2b**).

Lignin and cellulose loss from the decomposing litter mass did not show much variation among the species. Initially (0-30 days), 9-19% of the initial lignin was lost, the highest being from *A. catechu* and the lowest from *C. indica* Thereafter, the rate of loss slowed down during subsequent months and at the end of the decomposition period 55-61% of initial lignin still remained in the litter mass (**Figure 3a**). Similarly, loss of cellulose also showed similar pattern resulting in 9-23% loss during the initial month. The maximum loss was recorded in *M. indica* and the minimum was observed in *A. heterophyllus*. At the end of the study period, about 41-56% of the initial cellulose remained in the litter mass (**Figure 3b**). At the end, among the five tree species, the two components remained the highest in *A. heterophyllus* and the lowest in *M. indica*.

6.3.2.4 Decomposition dynamics

In the present study, leaf litter of the different homegarden tree species showed varying pattern of decomposition. For *A. heterophyllus*, in the initial two months the litter decomposed only around 20 % of its initial mass but in the following two months the mass loss was about 40% and after that phase the decomposition became gradually slow where only 16% and 7% mass loss took place in subsequent two months respectively. It took six months to decompose more than 85 % of its initial mass.

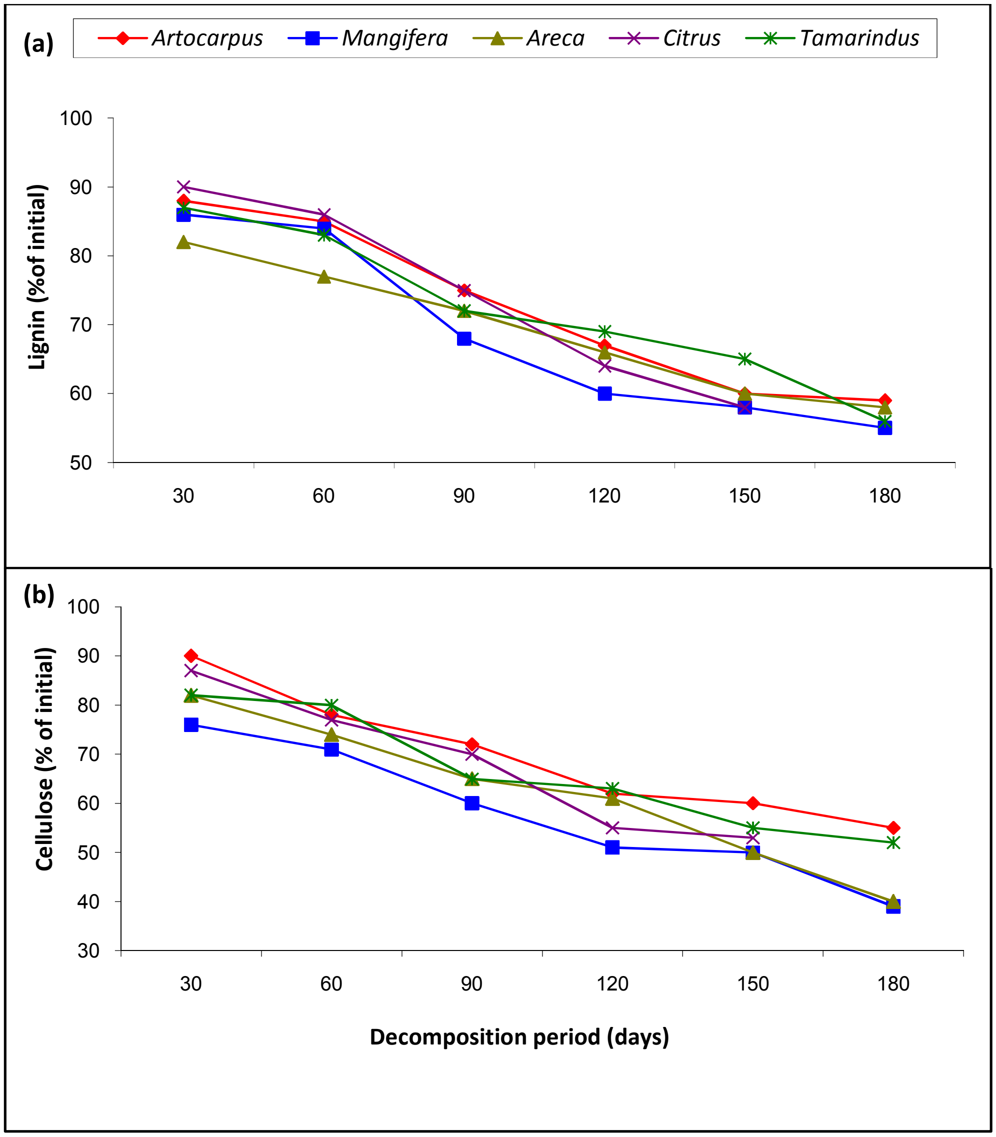


Figure 6.3**:** Residual lignin (a) and cellulose (b) from leaf litter of five homegarden trees.

6.3.2.5 Nutrient dynamics

In this study nitrogen dynamics showed varying pattern in decomposing litter of different species revealing initial decline of N concentration followed by net accumulation and release in some species (**Figure 2a**). A three phase pattern of N release was obtained in *A. heterophyllus* and *M. indica* – an initial release followed by immobilization and faster release. However, in *M. indica*, N immobilization was observed only between 30-60 days of incubation while in the former immobilization occurred upto 90 days period. In case of *A. catechu*, *C. indica* and *T. indica* N release was faster and did not show any immobilization. P content declined rapidly contributing to its faster release till 90 days period in all the species followed by a slow release thereafter.

6.3.3 Effects of aqueous leaf extracts on germination

6.3.3.1 Bioassays

Soybean: The extracts were less inhibitory to soybean germination, except 20% extract concentration of *T. indica* resulting in 48% reduction over control (**Figure 6.4**). All trees extracts significantly suppressed the shoot length and the influence was concentration dependent as evident from low RER (**Figure 6.5**). *T. indica* extract at highest concentration was most inhibitory to both shoot and root lengths. *A. heterophyllus* significantly suppressed the root length at all concentrations level of the extracts (**Figure 6.6**). However, dilution lessened the magnitude of root length inhibition by all trees leaf extracts.

Maize: The leaf extracts had no discerning effect on germination of maize. This was true for all the five homegarden trees (**Figure 6.4**). The extracts of *A. heterophyllus* and *M. indica* also had no inhibitory effect on shoot elongation while those of *A. catechu, T. indica* and *C. indica* suppressed shoot length at 16 and 20% extract concentrations (**Figure 6.5**). The root elongation got suppressed significantly by leaf extracts at 20% concentration whereas at lower concentrations (4, 8 and 16%), the inhibitory effect was minimal (**Figure 6.6**).

Paddy: The leaf extract of *A. catechu* suppressed germination of paddy by 15-35%, the highest being at 20% and lowest at 4% extract concentration. Other species, however, did not influence seed germination in paddy (**Figure 6.6**). The extracts of *A.catechu*, *C.indica* and *T. indica* at 20% concentration suppressed shoot elongation over 55% and at 8 and 16% concentrations by 20-40% when compared with control (**Figure 6.5**). On the other hand root elongation was inhibited by all the five tree species as evident by low RER (**Figure 6.6**) and the highest inhibition (30% over control) was observed at 20% extract concentration.

Chilli: The leaf extract of *M. indica* inhibited germination in chilli irrespective of their concentration. This was also true in case of *C. indica* but at 20% concentration (**Figure 6.4**). *A. catechu, A. heterophyllus* and *T. indica* also showed suppressed germination at 20% extract concentration. The inhibition in shoot length was clearly a concentration dependent in *A. heterophyllus* as is evident from a gradual decrease in RER with an increase extract concentration from 4 to 20% (**Figure 6.5**). The extracts of C. *indica* and *T. indica* also caused reduction in shoot length over 70.0% compared to control at 20% extract concentration. The extracts of *A. heterophyllus* and *T. indica* suppressed the root length of chilli which ranged from 35.2 to 76.4% while the leaf extract of *M. indica* had no discerning effect on root length irrespective of concentration (**Figure 6.6**).

Lady's finger: The leaf extract of home garden tree species had differential response with respect to germination in lady's finger. The extracts of *M. indica* and *C. indica* had strong inhibitory effect on germination compared to those of *A. catechu* and *T. indica* which were less inhibitory. *A. heterophyllus,* on the other hand, did not influence germination. The extracts of all tree species (except *A. catechu*) suppressed shoot elongation wherein the effects got reduced with decrease in extracts concentration (**Figure 6.5**). Similar trend was also observed for root length. This was clearly evident at 4% extract concentration wherein the inhibition to root elongation was completely nullified for *T. indica* (**Figure 6.6**).

6.3.3.2 Pot culture

Soybean: The leaf extracts of different tree species (except *Tamarindus* at 20% concentration) did not influence the germination of soybean. (**Table 6.6**). Shoot length was most adversely affected by *Tamarindus*, whereas, *Artocarpus* reduced only at higher concentration. The other tree species had variable responses with change in concentrations (**Figure 6.7**). Similarly, root length was adversely affected most by *Artocarpus* and *Tamarindus* (**Figure 6.8**). All tree species extracts reduced the dry matter production at 16 and 20% concentrations (**Figure 6.7**). However, the *Tamarindus* extracts were inhibited at all concentrations. The reduction in dry matter may be ascribed to the suppressed shoot and root growth.

Maize: The extracts of *A. heterophyllus* and *T.indica* prevented germination of maize at 20% concentration by 23% and 33% respectively over control (**Table 6.6**). *A.catechu* and *C.indica* inhibited shoot elongation only at higher level of extract concentration. Similarly both *A. heterophyllus* and *M. indica* at highest level of extract concentration reduced root length by 26% over control (**Figure 6.8**). It was observed that while *A. catechu* suppressed dry matter production at 8% extract concentration but for *T. indica* it was noticed at 20% concentration.

Paddy: Leaf extract application of the donor trees had no significant influence on the germination of paddy (**Table 6.6**). Similar was also the case for dry matter production. However, all the trees had stimulatory effect on shoot length of the test crop (**Figure 6.7**). Root length was significantly inhibited by *A. heterophyllus* at higher concentrations of leaf extracts i.e at, 16 and 20% levels (**Figure 6.8**).

Chilli: Germination in chilli was most significantly suppressed by leaf extract of *A. heterophyllus* at 20% concentration (**Table 6.6**). The dry matter production of the test crop was enhanced with application of leaf extract at 8% concentration for *C. indica* and at 16 and 20% concentration levels for *A. catechu*; other species however, did not affect dry matter production (**Figure 6.7**). Shoot length of the test crop was most suppressed by *A. heterophyllus* and *C. indica* at 8 and 16% extract concentrations (**Figure 6.8**). Similarly root length of the test crop was suppressed by *A. heterophyllus* and *T. indica* at 16 and 20% extract concentration (**Figure 6.7**).

Lady's finger: All the donor tree species suppressed seed germination of lady's finger at 20% extract concentration which ranged from 22.5% (*A. heterophyllus*) to 27.9% (*T. indica*) (**Table 6.6**). The application of leaf extract of the trees had differential response on dry matter production of the test crop (**Figure 6.7**). For example, at lowest concentration *A. catechu* inhibited dry matter production by 40% over control and its effect got reduced with increase in higher concentration. On the contrary, *C. indica* showed more inhibition at higher extract concentration levels. Opposite was the case with *T. indica* which showed promotion in dry matter production with increase extract concentration. It was only *M. indica* which showed a clear trend of promotion on dry matter production at all concentrations. All tree species exhibited significant inhibitory effect on shoot length of the test crop at 16 and 20% levels (**Figure 6.8**). Although no clear concentration-depended trend was noticed on the root length, two donor species viz. *M. indica* and *A. heterophyllus* promoted of root length at lowest (4%) and highest (20%) extract concentrations respectively (**Figure 6.9**) while other species inhibited the root length of the test crop.

Table 6.6. Effects of different concentrations of aqueous leaf extract of 5-tree species on germination of test crops after 30 days in pot culture.

Tree species	Treat-ments	Soybean	Maize	Paddy	Chilli	Lady's finger
Control	**T0**	**97.1**	**96.2**	**91.1**	**87.5**	**92.1**
Artocarpus heterophyllus	T1	85.3 (12.2)	92.1 (4.3)	87.5 (4.0)	90.1 (-3.0)	90.2 (2.1)
	T2	94.1 (3.1)	87.4 (9.1)	85.2 (6.5)	85.6 (2.2)	87.4 (5.1)
	T3	90.4 (6.9)	85.4 (1.2)	80.2 (12.0)	87.1 (0.5)	78.0 (15.3)
	T4	85.1 (12.4)	73.7 (23.4)	78.4 (13.9)	70.2 (19.8)	71.4 (22.5)
Mangifera indica	T1	94.3 (2.9)	87.3 (9.3)	90.4 (0.8)	91.2 (-4.2)	90.7 (1.5)
	T2	97.4 (-0.3)	85.3 (11.3)	88.7 (2.6)	87.4 (0.1)	87.6 (4.9)
	T3	95.4 (1.8)	75.9 (2.1)	84.2 (7.6)	85.4 (2.4)	76.2 (17.3)
	T4	84.4 (13.1)	80.2 (16.6)	78.2 (14.2)	78.4 (10.4)	70.1 (23.6)
Areca catechu	T1	91.4 (5.9)	89.7 (6.8)	89.7 (1.5)	92.1 (-5.3)	89.4 (2.9)
	T2	94.3 (2.9)	87.4 (9.1)	85.7 (5.9)	87.8 (-0.3)	81.1 (11.9)
	T3	85.1 (12.4)	90.1 (6.3)	80.7 (11.4)	90.2 (-3.1)	75.8 (17.7)
	T4	89.7 (7.6)	84.7 (12.0)	78.7 (13.6)	78.8 (9.9)	67.4 (26.8)
Citrus indica	T1	91.4 (5.9)	91.5 (4.9)	87.8 (3.6)	90.5 (-3.4)	89.7 (2.6)
	T2	87.3 (10.1)	90.2 (6.2)	85.4 (6.3)	87.4 (0.1)	85.7 (6.9)
	T3	88.1 (9.3)	88.6 (7.9)	80.7 (11.4)	82.4 (5.8)	81.2 (11.8)
	T4	78.2 (19.5)	87.9 (8.6)	75.4 (17.2)	78.4 (10.4)	75.4 (18.1)
Tamarindus indica	T1	97.2 (-0.1)	94.5 (1.8)	90.7 (0.4)	87.4 (0.1)	88.4 (4.0)
	T2	91.2 (6.1)	90.5 (5.9)	85.7 (5.9)	85.4 (2.4)	81.2 (11.8)
	T3	89.4 (7.9)	87.5 (9.0)	87.5 (4.0)	80.2 (8.3)	75.4 (18.1)
	T4	61.2 (37.0)	64.2 (33.3)	75.5 (17.1)	76.5 (12.6)	67.1 (27.9)

Values in the parentheses indicate % inhibition/stimulation in comparison to control treatment. **-**ve sign denotes stimulatory effect.

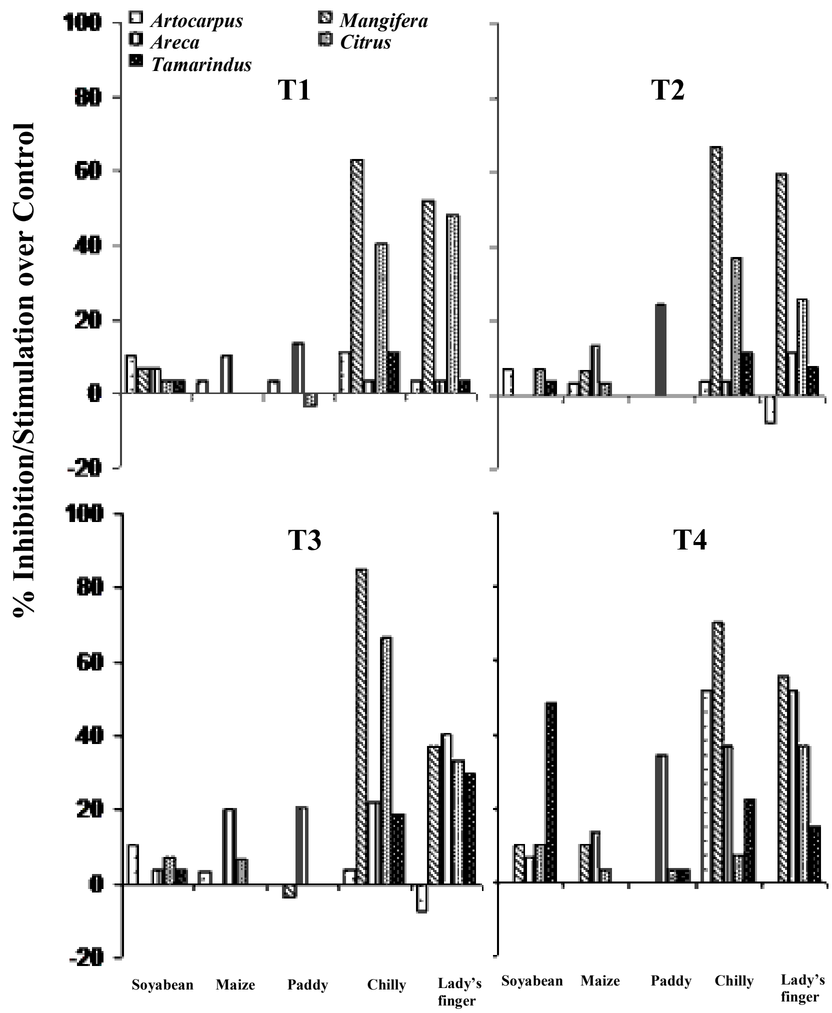


Figure 6.4: Effect of leaf extracts from five tree species on seed germination of test food crops.

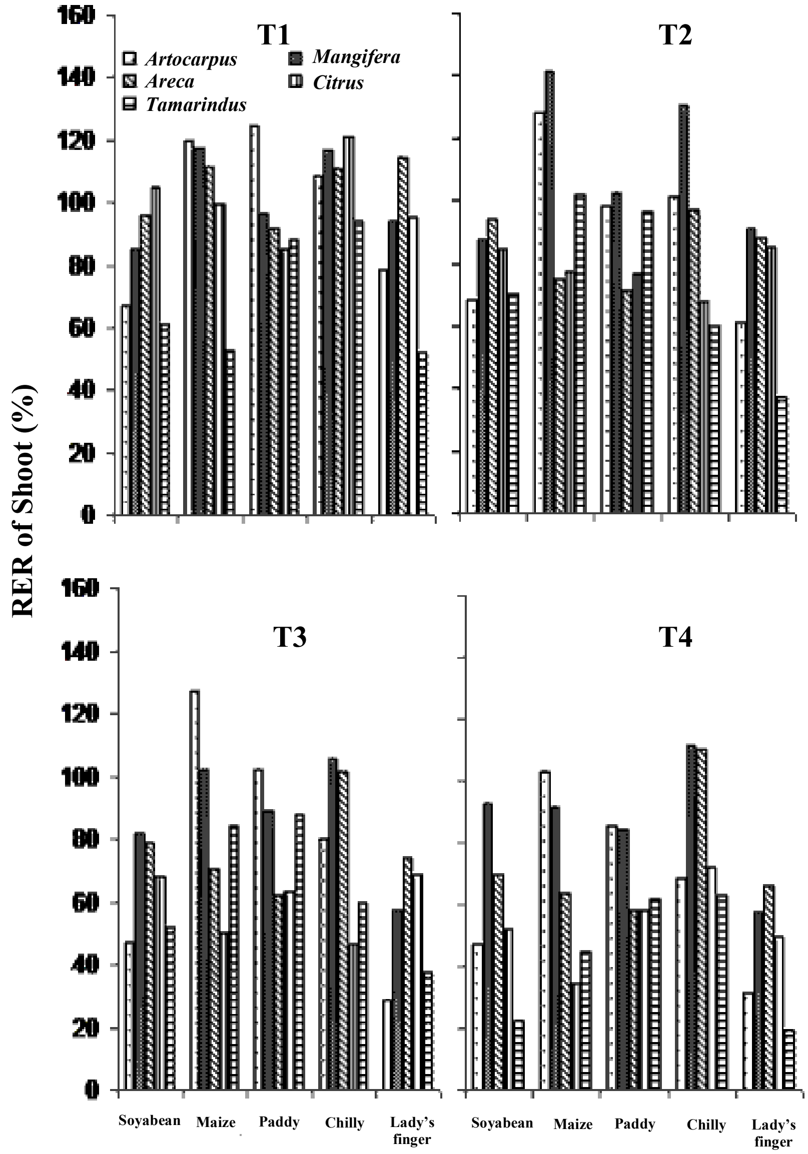


Figure 6.5: Effects of leaf extract of five tree species on the Relative elongation ratio (RER) of Shoots of test crops.

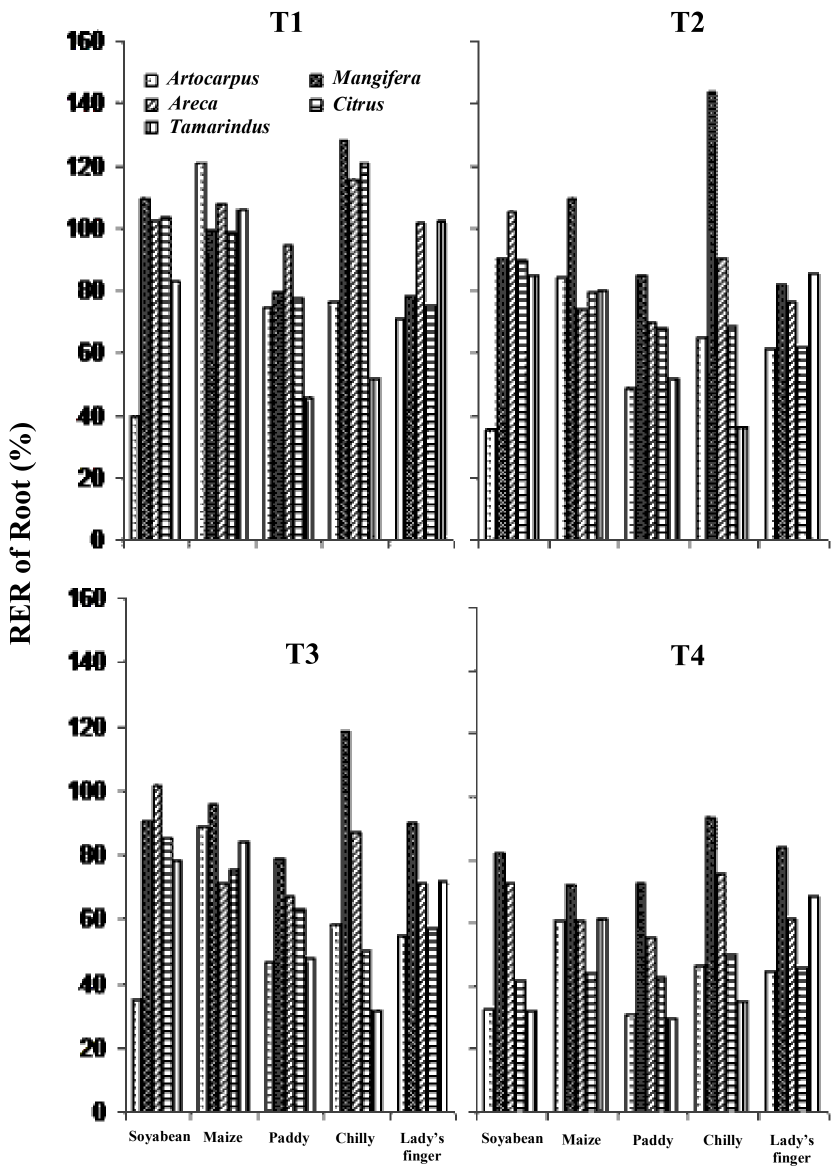


Figure 6.6: Effects of leaf extract of five tree species on the Relative elongation ratio (RER) of Roots of test crops.

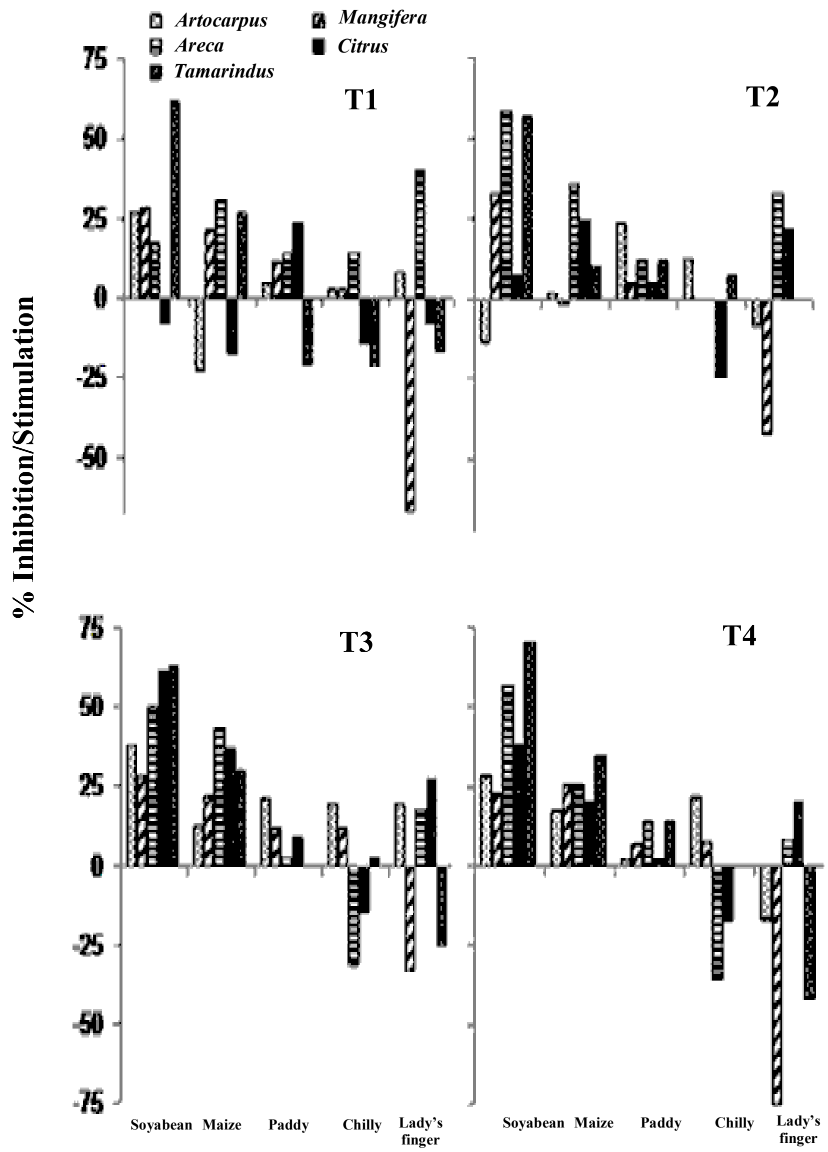


Figure 6.7: Effect of leaf extract from tree species on dry matter of test crops after 1-month pot culture.

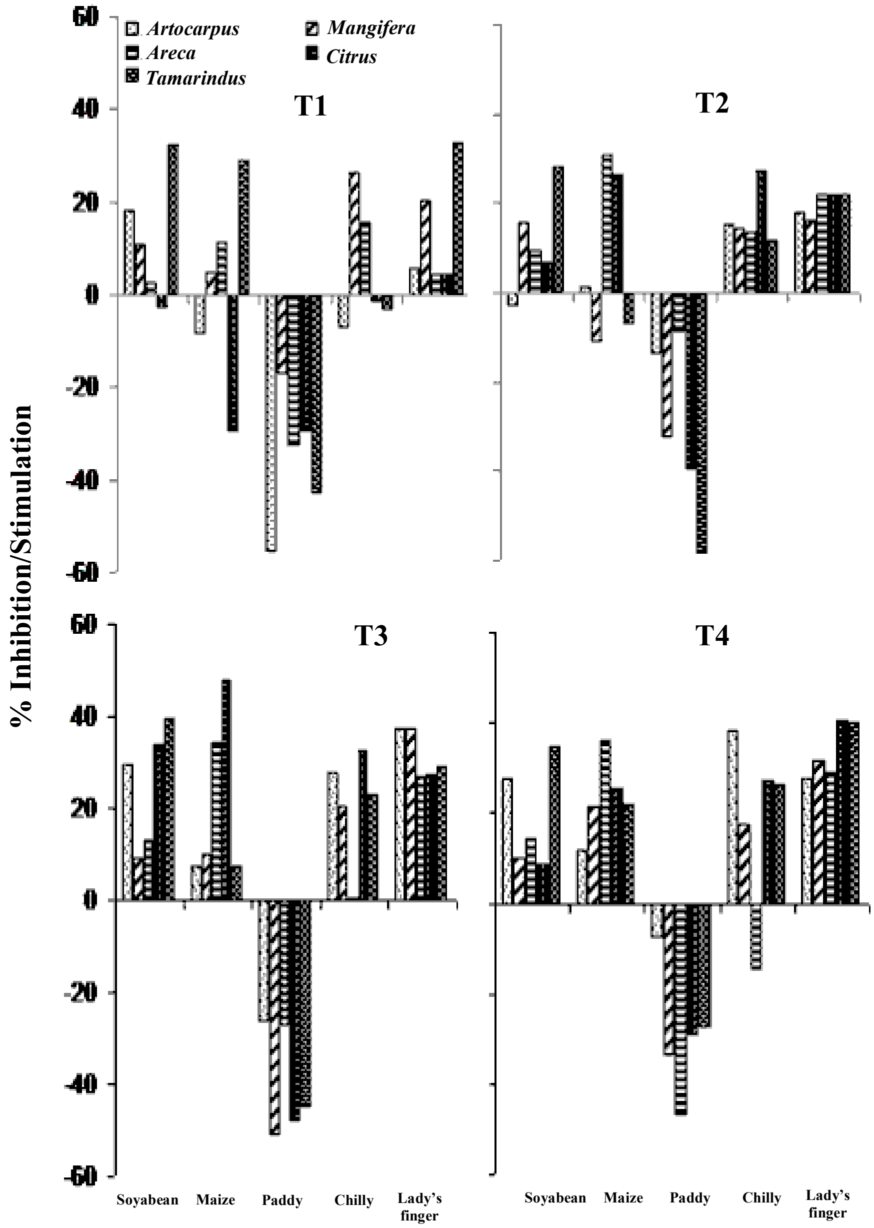


Figure 6.8: Effects of leaf extract from tree species on shoot length of test crops under pot culture after 1-month in pot culture.

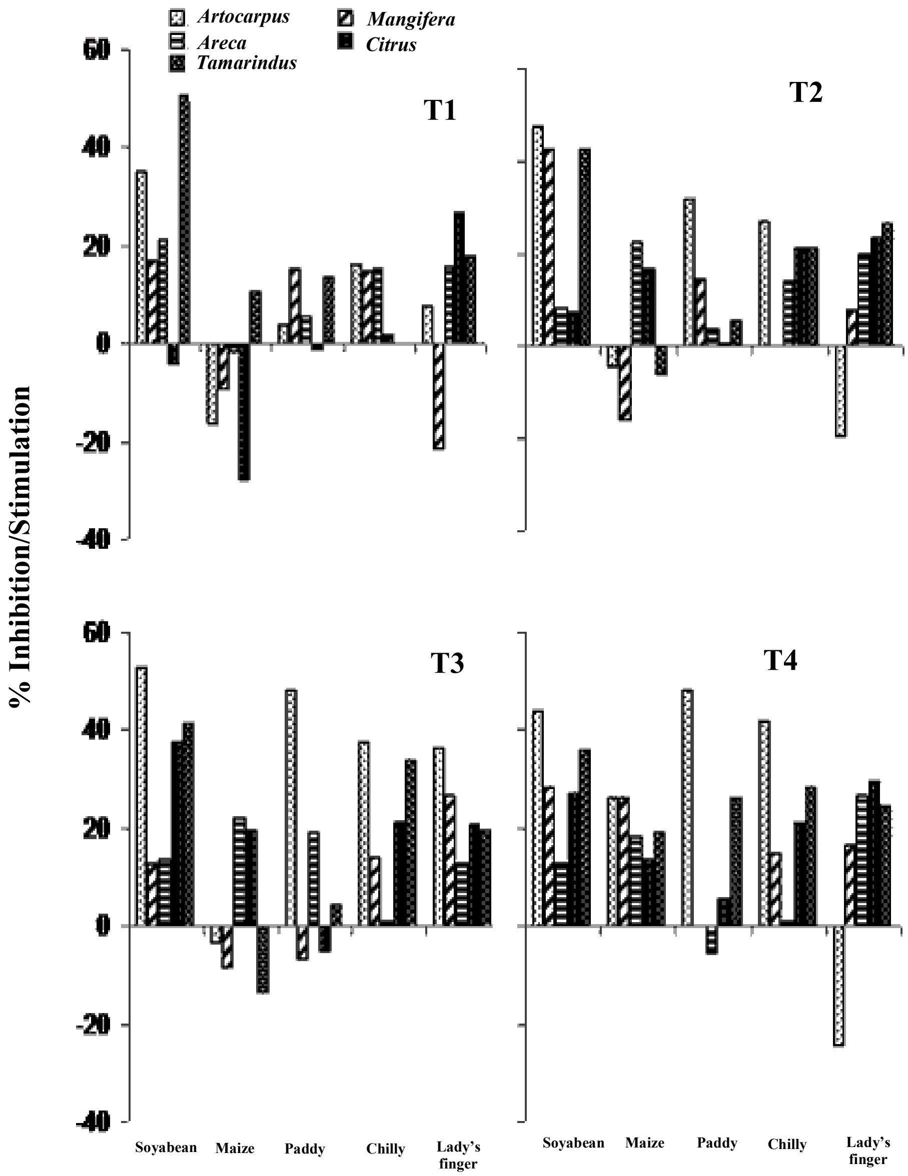


Figure 6.9: Effects of leaf extracts from tree species on root length of test crops after 1-month in pot culture.

6.3.4 Effects of canopy on the germination and growth of some agriculture crops.

Germination profiles of the 5 important agricultural crops are presented in the form of graphs (**Figure 6.10-6.14**). Germinations did not show too much variation under the tested conditions, as most of them germinated almost at the same time. The mean root length of maize (**Figure 6.15**) showed least value under Canopy I (full canopy), more or less the same in both the other two canopies. But the shoot length appears to be greatest under canopy II (26.82 cm) followed by canopy III and least under canopy I (**Figure 6.16**). Seedling root length of french bean and lady's finger showed maximum value (13.35 and 11.97 cm respectively) in canopy III and least under canopy I in french bean but the root length of lady's finger was shortest (8.80 cm) under canopy II. The seedling shoot length of french bean and lady's finger showed highest value (30.57 and 17.51 cm) under canopy I and minimum under canopy III. Seedling root length in case of chilli showed unequivocally greatest (6.9 cm) under canopy III and the mean value for root length under both canopies I & II showed more or less the same trend, but under canopy I the shoot length appears to have the longest length (10.21 cm) followed by canopy III and canopy II. Mustard seedling root length under canopy II seems to proliferate but its shoot length appears to have the least under the same condition. The mean value of root and shoot length in mustard did not vary much in all the tested condition. However, the mean value for root length of this crop was highest under canopy II. The variation in the light intensities and temperature at the experimental site are presented in **Figure 6.17**.

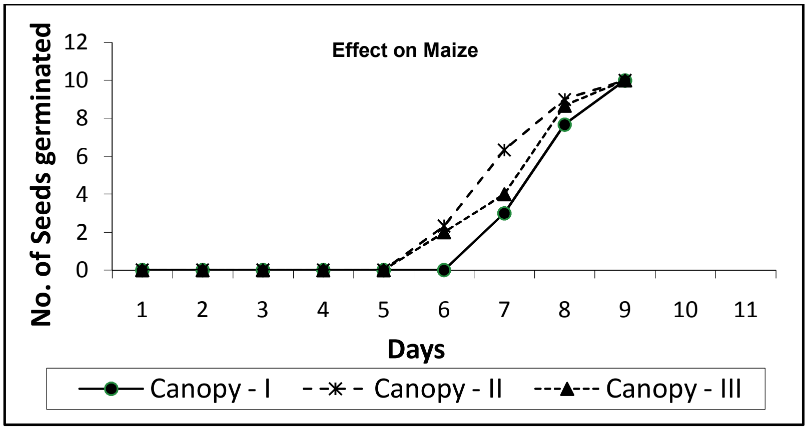


Figure 6.10: Mean number of maize seeds germinated over time under different canopies

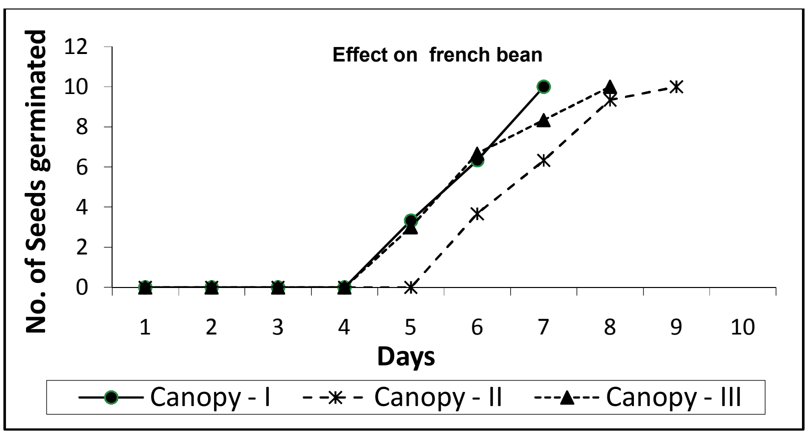


Figure 6.11: Mean number of french bean seeds germinated over time under different canopies

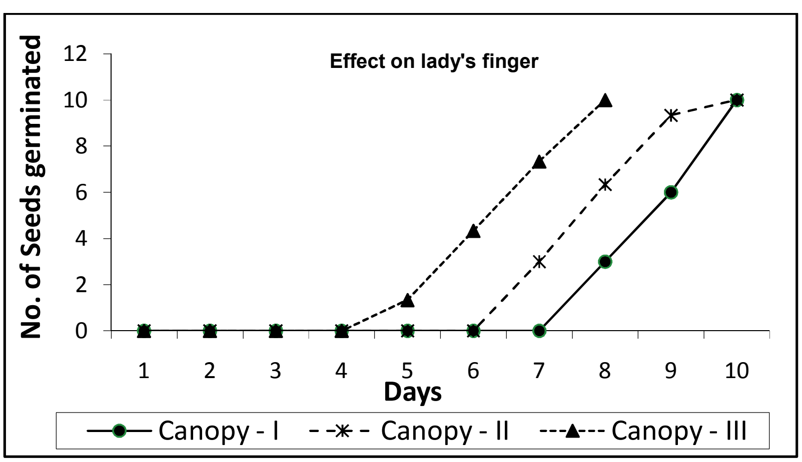


Figure 6.12: Mean number of maize seeds germinated over time under different canopies

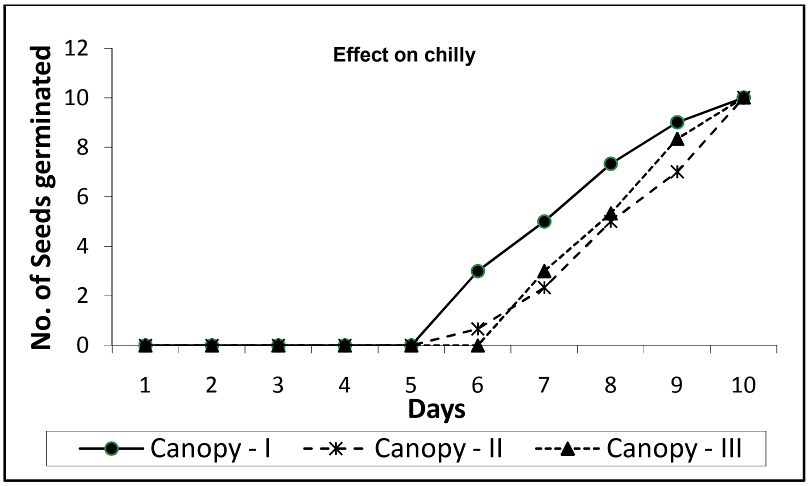


Figure 6.13: Mean number of chilly seeds germinated over time under different canopies

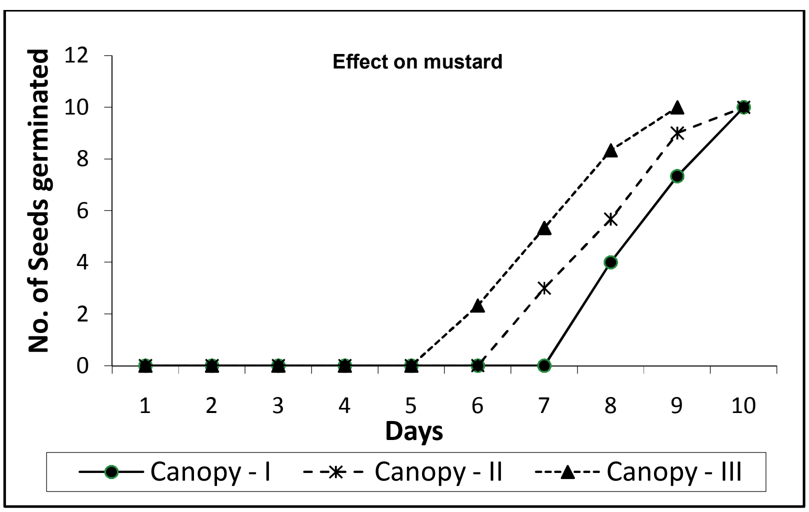


Figure 6.14: Mean number of maize seeds germinated over time under different canopies

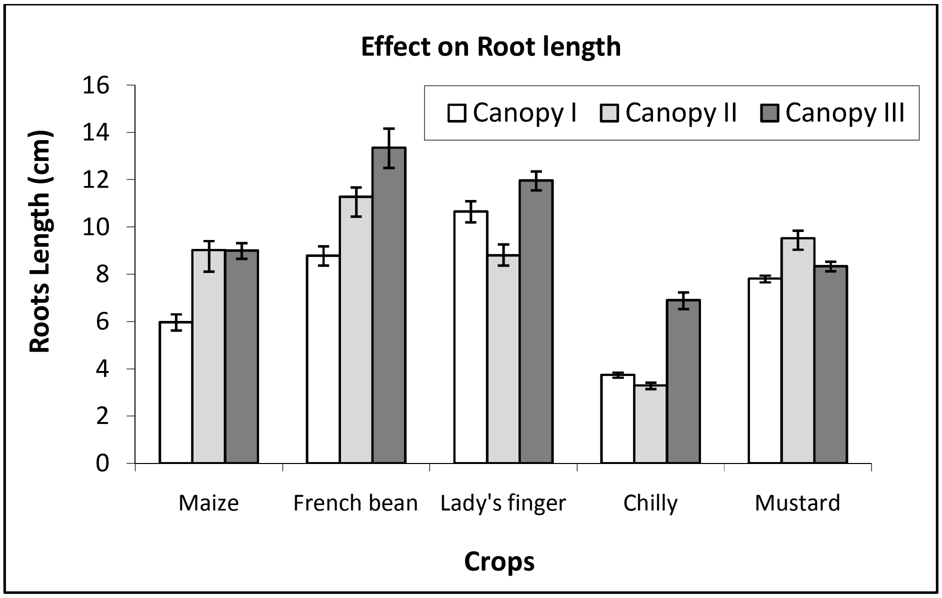


Figure 6.15: Effect of different canopies on the root lengths of test crop seedlings.

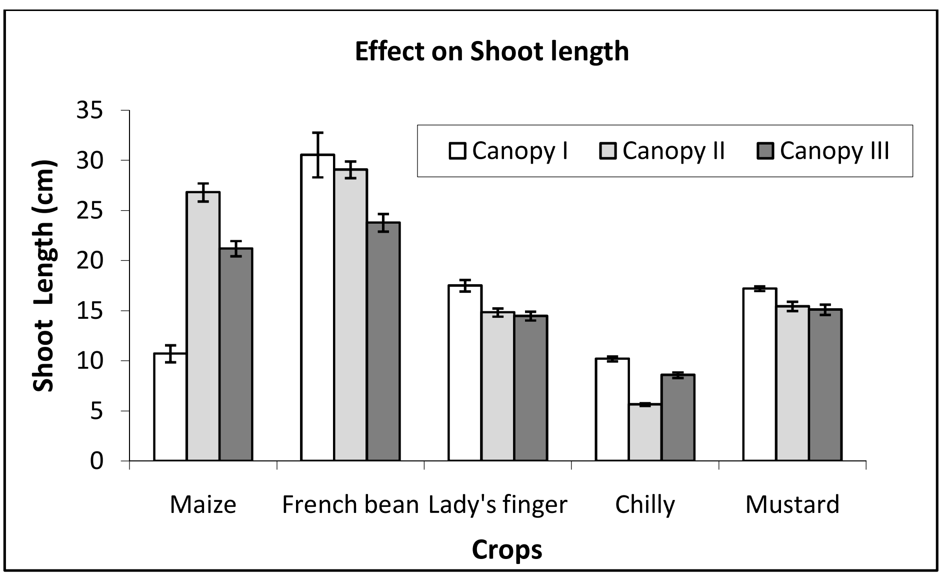


Figure 6.16: Effect of different canopies on the shoot lengths of test crop seedlings.

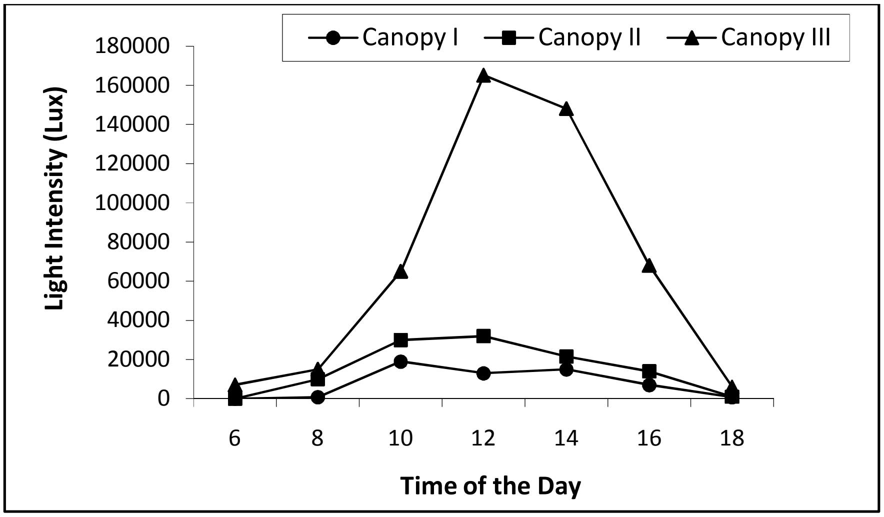


Figure 6.17: Light intensities at the experimental site

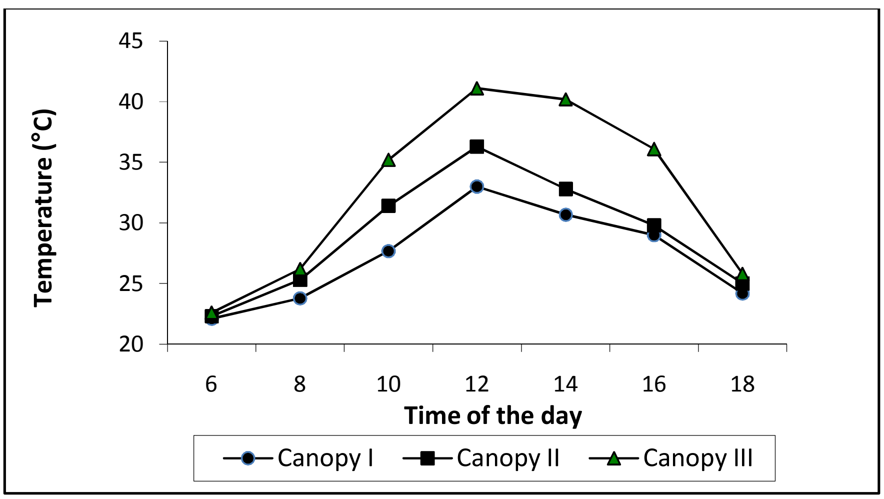


Figure 6.18: Temperatures at the experimental site

6.4 Discussions

6.4.1 *Physico-chemical properties of soil in the homegardens*

A relatively higher soil moisture content (SMC) and water holding capacity (WHC) recorded in the low altitude homegardens as compared to the high and mid altitudes might be due to dense litter layer on the floor of the lowland homegarden and also greater accumulation of organic matter, obviously related to the greater trees and shrub density. WHC of soil as influenced by organic matter accumulation is considered as one of the important indicators of sustainability. WHC in the sites declined with increasing soil depth registering greater value in the surface (0-15 cm) soil layer in all the homegardens. Water retention capacity reflects availability of water for plant uptake and is very crucial which affects crop growth particularly in areas which rely on rain-fed agriculture. In this context, Gupta et al. (1977) have reported increased WHC with greater waste application. SMC was also greater in the upper soil layer in all the home gardens. Abebe et al. (2006) opined that animal wastes along with the other contributors also play an important ecological role by providing manure for the improvement of soil fertility and crop productivity in the homegarden system. Higher values of the major soil physical properties in the top (0-15 cm) layer in the present study sites might also be ascribed to the greater accumulation of litter and other domestic waste on the floor of the traditional home gardens as use of animal wastes such as pig dung and poultry excreta is also a common practice.

However, decreasing pH with increasing soil depth in the present study may be related to organic matter content and nutrient availability which also decreased with soil depth. Organic matter produced in the homegardens may have a buffering effect on soil pH due to several processes, which include the increase in CEC and the size of the exchange complex from humification of organic matter additions, the formation of complexes with Aluminum ion, and the release of calcium and magnesium in the soil solution, thus reducing the activity of hydrogen ion (Miyazawa et al., 1993). Soil organic matter is of great importance because of its influence on soil physical, chemical and biological properties and on creating a favorable medium for biological reactions and life support in the soil environment (Franzluebbers and Arshad, 1996) and once the levels decreased; they are generally slow to recover (Webster and Wilson, 1980).

Organic matter differed across the study sites which might be due to difference in plant species composition and organic matter in the soil surface. In the medium altitude homegardens trees and shrub diversity, density and basal area are higher which must have resulted in higher litter accumulation on garden floor leading to higher SOM.

The difference in the available nutrients among homegardens may be related to the variation in SOM which might have resulted in varied level of soil micro fauna which in turn affect the availability of soil nutrients, especially, available N for plant uptake or loss mainly through concurrent processes of mineralization and immobilization (Shi et al., 2006; Pandey and Srivastava, 2009). Also low soil pH level affects the availability of phosphorous (Shah et al., 1998) as is evedient from the data of homegardens at low altitude in the present study which revealed lower level available-P. However, further investigations are needed to support these hypotheses for the homegarden system in the region.

6.4.2 *Decomposition dynamics of home garden tree leaf litter*

Many literatures suggest that litter quality and environmental factors play important role in determining the plant litter decomposition pattern. Substrate quality, climate and quality & quantity of decomposer organisms are the primary determinants of litter quality rates (Swift et al., 1979). The present pattern of decomposition can be attributed to the initial chemical composition of the leaf litter of tree species (**Table 6.3**). The lignin concentration of *A. heterophyllus* leaf litter is quite high (17.50 %) and lignin nitrogen ratio is also maximum (14.46%) which might have caused the initial slow decomposition. The microbial colonization might have been slow due to high lignin and cellulose content and low N content. The slow decomposition of leaf litter towards the end of the decomposition may be due to major release of N from the litter mass during mid decomposition phase and slow decomposition of lignin and cellulose components (**Figure 6.3**) as suggested by Austin and Vitousek (2000). The dependence of decomposition of litter mass on the initial chemical chemistry was also observed in *Artocarpus hirsutus* leaf litter decomposition by Isaac et al. (2004). In case of *M. indica* too, we may relate the nature of decomposition pattern with the initial litter quality. In *A. catechu* although the N content was higher than *A. heterophyllus* and *M. indica* leaf litters but due to its high lignin and cellulose content and lignin/N ratio ultimately the species resulted in slower decay rate after mid decomposition period. On the other hand, the faster rate of decomposition in *T. indica* and *C. indica* may be due to the high N content of leaf litters and significantly lower lignin/N ratio. Douglas and Richkman (1992) also reported that plant residues with high N content decompose faster. Our study also revealed higher decay rates compared to the values for many multipurpose tree species reported earlier in India (Jamaludheen and Kumar, 1999; Semwal et al*.*, 2003; Isaac and Nair, 2006; Das and Das, 2010).

6.4.3 *Nutrient dynamics*

At the end of the decay period, N and P contents were found to decline relative to the weight of the litter suggesting release of these elements. Nitrogen, the most common limiting factor in litter decomposition determines the growth and turnover microbial mineralizing organic carbon (Bo et al., 2006).

In case of *A. catechu*, *C. indica* and *T. indica* N release was faster and did not show any immobilization. In the other two species, higher N concentration, low lignin and significantly lesser lignin/N ratio might have contributed to mineralization and faster release of N. However, this trend could not be ascribed to the above litter quality traits for *A. catechu* because of its inferior litter chemistry as compared to *M. indica* where we obtained a slower N release and immobilization. Other litter parameters such as C/N ratio, which was not calculated in our study, might explain this deviation. Bockheim et al. (1991) and Isaac and Nair (2006) observed that phosphorous concentration increased initially followed by a decrease in decaying leaf litter; the decrease being attributed to microbial immobilization. On the contrary we did not obtain immobilization pattern for this element.

During decomposition, soluble compounds from leaf litter are rapidly lost followed by polysaccharides, cellulose, hemicellulosesle and lastly lignin (Wedderburn and Carten, 1999). High concentration of cellulose and lignin hinder the attack of decomposing microorganisms, reducing decomposition rate (Gallardo and Merino, 1993). Unlike some reports where lignin and cellulose were found to remain more or less stable or increased during decomposition (Costa et al., 2005), in our study these components reduced significantly after six months period. This could also be one of the reasons for much higher decay rate obtained for the species in the present investigation. However further studies are needed to establish this hypothesis.

6.4.4 *Bioassay*

The inhibition in seed germination was concentration dependent i.e. increase in concentration exerted more inhibition (Rice, 1984) and various species varied in their response to different leachates (Assaeed and Al-Doss, 1997). The inhibitory effect of leaf extracts was more prominent on germination in chilli. Shoot length was adversely affected in lady's finger, whereas the root elongation was suppressed in paddy. The germination inhibited followed the order: *Artocarpus heterophyllus*: chilli > lady's finger > soybean > paddy > maize; *Mangifera indica*: chilli > lady finger > soybean > maize > paddy; *Areca catechu*: lady's finger > chilli > paddy > soybean > maize; *Citrus indica*: chilli > lady's finger > soybean > maize > paddy; *Tamarindus indica*: Soybean > lady finger > chilli > paddy > maize (**Table 6.6**). Various other studies conducted elsewhere also revealed allelopathic suppression in soybean, maize and chilli. *Melia azedarach*, *Morus alba* and *Moringa oleifera* leaf leachates inhibited the germination, radicle and plumule growth of soybean (Kumar et al., 2009). However, leaf leachates of *Aporusa octandra, Anthocephalus chinensis* and *Albizia procera* did not affect the germination and radicle length of soybean (Kumar et al., 2008). Teak and *Leucaena* leaf extracts inhibited the radicle extension of maize. Leaf extracts of selected legumes were reported to have inhibitory effect on seedling growth of maize and rice (Akobundu, 1986).

The plants parts contains allelochemicals, their release in soil can either inhibit or promote germination, growth and development of plants (Tukey, 1969) and our germination results do agree with it. In our study the germination was promoted by *A. heterophyllus* extracts in chilli (at 8 & 16% concentration), lady's finger (at 8, 16 & 20% concentrations), both maize and soybean (at 20% concentration); *M. indica* extracts in paddy (at 4, 8 & 20% concentrations), lady's finger (at 16% concentration); *A. catechu* extracts in soybean (at 8% concentration); *C. indica* extracts in paddy (at 4% concentration), chilli (at 20% concentration) and lady's finger in all treatments.

6.4.5 *Pot culture*

The germination of seeds increased with decreasing concentration of extracts in all test crops and similar observations were reported elsewhere (Rice, 1984). Compared to control, maximum inhibition in seed germination was exhibited by *T. indica* followed by *C.indica, M. indica, A. heterophyllus* and *A. catechu*. The degree and nature of allelopathic effects varied with crop species. The leaf leachates of *Mangifera* and *Tamarindus* inhibited the growth of vegetable crops (Jacob et al., 2007). Of all test crops, germination and seedling vigour was drastically reduced in lady's finger.

Many secondary metabolites are released into the environment either as exudation from living plant tissues or by decomposition of plant materials under certain conditions (Chou and Waller, 1980; Chou and Kuo, 1984; Siddiqui and Arif, 2005; Sahoo et al., 2007; Fang et al., 2009). The chemicals like phenolics, terpenoids and alkaloids and their derivatives are inhibitors of germination and seedling growth (Rice, 1974, 1984; Narwal, 1994; Hattenschwiler and Vitousek, 2000). *Tamarindus* leaf extracts contain flavoinoides (Jacob et al., 2007) which might have caused inhibition in test crops in our study. Castells et al. (2005) concluded that chemical compounds released from *Ledum palustre* and *Empetrum hermaphroditum* may circuitously affects both the performance and propagation of *P. glauca* probably by diminishing the N present in the soil. *Capsicum* leachate inhibited the germination of *Vigna radiata* (L) and at 50 or 75% concentrations reduced the root and shoot growth (Siddiqui and Arif, 2005). The root and shoot growth was inversely correlated to concentration of the leachates as increase in concentration retarded the growth of both root and shoot and eventually reduced the seedling length and our results agree with these findings. Nevertheless, leaf extracts inhibited the growth of seedlings and the extent of their effect depend on the rate of production, leaching amount and time of release in the soil (May and Ash, 1990; Narwal, 1994). The leaf leachates are also very effective in reducing seed germination (Sahoo et al., 2007), its elongation and may cause complete failure of germination (Assaeed and Al-Doss, 1997). Our results indicate variation in germination, which agrees with Patil (1994) who reported the same observation with *Glyricidia maculata* leaf extract in the field. Although it was difficult to relate the bioassay results with the pot culture, there has been clear indication on the role played by higher concentration of leachates either in promotion or inhibition of germination, root and shoot growth of test crops. Nevertheless, the present study indicates that inhibitory effect of tree species on food crops can be decreased by dilution of the leaf extracts. The results further reveal that crops could be irrigated sufficiently during peak litter fall to minimise adverse effects.

6.4.6 *Effect of tree canopy on crops*

Data from the present study shows that plant growth parameters like shoot length and root length in the tested agricultural crops were adversely affected by low light intensities, presumeably, related to reduced photosynthetic active radiation (PAR) under close (canopy I) and partially closed canopy (canopy II) conditions. Several researchers have assesed the effects of light intensities on initial growth parameters viz. shoot length, dry weight per plant and P conditions. up take per plant in plants like *P. mungo, T. aestivum, E. tereticornis* and *A. procera* which got adversely affected by lowlight intensities, ascribed to the reduction in photosynthetic active radiation (PAR) under net house circumstance (Shukla et al., 2008).

Ludlow (1988) also found that decreasing light intensity caused decrease in yield in most tropical grass species, however, the shade tolerant grasses did not show any significant increase in yield even under moderate light intensity (Wong et al., 1985; Samarakoon et al., 1990). Shukla et al. (2008) conducted a novel experiment to investigate how different degrees of light intensities effected the arbuscular mycorrhizal (AM) colonization and the growth of two intercrops *Phaseolus mungo* and *Triticum aestivum* and seedlings of *Eucalyptus tereticornis* and *Albizia procera* found in Central India and concluded that light intensities had affected the growth parameters and phosphorus uptake. Experiment conducted on the effects of shading of five grasses proved that shading decreases yields of grasses like setaria, green panic, guinea grass and signal grass (Shukla et al., 2008). Most of the warm-season grasses yields decreased by 35% or more when planted under 50% shade and up to 65% or more under 80% shade intensity (Lin et al., 1999). Upon casual observations air temperature in the full sun and shade environments found in average about 1–6°C difference between the three canopies (**Figure 6.18**).

Tree crop interactions in homegardens are very complex phenomena. The yield in each component is largely governed by how it nullifies the competitive effect in utilization of resources such as light, water, space, nutrients etc and allelopathic effects from the others. The canopy in the present context offered differential response to the field crops and even the root length and shoot length of a crop behave differently when exposed to different degree of light intensity. For example, root length is French bean was increased with increase exposure of the plant to light while the shoot length showed an opposite trend.

Conclusion

This chapter revealed that all the homegarden sites were sandy loam and acidic in nature. WHC was higher in low altitude homegardens followed by mid altitudes. Higher concentration of total nitrogen and available phosphorus were found in mid altitude homegardens while ammonium N and nitrate N were higher in low altitude gardens. In general upper soil layer (0-15cm) contained more nutrients than deeper layer (15-30 cm) in all the sites which is due to the infiltration and percolation of water along the soil profile that causes a vertical leaching of available nutrients and C/N ratio was higher in high altitude. Ammonium N was significantly ($p<0.01$) correlated with nitrate N while available P was significantly ($p<0.01$) correlated with pH, SOC and TKN. Decomposition and nutrient release of different leaf litter are mainly dependent on the initial litter chemistry. Tree species in homegardens produce a variety of low and high quality litter with variable nutrient release pattern which fulfill the different rate of nutrient demand in the system. Among the leaf litter under study for decomposition *Citrus indica* was fastest followed by the *Tamarindus indica* leaf litter. The decay rate calculated ranged from 3.90 to 8.16 in the order of *Citrus indica* > *Tamarindus indica* >*Mangifera indica* > *Areca catechu* > *Artocarpus heterophyllus.* The bioassay experiment revealed that germination of maize was not affected by any of tree leave extract, while paddy germination was suppressed by *Areca catechu* extract. All the tree leaf extract had a stimulatory effect on the shoot length of paddy, while soyabean shoot growth was suppressed by *Tamarindus* extract. The shoot length of chilly, lady's finger and French bean was recorded higher in closed canopy condition while maize shoot length was highest in medium canopy and mustard seedlings didn't show any much variation under the different canopy conditions.

Chapter 7

House hold food security and nutritional support from homegardens in Mizoram

7.1 Introduction

Food and Agriculture Organization (FAO) defines food security as a condition that "exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life". Individuals who are food secure do not live in hunger or fear of starvation.

Food security at household level takes place when there is food availability as well as access to food by a household (Labadarious et al., 2009). Home gardens are known as the best method of supplementary food production system for a household and homegardening is one of the strategies that has the potential of enhancing food security for the poor (Mutotsi et al., 2006; Marsh, 1998). One of the easiest ways of ensuring access to a healthy diet that contains adequate macro- and micronutrients is to produce many different kinds of foods in the home garden. This is especially important in rural areas where people have limited income-earning opportunities and poor access to markets and an important source of food and income for poor households in peri-urban and urban areas. They have multiple potential benefits and are vital such as a direct increased access to nutritious food by food insecure households on a daily basis and a source of medicinal plants. Home gardening can be done using only the available local planting material, green manures, fencing and indigenous pest control methods without any virtually economic resources (Marsh, 1998).

Vegetables being the rich source of carbohydrates, fats and proteins, which form the major portion of the human diet, are the cheapest source of energy. Proximate and nutrient analysis of edible fruit and vegetables plays a crucial role in assessing their nutritional significance (Pandey et al., 2006). Traditional Mizo ethnic food comprises of plenty of uncommon leafy vegetables, fresh as well as preserved through smoking, such as mustard leaves, pumpkin leaves, beans leaves, varieties of bamboo shoot, apart from meat. Mizo meals are mildly spicy and simple in taste with high nutritive value. The dishes are cooked with the least amount of oil and boiling, steaming and sautéing are the most preferred cooking methods, probably to retain the maximum possible nutritive value of the ingredients.

The considerable use of uncommon vegetable species by the local people in their diet motivated the present study to carry out the proximate analysis of few common food plants of Mizoram, and to understand whether the vegetables constituents of the home gardens are able to meet some of the nutritional requirements as a locally available dietary component and household food security in a rural landscape.

7.2 Methodology

In the present study a total of fourteen common vegetable species identified from the homegardens were procured from the local market of Aizawl, Mizoram. The plant samples were air dried for two weeks and ground into uniform powder using a blender.

The samples were oven dried at 60°C until constant weight (AOAC, 1990; AOAC, 2000). The dried matter obtained was ground to a fine powder using a mixer/blender, sieved, and transferred to airtight plastic bottles and were stored in a refrigerator at 4°C until required for analysis. The cold stored samples were allowed to attain room temperature and mixed thoroughly with a spatula before withdrawing samples for further proximate constituent analysis. Proximate analysis was done on ground samples for each sample to yield result from which the compositions were computed.

The proximate analyses (moisture, ash, crude fats, proteins and carbohydrates) of all the samples were determined according to the procedure of Association of Official Analytical Chemist (AOAC, 1990). The moisture content was determined using weight difference method. Nitrogen and total crude protein content were determined on a dry weight basis according to the Micro- Kjeldahl distillation method (AOAC, 1990) involving the process of digestions, distillation and finally titration of the samples. Total carbohydrate content was determined by the anthrone method as described by Sadasivam and Manickam (2008). Total fats were determined by gravimetric method (Phillips et al., 1997). A dry ashing method was used to determine the ash content by incinerating the sample in a furnace at 550ºC. All the proximate values are reported in percentage. The results for chemical composition were expressed in percentage of dry weight. The caloric value was calculated by summing up the percentages of crude-protein and carbohydrate multiplied by a factor of 4 (kcal/100g) and total crude fat multiplied by a factor of 9 (kcal/100g).

7.3 Results

7.3.1 Proximate analysis of food plants

The result of proximate analysis showed variation in concentration/proportions of bio-chemicals (carbohydrate, fats and protein) and other contents (ash, fiber, moisture). The result of proximate analysis shows variant concentration of proximate composition of the 14 vegetables plant species, details is as shown in **table 7.1**. Overall the samples showed higher proportion of moisture, carbohydrate, followed by crude protein, ash and crude fat, respectively. The moisture content of each species revealed different values ranging from 18.9 to 86.2, giving a wide variation, of the 14 vegetables, *Parkia timoriana* had the lowest moisture content of 18.9, and *Solanum anguivi* had the highest moisture content (86.2), remaining 4 and 10 plant species had moisture content of below and above 50% respectively. The content of carbohydrates was relatively high, ranging from 7.5 to 46.2 % DW in comparison to other chemical constituents. Among the vegetables samples, *P. timoriana* contained the highest carbohydrate content (46.2%), followed by *Musa paradisica, S. nigrum, Colocasia* sp. and the remaining vegetables revealed below 20% carbohydrate content (**Table 7.1**). The protein content of the 14 vegetables species range from 1.8 to 33.1% with *Acacia pennata* the maximum followed by *Clerodendron colebrookianum*, *Dysoxylum gobara* and *P. timoriana*. Plant species *viz*. *Colocasia* sp*., Cucurbita maxima, Dioscorea escullenta, Eurya cerasifolia, Hibiscus sabdariffa, S. anguivi, S. nigrum, S. acmella* and *Zanthoxylum rhetsa* had lower amount of protein content of below 10 %.

The ash content ranged from very low 1.2% to the highest of 22.1. Vegetable species of *S. acmella, D. gobara, C. colebrookianum, Z. rhetsa* showed above 10% ash content. The crude fat content in 11 samples was relatively low ranging from 0.1 to 3.8 % DW. The highest content of crude fat was found in *P. timoriana* (12.4%), followed by *S. nigrum* (9.3%) and *E. cerasifolia* (5.7%). The energy content in Kcal/100g as per the proximate principles of the 14 traditional food plants prevalent in homegardens of Mizoram showed

Table 7.1: Proximate principal of prominent traditional food plants prevalent in homegardens of Mizoram

Plant Species	Local names	Carbohydrate %	Crude Protein %	Fats (Lipids) %	Ash content %	Moisture %	Energy k Cal/100g
Acacia pennata	Khanghu	17.9±0.8	33.1±2.8	2.0±0.2	7.9±1.1	39.1±2.7	332±16
Clerodendron colebrookianum	Phuinam	9.0±1.2	19.6±2.5	1.6±0.3	11.5±0.8	58.3±3.7	274±9
Colocasia sp.	Dawl	23.4±2.2	1.8±0.1	0.3±0.0	0.9±0.0	73.6±3.2	64±2
Cucurbita maxima	Maien	11.3±2.0	3.9±0.3	0.8±0.1	2.8±0.3	81.2±4.1	231±7
Dioscorea escullenta	Baibing	19.3±1.7	1.5±0.2	0.3±0.0	1.70.5	78.2±4.3	386±11
Dysoxylum gobara	Thing thu pui	11.9±1.1	16.3±0.9	2.6±0.2	12.3±1.5	56.9±2.6	162±8
Eurya cerasifolia	Sineh	7.5±0.5	5.8±0.2	5.7±0.3	6.4±0.7	74.7±2.1	125±5
Hibiscus sabdariffa	Anthur	9.5±0.9	2.2±0.1	1.3±0.0	1.5±0.1	85.5±3.2	289±7
Musa paradisica	Changel	30.6±3.3	0.9±0.1	0.1±0.0	1.3±0.2	67.1±2.7	84±2
Parkia timoriana	Zawngtha	46.2±2.4	16.4±1.3	12.4±0.8	6.1±0.9	18.9±2.2	483±8
Solanum anguivi	Samtawk	10.6±1.7	1.4±0.2	0.6±0.0	1.2±0.0	86.2±3.7	251±6
Solanum nigrum	Tawkte	25.5±1.8	7.6±0.3	9.3±0.8	3.2±0.1	54.4±2.2	38±3
Spilanthes acmella	Ankasa	16.4±0.9	16.1±1.4	3.4±0.2	18.3±1.4	45.9±2.3	184±7
Zanthoxylum rhetsa	Chingit	7.5±1.2	8.6±0.9	2.0±0.2	10.4±0.8	71.5±6.5	107±4

the maximum energy content in *P. timoriana* (483 Kcal/100g) followed by *D. escullenta* (386 Kcal/100g), *A. pennata* (332 Kcal/100g), *H. sabdariffa* (289 Kcal/100g), *C. colebrookianum* (274Kcal/100g), *S. anguivi* (251 Kcal/100g) and *Cucurbita maxima* (231 Kcal/100g). The other vegetables had less than 184 Kcal/100g and minimum energy level of 38 Kcal/100g was recorded in *S. nigrum.*

7.3.2 Homegarden plants for nutritional needs and household food security

Homegardens are an important source of vegetable for household consumption and animal food. The number of crops that a household had in its homegarden varied across the altitudes. In the present study 133 out of 351 plants were food plants supplying numerous vegetables and fruits (Chapter 5: **Figure 5.10**), with higher diversity of food plants in high altitudes (104) followed by low altitude (95) and mid altitude (85). Out of all the food plants herbaceous vegetables were a major constituent (**Table 7.2**). In the high altitude gardens occurrence of guava fruit was very high followed by the small tree *C. colebrookianum* (phuinam) followed by *Colocasia esculenta* (dawl) and *Cucurbita maxima* (maien) whose leaves are used as vegetables (**Table 7.4**). Passion fruit, mustard and sweet potato were recorded in 72% of the gardens. *P. timoriana* occurred in 79% of the gardens whose pods are delicacy during winter.

Table 7.2: Food plants in the homegardens at different altitudes

Altitude	Trees	Shrubs	Herbs	Climbers	Total
High	29	15	46	14	104
Mid	30	11	33	11	85
Low	28	15	35	16	95

Herbs recorded maximum number and proportion (44%) in high altitude and least proportion in low altitude (37%). Trees (usually fruits trees) were the second major contributor to the food plants in all the altitudes. Although good number of herbal food plants were also recorded in the low altitude those with high frequency of occurrence among the gardens were very low (**Table 7.3**), represented by only five herbs. In the high altitude more variety of seasonal vegetables were recorded with high frequency of occurrence among the garden. Thus, in high altitudes not only were there variety of seasonal vegetables throughout the year but also were cultivated in most of the gardens.

Table 7.3: Food plant varieties which are more than 30% of occurrence among the homegardens

Altitude	Trees	Shrubs	Herbs	Climbers	Total
High	15	5	15	3	38
Mid	13	4	8	3	27
Low	10	1	5	1	17

In the mid altitude mangoes were recorded in more than 93% of the gardens and fruits of different *Citrus* species were observed (**Table 7.5**). Guava and *C. colebrookianum* were also common similar to high altitudes. *Acacia pennata* a prickly leguminous woody climber whose stinky leaves are a favourite vegetable was recorded in many of the gardens. *Trevesia palmata* whose flower buds are a costly vegetable was also found frequently in the gardens in mid altitudes.

Table 7.4: Top ten food plants recorded in high altitude based on frequency of occurrence

Botanical names	**% Frequency**
Psidium guajava	88.37
Clerodendrum colebrookianum	86.05
Colocasia esculenta	83.72
Cucurbita maxima	79.07
Parkia timoriana	79.07
Hibiscus sabdariffa	76.74
Mangifera indica	74.42
Passiflora edulis	74.42
Brassica juncea	72.09
Ipomea batatas	72.09

Table 7.5: Top ten food plants recorded in mid altitude based on frequency of occurrence

Botanical names	**% Frequency**
Mangifera indica	93.75
Citrus reticulata	81.25
Trevesia palmata	81.25
Psidium guajava	75.00
Citrus grandis	62.50
Clerodendrum colebrookianum	62.50
Colocasia sp.	62.50
Acacia pennata	56.25
Citrus macroptera car anamensis	56.25
Carica papaya	50.00

Table 7.6: Top ten food plants recorded in low altitude based on frequency of occurrence

Botanical names	**% Frequency**
Mangifera indica	87.88
Musa paradisiaca	78.79
Carica papaya	69.70
Psidium guajava	69.70
Cocos nucifera	63.64
Tamarindus indica	63.64
Ananas comosus	60.61
Colocassia affinis	54.55
Citrus macroptera var. *anamensis*	48.48
Citrus medica var. *acidus*	48.48

7.4 Discussions

Proximate analysis of common food plants

Edible vegetables are a vital component of human diet comprising essential biochemicals important for human metabolism (Aliyu, 2006). The result of proximate analysis of the fourteen common vegetables selected from the homegardens of Mizoram showed a varied concentration of nutrients (carbohydrate, fats, protein, ash, fiber, moisture). The moisture content of the 14 plants species showed a maximum of 86.2% in *S. anguivi* and as low as 18.9% in *P. timoriana,* lower moisture content will ensure lower rate of spoilage with longer shelf-life and less susceptibility to microbes and vice- versa

(Adepoju, 2009, Adeyeye and Ayejuyo, 1994). Other species showed relatively high moisture content of above 30% *viz. H. sabdariffa* (85.5%), *C. maxima* (81.2%), *D. escullenta* (78.2%), *E. cerasifolia* (74.7%), *C.* (73.6%), *Z. rhetsa* (71.5%), *M. paradisica* (67.1%), *C. colebrookianum* (58.3%), *D. gobara* (56.9%), *S. nigrum* (54.4%), *S. acmella* (45.9%) and *A. pennata* (39.1%). This result is however similar to those obtained by other workers (FAO, 1990; Abidemi et al., 2009; Chimma and Igyor, 2007). As the Mizoram weather condition range from maximum average temperature rarely exceeding 26°C, thus shelf life will be comparatively better to other hot regions despite the higher moisture content.

Carbohydrates has been categorized a good and essential cheap source of energy, constituting a major portion of a balanced diet. In our study, *P. timoriana* contained the highest carbohydrate content (46.2%), followed by *Musa paradisica* (30.6%), and the remaining vegetables showed below 20% carbohydrate content. The carbohydrate content of these vegetables is very high as compared to the values obtained in the studies of Agbaire et al. (2012). On the contrary Asibey-Berko and Tayie (1999) revealed vegetables with higher carbohydrate content ranging from 75% to 82.8%.

Protein content of the 14 vegetables species ranged from 1.8 to 33.1% with highest in *A. pennata* followed by *colebrookianum* (19.6%), *D. gobara* (16.3%), *P. timoriana* (16.4%), *S. acmella* (16.1%). According to Pearson (1976) plant food that provide more than 12% of its calorific value from protein are considered good source of protein. Furthermore, adults, pregnant and lactating mothers required 34-56 g, 13-19 g and 71 g of protein daily respectively (Anon., 2002). The results of this investigation showed that adequate amount of protein are present in these vegetables. Therefore, as these plants can be utilized as a good source of non-conventional proteins. Remaining vegetables species had lower amount of protein content of below 10 %, however some of this has a fairly good protein content and can very well blend with other food items with average content so as to make-up the required amount.

The ash content which is a measure of the mineral content of food was highest of in *S. acmella* (18.3%), and 3 other vegetables also showed a very high value of above 10% ash content i.e. *D. gobara* (12.3%), *C. colebrookianum* (11.5%) and *Z. rhetsa* (10.4%). The result therefore suggests a high deposit of mineral elements in these leaves (Antia et al., 2006). Other species had relatively lower value but can definitively serve a fair source of mineral. The values were comparatively higher except for *M. paradisica* (1.3%), *S. anguivi* (1.2%) and *Colocasia* sp. (0.9%), compared to the reported value by Agbaire et al. (2012) and Abidemi et al. (2009) who reported of ash content ranging from 1.52 to 2.0%, which was also the acceptable range for edible vegetables in Nigeria, according to Lucas (1988).

The crude fat content in majority of the samples were relatively low ranging from 0.1 to 12.4% DW which shows that the vegetables will be beneficial for maintenance of good health. The highest content of crude fat was found in *P. timoriana* (12.4%), *S. nigrum* (9.3%) and *Eurya cerasifolia* (5.7%), suggesting them to be a good sources of lipids. The study by Rumeza et al. (2006) reported low percentage of fat in vegetables ranging 0.1%

to 0.38%, however the present findings had wide variation in the results ranging from low, intermediate to high fat content.

Energy in terms of calorific value was found to vary from very good value of 483 Kcal/100g the lowest of 38kcal/100g. Some of these results are in agreement with the studies of Kanchan et al. (2011) and found to be in the normal range of 134.6 kcal/100gm to 431.6 kcal/100g. The highest value was found in *P. timoriana* (483 Kcal/100g) which is higher than the reported value of energy in vegetables by other workers (Isong et al., 1999; Hassan et al., 2006; Kulkarni et al., 2003; Kanchan et al., 2011) but are well within the reported value of energy content in different parts of *P. timoriana* pods by Elangbam and Singh (2012). Thus this study could identify some very good source of energy singly or in combinations as most of the vegetables gave relatively good values of nutrients and can serve as a component of a well balanced diet.

Homegarden plants for nutritional needs and household food security

People all over the world grow gardens. In the tropics, anyone with any land can grow something all year round. Most rural tropical families have gardens around their houses Fundamentally, home gardening provides a supplemental source of foodstuff for the family. But their importance goes beyond that. In many developing countries, home gardening becomes a survival strategy when food security is threatened by limited food availability and access. At other times, it is a resilience strategy to mitigate risk and vulnerability due to different natural and man-made stresses.

Among the homegardens in Mizoram the high altitude gardens tend to be more secure with sufficiency of household food supply as evident from the varieties of leafy vegetables and tubers like mustard, pumpkin, sweet potatoes, chilly, chayote (*Schium edule*, Iskut), brinjal, roselle, garden pea, lablab, lady's finger, winged beans, and other varieties of bean etc., apart from varieties of the fruits. The fewer occurrences of vegetables among the food plants in the low altitude might be attributed to the fact that as the gardens were dominated with dense canopy of areca nut trees the gardeners might not have enough space to grown seasonal vegetables to supply all year round. And since the areca nuts from these gardens could fetch direct cash income at the farm itself without taking them to the market (since traders come to the farm to collect the nuts), they have more liquid cash to but vegetables from the market. In the mid altitudes the status of food plants was intermediary in nature inbetween the high and low altitude. More varieties of vegetables in high altitude might also be due to the favourable climatic conditions and also the age of the garden which were comparatively older (**Table 5.7**, Chapter 5). Over the years the farmers might have tried varieties of wild and domesticated plants and with long trail they might have stabilized certain plants in the garden as compared to the mid and low altitudes which are younger.

Overall, the occurrence to numerous varieties of traditional food plants other than staple crops in the homegarden of Mizoram shows a picture of household food security and meeting the nutritional requirements of the rural poor. Dietary diversity, i.e. the number of foods consumed across and within food groups over a reference period, is widely recognized as a key indicator of nutrient adequacy (Ruel, 2003; Mirmiran et al, 2004).

Studies show that the overall nutritional quality of the diet improves with increasing number of food groups (Torheim et al., 2003; Steyn et al., 2006; Kennedy et al., 2007). Foods from the homegarden supplements the staple foods from the paddy fields or jhum fields, which are usually high in calories, but not very high in vitamin and mineral nutrients and since homegarden usually produce crops extremely high in nutrients and they tend to possess a high 'nutrient density'.

Humans need carbohydrates, protein, and fats, which are problem enough, but more critical in much of the tropics are vitamin and mineral nutrients. Roots and tubers are rich in energy and legumes are important sources of protein, fat, iron and vitamins. Green leafy vegetables and yellow- or orange-coloured fruits provide essential vitamins and minerals, particularly foliate, and vitamins A, E and C. Vitamin A which is necessary for good eyes are made by the body from carotenes and Green leafy vegetables are good sources of ß–carotene, the precursor of vitamin A. Vegetables like cauliflower, mustard greens, etc are good source of vitamin B1, and it's common in most green vegetables, as well as most of the vitamin A sources. Oranges, greens chillies, and guavas are good source of vitamin C which is to be consumed frequently as the body can not store vitamin C for more than a week. Chillies are also rich in iron.

Maize, corm of 'iskut' (*S. edule*), sweet potato, *Manihot esculenta* (pangbal), *Ipomea batatas,* etc., which are the starchy crops provide additional carbohydrates to the household. Beans are excellent sources of protein. Tree beans (*P. timoriana*), winged bean, pegion pea (Behlawi) etc., are good sources of protein but being consumed fresh are also rich in vitamin C. *Acacia pennata* shoots are also a good source of protein. Mangoes are extremely high vitamin A and C values. Bananas are good carbohydrate, but there is some vitamin C value, and some minerals, notably potassium. The coconut water are rich in vitamins and minerals.

The homegarden also provide lots of needed protein (and some fat), especially in the form of small livestock. For protein and iron, and for getting rid of weeds and garbage, livestock like pigs and poultry are a valuable part of the garden world. Homegardens in all the altitudes in Mizoram possess some livestock which provide meat and eggs. Their wastes also provide manure for the garden. Rearing honey bees were also common in the homegardens (more in high altitude, **table 5.4**).

Furthermore, consuming diverse diets offers protection against chronic diseases (Cummings and Bingham, 1998). Although not mentioned as medicinal plants, almost all plants found in the homegardens such as fruit trees, tubers, vegetables, beans or spices have a potential medicinal use and helps in maintaining a sound health. For example consumption of boiled *Clerodendrum colebrookianum* leaves is popular among Mizos and it has been reported to minimize high blood pressure, and consequently incidence of high blood pressure is very low among Mizo (Sharma et al., 2001).

In general, homegardens in Mizoram produce food year round, unlike the seasonal harvest in paddy field and jhum lands. Although yields are normally low, it is compensated by the diversity and nutritious nature of the products obtained.

7.5 Conclusion

The proximate analyses results showed that the homegarden vegetables are fairly endowed with energy content, moisture, and carbohydrate, followed by crude protein, ash and crude fat, respectively. Carbohydrate constituted the highest constituent in the plants followed by protein percentage and ash content while most of the plants showed low fat content. *Parkia timoriana* possessed highest value of carbohydrate, fat and energy value while highest protein was recorded in *Acacia pennata*. Unconventional food plants like *Spilanthes acmella*, *Dysoxylum gobara, Clerodendron colebrookianum, Zanthoxylum rhetsa* showed a very high ash content. Overall, these vegetables had a good proportion of nutritional attributes. The diverse food plants by increasing availability, accessibility, and utilization of food products. Household food supply was higher in high altitude homegarden with diverse vegetables and food crops than mid and low altitude gardens. Integration of livestock, poultry and apiculture activities into home gardening reinforced food and nutritional security for the rural poor. Since homegarden produce crops extremely high in nutrients, they supplement the staple foods from the paddy fields or jhum fields, which are usually high in calories, but not very high in vitamin and mineral nutrients. Most of the traditional food plants also have good medicinal value. Because of the homegarden the rural farmers with limited sustainable livelihood options have access to healthy diet. Thus home gardens can be an alternative source for balanced nutritional diets serving the perennial needs of the poor rural and the sub-urban societies.

Chapter 8

General Discussions

Traditional homegardens in hilly rural area of Mizoram are characterized by diverse variety of plants maintained for variety of purposes on the basis of choice, needs and importance of plants. Although they have not received enough attention from scientists and researchers, they continue to play a vital role in the livelihoods of many rural marginal farmers. They are the second most important farming systems next to shifting cultivation and locally called '*inbul huan*' or '*Chuaktuah huan'* common in all villages irrespective of agroclimatic zones (Sahoo, 2007). They are typical indigenous agroforestry systems in both rural and urban settings where people have been cultivating, managing, and conserving diverse plants in and around their houses for alternative sources of forest products and services, supporting the idea that these managed patches could be of significant conservation value. Many of the trees yielding food and fruits are grown by the farmers while others are retained from what was naturally available in the plot. These crops are grown in close association with a multitude of crops and tree species and livestock and bee keeping in a multistory agroforestry system. Majority of these gardens have evolved from forests while few have been developed from degraded open wastelands.

Similar to report from many other studies from homegardens in tropical countries these homegardens in Mizoram also exhibit high plant diversity. The enumerated plants comprising of 351 species belonging to 101 plant families in the present study was higher than the reported value of 15 families in homegarden of Southern Andaman (Pandey et al., 2002), 197 plants belonging to 77 families from Khasi Hills of Meghalaya (Tynson and Tiwari, 2010), 294 plants belonging to 92 families in

Upper Assam (Saikia et al., 2012) but slightly less than the 419 species belonging to 109 families in Bangladesh homegardens (Kabir and Webb, 2008). Still the tree species recorded in the present study (170) is much higher than the Bangladesh homegardens which must be due to the wide range of topographical and climatic conditions in the present surveyed villages ranging from low lying foot hills (80m asl) to high altitudes (>1300 m asl). The higher report of plant species from the Bangladesh homegardens may be due to their large sample size (402 gardens) and larger geographical extent of the samples. Presence of more plant families in the present study sites may be due to the fact that the systems were human manipulated planting several seasonal crops at a time with other perennials. From total 101 plant families recorded, Euphorbiaceae, Moraceae and Pappillonaceae were recorded higher as most of the fruits and vegetable crops preferred by the local farmers belong to these plant families. Species rich homegardens are found where a household's subsistence depends on their products and where the environmental conditions are more conducive.

Floristic composition is highly variable. Only 5 of the 351 plant species were grown in more than 60% of the gardens and no single species was found to be occurring in all the gardens. In contrast 155 plants were found only in less than 3% of the gardens. Similar natures of the floristic composition were also reported by Vogl et al. (2002) from Palanque, Mexico. Although more plant species were encountered in the homegardens of low altitude as compared to high and mid altitudes, less diversity index was observed in the former than the latter two owing to the fact that more of the commercial plant (areca nut) was dominating in all the gardens with high density (Chapter 4) and in the high altitudes trees of *P. timoriana* were more popular with the farmers and since it has a wide but thin crown only few individuals were recorded in each garden.

The species diversity in the homegardens is always high. High diversity of the species always promote high soil fertility and retain soil humidity (Ninez, 1985; Rico-Gray et al., 1990; Gomez-Poppa et al. 1997; Nair 1997; Declerk and Negreros Castillo, 2000; Nair, 2001). According to Nair (1997) horizontal and vertical distribution of the species brings a dynamic equilibrium with respect to organic matter and plant nutrients on the garden floor because the root systems have little or no-overlapping at this layer. The root systems help in continuous addition of leaf litter and its constant removal though decomposition and the compatible admixture of the species in homegarden offer to enrich the top soil. However, at lower soil depth, the root competition will be high, which may be in proportion to the canopy volume (Nair, 1977). Annual monoculture systems of cultivation invite habitats for pests and thrive by colonizing new welcoming environments. Since homegardens have mixed stand they tend to posses natural resistance against pests and diseases outbreaks (Michon et al., 1983).

The high plant diversity is deliberate and designed to allow harvesting in most part of the year so that products of economic value are always available for household use or cash sale of the surplus. Besides, the diversity can, over time, provide ecological resilience and contribute to the maintenance of beneficial ecological functions.

Furthermore, contribution of smaller plants such as herbaceous weeds, ferns and grasses to the floristic diversity of the sites was critical. For example, *Solanum nigrum, Spilenthes acemella, Marsdenia maculata* were used as vegetables.

The cultural pattern and biotic pressure seems to play an important factor in deciding the plant species diversity in the gardens. For example less number of vegetable plants was recorded in the low altitudes as the farmers normally do not popularly grow vegetables in the gardens but they are cultivated in the shifting cultivation fields. Large shifting cultivation fields were recorded in the low altitudes as compared to the high altitudes and most of the farmers in high altitude grow vegetables in the homegarden. The low altitude homegardens are usually covered with dense canopy of areca nut.

The wide spectrum of useful plants creates a multilayered vegetation structure. The homegardens positioned in different altitudes showed 3-4 vertical stratification. From the ground layer to upper canopy, the gradient of light and humidity determine different niches that the species exploit according to their requirements. The position, height and shade tolerance of plants are nevertheless important traits that are acquired with time. The distribution of plants at different heights and architecture across the homegardens perfectly occupied the available space both horizontally and vertically. All the homegardens, in general, consisted of a herbaceous layer near the ground, a tree layer at the upper levels and an intermediate layer or two in between (Chapter 4) which is responsible for many benefits and advantages of the system. This diversity results in favourable microclimate, reduced risk of pests and diseases, efficient use of resources, soil fertility management etc. According to Montagini (2006), vertically stratified homegardens are potentially more productive, on an area basis, than arrangements without stratification, because they capture more resources and exhibit better nutrient cycling. The recycling of resources within the system is an interesting feature of the homegardens, eg., the wastes from human consumption and left over are fed to the pigs and poultry and the wastes from these livestock are used as manure. In the survey only 4.3 % of the respondents use chemical fertilizers (Chapter 5) and the rest use manures which are by products from poultry or piggery.

The management of biological resources and economic production of homegarden was shared by both men and women. Through their different activities of management practices, men and women have developed different expertise and the knowledge about the local environment, plant and animal species and their products and uses. The woman tended to be more actively involved than man in the household economy which typically involved the use of wider diversity of species for food and medicines while men involved in pruning and harvesting of the homegarden produce.

Homestead gardens are playing a potential role in biodiversity conservation as well as uplifting the socioeconomic condition by contributing families or household's annual income and providing nutritional diet to families. Variable homestead garden products such as seasonal fruits, firewood, medicinal plants, timber, and vegetables and spices were mostly used by the small and medium household owners for their daily needs but large owners get their products into the market for sale.

Many studies of tropical homestead garden have reported reduced species diversity and stem density in homestead garden with closer proximity to market but in the present study although the low land gardens were more oriented towards growing large number of areca nut they still tend to retain other fruits and crops which is a good sign of maintaining biodiversity. Unlike the adjacent Barak valley in Assam state where clear zone exist in homegardens for particular group of crops and linked to the proximity of the house (Das and Das, 2005), no clear crop zone was observed in the present homegardens except vegetable were grown close to the house.

Although the choice of species is determined to a large extent by environmental and socioeconomic factors, as well as the dietary habits and market demands of the locality remarkable similarity with respect to species composition among different altitude homegardens were observed in case of the fruits trees and some herbaceous plants. This may be so because food production is the predominant role of most homegardens and the presence of an over-story requires that the species are shade-tolerant. Thus, tuber crops such as ginger, taro, and sweet potato were common as they can be grown with relatively little care as understory species in partial shade. The crop combinations found in the homegarden of Mizoram, like other homegardens of the tropics, are influenced by biophysical and socio cultural factors, besides the specific needs and preference of the households and nutritional complementarity with other major food sources.

The amount of labour invested in homegarden was related to garden size and family's dependence on income from homegarden which was more pronounce in the high altitude and the labour investment was found to be associated with trees and shrub species richness similar to the observation by (Kabir and Webb, 2009). In large homegardens, however, the division of labour is not very clear; most of the work required is done through hired labour (Chapter 5). However, women folks look after the livestock, raising of ornamental and medicinal plants.

Although the main purpose of maintaining a homegarden is for subsistence for many of the farmers, majority of them sold their surplus products for income generation while larger gardens tended towards commercialization for higher economic benefits and as a choice of employment opportunity. From the sale of surplus products about 19.6% in small to 52.1% in large gardens were contributed by the homegardens to the total household income. The diversity and composition of the plants also depend on the dependence of the household on income from the homegarden.

Understanding the forces shaping farmers' decisions about homegarden investment is important not only for exploring the human–environment linkage, but also to potentially improve livelihoods through improved management strategies. In terms of output per unit area, the highest was found to be small homegardens followed by large homegardens and finally medium homegardens. This implies that the higher input per unit area for small homegardens indeed translates into higher yields for farmers. It might therefore be advisable for farmers with larger land holdings to keep small homegardens in combination with a large farm.

Plant species composition nevertheless has a profound bearing on the soil conditions such as nutrient status, retention of moisture in the homegarden. In homegarden, soil nutrient is said to be maintained and several studies have reported that soil fertility under tree situation is improved due to increased input of organic matter through litter (Dunham, 1991; Kesseler, 1992; Campbell et al., 1994; Dhyani, 1997). Improvement in soil fertility under homegarden agroforestry systems occur mainly through addition of plant biomass. However in certain situations trees may have an adverse effect on soil. The magnitude of benefits or adverse effects depends on a number of site specific factors and attributes of associated trees species. The efficient conversion of this litter to soil humus by micro-organisms (Johnson and Bradshaw, 1979) depends largely on climatic factors and the selected species *i.e.* litter quality. Leaf litter is the major source of phenolic compounds as a by-product during putrefaction and green leaf leachate contains tannin (Hattenchwiler and Vitousek, 2000). Many secondary metabolites are released into the environment either as exudation from living plant tissues or by decomposition of plant materials under certain conditions (Chou and Kou, 1984; Sahoo et al., 2007; Fang et al., 2009). Thus the efficient use of the resources for optimum production in a homegarden lies in the tree crop species mixture.

A prominent feature of the tree-crop component in homegardens is the predominance of fruit trees, and other food-producing trees. Apart from providing a steady supply of various types of edible products, these fruit and food trees are usually compatible, both biologically and environmentally, with other components of the system (Nair, 1984). Produce from these plants often provides a substantial proportion of the energy and nutritive requirement of the local diet (Chapter 7). It is well known that several tree fruits in homegardens are nutritionally rich, and carbohydrate-rich grain crops are also a main source of vitamins and minerals for the family (Nair, 2006). For example, Terra (1954) and Stoler (1975) reported that Javanese homegardens provided more than 40% of the whole energy requirement of the local farming communities. Soemarwoto and Conway (1991) reported that compared with the rice fields of Java, the homegarden has a greater diversity of production and usually produces a higher net income; in West Java, fish production in homegarden ponds is common, with an income of 2 to 2.5 times that of rice fields in the same area. Food production is thus the primary function and role of most, if not all, of the homegardens. An aspect of food production in homegardens is the almost continuous production that occurs throughout the year. The combination of crops with different production cycles and rhythms results in a relatively uninterrupted supply of food products. Depending upon the climate and other environmental characteristics, there may be peak and slack seasons for harvesting the various products, but generally there is something to harvest daily from most homegardens.

Since species diversity in Mizoram is very high the diverse food plants in these gardens contribute to household food security by providing direct access to food that can be harvested, prepared and fed to family members, often on a daily basis throughout the year ensuring nutritional security. The garden may become the principal source of household food and income during periods of stress, e.g. 'mautam' which is related to bamboo flowering and famine. When the diversity of crops is high and in medium sized gardens and those with larger land holdings it provides part employment and self sustenance to the farmers.

Homegardening in Mizoram is an age old practice and evolved with time. The farmers have developed the system out of necessity but without proper technical knowhow of the tree crop interaction, although they have acquired some knowledge of the trees which enriches the soil. If proper guidance on the ecology of tress and crops and their interaction are imparted to the farmers they can manage the homegardens for optimum utilization of the resource for better productions from the garden. So, if the extension officers of the Agriculture Department organize proper training on the management of the gardens for tree crop compatibility, methods to control soil erosion, management of trees, etc., it would encourage many to draw more attention to their homegarden for enhancing the productivity and thereby may reduce the dependency of shifting cultivation to some extent. The government department can also distribute better varieties of seeds and other economically important nutritious crops/fruit trees for enhancing their income (many of the farmers obtained their seeds from friend circles), creating habitats for animals, improving environmental conditions, enhancing biodiversity and sequestering carbon. Training can also be imparted on practice of making and using compost/vermicompost.

The results of this study revealed that homegarden is designed to fulfill a wide array of functions, and provide a range of benefits and demonstrate that properly managed homegardens can improve people's livelihoods and quality of life, reduce poverty, and foster economic growth into the future on a sustainable basis.

Summary

Tropical homegardens are known to be a complex, species rich agro-ecosystem sustainably managed for the production of food and other essential products over the years. They are managed with the primary purpose of subsistence production and income generation while fulfilling ecological, social and cultural functions. Plant diversity has been considered as a measure of homegarden productivity and sustainability, but this diversity of plant species and composition are influenced by different agroecological and socio-economic factors which has not been well addressed till date in most of the studies on homegarden in this part of north east. The present work was undertaken to assess the diversity of the homegardens at different landscapes in Mizoram and to understand the underlying factors focusing on plant diversity, socio-economics of management, and soil and tree crop association in the system and an attempt to assess their potential for household food security.

The study was conducted in undivided Aizawl district of Mizoram at different agro-ecological setup ranging from hilly low lands to high altitude homegardens in eastern Mizoram ranging from 60m asl to about 1500m asl. Ninety two households were randomly selected from different villages across the altitudes and their sizes of the homegardens were measured. Complete plant species inventory was done to determine the number and abundance of tree and shrub species and frequency of occurrence of crop species. GBH and height were measured for trees and shrubs.

Several diversity indices dominance and similarity indices were calculated apart from the frequency, abundance and importance value index. Floristic composition and structure of the garden was analysed using these vegetation data. All the garden owners were interviewed about the plant use, management, sale and data on the demography and economic activities of the household were also collected. Quantification of some of the benefits provided by the homegardens was conducted to derive the cost and benefits from the homegarden. Soil samples were collected from few selected homegardens in each altitudinal zones and analysed for water holding capacity, moisture content, texture, pH value, ammonium-nitrogen, nitrate-nitrogen, available phosphorous and soil organic carbon. Allelopathic effect of selected trees leaves and canopy structure on crops was studied in a homegarden in Aizawl. Edible parts of few common plants grown in the homegardens were analysed for their proximate principal using standard procedure. The important findings of the present investigation may be summaries as follows:

1) 351 plants belonging to 101 families were recorded from the survey across the study area. Euphorbiaceae was represented by maximum number of species (27) followed by Moraceae and Pappillonaceae (15 each) while 52 families were represented by only 1 species. Of the 351 species 170 were trees, 42 were shrubs, 94 herbs, 5 epiphytes, 34 climbers and 6 bamboo species

2) *Mangifera indica* was the most frequent species recorded in 83% of the gardens followed by *Psidium guajava* (79 %) while 155 plants were recorded in less than 3% of the gardens. An average of 34 plant species (sd, ±14) per

garden were recorded and more than fifty percent of the gardens contain 21-40 plant species.

3) Total plant species and trees species were recorded higher in the low altitude gardens than high and mid altitude while herbs and climbers were more in the high altitude, whereas the diversity of plant species per individual garden was slightly higher in the high altitudes than mid altitudes but significantly ($p<0.01$) less in the low altitudes.

4) Shannon-Weiner diversity index of trees and shrubs revealed that diversity was significantly ($p<0.01$) higher (H'=3.89) in the mid altitudes and minimum (H' =2.73) in the low altitudes. Trees density per garden was significantly ($p<0.01$) more in low altitudes and least in the high altitude. Basal area of trees and woody shrubs per unit area in the garden was significantly higher ($p<0.05$) in the mid altitude and lesser in the low and high altitude gardens.

5) *Psidium guajava, Parkia timoriana, Clerodendrum colebrookianum,* were the most frequently found trees and shrubs in the high altitude gardens, *Mangifera indica, Trevesia palmata* and *Psidium guajava* were common mid altitude while *Areca catechu, Mangifera indica* and *Artocarpus heterophyllus* were the most frequently found trees in low altitude.

6) High altitude homegardens were dominated by Zawngtha (*Parkia timoriana*) with a density of 5 trees per garden and important value index (IVI) of 19.76, while it was areca nut in low altitudes with 44 trees per garden and IVI of 16.61.

7) The relationship between garden size and the number of species encountered at different altitudes showed an weak increasing trend but was significant at the high altitude gardens ($p<0.01$).

8) The vertical structure of homegardens composed of 3-4 canopy layers. *Parkia timoriana* was the principal crop in the emergent layer in high altitude while *Areca catechu* occupies the top canopy in low altitude. *Artocarpus heterophyllus, Mangifera indica* and different *Citrus* species occupy the middle canopies while *Psidium guajava, Camellia sinensis, Trevesia palmata* etc., occupy the lowest canopies.

9) The study revealed that the homegardens in the higher altitudes were comparatively older than the mid hills and lowlands; and smaller homegardens were more prevalent than the medium and large sized homegardens.

10) The overall mean garden size was 3940 m^2 which ranged from 144m^2 in the mid altitudes to 20000 m^2 in the higher altitudes. Smaller gardens were more prevalent (> 58%) followed by medium sized (28%) and large sized gardens (14%).

11) The average time spent in gardening was closely related to the trees and shrubs species richness. Mean monthly working hour of 91.0 hour was observed in large gardens of high altitude. Larger gardens investing significantly ($p<0.01$) more labour was observed in high altitude ($p<0.01$) and mid altitude ($p<0.05$).

12) Women predominantly maintain and control the homegarden with very less participation and control by their male counterparts in the high altitude while it was the reverse in low land and more or less equal participation in mid altitude.

13) The energy efficiency was the highest in small gardens (102.09) of mid hills, with no significant variation among the different sizes within the altitudes in mid hills and lowlands, but there was significant variation across the altitudes ($p<0.01$).

14) About a quarter of the respondents didn't sell any of the garden products while about 40% of them sold more than half of their garden produce mostly by themselves to market.

15) Homegardens in higher altitude recorded higher economic value in all garden sizes compared to the corresponding categories in mid and low altitudes. However, since the intensity of production was greater in case of small gardens, the intensity of profit generation was also more in small gardens.

16) Mean financial value of homegarden was the highest in large gardens of in high altitude and estimated at ₹1,58,161 during 2009-10. The mean annual proceeds from the sale of the garden were also highest in large garden of high altitude with an estimated amount of ₹78,875 contributing about 52% to annual family income.

17) Passion fruit (*Passiflora edulis*) and tree bean (*Parkia timoriana*) contributed maximum to the homegarden income in the high lands, followed by ginger,

guava, mustard, etc. In the mid altitudes it was *P. timoriana* followed by *Areca catechu*, *Citrus reticulata, Mangifera indica*, etc., and in low altitudes largest contribution came from *A. catechu.*

18) Among the plant use, food or vegetable category (44.6%) was observed highest followed by timber (17.9%), ornamental (11.6%), fuelwood (8.9%) and medicinal (5.9%). Of the 351 plants recorded 236 have only one indicated use while the rest have more than one indicated utility.

19) Significantly ($p<0.01$) higher concentration of soil organic carbon, total Kjeldalh nitrogen and available phosphorus were found in mid altitude homegardens while ammonium N and nitrate N were higher in low altitude gardens. C/N ratio was higher in high altitude gardens and lowest in low altitude gardens. Ammonium N was significantly ($p<0.01$) correlated with nitrate N while available P was significantly ($p<0.01$) correlated with pH, SOC and TKN.

20) Among the leaf litter under study for decomposition *Citrus indica* was the fastest followed by the *Tamarindus indica* leaf litter. The decay rate calculated ranged from 3.90 to 8.16 in the order of *Citrus indica* > *Tamarindus indica* >*Mangifera indica* > *Areca catechu* > *Artocarpus heterophyllus.*

21) Litter decay rate (k) and initial nitrogen concentration in leaf litter have a significant ($p<0.01$) positive correlation. Initial lignin and cellulose content and lignin/N ratio showed significant ($p<0.01$) negative correlation with decay

rate, of which lignin content was found to be the most influential component (R^2=0.8906).

22) Nutrient release pattern of leaf litter was fast and did not show any immobilization in case of *Areca catechu, Citrus indica* and *Tamarindus indica*. A three phase pattern of N release was observed in *Artocarpus heterophyllus* and *Mangifera indica* – an initial release followed by immobilization and faster release.

23) The bioassay experiment revealed that germination of maize was not affected by any of tree leaf extract, while paddy germination was suppressed by *Areca catechu* extract. All the tree leaf extract had a stimulatory effect on the shoot length of paddy, while soyabean shoot growth was suppressed by *Tamarindus* extract.

24) The shoot length of chilly, lady's finger and french bean was recorded higher in closed canopy condition while maize shoot length was highest in medium canopy and mustard seedlings didn't show any much variation under the different canopy conditions.

25) Among the edible parts of common food plants tested for their proximate principles, carbohydrate constituted the highest constituent followed by protein and ash content while most of the plants showed low fat content. *Parkia timoriana* possessed highest value of carbohydrate, fat and energy value while highest protein was recorded in *Acacia pennata*. Unconventional

food plants like *Spilanthes acmella*, *Dysoxylum gobara, Clerodendron colebrookianum, Zanthoxylum rhetsa* showed a very high ash content.

26) Household food supply was higher in high altitude homegarden with diverse vegetables and food crops than mid and low altitude gardens. Homegarden products which are rich in vitamin and mineral nutrients supplements the dietary nutritional requirements.

The homegardens of undivided Aizawl district of Mizoram are nevertheless food producing subsistence farming systems which increase the general well being of the society. They area in general rich source of biodiversity, the proportion of which depended upon the socio-economic and ecological factors and preferences of the homegardeners. The findings suggest these systems could be important platform, for conservation of plant biodiversity through use, for diversifying the nutrition of rural poor that would contribute to food security at household and community level. The low productivity in the homegarden, are however, due to lack of proper knowledge on crop husbandry. Some of the future studies could be directed at working out stocking rate of trees for the multistory cropping system, introduction of wilt resistant varieties of crop and integration of animals that will ensure milk and egg production for domestic consumption and sale and studies on interdependent and interrelated components of homegardens for ecological and economic sustainability.

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Appendix -1

Questionnaire for Homegarden Survey

1. Name of family head:
2. Age:
3. Sex:
4. Education Status:
5. No. of Members: (M/F)
6. Highest Education level in the family:
7. Occupation:
8. Main Source of Income:
9. Annual Income:
10. Farm Size (Tin/Biga):
11. Any other garden owned by the farmer, area?
12. Distance to Market:
13. Distance to Main/Major road:
14. Number of Livestock: (Cow, Buffallo, Piggery, Poultry, Dog, etc.)
15. During off-farm time what do they do? (Govt. Service/Wage labour/Carpentry/Trading. etc)
16. How much labour do they devote for farm? Male and female (hrs per day, days per week or month)
17. Do they engage labour for maintaining the farm?
18. If yes, how many days per week or month or year?
19. How many times they do weeding in a year?
20. What is the cropping pattern/calendar of the crop?
21. How old is the garden?
22. What was the land use before in the past before the garden came to use?
23. For what purpose they planted the trees? (timber/firewood/shade/fruit/any other use)
24. How much fire wood they require in a year?
25. What is the firewood use for? (cooking/warming water/ cooking pig meal, etc.)
26. How much is required per day?
27. How much firewood they require in a year?
28. Whether they buy the firewood or collected freely?
29. Which trees do the collect for firewood?
30. Do they collect any product from the forest?
31. From where do they get the seeds for farm? (Govt/marget/Relatives/Jungle)
32. What farm produce are sold?
33. How much of the product is sold? [(1/2),(1/3),(1/4), (%wise ratio of sold and consumed)]
34. Whether it is sold through middleman/commission or by self in the market?
35. How much income do they get from the sale?
36. Any plant/tree which they use for medicinal purpose.
37. Parts used and for what ailments?
38. Which tree/crop they think is the most preferred in terms of income or taste or use?
39. Any fertilizer is used? If yes which fertilizer and how much?
40. How is the fertility managed?
41. Any modern technique/crops introduced in their farms from Govt. dept? Any Loan taken from Govt.?

Appendix -2

Species prevalence in homegardens at different altitudes

High Altitude:

Sl No	Local Name	Botanical Name	% F	IVI
1	Zawngtah	*Parkia timoriana*	79.07	48.42
2	Phui-hnam	*Clerodendrum colebrookianum*	86.05	19.69
3	Thei hai	*Mangifera indica*	74.42	16.47
4	Kawlthei	*Psidium guajava*	88.37	15.01
5	Sa-sua	*Quercus serrata*	20.93	12.39
6	Thingpui kung	*Camellia sinensis*	46.51	10.17
7	Sêr-thlum	*Citrus reticulata*	41.86	9.74
8	Kawh-te-bêl	*Trevesia palmata*	67.44	8.24
9	Lamkhuang	*Artocarpus heterophyllus*	30.23	6.73
10	Japan Thei te	*Prunus domestica*	67.44	6.35
11	Zamir	*Citrus sp.*	55.81	6.29
12	Thingfanghma	*Carica papaya*	44.19	6.20
13	Khiang	*Schima wallichii*	34.88	5.81
14	Pom/manding	*Punica granatum*	44.19	5.75
15	Sertawk	*Citrus grandis*	37.21	5.59
16	Pear thei	*Pyrus communis*	39.53	5.52
17	Sarjuk	*Elaeagnus caudata*	53.49	5.04
18	Thing thu pui	*Dysoxylum gobara*	46.51	4.74
19	Thing thei hmu	*Morus alba*	37.21	4.40
20	Tung	*Vernicia montana*	25.58	4.21
21	Japan Zawngtah	*Leucaena leucocephala*	41.86	4.05
22	Thing sia	*Castanopsis tribuloides*	25.58	4.00
23	Thei tat	*Artocarpus lacucha*	18.60	3.89
24	Thei te hmul	*Prunus persica*	41.86	3.62
25	Samtawk te	*Solanum anguivi*	34.88	3.49
26	Thing be râ	*Cyphomandra betacea*	37.21	3.42
27	Fâr	*Pinus kesiya*	13.95	3.42
28	Pâng-bal	*Manihot esculenta*	25.58	3.29
29	Keifang	*Myrica esculenta*	27.91	3.07
30	Thei-ria	*Carallia brachiata*	16.28	2.72
31	Cedar	*Cupressus torulosa*	18.60	2.65
32	Coffee	*Coffea arabica*	16.28	2.62
33	Khawmhma	*Rhus semialata*	32.56	2.59

F- Frequency, IVI-Importance Value index

Sl No	Local Name	Botanical Name	% F	IVI
34	Sun-hlû	*Emblica officinalis*	25.58	2.53
35	Si neh	*Eurya cerasifolia*	18.60	2.52
36	Vau be	*Bauhinia variegata*	16.28	2.05
37	Hnah kiah	*Callicarpa arborea*	18.60	1.94
38	Champara/ser te	*Citrus aurantifolium*	13.95	1.87
39	Sêr-nam	*Litsea cubeba*	11.63	1.74
40	Chalthei	*Pyrus pashia*	9.30	1.55
41	Neem	*Azadirachta indica*	6.98	1.52
42	Rose	*Rosa indica*	16.28	1.36
43	Silver oak	*Grevillea robusta*	11.63	1.36
44	Fah	*Lithocarpus dealbata*	6.98	1.29
45	Ngiau	*Michelia oblonga*	9.30	1.23
46	Thil	*Quercus polystachya*	9.30	1.23
47	Hriangpui	*Alnus nepalensis*	6.98	1.23
48	Thei-pui	*Ficus semicordata*	6.98	1.23
49	Chhimhruk	*Rhus succedanea*	9.30	1.10
50	Tlaizawng	*Prunus cerasoides*	9.30	1.03
51	Butter thei	*Persea americana*	11.63	1.02
52	Thlan vawng	*Gmelina arborea*	2.33	0.91
53	Arsarimnam	*Alangium chinensis*	6.98	0.90
54	Tengtere	*Tamarindus indica*	6.98	0.86
55	Tei	*Toona ciliata*	6.98	0.82
56	Limbu	*Citrus medica* var. *acidus*	9.30	0.80
57	Thelret	*Ficus elastic*	9.30	0.78
58	Mulberry	*Morus macroura*	9.30	0.78
59	Tawkte	*Solanum*	9.30	0.78
60	Tum	*Caryota urens*	6.98	0.77
61	Sêr-fâng	*Citrus limon*	6.98	0.77
62	Thei-hmu	*Rubus acuminatus*	4.65	0.72
63	Then	*Quercus leucotrichophora*	4.65	0.71
64	Bung	*Ficus benghalensis*	6.98	0.65
65	Fartuah	*Erythrina stricta*	4.65	0.54
66	Bottle brush	*Callistemon citrinus*	4.65	0.52
67	Ser pui/ Ser	*Citrus indica*	4.65	0.52
68	Tawitawh	*Spondias mangifera*	4.65	0.45
69	Thei-she-rêt	*Aphananthe cuspidata*	2.33	0.45
70	Eucalyptus	*Eucalyptus sp*	4.65	0.39

Sl No	Local Name	Botanical Name	%F	IVI
71	Thing antam	*Moringa oleifera*	4.65	0.39
72	Tawkpui	*Solanum torvum*	4.65	0.39
73	Chimchawk	*Aralia foliosa* var. *sikkimensis*	2.33	0.39
74	Sialhmâ	*Helica excelsa*	2.33	0.39
75	Tlangham	*Lyonia ovalifolia*	2.33	0.39
76	Keipui	*Prunus jenkinsii*	2.33	0.39
77	Lengau	*Debregeasia longifolia*	2.33	0.39
78	Thing ar thau	*Ailanthus integrifolia* ssp. *calycina*	2.33	0.32
79	Theitit	*Ficus prostata*	2.33	0.32
80	Tiar	*Saurauia punduana*	2.33	0.32
81	Len hmui	*Syzigium cumini*	2.33	0.32
82	Archangkawm	*Oroxylum indicum*	2.33	0.27
83	Tuai tit	*Antidesma bunius*	2.33	0.26
84	Saper	*Lindera nacusua*	2.33	0.26
85	Hlai	*Quercus helferiana*	2.33	0.26
86	Belphuar	*Trema orientalis*	2.33	0.26
87	Batling	*Wendlandia grandis*	2.33	0.26
88	Sehnap	*Urena lobata*	2.33	0.26
89	Pang	*Bombax insigne*	2.33	0.19
90	Sial lu	*Borassus flabellifer*	2.33	0.19
91	Theifeihmung	*Euphoria longan*	2.33	0.19
92	Hmawng	*Ficus religiosa*	2.33	0.19
93	Thingpawn chhia	*Glochidion velutinum*	2.33	0.19
94	Chhankhen	*Heteropanax fragrans*	2.33	0.19
95	Kangdamdawi	*Jatropha curcas*	2.33	0.19
96	Thingsawn	*Premna racemosa*	2.33	0.19
97	Chhawk hlei par sen	*Rhododendron arboretum*	2.33	0.19
98	Thingvawkpui	*Sapium baccatum*	2.33	0.19
99	Thei chhawl	*Syzigium grandis*	2.33	0.19
100	Sir kâm	*Vaccinium sprengelii*	2.33	0.19
101	Tumthang	*Crotolaria juncea*	2.33	0.19
102	Duranta	*Duranta repens*	2.33	0.19
103	Hnah sen	*Euphorbia pulcherrima*	2.33	0.19
104	Rokhuah (hlo khâ)	*Jasminum amplexicaule*	2.33	0.19
105	Chawkhlei	*Luculia pinceana*	2.33	0.19
106	Mutih	*Ricinus communis*	2.33	0.19
107	Pawhrual	*Sarcococca coriacea*	2.33	0.19

Mid altitude:

Sl No	Local Name	Botanical Name	%F	IVI
1	Thei hai	*Mangifera indica*	93.75	19.02
2	Zawngtah	*Parkia timoriana*	50	15.92
3	Teak	*Tectona grandis*	25	15.69
4	Sêr-thlum	*Citrus reticulata*	81.25	13.58
5	Coffee	*Coffea arabica*	50	11.64
6	Kawh-te-bêl	*Trevesia palmata*	81.25	10.90
7	Kuhva	*Areca catechu*	31.25	10.50
8	Lamkhuang	*Artocarpus heterophyllus*	68.75	10.00
9	Phui-hnam	*Clerodendrum colebrookianum*	62.5	9.20
10	Kawlthei	*Psidium guajava*	75	8.04
11	Thingdawl	*Tetrameles nudiflora*	31.25	7.90
12	Thingfanghma	*Carica papaya*	50	7.11
13	Thingpui kung	*Camellia sinensis*	43.75	6.84
14	Coconut	*Cocos nucifera*	18.75	6.57
15	Hatkora	*Citrus macroptera* var. *anamensis*	56.25	6.55
16	Tung	*Vernicia montana*	25	6.39
17	Thing thu pui	*Dysoxylum gobara*	50	5.23
18	Sertawk	*Citrus grandis*	62.5	4.85
19	Vang thing	*Albizia chinensis*	31.25	4.32
20	Japan Thei te	*Prunus domestica*	50	4.31
21	Thlan vawng	*Gmelina arborea*	12.5	3.46
22	Chengkek	*Garcinia lanceaefolia*	37.5	3.45
23	Tengtere	*Tamarindus indica*	25	3.43
24	Thei-hmu	*Rubus acuminatus*	31.25	3.43
25	Khiang	*Schima wallichii*	12.5	3.37
26	Thei-ria	*Carallia brachiata*	37.5	3.35
27	Vau be	*Bauhinia variegata*	31.25	3.29
28	Zamir	*Citrus* sp.	25	2.69
29	Tawkte	*Solanum*	37.5	2.68
30	Sun-hlû	*Emblica officinalis*	31.25	2.60
31	Fartuah	*Erythrina stricta*	25	2.55
32	Butter thei	*Persea americana*	37.5	2.51
33	Pear thei	*Pyrus communis*	25	2.27
34	Thingrai	*Aquilarria malaccensis*	12.5	2.24
35	Kawlsunhlu	*Phyllanthus acidus*	18.75	2.20
36	Neem	*Azadirachta indica*	25	2.01
37	Tat	*Artocarpus nitidus ssp griffithii*	18.75	1.89
38	Thei tat	*Artocarpus lacucha*	12.5	1.87
39	Japan Zawngtah	*Leucaena leucocephala*	25	1.66

Sl No	Local Name	Botanical Name	%F	IVI
40	Thuja	*Thuja compacta*	18.75	1.63
41	Limbu	*Citrus medica* var. *acidus*	25	1.55
42	Arsarimnam	*Alangium chinensis*	12.5	1.47
43	Bottle brush	*Callistemon citrinus*	12.5	1.47
44	Nganbawn	*Acrocarpus fraxinifolius*	18.75	1.43
45	Mei hle	*Caryota mitis*	18.75	1.43
46	Theitit	*Ficus prostata*	18.75	1.28
47	Bangla par	*Hibiscus rosa chinensis*	18.75	1.28
48	Sêr-fâng	*Citrus limon*	12.5	1.21
49	Hnah kiah	*Callicarpa arborea*	12.5	1.16
50	Hling si	*Sapindus mukorossi*	12.5	1.16
51	Len hmui	*Syzigium cumini*	12.5	1.16
52	Belphuar	*Trema orientalis*	12.5	1.16
53	khawmhma	*Rhus semialata*	18.75	1.12
54	Vai-thei-fei-mung	*Litchi sinensis*	6.25	1.11
55	Sarjuk	*Elaeagnus caudata*	18.75	1.11
56	Keltebengbe	*Taberna montana divarigata*	18.75	1.07
57	Pâng-bal	*Manihot esculenta*	18.75	1.06
58	Rose	*Rosa indica*	18.75	1.06
59	Fâr	*Pinus kesiya*	6.25	1.04
60	Sandal wood	*Santalum album*	6.25	1.04
61	Thing sia	*Castanopsis tribuloides*	12.5	1.01
62	Ngiau	*Michelia oblonga*	12.5	1.01
63	Beltur	*Ostodes paniculata*	12.5	1.01
64	Silver oak	*Grevillea robusta*	6.25	0.89
65	Lungkhup	*Haldina cordifolia*	6.25	0.89
66	Apple	*Malus pumila*	6.25	0.89
67	Tum	*Caryota urens*	12.5	0.85
68	Anku	*Celtis tetranda*	12.5	0.85
69	Thei-pui	*Ficus semicordata*	12.5	0.85
70	Tawitawh	*Spondias mangifera*	12.5	0.85
71	Thing thei hmu	*Morus alba*	12.5	0.74
72	kangtek	*Albizia procera*	6.25	0.73
73	Chimchawk	*Aralia foliosa* var. *sikkimensis*	6.25	0.73
74	Zuang	*Duabanga grandiflora*	6.25	0.73
75	Red oil palm	*Elaeis guineensis*	6.25	0.73
76	Thinglung	*Eleocarpus floribundus*	6.25	0.73
77	Buarpui	*Livinstonia chinensis*	6.25	0.73
78	Herse	*Mesua ferrea*	6.25	0.73
79	Bil	*Protium serratum*	6.25	0.73

Sl No	Local Name	Botanical Name	%F	IVI
80	Hmarleng	*Styrax serrulatum*	6.25	0.73
81	Thingkha	*Derris robusta*	6.25	0.68
82	Thuamriat	*Aegle marmelos*	6.25	0.58
83	Khwangthli	*Bischofia javanica*	6.25	0.58
84	Tejpat	*Cinnamomum tamala*	6.25	0.58
85	Thing be râ	*Cyphomandra betacea*	6.25	0.58
86	Eucalyptus	*Eucalyptus* sp.	6.25	0.58
87	Kangdamdawi	*Jatropha curcas*	6.25	0.58
88	Chawmzil	*Ligustrum robustum*	6.25	0.58
89	Fah	*Lithocarpus dealbata*	6.25	0.58
90	Thingtumbu	*Magnolia hodgsonii*	6.25	0.58
91	Thingkhawihlu	*Vitex peduncularis*	6.25	0.58
92	Batling	*Wendlandia grandis*	6.25	0.58
93	Thei te hmul	*Prunus persica*	6.25	0.57
94	Ser pui/ Ser	*Citrus indica*	6.25	0.57
95	Thlado	*Lagerstroema speciosa*	6.25	0.51
96	Tei	*Toona ciliata*	6.25	0.48
97	Thing chawk e	*Albizia lebbeck*	6.25	0.43
98	Thuamriat	*Alstonia scholaris*	6.25	0.43
99	Zairum	*Anogeissus acuminata*	6.25	0.43
100	Chhawntual	*Aporusa octandra*	6.25	0.43
101	Thei her awt	*Averrhoa carambola*	6.25	0.43
102	Pangkai	*Baccaurea ramiflora*	6.25	0.43
103	Phaktel	*Bridelia monoica*	6.25	0.43
104	Thakthing	*Cinnamomum verum*	6.25	0.43
105	April par	*Delonix regia*	6.25	0.43
106	Si neh	*Eurya cerasifolia*	6.25	0.43
107	Rihnim	*Ficus geniculata*	6.25	0.43
108	Thingpawn chhia	*Glochidion velutinum*	6.25	0.43
109	Vaiza	*Hibiscus macrophyllus*	6.25	0.43
110	Thral teh	*Kydia calycina*	6.25	0.43
111	Nauthak	*Litsea monopetala*	6.25	0.43
112	Phunbarh	*Macropanax dispermus*	6.25	0.43
113	Zuk buh	*Oreocnide integrifolia*	6.25	0.43
114	Ngha leng lu thar	*Persia minutiflora*	6.25	0.43
115	Par rim tui	*Plumeria acuminata*	6.25	0.43
116	Saisiak	*Securinega virosa*	6.25	0.43
117	Sentet	*Sophora benthamii*	6.25	0.43
118	Thingvandawt	*Terminalia bellerica*	6.25	0.43
119	Thleng reng	*Vitex heterophylla*	6.25	0.43

Sl No	Local Name	Botanical Name	%F	IVI
120	Chingit	*Zanthoxylum rhetsa*	6.25	0.43
121	Kananpar	*Nerium indicum*	6.25	0.43
122	Borai	*Ziziphus mauritiana*	6.25	0.41
123	Ngul ri thet	*Coffea khasiana*	6.25	0.37
124	Shillong Tlang sam	*Lantana camara*	6.25	0.37
125	Kawlkarh	*Leea indica*	6.25	0.37
126	Hlonuar	*Mimosa pudica*	6.25	0.35
127	Samtawk te	*Solanum anguivi*	6.25	0.35

Low altitude :

Sl No	Local Name	Botanical Name	% Freq	IVI
1	Kuhva	*Areca catechu*	89.81	90.91
2	Thei hai	*Mangifera indica*	13.16	87.88
3	Lamkhuang	*Artocarpus heterophyllus*	11.43	75.76
4	Thingfanghma	*Carica papaya*	7.49	69.70
5	Kawlthei	*Psidium guajava*	7.96	69.70
6	Coconut	*Cocos nucifera*	17.60	63.64
7	Tengtere	*Tamarindus indica*	8.74	63.64
8	Hatkora	*Citrus macroptera car anamensis*	6.35	48.48
9	Phui-hnam	*Clerodendrum colebrookianum*	5.27	48.48
10	Limbu	*Citrus medica* var. *acidus*	6.04	48.48
11	Zawngtah	*Parkia timoriana*	8.72	42.42
12	Thingkha	*Derris robusta*	5.47	39.39
13	Vai-thei-fei-mung	*Litchi sinensis*	8.70	36.36
14	Neem	*Azadirachta indica*	3.63	33.33
15	Teak	*Tectona grandis*	8.82	30.30
16	Kawh-te-bêl	*Trevesia palmata*	2.88	30.30
17	Sertawk	*Citrus grandis*	2.51	24.24
18	Archangkawm	*Oroxylum indicum*	1.83	24.24
19	Borai	*Ziziphus mauritiana*	2.02	24.24
20	Chengkek	*Garcinia lanceaefolia*	3.22	24.24
21	Thlan vawng	*Gmelina arborea*	5.51	21.21
22	Thlado	*Lagerstroema speciosa*	1.98	21.21
23	Thei tat	*Artocarpus lacucha*	2.85	18.18
24	Japan Thei te	*Prunus domestica*	1.31	18.18

Sl No	Local Name	Botanical Name	%F	IVI
25	Tei	*Toona ciliata*	1.65	18.18
26	Tatkawng	*Artocarpus chama*	2.73	15.15
27	Pangkai	*Baccaurea ramiflora*	1.79	15.15
28	Thei-ria	*Carallia brachiata*	1.48	15.15
29	Kawthindeng	*Dillenia indica*	1.30	15.15
30	Paite maien	*Ficus hispida*	1.26	15.15
31	Len hmui	*Syzigium cumini*	1.33	15.15
32	Sêr-thlum	*Citrus reticulata*	1.90	15.15
33	Zamir	*Citrus* sp.	1.39	15.15
34	Sarjuk	*Elaeagnus caudata*	1.10	15.15
35	Pâng-bal	*Manihot esculenta*	1.03	15.15
36	Vau be	*Bauhinia variegata*	1.31	12.12
37	Red oil palm	*Elaeis guineensis*	1.67	12.12
38	Kangdamdawi	*Jatropha curcas*	1.50	12.12
39	Kawlsunhlu	*Phyllanthus acidus*	0.92	12.12
40	Bil	*Protium serratum*	0.92	12.12
41	Thingkhawihlu	*Vitex peduncularis*	1.04	12.12
42	Coffee	*Coffea arabica*	1.59	12.12
43	Keltebengbe	*Taberna montana divarigata*	0.87	12.12
44	Thei her awt	*Averrhoa carambola*	1.21	9.09
45	Hnah kiah	*Callicarpa arborea*	1.04	9.09
46	Zuang	*Duabanga grandiflora*	1.27	9.09
47	Vaiza	*Hibiscus macrophyllus*	0.75	9.09
48	Bangla par	*Hibiscus rosa chinensis*	0.69	9.09
49	Japan Zawngtah	*Leucaena leucocephala*	0.74	9.09
50	Nauthak	*Litsea monopetala*	0.75	9.09
51	Thing thei hmu	*Morus alba*	0.80	9.09
52	Butter thei	*Persea americana*	0.69	9.09
53	Tawitawh	*Spondias mangifera*	0.69	9.09
54	Thingpui kung	*Camellia sinensis*	3.42	9.09
55	Phuinam chhuak	*Clerodendrum viscosum*	0.84	9.09
56	Chawng	*Euphorbia royleana*	0.62	9.09
57	Thei-hmu	*Rubus acuminatus*	0.70	9.09
58	Kalsiamthing	*Acacia auriculiformia*	0.69	6.06
59	Thingrai	*Aquilarria malaccensis*	1.10	6.06
60	Bottle brush	*Callistemon citrinus*	0.46	6.06
61	Tum	*Caryota urens*	0.46	6.06

Sl No	Local Name	Botanical Name	%F	IVI
62	April par	*Delonix regia*	0.52	6.06
63	Zo thing hang	*Diospyros toposia*	0.46	6.06
64	Umkhal	*Elaeocarpus tectorius*	0.52	6.06
65	Sun-hlû	*Emblica officinalis*	0.45	6.06
66	Fartuah	*Erythrina stricta*	0.55	6.06
67	Hmawng	*Ficus religiosa*	0.46	6.06
68	Bungbutuairam	*Garuga pinnata*	0.46	6.06
69	Hnakhar-nu	*Macaranga indica*	0.52	6.06
70	Thingkhei	*Mallotus phillipensis*	0.52	6.06
71	Herse	*Mesua ferrea*	0.46	6.06
72	Ardahpui	*Pithecellobium dypearia*	0.52	6.06
73	Tiar	*Saurauia punduana*	0.63	6.06
74	Ser pui/ Ser	*Citrus indica*	0.70	6.06
75	Curry pata	*Murraya Koenigii*	0.42	6.06
76	Pom/manding	*Punica granatum*	0.46	6.06
77	Tawkte	*Solanum* sp.	0.41	6.06
78	Tawkpui	*Solanum torvum*	0.45	6.06
79	Thuamriat	*Aegle marmelos*	0.23	3.03
80	Arsarimnam	*Alangium chinensis*	0.23	3.03
81	Thing chawk e	*Albizia lebbeck*	0.23	3.03
82	Thuamriat	*Alstonia scholaris*	0.23	3.03
83	Zairum	*Anogeissus acuminata*	0.23	3.03
84	Tuai tit	*Antidesma bunius*	0.29	3.03
85	Chimchawk	*Aralia foliosa* var. *sikkimensis*	0.58	3.03
86	Khwangthli	*Bischofia javanica*	0.23	3.03
87	Pang	*Bombax insigne*	0.29	3.03
88	Phaktel	*Bridelia monoica*	0.23	3.03
89	Hmakpazangkang	*Cassia nodosa*	0.23	3.03
90	Thinghmarcha	*Celtis timorensis*	0.23	3.03
91	Tejpat	*Cinnamomum tamala*	0.23	3.03
92	Ser sawr	*Citrus acida*	0.35	3.03
93	Mukh	*Cordia fragrantissima*	0.23	3.03
94	Cedar	*Cupressus torulosa*	0.23	3.03
95	Thing be râ	*Cyphomandra betacea*	0.23	3.03
96	Saha tah	*Dysoxylum binectariferum*	0.23	3.03
97	Thing thu pui	*Dysoxylum gobara*	0.27	3.03
98	Raisentu	*Embelia tsjeriam-cottam*	0.23	3.03

Sl No	Local Name	Botanical Name	%F	IVI
99	Fartuah hling nei lo	*Erythrina subumbrans*	0.23	3.03
100	Theitit	*Ficus prostata*	0.23	3.03
101	Thei-pui	*Ficus semicordata*	0.23	3.03
102	Hmeithai thei	*Ficus tinctoria*	0.23	3.03
103	Sakhithei	*Flacourtia jangomas*	0.23	3.03
104	Silver oak	*Grevillea robusta*	0.23	3.03
105	Rubber tree	*Hevea brasilensis*	0.23	3.03
106	Anpangthuam	*Lepionurus sylvestris*	0.29	3.03
107	Thingpuithing	*Lithocarpus elegans*	0.23	3.03
108	Theikawarh	*Memecylon celastrinum*	0.23	3.03
109	Thing antam	*Moringa oleifera*	0.23	3.03
110	Date palm	*Phoenix sylvestris*	0.23	3.03
111	Par rim tui	*Plumeria acuminata*	0.23	3.03
112	Thingsawn	*Premna racemosa*	0.23	3.03
113	Tlaizawng	*Prunus cerasoides*	0.23	3.03
114	Thei te hmul	*Prunus persica*	0.21	3.03
115	Siksil	*Pterospermum acerifolium*	0.29	3.03
116	Hling si	*Sapindus mukorossi*	0.23	3.03
117	Mualhawih	*Saraca asoca*	0.29	3.03
118	Khiang	*Schima wallichii*	0.23	3.03
119	Khopui	*Sterculia villosa*	0.29	3.03
120	Zih nghal	*Stereospermum colias*	0.23	3.03
121	Clove	*Syzigium aromaticum*	0.23	3.03
122	Chhar thing	*Terminalia myriocarpa*	0.23	3.03
123	Belphuar	*Trema orientalis*	0.23	3.03
124	Tung	*Vernicia montana*	0.42	3.03
125	Thurte an	*Antidesma acidium*	0.23	3.03
126	Da du hlo	*Cassia alata*	0.29	3.03
127	Sêr-fâng	*Citrus limon*	0.28	3.03
128	Thak pui	*Dendrocnide sinuata*	0.21	3.03
129	Rokhuah (hlo khâ)	*Jasminum amplexicaule*	0.21	3.03
130	Shillong Tlang sam	*Lantana camara*	0.21	3.03
131	Ru lei	*Millettia pachycarpa*	0.21	3.03
132	Mutih	*Ricinus communis*	0.21	3.03
133	Rose	*Rosa indica*	0.21	3.03
134	Per pawng chaw	*Scoparia duicis*	0.21	3.03
135	Samtawk te	*Solanum anguivi*	0.21	3.03
136	Yellow oleander	*Thevetia neriifolia*	0.21	3.03
137	Thuja	*Thuja compacta*	0.21	3.03

Appendix-3

Plants species inventoried in the homegardens with their local names and common use

Botanical Name	**Local Name**	**Life Form**	**Family**	**Uses**
Abelmoschus esculentus (L.) Moench	Bawrseibe	Herb	Malvaceae	Food
Acacia auriculiformis A. Cunn.	Kalsiamthing	Tree	Mimosaceae	Timber
Acacia penneta (L.) Willd.	Khanghu	Climber	Mimosaceae	Food
Acorus calamus (L.)	Sweet flag	Herb	Acoraceae	Medicinal
Acrocarpus fraxinifolius Wight. & Arn.	Nganbawn	Tree	Caesalpiniaceae	Timber
Aegle marmelos (L.) Correa	Thuamriat	Tree	Rutaceae	Timber
Ageratum conyzoides L.	Vailen hlo	Herb	Compositae	Medicinal
Ailanthus integrifolia ssp *calycina* (Pierre) Noot.	Thing ar thau	Tree	Simarubaceae	Timber
Alangium chinense (Lour.) Harms	Arsarimnam	Tree	Alangiaceae	Firewood
Albizia chinensis (Osbeck) Merr.	Vang thing	Tree	Mimosaceae	Timber
Albizia lebbeck (L.) Benth.	Thing chawk e	Tree	Mimosaceae	Timber
Albizia myriophylla Benth.	Zamjou/Zang-zu	Climber	Mimosaceae	Medicinal
Albizia procera (Roxb.) Benth.	kangtek	Tree	Mimosaceae	Timber
Allium cepa var. *cepa* L.	Purun (zo)	Herb	Liliaceae	Food
Allium hookeri Thw.	Mizo purun	Herb	Liliaceae	Food
Alnus nepalensis D. Don.	Hriangpui	Tree	Betulaceae	Firewood
Alocasia indica (Lour.) Koch.	Taro	Herb	Araceae	Food
Alocasia macrorrhiza (L.) Schott.	Batra	Herb	Araceae	Medicinal
Aloe vera (L.) Burm. f.	Aloe vera	Herb	Xanthorrhoeaceae	Ornamental
Alpina galanga (L.) Willd.	Aichal	Herb	Zingiberaceae	Food
Alstonia scholaris (L.) R. Br.	Thuamriat	Tree	Apocycaneae	Medicinal
Amomum dealbatum Roxb.	Aidu	Herb	Zingiberaceae	Food
Amorphophallus paeonifolius (Dennst.) Nicolson	Batel hawng	Herb	Araceae	Food
Ananas comosus (L.) Merr.	Lakhuithei	Herb	Bromeliaceae	Food
Anogeissus acuminata Roxb.	Zairum	Tree	Combretaceae	Timber
Antidesma acidium Retz.	Thurte an	Shrub	Euphorbiaceae	Firewood
Antidesma bunius (L.) Spreng.	Tuai tit	Tree	Euphorbiaceae	Firewood
Aphananthe cuspidate (Bl.) Planch	Thei-she-rêt	Tree	Ulmaceae	Firewood
Aporusa octandra (Buch.-Ham. ex D. Don) A.R. Vickery	Chhawntual	Tree	Euphorbiaceae	Timber
Aquilarria malaccensis Lamk.	Thingrai	Tree	Thymeleaceae	Firewood
Aralia foliosa var. *sikkimensis*	Chimchawk	Tree	Araliaceae	Food
Areca catechu L.	Kuhva	Tree	Palmae	Food
Artocarpus chama Buch.-Hum.	Tatkawng	Tree	Moraceae	Timber
Artocarpus heterophyllus Lamk.	Lamkhuang	Tree	Moraceae	Timber

Botanical Name	Local Name	Life Form	Family	Uses
Artocarpus lakoocha Roxb.	Thei tat	Tree	Moraceae	Timber
Artocarpus nitidus ssp *griffithii* (King) F.M. Jarrett	Tat	Tree	Moraceae	Timber
Asparagus racemosus Willd.	Arkebawk	Climber	Liliaceae	Ornamental
Averrhoa carambola L.	Thei her awt	Tree	Oxalidaceae	Timber
Azadirachta indica A. Juss.	Neem	Tree	Meliaceae	Timber
Baccaurea ramiflora Lour.	Pangkai	Tree	Euphorbiaceae	Firewood
Bambusa arundinaceae Retz.	Rua	Bamboo	Graminae	Misc
Bambusa bambos (L.) Voss.	Zoramthanga maw	Bamboo	Graminae	Misc
Basella alba L. var. *rubra*	Nawi nawk	Climber	Basellaceae	Food
Bauhinia variegata L.	Vau be	Tree	Caesalpiniaceae	Firewood
Benincasa hispida (Thunb) Cogn.	Maipawl	Climber	Cucurbitaceae	Food
Bidens biternata (Lour.) Merr. & Sherff.	Vawkpui thal	Herb	Compositae	Fodder
Bischofia javanica Blume	Khwangthli	Tree	Euphorbiaceae	Timber
Bombax insigne Wall.	Pang	Tree	Bombacaceae	Fibre
Borassus flabellifer L.	Sial lu	Tree	Palmae	Ornamental
Bougainvillea spectabilis Willd.	Sarawn	Climber	Nyctaginaceae	Ornamental
Brassica juncea (L.) Czern. & Coss.	Antam	Herb	Cruciferae	Food
Brassica oleracea L. var. *capitata*	Ziklum	Herb	Cruciferae	Food
Brassica oleracea L. var. *gongylodes*	Bulbawk	Herb	Cruciferae	Food
Brassica oleracea L. var. *italica*	Brokoli	Herb	Cruciferae	Food
Brassica oleracea L. var. *botrytis*	Parbawr	Herb	Cruciferae	Food
Brassica rapa L.	Antam	Herb	Cruciferae	Food
Brassica sp.	Cabbage	Herb	Cruciferae	Food
Bridelia monoica Merr.	Phaktel	Tree	Euphorbiaceae	Timber
Bulbophyllum lobbii Lindl.	Naobang	Epiphyte	Orchidaceae	Ornamental
Butea parviflora Roxb.	Zathoh	Climber	Papilionaceae	Fibre
Cactus	Cactus	Herb	Euphorbiaceae	Ornamental
Cajanus cajan (L.) Millsp.	Behliang	Herb	Papilionaceae	Food
Calamus andamanicus Kurz.	Mawt	Climber	Palmae	Ornamental
Calamus erectus Roxb.	Hruipui	Climber	Palmae	Ornamental
Calamus sp.	Cane	Climber	Palmae	Ornamental
Calamus tenius Roxb.	Thilte	Climber	Palmae	Ornamental
Callicarpa arborea Roxb.	Hnah kiah	Tree	Verbenaceae	Timber
Callistemon citrinus (Curtis) Skeels	Bottle brush	Tree	Myrtaceae	Ornamental
Camellia sinensis (L.) O. Kuntze	Thingpui kung	Shrub	Theaceae	Beverage
Canavalia ensiformis (L.) DC.	Fangra	Herb	Papilionaceae	Food
Canna orientalis Rosc.	Kungpui muthi	Herb	Cannaceae	Medicinal
Cannabis sativa L.	Kanja	Herb	Cannabinaceae	Narcotics

Botanical Name	Local Name	Life Form	Family	Uses
Capsicum annuum L.	Hmarchate	Herb	Solanaceae	Food
Capsicum fructescens L. (Bail.)	Hmarcha pui	Herb	Solanaceae	Food
Carallia brachiata (Lour.) Merr.	Thei-ria	Tree	Rhizophoraceae	Timber
Carica papaya L.	Thingfanghma	Tree	Caricaceae	Food
Caryota mitis Lour.	Mei hle	Tree	Palmae	Ornamental
Caryota urens L.	Tum	Tree	Palmae	Ornamental
Cassia alata L.	Da du hlo	Shrub	Caesalpiniaceae	Medicinal
Cassia nodosa Buch.-Ham. ex Roxb.	Hmakpazangkang	Tree	Caesalpiniaceae	Firewood
Cassia occidentalis L.	Rengan	Herb	Caesalpiniaceae	Food
Castanopsis tribuloides (Sm.) A. DC.	Thing sia	Tree	Fagaceae	Timber
Catharanthus roseus (L.) G. Don.	Kumtlung	Herb	Apocycaneae	Ornamental
Celtis tetranda Roxb.	Anku	Tree	Ulmaceae	Timber
Celtis timorensis Span.	Thinghmarcha	Tree	Ulmaceae	Timber
Centella asiatica (Urb.)	Lambak	Herb	Umbelifereae	Food
Chimnocalamus longispiculata	Rawthing	Bamboo	Graminae	Misc
Chrysanthemum indicum L.	October par	Herb	Compositae	Ornamental
Cinnamomum tamala Fr. Nees	Tejpat	Tree	Lauraceae	Firewood
Cinnamomum verum J.S. Presl.	Thakthing	Tree	Lauraceae	Firewood
Citrus acida (L.)	Ser sawr	Tree	Rutaceae	Food
Citrus aurantifolium (Christm.) Swingle	Champara/ser te	Shrub	Rutaceae	Food
Citrus grandis L. Osbeck	Sertawk	Tree	Rutaceae	Food
Citrus indica Tanaka	Ser pui/ Ser	Shrub	Rutaceae	Food
Citrus limon L. Burm.	Sêr-fâng	Shrub	Rutaceae	Food
Citrus macroptera var. *anamensis* Montrouz	Hatkora	Tree	Rutaceae	Food
Citrus medica L. var. *acidus*	Limbu	Shrub	Rutaceae	Food
Citrus reticulata Blanco.	Sêr-thlum	Shrub	Rutaceae	Food
Citrus sp.	Zamir	Shrub	Rutaceae	Food
Clerodendrum colebrookianum Walp.	Phui-hnam	Tree	Verbenaceae	Food
Clerodendrum viscosum Vent.	Phuinam chhuak	Shrub	Verbenaceae	Medicinal
Cocos nucifera L.	Coconut	Tree	Palmae	Food
Coffea arabica L.	Coffee	Shrub	Rubiacaea	Beverage
Coffea khasiana Hook. f.	Ngul ri thet	Shrub	Rubiacaea	Misc
Colocasia esculenta (L.) Schott	Dawl/bal	Herb	Araceae	Food
Colocasia sp.	Dawl	Herb	Araceae	Food
Colocassia affinis Schott.	Baibing	Herb	Araceae	Food
Cordia fragrantissima Kurz.	Mukh	Tree	Boraginaceae	Firewood
Coriandrum sativum L.	Dhania	Herb	Apiaceae	Spice
Costus speciosus (Koenig) Sm.	Sum bul	Herb	Zingiberaceae	Medicinal

Botanical Name	Local Name	Life Form	Family	Uses
Crotolaria juncea L.	Tumthang	Shrub	Papilionaceae	Food
Cucumis melo var. *saccharinus* H. Jacq.	Hmazil	Climber	Cucurbitaceae	Food
Cucumis sativus L.	Fanghma	Climber	Cucurbitaceae	Food
Cucurbita maxima Duchesne ex Lam.	Maien	Herb	Cucurbitaceae	Food
Cupressus torulosa D. Don.	Cedar	Tree	Cupressaceae	Timber
Curculigo crassifolia (Bak.) Hook. f.	Phaiphak	Herb	Amaryllidaceae	Medicinal
Curcuma caesia Roxb.	Ailiaidum	Herb	Zingiberaceae	Medicinal
Curcuma longa L.	Aieng	Herb	Zingiberaceae	Condiments
Cyathea spinosa Wall. ex Hook.	Tree fern	Herb	Cyatheaceae	Ornamental
Cyphomandra betacea (Cav.) Sendt.	Thing be râ	Tree	Solanaceae	Food
Dahlia rosea (Herb Smith)	Dalhia	Herb	Compositae	Ornamental
Debregeasia longifolia (Burm. f.) Wedd.	Lengau	Shrub	Urticaceae	Food
Delonix regia (Boj.) Raf.	April Par	Tree	Caesalpiniaceae	Firewood
Dendrobium chrysotoxum Lind.	Nau ban pui	Epiphyte	Orchidaceae	Ornamental
Dendrocalamus giganteus Munro.	Vaimaw	Bamboo	Graminae	Misc
Dendrocalamus longispathus Kurz.	Rawnel	Bamboo	Graminae	Misc
Dendrocnide sinuate (Bl.) Chew.	Thak pui	Shrub	Urticaceae	Food
Derris robusta (DC.) Benth.	Thingkha	Tree	Papilionaceae	MPT
Dichrocephala integrifolia (L. f.) Kuntze	Vawk ek a tum tual	Herb	Compositae	Medicinal
Dillenia indica L.	Kawthindeng	Tree	Dilleanaceae	Timber
Diospyros toposia Buch.-Ham.	Zo thing hang	Tree	Ebenaceae	Timber
Duabanga grandiflora Roxb. ex DC.	Zuang	Tree	Lythraceae	Timber
Duranta repens L.	Duranta	Shrub	Verbenaceae	Ornamental
Dysoxylum binectariferum Hook.	Saha tah	Tree	Meliaceae	Timber
Dysoxylum gobara (Buch.-Ham.) Merr.	Thing thu pui	Tree	Meliaceae	Food
Elaeagnus caudate Schl. ex Momiyana	Sarjuk	Shrub	Eleagnaceae	Food
Elaeis guineensis Jacq.	Red oil palm	Tree	Palmae	Misc
Elaeocarpus tectorius (Lour.) Poir	Umkhal	Tree	Tiliaceae	Timber
Eleocarpus floribundus Bl.	Thinglung	Tree	Tiliaceae	Timber
Elsholtzia communis (Collett & Hemsley) Diels.	Lengsher	Herb	Labiatae	spice
Embelia tsjeriam-cottam A.DC.	Raisentu	Tree	Myrsinaceae	Firewood
Emblica officinalis Gaertn.	Sun-hlû	Tree	Euphorbiaceae	Food
Ensete superbum (Roxb.) Cheesman	Saisu	Herb	Musaceae	Food
Entada pursaetha DC.	Kawi hrui	Climber	Mimosaceae	Food
Eryngium foetidum L.	Bakhawr	Herb	Umbelifereae	spice
Erythrina stricta Roxb.	Fartuah	Tree	Papilionaceae	Ornamental

Botanical Name	Local Name	Life Form	Family	Uses
Erythrina subumbrans (Hassk.) Merr.	Fartuah hling nei lo	Tree	Papilionaceae	Ornamental
Eucalyptus sp.	Eucalyptus	Tree	Myrtaceae	Timber
Euphorbia milli Ch. des Moulins	Christ thorn	Herb	Euphorbiaceae	Ornamental
Euphorbia milli var. *splendens*	Euphorbia	Herb	Euphorbiaceae	Ornamental
Euphorbia pulcherrima Willd. ex Klotz.	Hnah sen	Shrub	Euphorbiaceae	Ornamental
Euphorbia royleana Boiss.	Chawng	Shrub	Euphorbiaceae	Ornamental
Euphoria longan (Lour.) Steud.	Theifeihmung	Tree	Euphorbiaceae	Timber
Eurya cerasifolia (D. Don) Kobuski	Si neh	Tree	Theaceae	Timber
Ficus geniculata Kurz.	Bung	Tree	Moraceae	Firewood
Ficus hispida L.	Thelret	Tree	Moraceae	Firewood
Ficus geniculata Kurz.	Rihnim	Tree	Moraceae	Firewood
Ficus hispida L.	Paite maien	Tree	Moraceae	Firewood
Ficus prostata	Theitit	Tree	Moraceae	Firewood
Ficus religiosa L.	Hmawng	Tree	Moraceae	Firewood
Ficus semicordata Buch.-Ham. ex Serr.	Thei-pui	Tree	Moraceae	Firewood
Ficus tinctoria G. Forster	Hmeithai thei	Tree	Moraceae	Firewood
Flacourtia jangomas (Lour.) Raeusch.	Sakhithei	Tree	Flacourtiacaea	Firewood
Garcinia lanceaefolia Roxb.	Chengkek	Shrub	Guttifereae	Food
Garuga pinnata Roxb.	Bungbutuairam	Tree	Burseraceae	Timber
Glinus oppositifolius (L.) Aug. DC	Bakhate	Herb	Aizoaceae	Food
Glochidion velutinum Wight.	Thingpawn chhia	Tree	Euphorbiaceae	Firewood
Glycine max (L.) Merr.	Bekang	Herb	Papilionaceae	Food
Gmelina arborea Roxb.	Thlan vawng	Tree	Verbenaceae	Timber
Grevillea robusta A. Cunn. ex R. Br.	Silver oak	Tree	Protaceae	Timber
Haldina cordifolia (Roxb.) Ridsd.	Lungkhup	Tree	Rubiaceae	Timber
Hedyotis scandens Roxb. ex G. Don	Kelhnamtur	Climber	Rubiacaea	Medicinal
Helica excelsa	Sialhmâ	Tree	Protaceae	Timber
Heteropanax fragrans (Roxb.) Seem	Chhankhen	Tree	Araliaceae	Timber
Hevea brasilensis (Willd. ex Adr. de Juss.) Muell.-Arg.	Rubber tree	Tree	Euphorbiaceae	Firewood
Hibiscus macrophyllus Roxb.	Vaiza	Tree	Malvaceae	Timber
Hibiscus rosa chinensis L.	Bangla par	Tree	Malvaceae	Ornamental
Hibiscus sabdariffa L.	Anthur	Herb	Malvaceae	Food
Hibiscus sabdariffa L.Var.. *sabdariffa*	Vai anthur	Herb	Malvaceae	Food
Hodgsonia macrocarpa (Bl.) Congn.	Kha um	Climber	Cucurbitaceae	Food
Homalomena aromatic (Roxb.) Schott	Anchiri	Herb	Araceae	Food
Impatiens balsamina L.	Nuai thang	Herb	Balsaminaceae	Ornamental

Botanical Name	Local Name	Life Form	Family	Uses
Imperata cylindrical (L.) P. Beauv.	Di pangpar	Herb	Graminae	Misc
Ipomea batatas (L.) Lam.	kawl ba hra	Herb	Convolvulaceae	Food
Jasminum amplexicaule Buch.-Ham. ex G. Don.	Rokhuah (hlo khâ)	Shrub	Oleaceae	Ornamental
Jatropha curcas L.	Kangdamdawi	Tree	Euphorbiaceae	Ornamental
Justicia gendarussa Burm. f.	Justicia	Herb	Acanthaceae	Ornamental
Kalanchoe pinnata (Lam.) Pers.	Bryophyllum	Herb	Crassulaceae	Ornamental
Kydia calycina Roxb.	Thral teh	Tree	Malvaceae	Timber
Lablab purpureus (L.) Sweet.	Bepui	Climber	Papilionaceae	Food
Lagenaria siceraria (Molina) Standley	Um mei	Climber	Cucurbitaceae	Food
Lagerstroema speciosa (L.) Pers.	Thlado	Tree	Lythraceae	Timber
Lantana camara L.	Shillong Tlang sam	Shrub	Verbenaceae	Misc
Lactuca indica L.	Khuang lawi	Herb	Compositae	Food
Leea indica (Burm. f.) Merr.	Kawlkarh	Shrub	Ampelidaceae	Misc
Lepionurus sylvestris Blume	Anpangthuam	Tree	Olacaceae	Food
Leucaena leucocephala (Lam.) de Wit	Japan Zawngtah	Tree	Mimosaceae	Food
Ligustrum robustum (Roxb.) Blume	Chawmzil	Tree	Oleaceae	Firewood
Lilium wallichianum Schult. f.	Ba dai	Herb	Liliaceae	Ornamental
Lindera nacusua (D. Don) Merr.	Saper	Tree	Lauraceae	Timber
Litchi sinensis Sonn.	Vai-thei-fei-mung	Tree	Sapindaceae	Food
Lithocarpus dealbata (Hook. f. & Thomson ex Miq.) Rehder	Fah	Tree	Fagaceae	Timber
Lithocarpus elegans (Blume.) Hatus. ex Soepadmo	Thingpuithing	Tree	Fagaceae	Timber
Litsea cubeba (Lour.) Pers.	Sêr-nam	Tree	Lauraceae	Timber
Litsea monopetala Pers.	Nauthak	Tree	Lauraceae	Timber
Livinstonia chinensis R. Br. ex Mart.	Buarpui	Tree	Palmae	Ornamental
Lobelia angulata (G. Forst.) Hook. f.	Cho ak a thi	Herb	Campanulaceae	Medicinal
Luculia pinceana Hook.	Chawkhlei	Shrub	Rubiacaea	Ornamental
Luffa acutangula (L.) Roxb.	Awmpawng	Climber	Cucurbitaceae	Food
Lycopersicon esculentum Mill.	Sap bawk bawn	Herb	Solanaceae	Food
Lyonia ovalifolia (Wall.) Drude	Tlangham	Tree	Ericaceae	Timber
Macaranga indica Wight.	Hnakhar-nu	Tree	Euphorbiaceae	Timber
Macropanax dispermus (Blume.) Kuntze	Phunbarh	Tree	Araliaceae	Food
Magnolia hodgsonii (Hook. f. & Thomson) H. Keng	Thingtumbu	Tree	Magnoliaceae	Timber
Mallotus phillipensis Muell.-Arg.	Thingkhei	Tree	Euphorbiaceae	Firewood
Malus pumila Mill.	Apple	Tree	Rosaceae	Food

Botanical Name	Local Name	Life Form	Family	Uses
Mangifera indica L.	Thei hai	Tree	Anacardaceae	Food
Manihot esculenta Crantz.	Pâng-bal	Shrub	Euphorbiaceae	Food
Marsdenia maculate Hook. f.	Ankhapui	Climber	Asclepiadaceae	Food
Melocanna baccifera (Roxb.) Kurz.	Mautak	Bamboo	Graminae	Misc
Memecylon celastrinum Kurz.	Theikawarh	Tree	Melastomaceae	Timber
Mentha viridis L.	Pudina	Herb	Labiatae	Food
Mesua ferrea L.	Herse	Tree	Rubiacaea	Timber
Michelia oblonga Wall. ex Hook. f. & Thoms.	Ngiau	Tree	Magnoliaceae	Timber
Mikania micrantha Kunth.	Japan hlo	Climber	Compositae	Fodder
Millettia pachycarpa Benth.	Ru lei	Shrub	Papilionaceae	Misc
Mimosa pudica L.	Hlonuar	Shrub	Mimosaceae	Medicinal
Mirabilis jalapa L.	Artukhuan	Herb	Nyctaginaceae	Ornamental
Momordica charantia L.	Changkha	Climber	Cucurbitaceae	Food
Momordica mixta Roxb.	Maitamtawk	Climber	Cucurbitaceae	Food
Moringa oleifera Lamk.	Thing antam	Tree	Moringaceae	Food
Morus alba L.	Thing thei hmu	Tree	Moraceae	Food
Morus macroura Miq.	Mulberry (fruit big)	Tree	Moraceae	Food
Murraya koenigii (L.) Spreng.	Curry pata	Shrub	Rutaceae	Food
Musa paradisiaca L.	Banhla	Herb	Musaceae	Food
Musa paradisiaca L. Var.. *sylvestris*	Changel	Herb	Musaceae	Food
Myrica esculenta Buch.- Ham.	Keifang	Tree	Myricaceae	Food
Nerium indicum Mill.	Kananpar	Shrub	Apocycaneae	Ornamental
Nicotiana tobaccum L.	Vaihlo	Herb	Solanaceae	Narcotics
Occimum americanum L.	Run hmui	Herb	Labiatae	Medicinal
Oreocnide integrifolia Miq.	Zuk buh	Tree	Urticaceae	Timber
Oroxylum indicum (L.) Vent.	Archangkawm	Tree	Bignoniaceae	Timber
Oryza collina (Trimen) S.D Sharma & Shastry	Buh	Herb	Oryzeae	Food
Ostodes paniculata Bl.	Beltur	Tree	Euphorbiaceae	Timber
Parkia timoriana (A. DC.) Merr.	Zawngtah	Tree	Mimosaceae	Food
Passiflora edulis Sims.	Sapthei	Climber	Passifloraceae	Food
Persea americana Mill.	Butter thei	Tree	Lauraceae	Food
Persea minutiflora Kosterm	Ngha leng lu thar	Tree	Lauraceae	Firewood
Phaseolus vulgaris L.	Beans	Climber	Papilionaceae	Food
Phoenix sylvestris (L.) Roxb.	Date palm	Tree	Arecaceae	Ornamental
Phrynium capitatum Willd.	Hnathial	Herb	Marantaceae	Misc
Phyllanthus acidus (L.) Skeels	Kawlsunhlu	Tree	Euphorbiaceae	Food
Phyllanthus urinaria L.	Mithi sunhlu	Herb	Euphorbiaceae	Food
Pinus kesiya Royle ex Gordon	Fâr	Tree	Abeitaceae	Timber

Botanical Name	Local Name	Life Form	Family	Uses
Piper betle L.	Pan nah	Climber	Piperaceae	Condiments
Piper nigrum L.	Black pepper	Climber	Piperaceae	Spice
Pisum sativum L.	Pea	Herb	Papilionaceae	Food
Pithecellobium clypearia (Jack) Benth.	Ardahpui	Tree	Mimosaceae	Timber
Platycerium wallichii Hook.	Awm vel	Epiphyte	Polypodaceae	Ornamental
Plumeria acuminate Ait.	Par rim tui	Tree	Apocycaneae	Ornamental
Poikilospermum suaveolens (Bl.) Merr.	Khuang khau	Climber	Moraceae	Food
Polygonum nepalense Meissn.	Chakaifuh	Herb	Polygonaceae	Food
Premna racemosa Wall. ex Schauer	Thingsawn	Tree	Verbenaceae	Firewood
Protium serratum Wall. ex Colebr.	Bil	Tree	Burseraceae	Timber
Prunus cerasoides D. Don.	Tlaizawng	Tree	Rosaceae	Food
Prunus domestica L.	Japan Thei te	Tree	Rosaceae	Food
Prunus jenkinsii Hook f. & Th.	Keipui	Tree	Rosaceae	Food
Prunus persica (L.) Strokes	Thei te hmul	Tree	Rosaceae	Food
Psidium guajava L.	Kawlthei	Tree	Myrtaceae	Food
Psophocarpus tetragonolobulus (A.P. de Cand.)	Bepuithlanei	Climber	Papilionaceae	Food
Pterospermum acerifolium Willd.	Siksil	Tree	Sterculiaceae	Timber
Punica granatum L.	Pom/manding	Shrub	Punicaceae	Food
Pyrus communis L.	Pear thei	Tree	Rosaceae	Food
Pyrus pashia Buch.-Ham. ex D. Don.	Chalthei	Tree	Rosaceae	Food
Quercus helferiana A. DC.	Hlai	Tree	Fagaceae	Firewood
Quercus leucotrichophora A. Camus	Then	Tree	Fagaceae	Timber
Quercus polystachya Wall. ex A. DC.	Thil	Tree	Fagaceae	Firewood
Quercus serrata Murray	Sa-sua	Tree	Fagaceae	Timber
Raphanus sativus L.	Bul uih	Herb	Cruciferae	Food
Renanthera imschootiana Rolfe	Sen hri	Epiphyte	Orchidaceae	Ornamental
Rhododendron arboreum Sm.	Chhawk hlei par sen	Tree	Ericaceae	Ornamental
Rhus semialata Murr.	khawmhma	Tree	Anacardaceae	Food
Rhus succedanea L.	Chhimhruk	Tree	Anacardaceae	Food
Ricinus communis L.	Mutih	Shrub	Euphorbiaceae	Misc
Rosa indica L.	Rose	Shrub	Rosaceae	Ornamental
Rubus acuminatus Sm.	Thei-hmu	Shrub	Rosaceae	Food
Saccharum longisetosum (Andersson) V. Naray. ex Bor.	Luang	Herb	Graminae	Fodder
Saccharum officinarum L.	Fuh	Herb	Graminae	Food
Sansevieria zeylanica Roxb.	Rul lei	Herb	Agavaceae	Ornamental

Botanical Name	Local Name	Life Form	Family	Uses
Santalum album L.	Sandal wood	Tree	Santalaceae	Timber
Sapindus mukorossi Gaertn.	Hling si	Tree	Sapindaceae	Firewood
Sapium baccatum Roxb.	Thingvawkpui	Tree	Euphorbiaceae	Firewood
Saraca asoca (Roxb.) de Wilde	Mualhawih	Tree	Caesalpiniaceae	Ornamental
Sarcococca coriacea (Hook.) Sweet.	Pawhrual	Shrub	Euphorbiaceae	Medicinal
Saurauia punduana Wall.	Tiar	Tree	Saurauiaceae	Timber
Schima wallichii (DC.) Korth.	Khiang	Tree	Theaceae	Firewood
Scoparia dulcis L.	Per pawng chaw	Shrub	Scrophulariaceae	Medicinal
Sechium edule (Jacq.) Sw.	Iskut	Climber	Cucurbitaceae	Food
Securinega virosa (Roxb. ex Willd.) Baill.	Saisiak	Tree	Euphorbiaceae	Timber
Sesamum orientale L.	Chhi bung	Herb	Pedaliaceae	Food
Sida acuta Burm. f.	Khingkhih	Herb	Malvaceae	Misc
Smilax perfoliata Lour.	Kai ha	Climber	Liliaceae	Medicinal
Solanum sp.	Tawkte	Shrub	Solanaceae	Food
Solanum anguivi Lamk.	Samtawk te	Shrub	Solanaceae	Food
Solanum melongena var. *esculentum* L.	Bawkbawn	Herb	Solanaceae	Food
Solanum nigrum L.	Anhling	Herb	Solanaceae	Food
Solanum torvum Swartz.	Tawkpui	Shrub	Solanaceae	Food
Solanum tuberosum L.	Alu	Herb	Solanaceae	Food
Solanum violaceum Ortega	Tawk	Herb	Solanaceae	Food
Sophora benthamii Steenis	Sentet	Tree	Papilionaceae	Timber
Sorghum cernum (Ard.) Host.	Chhawh chhi	Herb	Graminae	Food
Spathiphyllum wallisii Regel	Cobra	Herb	Araceae	Ornamental
Spilenthes acemella Murr.	Ankasa	Herb	Compositae	Food
Spilenthes acmella var. *oleracea* Hook. f.	Ansapui	Herb	Compositae	Food
Spondias mangifera Willd.	Tawitawh	Tree	Anacardaceae	Food
Sterculia villosa Roxb.	Khopui	Tree	Sterculiaceae	Timber
Stereospermum colais Mabb.	Zih nghal	Tree	Bignoniaceae	Fodder
Strobilanthes flaccidifolius Nees.	Ting	Herb	Acanthaceae	Medicinal
Styrax serrulatum Roxb.	Hmarleng	Tree	Styraceae	Timber
Syzigium aromaticum (L.) Merr. & Perry	Clove	Tree	Myrtaceae	Spice
Syzigium cumini (L.) Skeel.	Len hmui	Tree	Myrtaceae	Food
Syzigium grandis (Wight.) Blume	Thei chhawl	Tree	Myrtaceae	Food
Taberna montana divarigata (L.) R. Br. ex Roem. & Schult.	Keltebengbe	Shrub	Apocycaneae	Ornamental
Tagetes patula L.	Derh ken buk	Herb	Compositae	Ornamental
Tamarindus indica L.	Tengtere	Tree	Caesalpiniaceae	Food

Botanical Name	Local Name	Life Form	Family	Uses
Tectona grandis L.	Teak	Tree	Verbenaceae	Timber
Terminalia bellerica (Gaertn.) Roxb.	Thingvandawt	Tree	Combretaceae	Timber
Terminalia myriocarpa Heurck & Muell.-Arg.	Chhar thing	Tree	Combretaceae	Timber
Toona ciliate M. Roem.	Thingdawl	Tree	Datiscaceae	Timber
Thevetia neriifolia Juss. ex Steud.	Yellow oleander	Shrub	Apocycaneae	Ornamental
Thuja compacta	Thuja	Shrub	Cupressaceae	Ornamental
Thysanolaena maxima (Roxb.) O. Kuntze	Hmunphia	Herb	Graminae	Misc
Toona ciliate M. Roem.	Tei	Tree	Meliaceae	Timber
Trachyspermum roxburghianum Benth. ex Kurz	Pardi	Herb	Umbelifereae	Food
Trema orientalis (L.) Blume	Belphuar	Tree	Ulmaceae	Timber
Trevesia palmate (Roxb. ex Lindl.) Visiani	Kawh-te-bêl	Tree	Araliaceae	Food
Trichosanthes anguina L.	Behrul	Climber	Cucurbitaceae	Food
Triticum aestivum L.	Wheat	Herb	Poaceae	Food
Urena lobata L.	Sehnap	Shrub	Malvaceae	Medicinal
Vaccinium sprengelii (G. Don) Sleum. ex Rehd.	Sir kâm	Tree	Vaccinaceae	Firewood
Vanda coerulea Griff. ex Lindl.	Lawh lei	Epiphyte	Orchidaceae	Ornamental
Vernicia montana Lour.	Tung	Tree	Euphorbiaceae	Misc
Vigna unguiculata (L.) Walp.	Behlawi	Climber	Papilionaceae	Food
Vitex negundo var. *heterophylla* (Franch.) Rehd.	Thleng reng	Tree	Verbenaceae	Firewood
Vitex peduncularis Wall. ex Schauer	Thingkhawihlu	Tree	Verbenaceae	Firewood
Vitis vinifera L.	Grapes	Climber	Ampelidaceae	Food
Wendlandia grandis Cowan	Batling	Tree	Rubiacaea	Timber
Zanthoxylum rhetsa (Roxb.) D.C.	Chingit	Tree	Rutaceae	Food
Zea mays L.	Vaimim	Herb	Graminae	Food
Zingiber officinale Roscoe	Sawthing	Herb	Zingiberaceae	Food
Ziziphus mauritiana Lamk.	Borai	Tree	Rhamnaceae	Food