GROWTH AND YIELD OF THREE TURMERIC VARITIES (*Curcuma longa* L.) UNDER MANGO BASED AGROFORESTRY SYSTEM

A THESIS

BY

KAMRUN NAHAR KONA

Registration No. 1805102

Session: 2018

Thesis Semester: July-December, 2019

MASTER OF SCIENCE (M.S.)
IN
AGROFORESTRY AND ENVIRONMENT

DEPARTMENT OF AGROFORESTRY AND ENVIRONMENT

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR

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December 2019

Dedicated

To

My Beloved Parents And

Honorable Teachers

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December, 2019 *The Authoress*

GROWTH AND YIELD OF THREE TURMERIC VARITIES (*Curcuma longa* L.) UNDER MANGO BASED AGROFORESTRY SYSTEM

ABSTRACT

An experiment was conducted in the research field of the Department of Agroforestry and Environment, Hajee Mohammad Danesh Science and Technology University, Dinajpur during 24 March 2018 to 10 January 2019, in order to investigate the growth and quality of different turmeric varieties under mango tree and open control. The experiment was consisted of two factors with three replications. Among the two factors, one factor was two production systems: T_1 =Mango + Turmeric and T_2=Open control + Turmeric; another factor was three turmeric local varieties: V_1=thailand, V_2= malshira and V_3= debipat. Interaction treatments between Factor A and Factor B were T_1V_1, T_1V_2, T_1V_3, T_2V_1, T_2V_2 and T_2V_3 combinations.The experiment was laid out following Randomized Complete Block Design with Three replications. Findings of the study revealed that growth and quality of turmeric significantly varied in the main effect of different agroforestry production systems. The tallest plant height, length and width of leaf were recorded in (T_1) and lowest were found in (T_2). The maximum number of finger, length of the biggest rhizome and width of the biggest rhizome were recorded in (T_2), and minimum were found in (T_1). The highest fresh weight of rhizome 11000 kg/ha was obtained in (T_2) and lowest 7055 kg/ha in (T_1). And the highest dry weight of rhizome 2126 kg/ha was found in (T_2) and lowest 1456 kg/ha was observed in (T_1).The highest light intensity was 68.96 LUX observed in (T_2) and lowest 34.70 LUX in (T_1). Moreover, the highest germination speed was found in (T_1) and lowest in (T_2).The experimental results revealed that the main effect of varieties on growth and quality contributing characters of turmeric were significantly varied with each other. The tallest plant height, length of leaf, width of leaf, number of finger, length and width of the biggest rhizome with (V_2) were recorded. The highest fresh weight of rhizome was 9777 kg/ha found with (V_2) and lowest 8055 kg/ha with (V_3), the highest dry weight of rhizome was 2013kg/ha found in (V_1). Germination speed was found highest with (V_2) and lowest with (V_1).The interaction effect of different turmeric variety and production systems on the growth of turmeric was found significantly different at different days after planting (DAP). The longest plant height was recorded with T_1V_3 but maximum biggest rhizomes lengths were with T_1V_1 and maximum biggest rhizome width was found T_2V_2. The highest fresh rhizome weight 13611 kg/ha and dry rhizome weight 2631 kg/ha were recorded in (T_2V_2) and (T_2V_2) respectively, on the other hand the lowest were found in T_1V_2 (5944 kg/ha) and T_1V_2 (1208 kg/ha). Highest germination speed was found in T_1V_3 and lowest in T_1V_1.

CONTENTS

CONTENTS (CONTD.)

CONTENTS (CONTD.)

CONTENTS (CONTD.)

LIST OF TABLES

LIST OF TABLES (Contd.)

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

ABBREVIATION AND ACRONYMS

AEZ	= Agro-ecological zone
BARC	= Bangladesh Agricultural Research Council
BBS	= Bangladesh Bureau of Statistics
HSTU	= Hajee Mohammad Danesh Science and Technology University
RCBD	= Randomized Complete Block Design
e.g.	= For example
i.e.	= That is
MS Excel	= Microsoft Excel
et al.	= And others
FAO	= Food and Agriculture Organization
viz.	= Namely
LSD	= Least significance difference
CD	= Cowdung
Cv	= Cultivar
DAP	= Days after planting
m	= Meter
cm	= Centimeter
CV	= Coefficient of variance
N	= Nitrogen
P	= phosphorus
K	= Potassium
S	= Sulphur
Zn	= Zinc
CGR	= Crop Growth Rate
LAI	= Leaf Area Index
LER	= Land Equivalent Ratio
PAR	= Photosynthetically Active Radiation
kg/ha	= kilogram/hectare
t/ha	= ton/hectare

CHAPTER ONE

INTRODUCTION

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INTRODUCTION

Agriculture is the largest employment sector in Bangladesh. It is the single largest producing sector of the economy since it comprises about 30% of the country's GDP and employs around 60% of the total labor force. The performance of this sector has an overwhelming impact on major macroeconomic objectives like employment generation, poverty alleviation, human resources development, and food security.

Being an agrarian country enjoying tropical to sub-tropical climate, a plurality of the people of Bangladesh earn their living from agriculture. Her population is 164.7 million (2017) in an area of 147,570 km² with a growth rate of 7.3% annual change (2017) (BBS, 2017). The total forest area of the nation covers about 17.5% of the land (BBS, 2017). However, according to the Forest Master Plan and surveys conducted by multinational donor agencies, only 17.5% or a total of 2.53 million hectares land of the territory has actual tree coverage (Anonymous, 2009). But to have benefits of nature, any state should have at least 25% of her land covered with forests. So, The dominion is suffering from inadequate forest coverage coupled with overpopulation for limited land. The realm has neither the ability to increase command areas of agricultural crops nor the increase in the forest area for ecological demands. Under these fatal situations, various agroforestry systems like forest or fruit tree-based agroforestry systems can address the stress of the day to a considerable extent.

Agroforestry is a land-use management system in which trees or shrubs are grown around or among crops or pastureland. This intentional combination of agriculture and forestry has varied benefits, including increased biodiversity and reduced erosion. Agroforestry practices have been successful in sub-Saharan Africa (Kuyah *et al.,* 2016) and in parts of the United States (Iqbal, 2018, Schoeneberger and Michele, 2017). According to Ludgren and Raintree (1982), agroforestry is a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboo, etc.) are deliberately grown on the same land management unit as agricultural crops and/or animals either in spatial in a mixture or in temporal sequences. The agroforestry system can be defined as a planting system comprising combinations of plants with various morpho-phenological features to maximize the natural resource use efficiency and enhanced total factor productivity. The system comprise of a combination of perennial and annual plant species as different components in the same piece of land arranged in a geometry that facilities maximum utilization of space in four dimensions(length, width, height, and depth) leading to the maximum economic productivity of the system.

Agroforestry, the integration of tree and crop/vegetables on the same area of land is a promising production system for maximizing yield (Nair, 1990) and maintaining friendly environment all over the world including Bangladesh. Under storey crops (including vegetables) can be integrated with forestry, orchard, or other Agroforestry systems. But farmers face problems of growing crops after 4-5 years of tree plantations and even sometimes fail to grow under storey crops under and around trees because in Agroforestry systems, among different production limitations, light availability may be the most important limitation to the performance of the understory crops/vegetables particularly where an upperstorey perennial forms a continuous overstorey canopy (Miah *et al*., 1995). This problem may be overcome by introducing shade tolerant crops like ginger, turmeric, etc.

Turmeric (*Curcuma longa*), belonging to the Zingiberaceae family is one of the most useful herbal medicinal plants. Turmeric is a very important spices as well as a medicinal plant in Bangladesh. Common Bangladeshi people traditionally use various spices in curry in their daily life. Among them, turmeric (*Curcuma longa*) is the most important one. Besides making curries, it is also used for medicine as a carminative and aromatic stimulant to be the gastrointestinal tract (Purseglove *et al.,* 1981) and many other purposes. In addition, turmeric is a highly valued crop having good local as well as export potentials (Siddique, 1995). But total production of turmeric is 117 thousand metric tons from 21.41 thousand hectors land (BBS, 2011). The demand of turmeric for home consumption is increasing day by day with the over increasing population of Bangladesh and demand is worldwide also increasing.

Turmeric requires a hot and humid climate. It can be cultivated in most areas of the tropics and subtropics provided that rainfall inadequate or facilities for irrigation are available. It is usually grown in regions with an annual rainfall of 1000-2000 mm cultivation has been extended into moist areas with rain above 2000 mm per annum. It can be grown up to an altitude of 1220 m in the Himalayan foothills (Purseglove *et al.,* 1981). The humus-rich virgin soil of hill and forest is also suitable for turmeric production. All the above conditions for turmeric production is available in Bangladesh.

But most of the cultivated lands of our country are engaged to produce food crops. So, an attempt should be taken to increase the production of turmeric spices through appropriate techniques. Growing turmeric in association with trees and shrubs in and around the homestead/farmland, which is called the agroforestry system, maybe one of the ways. In the agroforestry system, turmeric must be shaded to some extent depending on the nature and characteristics of the upper storey tree spices. Turmeric has been traditionally known as shade loving spices crops of Bangladesh. Although it grows under partial shade condition, their degrees of shade tolerance and their demand of nutrients has not yet been standardized from the scientific point of view.

Mango (*Mangifera indica*) a commonly used herb in ayurvedic medicine. Studies indicate mango possesses antidiabetic, anti-oxidant, anti-viral, cardiotonic, hypotensive, anti-inflammatory properties. Various effects like antibacterial, antifungal, anthelmintic, anti-parasitic, anti-tumor, anti-HIV, anti bone resorption, antispasmodic, antipyretic, antidiarrhoeal, antiallergic, immunomodulation, hypolipidemic, antimicrobial, hepatoprotective, gastroprotective have also been studied. These studies are very encouraging and indicate this herb should be studied more extensively to confirm these results and reveal other potential therapeutic effects. Clinical trials using mango for a variety of conditions should also be conducted. However, mango litter decomposes at slower rate compared to many tropical trees (Musvoto *et al*., 2000).

We want to conduct the research on Mango based agroforestry system in order to select compatible ground story crops as well as to work out the economic viability of the systems.

Again Mango is a major fruit in the northern part of Bangladesh especially in the Dinajpur region due to its edaphoclimatic adaptability. In Dinajpur region, the mango is an integral component of homestead gardening. However, day by day mango gardens is increasing. Nowadays growing of different annual crops in association with mango is practiced by farmers but without many scientific considerations. So, we should develop some protocol and findings which are beneficial for growers. Keeping this view in mind, we want to conduct the research on mango based agroforestry system in order to select compatible ground storey crops as well as to work out the economic viability of the systems. Hence, attempts were taken to boos-up mango turmeric culture through appropriate local techniques. In this condition, the present study was undertaken to meet the following objectives.

1. To assess the effects of mango shade on the germination, growth and quality of turmeric varieties.
2. To find out the above and below ground biomass allocation of the tested crops.
3. To observe the root architecture of three crops under the mango orchards.

CHAPTER TWO

REVIEW OF LITERATURE

CHAPTER TWO

REVIEW OF LITERATURE

The agroforestry literature review will provide you with not only the additional information on the concept of agroforestry and its benefits but also its challenges. Many literatures are available where efforts have been made to understand various aspects of agroforestry systems, although information is inadequate with respect to quantification of biological interactions among the components in agroforestry systems. Keeping this in view, an attempt has been made to review findings on agroforestry practices with particular emphasis on turmeric in association with fruit trees. The relevant literature pertaining to the present study have been reviewed in this chapter under the following heads:

2.1 Agroforestry: A sustainable land use technology

Agroforestry is the idea of combining forestry and agriculture on the same piece of land. The basic concept of intercropping has been extended to agroforestry system. Many authors have defined agroforestry in different ways. A widely used definition given by the International Council for Research in Agroforestry (Nair, 1983) is that agroforestry is a collective name for all land use systems and practices where woody perennials are deliberately grown on the same land management unit as agricultural crop or animal in some form of spatial arrangement or temporal sequence.

Vergara (1982) defined agroforestry as a "System of combining agricultural and tree crops of various longevity ranging from annual through biennial and perennial plants, arranged either temporally (crop rotation) or spatially (intercropping) to maximize and sustain agricultural production."

PCARRD (1983) reported that agroforestry is an age old and ancient practice. It is an integral part of the traditional farming systems of Bangladesh. The concept of agroforestry probably originate from the realization that trees play an important role in protecting the long range interests of agriculture and in making agriculture economically viable. The emergence of agroforestry was mainly influenced by the need to maximize the utilization of soil resources through the "marriage of forestry and agriculture". This was brought about by the increasing realization that agro-forestry can become an important component of ecological, social and economic development efforts.

Harou (1983) stated that agroforestry is a combined agriculture-tree crop farming system which enables a farmers or land user to make more effective use of his land which may yield a higher net economic return on a sustainable basis. Again, Saxena (1984) pointed out that agroforestry utilizes the inter spaces between tree rows for intercropping with agricultural crops and this does not impair the growth and development of the trees but enable farmers to derive extra income in addition to benefits accrued from the use of fuel and timber from trees.

Michon *et al.* (1986) stated that Agroforestry is a dynamic, ecologically based, natural resources management system that through the integration of trees in farmland and range land, diversities and sustains production for increased social, economic and environmental benefits for land users at all levels. While Akter *et al.* (1989) stated that, in traditional agroforestry systems of Bangladesh, farmers consider trees as saving and insurance against risk of crop failure or compensate low yields of crops.

Stocking *et al.* (1990) reported that agro-forestry is considered as an efficient and sustainable land use option specially suited for poor farmers. On the other hand, MacDicken and Vergara (1990) stated that agroforestry in a means of managing or using land (i.e., a land use system) that combines trees or shrubs with agricultural/horticultural crops and/or livestock.

Rang *et al.* (1990) stated agro-forestry as an economic enterprise which aims to produce a combination of agricultural and forest crops simultaneously on the same land area while the trees which are grown in the crop land, homestead, orchard not only to produce food, fruits, fodder, fuel wood or to generate cash for various purpose (Chowdhury and Satter, 1993) but also gives better living environment (Haque, 1996).

Raintree (1997) mentioned that agro-forestry is an age-old practice but modern concept is now being developed. It is a sustainable management system for land that combines agricultural crops, trees, forest plants and/or animals simultaneously or sequentially, and applies management practices that are compatible with the cultural patterns of the local population, whereas Solanki (1998) considered agro-forestry as an technology which can significantly contribute in protecting and stabilizing the ecosystems, producing a high level output of economic goods (fuel, fodder, small timber, organic fertilizer etc) and providing stable employment, improvement income and ensure sustainable use of land resources.

The increased financial benefits from practicing Agroforestry may stem from increased biophysical productivity or reduction in input costs (Franzel, 2004).

Franzel (2004) observed that analyzing the economics of Agroforestry practices is more complicated than of annual crops because of the complexity of Agroforestry systems and the time lag between tree establishment and harvest. Also, the analysis should include the valuation of all components of the ecological systems, including the agriculture, forestry, wildlife, livestock and other activities to (Grado and Husak, 2004).

Jackson (1987) stated that Agroforestry systems that incorporate a range of tree and crop species offer much more scope for useful management of light interception and distribution than monoculture forest and agricultural crops. The potential benefits as a result of combining field crops with trees are so 5 obvious from consideration of the waste nutrient resources experienced in orchards and tree crop combination.

Agroforestry system offers a great scope for efficient nutrient use because of their distinct root system. Trees is known to be deep rooted and are desired as "Nutrient pump" which use nutrients from below the crop rooting zone and recycled them to the crop in litter fall and in the green pruning (Beer, 1988).

Agroforestry system that incorporate a range of tree and crop species offer much more scope for useful management of light interception and distribution than do monoculture forests and agricultural crops (Miah, 1993). Agroforestry is a dynamic, ecologically based, natural resource management system that, through the integration of trees in farm and rangeland, diversifies and/or sustains agricultural production for increased social, economic and/or environmental benefits (Leakey, 1996).

Abedin *et al.* (1990) mentioned that Agroforestry is considered as one of the strategies for augmenting tree production for a country like Bangladesh where there is a little scope of developing pure forest due to obvious priority for food crop production.

2.2 Benefits from agroforestry system

The past ten years have witnessed the potential usefulness of agroforestry practices in addressing today's concerns over the economic and environmental sustainability of farm land uses (Lassoie and Buck, 2000). Agroforestry practices meet the overall management objectives of many landowners by providing a consistent, periodic flow of income through products and farm income diversification, with conservation benefits as an added bonus

In an experiment conducted by Bhuva *et al.* (1989) at India and they plant mango cv. Rajpuri was planted in 1979 at 6x6 m, and was inter-planted from 1980 with (a) banana, (b) cassava, (c) tomato followed by cluster bean (*Cyamopsis tetragonoloba*), or (d) brinjal followed by cowpea (*Vigna unguiculata*). They reported that mango grown with tomato and cluster bean as intercrops gave the greatest financial return per hectare.

Atta-Krah (1990) reported that application of *Leucaena* prunings and 60 kg ha^{-1}, N fertilizer into alley cropping plots resulted in a maize yield, 40% higher than that of conventional cropping with the same input. Consequently the recent years public interests in planting trees in croplands have increased greatly in the southwest Bangladesh. In addition to planting traditional species, *Dalbergia sissoo* in croplands is one of the salient reasons behind such a practice was to reduce the risk of total crop failure (Akter *et al.,* 1990). On the other hand, York (1991) observed that, deep-rooted trees in agroforestry system absorb nutrients from great soil depths and deposit them on the surface as organic matter, thus making nutrients more available to shallow rooted crops.

Wannawong *et al.* (1991) studied the combinations of eucalyptus (*Eucalyptus camaldulensis*), leucaena (*Leucaena leucocephala*), or acacia (*Acacia auriculiformis*) intercropped with cassava (*Manihot esculenta*) or mung bean (*Vigna radiata*). Parameters considered were tree growth, charcoal production and crop yield. Evidence form trails at short, 3-yr rotations, demonstrates that early supplementary and complementary relations between some system components can imply synergistic financial gains. Although these biological interactions become competitive over time, in this case, the gains should be sufficient to make early adopters consider agroforestry (intercropping) systems financially preferable to traditional monocrops. Consequently, Kass *et al.* (1992) observed higher bean and maize yield in alley cropping systems using *Gliricidia sepium* both in on-station and farmers' field conditions. Soriano (1991) found that the grain yield of maize was generally higher in hedgerow plots than that in monoculture plots.

Marz (1992) stated that the introduction of alley cropping systems based on neem (*Azadirachta indica*) may have strong impacts on the traditional cropping pattern and economic performance of small farms in the Sudano-Sahelian Zone of West Africa. The analysis shows that the farm income and liquidity of farms in particular are increased significantly by integrating neem (for the production of wood and fruits) into the traditional cropping pattern. The potential benefits as a result of combining field crop with trees are so obvious form consideration of the waste of light resources while Haque *et al.* (1992) claimed that the practice of production trees in crop fields in pre-historic in Bangladesh but due to tremendous increase in cropping intensity many farmers are now reluctant in planting trees in crop fields, as they believe that the trees significantly reduce crop yield by shading and root competitions. There are possibilities to raise various species of trees in crop fields in such a fashion not much affecting the yield of field crops.

An experiment was conducted by Korikanthimath *et al.* (1997) to find out the suitability of mixed cropping of areca nut (*Areca catechu*) + *Elettaria cardamonn* on comparison with monoculture of A. catechu. The cost of cultivation was higher (Rs. 40683/ha) in mixed cropping than under monoculture (Rs. 27571/ha) and the net return (Rs. 161837/ha) realized in mixed cropping was 1.56 times higher than in monoculture (Rs. 103626/ha).

Afzalur and Islam (1997) conducted research under the government-initiated Community Forestry Project at Madhyapara, Dinajpur. Under this project, the participants were promised a 50% share from the sales proceeds of the final tree harvest in addition to 100% of all other benefits generated from agricultural crops, thinning materials and pruning. The plots were planted with mixed tree species (mainly *Eucalyptus camaldulensis* and *Acacia mangium*) at 1.5×1.5 m spacing in double rows, with 9m alleys between the rows, in which rice, sugarcane, maize, pulses, vegetables and sesame were grown as intercrops whereas, due to pruning of shoot and root the tree yield was reduced by 41% and crop (rice, wheat, jute and pulses) yield by 7%. It was observed that eucalyptus affected crop yield by 12% but the species had the highest wood production. While economic analysis was made, the species showed the most profitable compared to all other species (Hocking and Islam, 1998). On the other hand, Chauhan (2002) inferred that *Tagetes minuta* can be successfully grown at 50×75 cm spacing with 40 kg N/ha under eight year old Poplar, resulting in monetary gains (net profit) of about Rs. 52000/ha/year.

Tree-crop combination competes for available moisture in the soil, more severely under rainfed Agroforestry system. So, inadequate moisture will become the limiting factor which will deleteriously affect the growth and yield of the components (Singh *et al*., 1989; Corlett *et al*., 1989).

2.3 Fruit tree based agro-forestry systems

Gill *et al.* (2008) worked out on the effect of planting dates and methods of planting of turmeric (*Curcuma longa* L.) intercropped in Poplar (*Populus deltoids*) plantation and found out that the ridge method of planting produced 8%, 11%, and 9.8% more yield which was significantly higher than flat method of planting during 2004-05, 2005- 06, 2006-07, respectively.

Baghel *et al.* (2004a) reported that turmeric cv. Suroma grown under the shade of mango trees showed the tallest plants (52.85 cm) with more number of leaves (10.25) and number of tillers/clump (7.02). They also reported that variety Suroma led to record the highest fresh marketable yield (234.26 q/ha) and took more days (255) to reach maturity than other varieties.

Chowdhury *et al.* (2010) the study was conducted at farmer's ghora neem wood lot adjacent to HSTU research farm, Dinajpur during the period from April to December 2007, to investigate the effect of fertilizer and lime on the performance of turmeric-ghora neem (*Melia agedirach)* based agroforesrty system. The experiment consisted of four treatments i,e. T_1 (no fertilizer), T_2 (cowdung), T_3 (cowdung and dolo choon), T_4 (recommended dose of fertilizers, cowdung and dolo choon). The experiment was laid out in Randomized complete block design (RCBD) with 3 replications.

Osei-Bonsu *et al.* (2002) have undertaken an experiment to compare the merits of four cocoa-coconut intercropping systems with the traditional cultivation of cacao under *Gliricidia sepium* shade at the Cocoa Research Institute of Ghana. Cocoa seedling girth was not affected when intercropped with coconut but was significantly (P=0.01) reduced when intercropped with *G. sepium*. High density cocoa facilitated better early canopy formation. Yield of cacao spaced at 2.5 m triangular (1739 plants ha^{-1}) with coconut at 9.8 m triangular (105 plants ha^{-1}) was significantly higher (P=0.005) than from the other treatments during 1993/94 to 1995/96. Widely spaced coconuts intercropped with cocoa spaced at 3 m × 3 m showed better flowering and gave higher coconut yields, but cocoa spaced at 2.5 m triangular under coconuts spaced at 9.8 m triangular was more profitable than the other treatments. Moisture stress was the greatest in cocoa system with *G. sepium* shade and this could be responsible for the low yield of cocoa in that treatment. It is suggested that properly arranged high density cocoa under widely spaced coconuts can be a profitable intercrop system for adoption by cocoa farmers in Ghana.

To evaluate the possibility of coffee production in the non-traditional and tribal area of Madhya Pradesh, India, yield variation in *Coffea robusta* cv.

Sanramon under different canopy shades was carried out by Gupta and Awasthi (1999). The experiment was conducted on 5 year old plants grown without shade, or with shade provided by mango, mango + banana, guava, guava + banana or teak (*Tectona grandis*). Mango, guava and teak were aged 50, 10 and 45 years, respectively. The coffee yield was highest (mean for 5 years of 345 kg/ha) under mango + banana, followed by guava + banana (294 kg/ha), with lower yields in pure stands of mango, guava and teak. Yield was zero under control conditions (no shade).

Korikanthimath *et al.* (2000) conducted an experiment at Sirsi, Karnataka during 1992-95 to explore the possibility of cultivating cardamom (*Elettaria cardamomum* Maton) as a mixed crop with coconut. The average size of coconut holdings is as low as 0.22 ha and 98% of the holdings are below 2 ha. The results revealed that tall coconuts and short cardamom plants with varying rooting patterns and spacings intercepted solar energy at different vertical heights, and their roots (rhizosphere) absorbed nutrients and soil moisture at different depths and lateral distances. The coconut canopy provided adequate shade for shade-loving cardamom in this multistoried cropping system. Intercropping with cardamom reduced coconut yield compared with coconuts in monoculture (mean values of 85.7 compared with 91.3 nuts/palm), but intercropping with high value cardamom increased overall profits (cardamom yields in 1993-94 and 1994-95 were 15.66 and 15.42 kg/ha, respectively).

An experiment was conducted by Singh *et al.* (2001) with six irrigated litchi orchards consisting of plants of different age groups (15-50 yr) around Jandwal and Kandwal areas in Kangra District, Himachal Pradesh to study the effects of shelterbelts of three species (*Eucalyptus, Grevillea* and *Leucaena*) on growth and yield of litchi plants. The shelterbelts were planted either earlier or after the establishment of the litchi orchards. Five litchi plants were selected randomly in different farmers' fields and at different distances from the shelterbelts, and data on plant height, girth, spread, leaf area and yield of litchis recorded during 1989-90. The results indicate that *Eucalyptus* had an inhibitory effect on growth and yield of litchi, which decreased with increasing distance from the shelterbelt. Growth at all distances from *Grevillea* and *Leucaena* shelterbelts was better than that associated with *Eucalyptus*. However, the best litchi growth was near to *Leucaena* shelterbelts.

Ghosh (1987) carried out field trials of 3 tier cropping systems during 1983-84 at the experimental farm of the Central Tuber Crops Research Institute, Kerala. The first tier comprised 4 perennial species: coconut, banana, *Eucalyptus* hybrid (*E. tereticornis*) and *Leucaena leucocephala*. The second tier contained cassava and the third tier groundnut and French bean. Pure stands of perennials and cassava were maintained separately as controls and all the crop species received the recommended dose of fertilizers. Significantly better vegetative growth of cassava plants was observed when grown in association with banana, while no significant differences were recorded in the growth of the plants raised in pure and mixed stands with the other perennial species. Similarly, maximum fresh tuber yield was obtained from the cassava plants under banana. Tuber yield of cassava under *E. tereticornis*, however, was minimum and significantly less than that of the pure stand. Yield differences among other treatment combinations were not significant. Growth of banana and *L. leucocephala* was adversely affected by cassava during the first 12 months, whereas in *E. tereticornis* intercropped with cassava small increases in growth occurred up to 18 months old. However, stem girths of *E. tereticornis* and *L. leucocephala* were greater in pure stands than in mixed stands with cassava. *L. leucocephala* gave better herbage yield in a pure stand.

Again, Ghosh *et al.* (1989) reported the results of the trials on sloping ground at the Central Tuber Crops Research Institute in Kerala in 1983-86 when cassava was planted under the canopy of coconut, banana, *Eucalyptus* or *Leucaena spp.* Cassava stimulated the growth of *Eucalyptus* but reduced the growth of *Leucaena spp.*, particularly during the first 6-12 months of its establishment. Shading by Eucalyptus increased from 15.0 to 52.6% over a 3-year period whereas shading by other perennials was observed only in adjacent rows of cassava. Growth and tuber yield of cassava in each year was greater when grown under banana than any other crop and averaged at 28.4 t/ha compared with 26.3 t for cassava grown in the pure stand and 11.3 t when grown under Eucalyptus and intercropped with groundnuts. *Vigna unguiculata* grown between rows of cassava reduced tuber yields less than the groundnuts and gave a fresh pot yield of 4.81 t/ha. Although the presence of cassava increased groundnut pod yield (1.07 t/ha), the perennial tree species, especially Eucalyptus, significantly reduced the yield (0.41ha).

From a Jackfruit-pineapple agroforestry system, Hossain (1999) estimated (made by using the models developed through the regression analysis) that the yield of pineapple would be maximized (64t/ha) at a mean-season PAR of 610 M mol m s^{-1} or 55 percent of open field condition. Such a light condition occurs in jackfruit orchards with an estimated crown cover of 9803 m^2 ha^{-1}.

Ali (1999) worked on the performance of red amaranth and lady's finger grown a different orientations and distances under guava and drumstick trees. He found that plant height, number of leaves, fresh and dry weight of amaranth; and plant height, dry matter yield, fruit length and yield of fruit per lady's finger plants grown under guava tree were significantly reduced than those grown under drumstick tree because the PAR was less under guava than under drumstick. But Wainwright (1995) reported that biomass of amaranth was not reduced compared to the control at light level up to 58 percent PAR level.

In a field study in Kerala India, yield correlations of twenty five green gram (*Vigna radiata*) genotypes grown under the shade of coconut trees were examined by Rajeswari and Kamalam (1999). They reported that seed yield/plant was positively associated with all the characters except the days to flowering, days to first harvest and seeds/pod. Pods/plant and pod length were the prime characters for yield improvement in green gram under partially shaded conditions.

The coconut based mixed species systems in the tropics often aim at improved resource capture through incorporating several trees and field crops. Productivity of palms and the associated tree components in such mixed systems are, however, known to vary in response to the tree characteristics, planting pattern/geometry and shade tolerance of the components. The effects of three fast growing trees (*Vateria indica*, *Ailanthus triphysa* and *Grevillea robusta*) grown in association with coconut palms following two planting geometries (single row and double row), on the productivity of coconuts and growth of multipurpose trees were studied in Kerala, India, during 1992-96 by Kumar and Kumar (2002). A. triphysa demonstrated better growth than others with mean annual increments of 118 and 2.62 cm $year^{-1}$ for height and basal stem diameter (at 50 months after planting), respectively, compared to 98 and 1.26cm $year^{-1}$ for *G. robusta*, which showed the next best height growth. Shade tolerance appears to be a major determinant of tree growth rates. It is concluded that integrating shade tolerant timber trees in the coconut based production systems could increase the overall productivity and profitability of coconut farms with no adverse effect on the main crop yield in the short term.

The effect of irrigation and 3 multiple crop systems: (A) black pepper (*Piper nigrum*) +cocoa + elephant foot yam; (B) banana + black pepper + acid lime +arrowroot and (C) banana + betel vine + pineapple + elephant foot yam, on areca nut yield in a 16-year-old plantation was studied in Jalpaiguri and Coochbehar, West Bengal between 1983 and 1988 by Singh and Baranwal (1993). In general, irrigation increased the yield of all crops compared with rainfed crops. The cultivation of mixed intercrops did influence the yield of areca nut; in crop system A (irrigated), the yield of areca nut rose by 4.1%, but areca nut yields decreased in all other plots by 10.5-24.2%. This decrease in yields was not as great as that observed in the control plot.

A series of experiments carried out in 1988-90 by Aiyelaagbe and Jolaoso (1992) at Ibadan, south-western Nigeria. In these experiments, papaya (*Carica papaya*) trees were intercropped with okra (*Abelmoschus esculenta*), watermelon (*Colocynthis citrullus/Citrullus lanatus*), sweet potato (*Ipomoea batata*), bush greens (*Amaranthus hybridus*), jew's mallow (*Corchorus olitorius*) and *Solanum gilo*. Sweet potato and *S. gilo* caused a market production in the yield of papaya. Land Equivalent Ratio (LER) values for papaya intercropped with okra, watermelon, sweet potato, bush greens, jew's mallow and *S. gilo* were 3.86, 3.13, 2.06, 1.86, 1.60 and 1.54, respectively, indicating that all the combinations were more advantageous than the monocrop of papaya. Monetary value of the mixtures, however, indicated that the inclusion of intercrops of sweet potato or *S. gilo*, is disadvantageous. It is suggested that although intercropping in papaya orchards in beneficial, it should be limited to the early vegetative and late fruiting phases of papaya when the Leaf Area Index (LAI) of papaya is low. A relay of okra followed by watermelon or bush greens, followed by sweet potato grown for fodder, is considered suitable for cropping in the alleys of papaya.

Leucaena leucocephala (var. K8) growth (height, collar diameter and diameter at breast height) and yield data (fresh and dry weight of fodder and fuel) are reported by Gill *et al.* (1992) from the first year investigation (1990-91) of an intercropping trial at Jhansi, Uttar Pradesh, India with mango (*Mangifera indica* 4 varieties, 'Amrapali', 'Mallika', 'Deshari' and 'Langra'. Each 10×10 m subplot included one mango tree, 2 leucaena trees, and one of 4 intercrops: a fallow control; fodder crops (cowpea and oats); grain crops (peanut and wheat); and vegetables okra (*Abelmoschus esculentus*) and onions. They reported that the above ground biomass yields of *L. leucocephala* ranged from 0.87 to 1.22 dry t/ha. Best leucaena fodder yields were in plots intercropped with vegetables and best fuel-wood yields in plots intercropped with grain crops (this system also supported the best total biomass yields). Both leucaena and mango (height, collar diameter and canopy width) growth were better in plots with intercrops than in fallow-plots.

Singh *et al.* (2013) conducted a field experiments to investigate the suitability and profitably with different intercrops of cowpea, frenchbean, arhar, soyabean, lentil, blackgram and chickpea in mango orchard (cv. Himsagar). The age of the plant was 7 years old with a spacing of 10x10m which provided the utilization of land space between the plants as an intercrop. Pooled data reveals that the maximum number of fruits 192.41 / tree and yield 46.09 kg / tree were found in Mango + Cowpea whereas maximum fruit weight (254.16 g) in Mango + Lentil. Most of the physical parameters such as fruit length and breadth maximum were recorded (8.20 cm and 7.21 cm respectively) in Mango + Cowpea. But, in case of peel weight (35.67 g) was highest in Mango + Soyabean whereas the higher stone weight (35.79 g) was in sole crop (Mango) only. Again, pulp weight and pulp: stone ratio (193.53 g and 5.80) were observed in Mango + French bean respectively. The quality parameters such as TSS, reducing sugar, vitamin c, acidity and shelf-life showed non-significant variation among the different treatments.

Emebiri and Nwufo (1994) carried out experiments at the Teaching and Research farm of the Federal University of Technology, Nigeria (Lake Nwaebere campus) during 1991-92 cropping season to study the yield of *Telfairia occidentalis* (a leafy vegetable fluted pumpkin) grown at various distances (3, 4, 5 and 6m) from a row of mango trees. The results support the suggestion that crops whose harvestable parts are vegetative tend to be less affected when grown in proximity to trees, provided adequate water is supplied.

A field trial was conducted by Braconnier (1998) on Santo Island, Vanuatu, where maize was incorporated with coconut palms, or grown in monocultures under full sunlight or with shading to give light transmission rates of 70, 40 and 30%. Under artificial shade, there was a simple linear relation between yield and photo-synthetically active radiation (PAR). Applying this relation to the maize-coconut intercropping system gave an estimated yield slightly higher than the actual harvest, possibly due to the difference between radiation interception by shading canvas and that obtained with a coconut cover. Root competition between the two crops was not detected. Maize net assimilation response to PAR was similar in all light treatments.

Field trials on the performance of mango-ginger (*Curcuma amada*) agroforestry system conducted at the college of Agriculture, Vellayani (Kerala, India) by Jayachandran and Nair (1998) for 2 seasons under varying levels of shade revealed that the rhizome yield under open and 25% shade were similar indicating that the crop is shade tolerant and is suitable for intercropping situations. In another field trial at Coimbatore, Tamil Nadu, they also studied the growth and development of 7 soya bean cultivars under shade in a coconut plantation. Greater shoot height, internodal elongation and lower leaf area index were the most significant growth changes noticed under shade. Leaf net photosynthesis, CGR and seed yield were also reduced under shade. Cv. Co 1, UGM 30 and UGM 37 recorded higher yield under shade when compared with other cultivars tested.

An experiment was conducted by Nizam and Jayachandran (1997) using three sizes of seed rhizomes (5, 10 and 15 g) of ginger cultivars Kuruppampady, Maran, Nedumangadu and Rio de Janeiro, Brazil. These were planted in the open, or as an intercrop in a 30 year old coconut plantation, at Thiruvananthapuram, Kerala, India. The crop was harvested 8 months after planting, when volatile oil, non-volatile ether extract (NVEE), crude fibre and starch contents were analysed. Volatile oil and starch contents were not significantly influenced by the rhizome size. NVEE was significantly influenced by rhizome size in open conditions; plants raised from 15 g rhizomes had significantly higher NVEE than plants raised from 5 or 10 g rhizomes. However, this effect was not observed in the intercropping treatment. In open conditions, plants raised from 5 g rhizomes had the highest crude fibre contents, but when grown as an intercrop plants raised from 15 g rhizomes had the highest crude fibre contents. The variety Kuruppampady recorded the highest NVEE under open and intercropped conditions.

In a field trial conducted during 1994-95 and 1995-96 by Hegde *et al.* (2000) to investigate the performance of ginger cv. Suprabha grown as intercrop in an adult areca nut plantation (30-year-old) at the Agricultural Research Station (Pepper), Sirsi, Karnataka, India, and its performance was compared with those planted under open conditions. Ginger plants grown as intercrop were significantly taller than those under open conditions (pure crop) when measured 200 days after planting and had significantly lower number of functional leaves and tiller per clump. Interception of photosynthetically active radiation (PAR) by ginger was maximum at 110 DAP, both in open conditions (1.088 ly/min) and in the intercrop (0.788 ly/min). Percentage of PAR intercepted by ginger out of total PAR was the lowest at 170 DAP in both open (74.4%) and under areca nut shade (56.41%). Mean duration of ginger crop grown in open conditions was 184.5 days, while it was 198.5 days when grown under shade as intercrop. Per plant yield of ginger under areca nut plantation was significantly higher (154.5 g) when compared to open conditions (118.8 g/plant).Individual rhizomes of ginger grown in areca nut plantation were slightly bigger (4.5 g/rhizome) than the crop grown in open (3.4 g/rhizome). Yield of areca nut was not affected due to intercropping with ginger during the two years study. However, there was slight improvement in the yield of areca nut (3.20 kg chali/palm) when compared to mono- cropping of areca nut (2.59 kg chali/palm).

Fifty cassava lines were evaluated by Sreekumari *et al.* (1998) for tuber yield under shade in a coconut garden in Kerala, India. Comparative information on the effect of shade on growth and development of 16 genotypes was gathered by raising them simultaneously in uniform shade in a 'shade house' as well as in the open conditions. Yield was significantly reduced under shade. Reduced number of sprouts, increased plant height, longer internodes, bigger leaves, reduced number of leaves and increased leaf retention were the other salient morphological changes noticed under shade.

Ravishankar and Muthuswamy (1986) intercropped *Zingiber officinale* in a six-year old areca nut plant. They reported a progressive improvement with five cash crops, inferred that ginger was one among the crops which can be profitably intercropped with areca nuts. Aiyadurai (1986) stated that turmeric is not adversely affected by partial shade and reported 67.2 to 89.6 q ha-^{1} of fresh turmeric yields under rainfed conditions.

Pushkaran *et al.* (1985) reported that in trials conducted for over 3 years, 14 cultivators of turmeric (*Curcuma longa* L.) were grown in coconut plantations with spaced at 8 m × 8 m. The yield of turmeric ranged from 4.78 t ha^{-1} (cv. Ventimetta) to 17.36 t ha^{-1} (cv. Arnruthaparri Kothapetto). He also reported that the plant height, number of tillers per plant, number of leaves per plant, the yield per plant, yield per hectare, rhizome length and rhizome breadth of ginger and turmeric were superior under Poplar intercrops compared to when grown as pure crops. Among different spacings of poplar (5×5m, 5×4m and 5×3m); 5×4m was found to be the most suitable for ginger and 5×5m for turmeric. Moreover, Sundararaj and Thulasidas (1976) emphasized that turmeric performs well under partial shade but the dense shade adversely affects the yield. They added that it is being recommended as an economic intercrop with coconut in coconut gardens. A yield of 8.61t ha^{-1} of ginger and 10.64 t ha^{-1} of turmeric was obtained when intercropped under coconuts in India, which like other intercropped cash crops, was found to yield in the range of 60 to 75 percent of the yield obtained from crops raised on open areas.

Baghel *et al.* (2004b) found that cultivation of turmeric as an intercrop in the vacant places of mango orchards gave maximum productivity (232.19 q/ha) followed by cultivation of turmeric in the aonla orchard (228.57 q/ha), whereas, minimum productivity (172.86 q/ha) of turmeric was recorded in mix orchard of mango+aonla.

Parthasarthy *et al.* (2006) reported that India has 149,410 ha area under turmeric cultivation with a total annual production of 527,960 tonnes the compound growth of turmeric area is 6.30 and production is 3.37 when comparing 2000 levels over those of 1970. It was found that site suitability is an important factor to determine the productivity of the crop. A highly suitable location may not result in larger yields than suitable or marginally suitable areas. Suitability maps are useful to determine areas which will have the greatest success for growing a particular crop in a region.

Leve (2008) reported that growing of turmeric with guava trees produced higher monetary return (Rs. 201950 /ha.) under raised bed method of planting than growing of turmeric alone (Rs. 195550 /ha.) and guava (Rs. 6400 /ha.) under Agrihorticulture practice of agroforestry.

Kumar and Gill (2010) carried out at Ludhiana (Punjab) to evaluate the effect of planting method, plant density and planting material on growth, yield and quality of turmeric and found out that fresh rhizome yield of 164.8 and 160.3 q ha^{-1} (pooled data) was produced in flat and ridge method of planting but the differences were non-significant. Closer plant spacing or higher plant density produced highest fresh, dry and processed turmeric yield and it decreased with decrease in plant density; whereas, number and weight of rhizomes increased with decrease in plant density. Planting of mother rhizomes produced highest fresh (207.7 q ha^{-1}), dry (46 q ha^{-1}) and processed 8 (44.1 q ha^{-1}) turmeric yield and it decreased significantly with decrease in seed size.

Satheean and Ramadasan (1980) studied relative performance of turmeric raised as an intercrop in coconut garden and as a pure crop. The incident Photo-synthetically active radiation (PAR) at any given time of the day was about 50 percent less under the coconut canopy. They observed that the leaf area index (LAI) and crop growth rate (CGR) reached their maximum much earlier in the pure crop than in the intercrop. This difference in the growth rate during the initial period of rhizome development was reflected in the significant differences observed in the final yield of the intercrop (4.8 t ha^{-1}) and pure crop (7.0 t ha^{-1}). They further added that the yield superiority observed in the pure crop was attributed to the higher CGR during rhizome formation and development, and higher solar energy input under open conditions during this period.

2.4 Effect of Light intensity on Turmeric production

Singh *et al.* (2001) observed that the effect of three tree species namely eucalyptus (*Eucalyptus camaldulensis*), acacia (*Acacia nilotica*) and poplar (*Populus deltoides*) on the performance of turmeric (*Curcuma longa* L.) was investigated in Kamal, Haryana, India. The mean germination of turmeric was maximum when grown in association with acacia and minimum in the control i.e. in open field. The mean height attained by turmeric after 90 days was highest under eucalyptus and lowest under poplar. The yield of turmeric was in the order:eucalyptus>control>poplar>acacia.

Sathish *et al.* (1998) evaluated the performance of 12 turmeric cultivars in a 20-year old coconut plantation. Plant crop cycle duration, yield and quality were assessed. The cv. Cuddapah produced the tallest plant (57.27 cm) and BSR-1 produced the greatest number of tillers (4.47 CLUMP).

Intercropping of turmeric with *Leucaena leucocephala*, *Eucalyptus camaldulensis*. Ghoraneem or *Manilkara spp.*were carried out in Madhya Pradesh, India. The highest yield of turmeric was observed in the *L. leucocephala* treatment. The yield of turmeric decreased with increasing tree age and with increasing density of planting of trees (Mishra and Pandey, 1998).

Michon *et al.* (1986) stated that multistoried agroforestry system is characterized by intensive integration of forest species and commercial crops forming a forest like system. Agroforestry is a profitable production system and provides a buffer between villages and protected forests.

Michon and Mary (1994) reported that multistoried village gardens in the vicinity of Bogor, West Java, Indonesia have long been essential multipurpose production system for low income households. However, they are being subjected to important conversion processes linked to socioeconomic changes presently found in over crowed semi urban zones.

Light not only plays the most vital role in photosynthesis but it carries out important function in various biological processes of plant life, viz. metabolism, growth and development. Plants grown at high irradiances had higher photosynthetic rate and stomatal conductance while intercellular CO_2 concentrations were lower than in plants grown at low irradiances (Sritham and Lenz, 1992).

Sarkar and Saha (1997) studied the influence of light intensities on the growth and development of radish in field trial at Birampur, India and found the reduction of light intensity (to 75 or 50% of full sunlight using muslin cloth supported on bamboo frames) adversely affected the elongation and thickening of radish hypocotyls. Yield of radish was also reduced by reducing light intensity.

Leonardi (1996) reported that shading (60% sunlight reduction) reduced vegetative and fruit growths but increased plant height. It also reduced chlorophyll content, stomatal density and transpiration rate and photosynthetic rate in peppers.

2.5 Tree Crop Interaction

Tree-crop combination competes for available moisture in the soil, more severely under rainfed Agroforestry system. So, inadequate moisture will become the limiting factor which will deleteriously affect the growth and yield of the components (Singh *et al.*, 1989; Corlett *et al.*, 1989).

The integration of agriculture and/or farming with forestry so the land can simultaneously be used for more than one purpose. This practice is meant to have both environmental and financial benefits.

In Agroforestry systems there are both ecological and economical interactions between the different components (Lundgren and Raintree, 1982).

When promoting Agroforestry one should then stress the potential of it to achieve certain aims, not only by making theoretical and qualitative remarks about the benefits of trees, but also, and more importantly, by providing quantitative information (Lundgren, 1982).

Whenever tree-crop combination is tried as an Agroforestry intervention, there can be strong above-ground and below-ground interaction for critical and limited resources. In general, trees have been found to improve soil physical and chemical properties by various means (Nair, 1984; Lai, 1989).

Trees act as nutrient pumps i.e. exploiting the nutrients from the deeper depths and in the process of recycling make it accessible to the companion shallow rooted ground crop (Kellman, 1979; Yamoah *et al*., 1986). This situation although is not applicable where "cut and carry" practice is a common feature which depletes the soil nutrients year after year and may result into unsustainable proposition (Nair, 1993). The intensity and severity of interaction for nutrients between the trees and crops will depend on the planting geometry and density of each component. However, direct evidence as to where, and how severely, nutrient competition occurs is limited due to the difficulties of separating nutrient competition from competition for light, water and from allelochemical interactions (Young, 1989). Imo and Timmer (2000) concluded that tree crop interactions are not constant, and may be affected by several factors, including total planting densities, component combinations, climatic and soil conditions, and management regimes.

Progress in promoting Agroforestry is held back because decision-makers lack reliable tools to accurately predict yields from tree-crop mixtures. Amongst the key challenges faced in developing such tools are the complexity of Agroforestry, including interactions between various system components, and the large spatial domains and timescales over which trees and crops interact. A model that is flexible enough to simulate any Agroforestry system globally should be able to address competition and complementarity above and below ground between trees and crops for light, water and nutrients. Most Agroforestry practices produce multiple products including food, fiber and fuel, as well as income, shade and other ecosystem services, all of which need to be simulated for a comprehensive understanding of the overall system to emerge. Several Agroforestry models and model families have been developed, but as of 2015 their use has remained limited for reasons including insufficient flexibility, restricted ability to simulate interactions, extensive parameterization needs or lack of model maintenance. An efficient approach to improving the flexibility and durability of Agroforestry models is needed. Various types of Agroforestry systems are currently being promoted in many contexts, and the impacts of these innovations are often unclear. Rapid progress in reliable modeling of tree and crop performance for such systems is needed to ensure that Agroforestry fulfills its potential to contribute to reducing poverty, improving food security and fostering sustainability (Luedeling *et al*., 2016).

Modeling competition and complementarity in capture of light, water and nutrients must often be considered in attempts to predict yield of tree-crop mixtures. The impact of trees on crop microclimate can be of key importance (Ong *et al*., 2015). In all crop models, crop growth is simulated as a response to available water and ambient temperature, often also to light capture. All of these are substantially altered by trees, and the impact will depend on tree canopy structure and, for water, on rooting patterns (Anderson and Sinclair, 1993). Accurate simulation of these interactions is one of the major challenges in Agroforestry modeling, since they are central for verifying one of the primary pathways through which Agroforestry is expected to contribute to climate change adaptation in hot climates. Likewise, competition and complementarity below-ground is an area for model development. How water and nutrients are partitioned between different parts of the tree, as well as between trees and crops is one of the more complex questions in Agroforestry modeling. To what level of detail these processes should be simulated is amongst the central decisions that an Agroforestry modeler has to take. There are certainly arguments for simulating many nutrient and water acquisition processes at the root level, including hydraulic lift, but the complexity that this might add to a model, its parameterization needs and processing time during simulation runs may often not be desirable.

Incorporation of tree hedges along contours has been proposed as a means of reducing soil erosion and increasing soil fertility of tea (*Camellia sinensis* L.) plantations on sloping terrain in high-rainfall zones of Srilanka. Tea yields in these hedgerow intercrops are determined by the balance between the positive (i.e., increased soil fertility) and negative (i.e., resource competition) effects of hedgerows. Tea yields, measured over one complete pruning cycle from October 1998 to September 2001, showed reductions relative to a sole tea crop under all hedgerow species except Euphatorium. The yield reductions ranged from 22 to 40%. Tea yields under Euphatorium showed increases up to 23% relative to the sole crop control. Addition of hedgerow pruning as mulch increased tea yields in all hedgerow intercrops. The yield increases ranged from 11 to 20%, with the highest being under Euphatorium. Tea yields showed a negative relationship (R2 =0.38) with the pruned biomass of hedgerows. Limitation of environmental resources (e.g., water and light) and hedgerow characters which intensified resource competition (i.e., greater canopy lateral spread and height and greater root length densities, especially in the top soil layer) were responsible for observed tea yield reductions in hedgerow intercrops (De Costa and Surenthran, 2005).

Integration of trees in Agroforestry system results in positive or negative interactions between trees and crops. Micro-climate amelioration and maintenance or improvements in soil productivity are the major positive interactions while competition for light, water and nutrients, and allelopathy are the major negative interactions in Agroforestry systems. The balance between negative and positive interactions determines the overall effect of interactions in a given Agroforestry system. Selection of suitable tree species for Agroforestry is important, however many a times it is not possible to select tree species having all the desirable characters for Agroforestry because of different production or protection goals. In such situations Agroforestry systems have to be managed through planting optimum density of trees, proper spatial arrangement and pruning and thinning of tree crowns and roots to reduce the negative effects of trees (Basavaraju and Rao, 2000).

In recent decades, integrating trees with crops for food and wood production has received considerable attention in both tropical (Garrity *et al*., 2010) and temperate regions (Palma *et al*., 2007). Agroforestry has shown potential to increase and sustain food production per unit area in systems like the parklands of the Sahel (Bayala *et al*., 2012), through the use of „fertilizer trees" intercropped or in fallow rotations with crops throughout sub-Saharan Africa (Sileshi *et al*., 2008) and through integrating trees with crops on sloping land (Tiwari *et al*., 2009). It is increasingly seen as a promising approach to improving food security (Glover *et al*., 2012), largely because the trees are associated with enhancing and sustaining soil health and hence crop yield (Barrios *et al*., 2012). Trees also produce fodder, fuel and construction materials, which are in high demand in many rural areas and if produced on farm may reduce the costs of obtaining them off-farm. Through production of high value timber, farmers can often generate substantial additional revenue in both temperate (Dupraz *et al*., 1997) and tropical contexts (Dupraz *et al*., 1997; Bertomeu, 2006; Santos-Martin and van Noordwijk, 2009). Fruits obtained from trees can enhance both income (Mithofer and Waibel, 2003; Luedeling and Buerkert, 2008) and human nutrition (Goenster *et al*., 2009; Kehlenbeck *et al*., 2013).

Agroforestry practices are often part of strategies to improve natural resource management (Ong and Kho, 2015), and they are often more effective than other land uses in providing regulating, supporting and cultural ecosystem services (Pagella and Sinclair, 2014), such as microclimatic buffering, amelioration of soil structure and water infiltration, reduction of overland flow, regulation of the water cycle and provision of habitat for wild species (Bayala *et al*., 2014). The potential of Agroforestry practices to sequester carbon in wood and soil has been widely demonstrated (Luedeling *et al*., 2011; Kuyah *et al*., 2013). Agroforestry may also affect emissions of other greenhouse gases either positively or negatively (Rosenstock *et al*., 2014) and is expected to help farmers adapt to climate change through the risk-mitigating effects of additional farm products derived from trees, positive microclimatic effects through shading and enhanced farm productivity through tighter nutrient and water cycles (Garrity *et al*., 2010).

The long life span of trees, and the large number of potential tree species means that it often takes a long time to establish the viability and relative merits of alternative Agroforestry practices in new environments through empirical approaches. This makes recommendation domains for particular technologies difficult to delineate. Tools are needed for faster ex-ante assessment of performance potentials. Since planted trees can remain in place for decades, such tools need to consider the impacts of climate change (Luedeling *et al*., 2014). Process-based modeling has been identified as a viable approach to making such projections (Bayala *et al*., 2015), but a number of obstacles must be overcome for Agroforestry models to successfully meet this challenge.

Zhang *et al.* (2013) a field experiment was conducted to investigate the relationship between root distribution and interspecific interactions between intercropped jujube tree (*Zizyphus jujuba* Mill.) and wheat (*Triticum aestivum* Linn.) in Hetian, south Xinjiang province, northwest China. They found that the interspecific competition effects in jujube tree/wheat Agroforestry systems. In agro-ecosystems, several weeds, crops, Agroforestry trees and fruits trees can interact negatively with crops by exerting an allelopathic influence on crops, thus, affecting their germination and growth adversely (Kohli *et al*., 1998).

2.6 Mango based Agroforestry system

Mango (*Mangifera indica* L.) is one of the most common and popular fruit and often mentioned as the 'King of fruits' (Purseglove, 1981) due to its excellent flavor, attractive color, delicious taste and high nutritive value. Mango is a tropical, and subtropical fruit belongs to the family Anacardiaceae. The leading mango growing districts of the country are Rajshahi, Chapainawabgonj and greater Dinajpur. Mango is seasonal cash crop of North-Western region of Bangladesh which dominates the economy of Rajshahi and Chapainawabgonj district. More than 500 varieties of sweet edible mangoes can be found in Rajshahi and Chapainawabgonj district. It is estimated that around 85% people of the mentioned districts are directly or indirectly dependent on mango cultivation and business (Dhaka Tribune, 2018a).

Abedin and Quddus (1990) recorded 28 different tree species in the homestead of the Barind Tract in Rajshahi district. *Mangifera indica* and *Phoenix sylvestris* were the most dominant species, whereas *Artocarpus heterophyllus* was only of minor occurrence. They also mentioned that the average tree density was higher in Potuakhali and Rangpur (1.5 and 1.4 trees/10 m2 respectively) than in Rajshahi (0.7) where the annual rainfall is the lowest in Bangladesh. Miah *et al.* (1990) found that farmers generally prefer fruit trees over fuel/timber species in their homestead.

Mannan (2000) in a study of 3 agro-ecological region found higher fruit diversity than that of vegetable and timber. Sellathurai (1997) also found higher diversity in his study. Mannan (2000) found higher fruit diversity in Gazipur than that of Bandarban and Naogaon. He also found fruit diversity ranged from 0.000 to 0.920 over the region. Mango was found highly diverse fruit species in the fruit group. Mannan *et al.* (2004) found fifty seven different mango local varieties at 150 household.

The Relative Prevalence of most common species like Banana, Betel nut, Coconut, Date, Mango, Papaya, Guava were very high while that of less common species like Kaow, Pineapple, litchi were found very low. Alam *et al.* (1990) found mango as the most prevalent among the horticultural species followed by guava, jackfruit, coconut and jujube.

Chowdhury and Sattar (1992) found coconut as the most prevalent among the fruit species followed by jackfruit, date palm, banana and mango. Mannan (2000) observed Mango as the most prevalent among the fruit species followed by Jackfruit, guava, jujube, coconut etc.

Singh *et al.* (2013) conducted a field experiments to investigate the suitability and profitably with different intercrops of cowpea, frenchbean, arhar, soyabean, lentil, blackgram and chickpea in mango orchard (cv. Himsagar). The age of the plant was 7 years old with a spacing of 10x10m which provided the utilization of land space between the plants as an intercrop. Pooled data reveals that the maximum number of fruits 192.41 / tree and yield 46.09 kg / tree were found in Mango + Cowpea whereas maximum fruit weight (254.16 g) in Mango + Lentil. Most of the physical parameters such as fruit length and breadth maximum were recorded (8.20 cm and 7.21 cm respectively) in Mango + Cowpea. But, in case of peel weight (35.67 g) was highest in Mango + Soyabean whereas the higher stone weight (35.79 g) was in sole crop (Mango) only. Again, pulp weight and pulp: stone ratio (193.53 g and 5.80) were observed in Mango + French bean respectively. The quality parameters such as TSS, reducing sugar, vitamin c, acidity and shelf-life showed non-significant variation among the different treatments.

A mango based cropping study was conducted with ginger, turmeric, tomato, cowpea, French bean, ragi, niger and upland paddy by Swain (2014). The results of the study revealed that the ginger were tried in mango orchard with and without application of biofertilizers. Growing of intercrops like ginger, turmeric and pineapple with biofertilizers and inorganic fertilizers in mango orchard revealed that maximum mango yield was recorded intercropping with turmeric with application of biofertilizers (36.87 quintal per hectare) followed by intercropping with mango + guava + cowpea combination exhibited better performance which has been reflected in the form of plant height, girth, canopy area, fruit weight and fruit yield of mango closely followed by mango + guava + French bean system. The mango plants, under study, however, did not exhibit any kind of variation in quality parameters in fruits. The leguminous intercrops, cowpea and French bean, were the most effective crop because of their desirable impact on improvement of nutrient status of soil and plant of mango orchard.

Behera *et al.* (2014) also studied on development of mango based intercropping and observed that it is the need of hour to increase production along with increasing income of mango growers. Keeping the above facts in to consideration different intercrops like pineapple, turmeric and ginger with application of biofertilizers (34.47 quintal per hectare) and minimum was recorded in control (22.07 quintal per hectare) where no intercrop was grown over the two years of investigation. The percentage increase of yield over control is 40 per cent. The application of biofertilizers also increased the yield over control and inorganic fertilizers to the ton of 48 per cent and 20 per cent, respectively.

Sarker *et al.* (2014) conducted a comparative study with a total of 85 mango growing farmers by interviewing. They observed that Barind ecosystem (Rajshahi Region) is unfavorable for field crop production but suitable for production of fruits like mango, litchi and jujube etc.

2.7 Properties of turmeric

Medicinal and Pharmacological Properties of Turmeric

i). Antidiabetic properties

A hexane extract (containing ar-turmerone), ethanolic extract (containing containing ar-turmerone, curcumin, demethoxycurcumin and bisdemethoxycurcumin) and ethanolic extract from the residue of the hexane extraction (containing curcumin, demethoxycurcumin and bisdemethoxycurcumin) were found to dose-dependently stimulate adipocyte differentiation. The results indicate that turmeric ethanolic extract containing both curcuminoids and sesquiterpenoids is more strongly hypoglycemic than either curcuminoids or sesquiterpenoids. Wickenberg *et al*. 2010 studied the effects of turmeric on postprandial plasma glucose and insulin in healthy subjects; they found out that the ingestion of 6g C. longa had no significant effect on the glucose response. The change in insulin was significantly higher 30min and 60min after the OGTT including C. longa. The insulin AUCs were also significantly higher after the ingestion of C. longa after the OGTT.

ii). Antimicrobial properties

Turmeric extract and the essential oil of *Curcuma longa* inhibit the growth of a variety of bacteria, parasites, and pathogenic fungi. A study of chicks infected with the caecal parasite Eimera maxima demonstrated that diets supplemented with turmeric resulted in a reduction in small intestinal lesion scores and improved weight gain. Another study, in which guinea pigs were infected with eitherdermatophytes, pathogenic molds, or yeast, found that topically applied turmeric oil inhibited dermatophytes and pathogenic fungi. Improvements in lesions were observed in the dermatophyte- and fungi-infected guinea pigs, and at seven days post-turmeric application the lesions disappeared. Curcumin has also been found to have moderate activity against Plasmodium falciparum and Leishmania major organisms. Khattak *et al*. 2005 studied the antifungal, antibacterial, phytotoxic, cytotoxic and insecticidal activity of an ethanolic extract of turmeric. The extract showed antifungal activity towards Trichophyton longifusus and Microsporum canis and weak antibacterial activity against Staphylococcus aureus. Toxic activity was observed against Lemna minor. The *Curcuma longa* treated rabbit group showed a significant higher mean value for contraction of the wound compared to controls. Furthermore the wounds showed less inflammation and an increasing trend in the formation of collagen

2.8 Varieties of turmeric

Turmeric comes from the root of *Curcuma longa*, a green plantTurmeric Varieties in the ginger family. Rhizome has a tough brown skin and bright orange flesh. Ground turmeric comes from fingers which extend from the root.There are approximately 30 varieties have been recognized in the type of Curcuma in which turmeric belongs. Amalapuram, Armour, Dindigam, Erode, Krishna, Kodur, Vontimitra, P317, GL Purm I and II, RH2 and RH10 are some popular Indian varieties among them.In India most of the turmeric used is of dried cured variety, the 'Erode' variety is the best and more popular. The 'Krishna' variety gives the highest yield of green turmeric.

Famous varieties of Turmeric

- Local Haldi
- China scented

- Thodopuza
- Red streaked
- Alleppey

Major varieties of Turmeric in India

- 'Alleppey Finger' (Kerala)
- 'Erode and Salem turmeric' (Tamil Nadu),
- 'Rajapore' and 'Sangli turmeric' (Maharashtra)
- 'Nizamabad Bulb' (Andhra Pradesh)

In Tamilnadu, the important varieties cultivated are Erode local, BSR-1, PTS-10, Roma, Suguna, Sudarsana and Salem local. Among these varieties, 70-75% is occupied by the local varieties

Allepey Finger Turmeric, Rajapuri, Madras and Erode are some of important exported varieties. Turmeric exported in the processed form is dry turmeric, fresh turmeric, turmeric powder and oleoresin. Alleppey finger turmeric is known for its high content of curcumin - a yellow colouring substance. Its bright yellow colour has been preferred by spices importers in Europe and other continents. In Middle East, the UK, USA and Japan, some of the well-accepted varieties are: 'Alleppey Finger' and 'Erode turmeric', 'Rajapore' and 'Sangli turmeric' and 'Nizamabad Bulb'

India also exports turmeric in powder form and as oleoresin

2.9 Factor affecting turmeric production in Agroforestry system

Light: The first factor is the intensity of light (full intensity, the light under the canopy of silk tress is not pruned, and 1/3 of the lower part head is prunned). While the second factor is NPK compound fertilizer 15-15-15 (dose 100, 150, and 200 kg ha-1), so there were 9 treatment combinations, each repeated 3 times resulting in 27 experimental units (13.5 x 40.5 m in size). The data of the observation were analyzed using variance (F0,05 test), if different was followed by Duncan test 0,05. Total N content (Kjedhal method), P (Olsen method) and K available (NH4O Ac 1 N pH7 extraction method), organic material (Walkley & Black method), pH (Walkley & Black type pH meter) and C-

Organic (Walkley & Black method), as well as C/N (Walkley & Black method) were analyzed before planting. 3 1234567890 ‘’“” ICSAE IOP Publishing IOP Conf. Series: Earth and Environmental Science 142 (2018) 012034 doi :10.1088/1755-1315/142/1/012034 The tillage was done two weeks before planting using hoe as deep as layers (20 cm) then added the basic fertilizer (manure) 20 ton ha-1 . The amount of litter silk trees observed within 3 months about polyphenol content, lignin, and selullose, as well as quantity. Planting material was the rhizome of turmeric cultivation in Central Research and Development of Medicinal Plants and Traditional Medicines (B2P2TOOT Tawangmangu). The rhizomes are first planted in polybag with a mixture of soil and manure (3:1, weight/weight). Small rhizomes (aged one day) is planted in the field by burying it into the planting hole, the rhizome is covered with soil, manually. Maintenance includes: irrigation using a bucket every 1 week based on soil conditions until the soil looks wet under the field capacity. Weed management was done manually every time weeds grow, various weeds include: Putri Malu (Mimosa pudica), Teki-tekian (Cyperus rotundus), and Bandotan (Ageratum conyzoides). Fertilizer was given according to treatment in three stages that is when the plants are 1 week, 1 month and 2 months, each 1/3 dose. Fertilizer was immersed into the hole around the plant (4 holes were made).

Spacing: The research was a field trial on individual silk tree forest land in Bakalan Village, Karanganyar, Central Java (geographical position 07° 41 '42.1 "LS and 110o 58' 46.7" BT and 400 m elevation above sea level), from November 2016 to March 2017. Turmeric is planted between silk trees (10 months aged in agroforestry system, plant spacing of 3 x 3 m), plant spacing turmeric is 50 x 50 cm, the tip of turmeric is 75 cm from silk tree, the area of each plot Unit experiments 150 x 150 cm. The experimental design was splitted and plot based Randomized Complete Block Design (between block 3 m).

Seed size: Turmeric (*Curcuma longa* L) plant species produces different sizes of daughter rhizomes (R) and mother rhizomes (MR), which are the only propagules (seed) for its cultivation. Here, we evaluated the effects of seed rhizome size on growth and yield of turmeric. Daughter rhizomes of 5-50 g (R-5 g–R-50 g) and mother rhizomes of 48-52 g (MR) were tested. The heavier the R up to 40 g, the better the plant growth, and the plants from the R-30 g, R-40 g, R-50 g and MR grew similarly well. The seed rhizomes with a greater diameter developed vigorous seedlings. The plants grown from

R-30 g, R-40 g and R-50 g had a similar plant height, tiller number and leaf number, which were significantly higher than those from lighter R. The plants from R-30 g, R-40 g and R-50 g had a significantly larger shoot biomass and higher yield than those from smaller R in both the greenhouse and field experiments. R-50 g was easily broken at the time of planting, and had secondary and tertiary daughter rhizomes, which developed thinner plants and resulted in a lower yield.

Turmeric is prized and valued for its ability to impart brilliant yellow-gold colour to food due to the presence of secondary metabolite (yellow pigment) i.e. curcumin (Rakhunde *et al*., 1998) and is considered as an important factor in sensory and consumer acceptance of products (Wang *et al.,* 2009). Besides being a spice crop, it has worldwide demand in cosmetic as well as in medicinal industry (Hossain *et al*., 2005a). Its role as an antimalarial (Nandakumar *et al.,* 2006), anti-inflammatory and antitumor (Gupta *et al*., 2012) has been well appreciated worldwide and it has also been known to modulate lipid metabolism, which has been implicated in obesity (Alappat & Awad, 2010).

So it is obvious that the selection of right size planting material (length, weight and number of growing buds per seed) is an important factor for turmeric cultivation. Although the standard size of turmeric rhizome for planting is 20-30 g as per the scientific package of practices yet many researchers reported that planting larger turmeric seed rhizomes resulted in higher yield compared to smaller seed rhizomes (Randhawa & Mishra, 1974; Borget, 1993; Hossain *et al*., 2005a). Further, Awasthy & Jessykutty (2017) also reported that a turmeric rhizome bit of approximate weight i.e. 7 g with 3 node recorded the highest sprouting percentage with good morphological characteristics.

2.10 Quality and growth of turmeric

1. Growth and yield of turmeric

Turmeric plant height did not vary significantly with the soil type, but it was slightly higher in dark red soil. The number of tillers and leaf biomass were not statistically different with the soil type, but red soil produced the lowest tiller number and leaf biomass. Root biomass of turmeric significantly varied with the soil type. Dark-red soil produced significantly highest root biomass of turmeric followed by gray soil. Shoot biomass and yield were significantly higher when turmeric was cultivated on dark-red soil than in gray and red soils.

It is difficult to explain the effects of individual or combined soil nutrient(s) on growth of turmeric plant in this study. Similarly, Oya (1972) reported that no general tendencies in the relationship between the plant growth and the concentrations of K, Ca and Mg were found in different soils. It is assumed that the lowest P and K contents, and the high NO3-N and NH4-N content of dark-red soil are comparatively good combinations, which resulted in higher vegetative growth. Gray soil had higher/highest NO3-N and NH4-N contents, but did not produce a large shoot biomass like dark-red soil, indicating that there was an interaction among the nutrient contents, which influenced plant growth. Similarly, other studies (Mazid, 1993; McCrea *et al*., 2004; Hao and Papadopoulos, 2004) reported that unbalanced nutrient resulted in lower growth and yield of plants. Dark-red soil was comparatively loose (apparent density was the lowest and it contained optimum moisture, which resulted in greater root and vegetative growth. Similarly, Houlbrooke *et al*. (1997) reported that root biomass and shoot biomass of ryegrass (Lolium perenne) were increased by the lower soil bulk (apparent) density. The waterlogging condition continued for some time in red and gray soils after water application, but it was not found in dark-red soil. In addition, red soil became compact when it dried, and gray soil remained wet for a longer time. Therefore, it is assumed that aeration and microbial activities were poor in red and gray soil, which probably caused in lower vegetative and reproductive growth of turmeric. A large shoot biomass of turmeric on dark-red soil resulted in a higher yield, which is in agreement with the results of our previous studies (Hossain *et al*., 2005a). Rhizomes grew bigger in dark-red soil because this soil was comparatively loose. Turmeric shoots on dark-red soil remained green for a longer period, resulting in a longer period of photosynthesis and increased the yield. Similarly, Zaman *et al*. (2001) reported that a longer period of photosynthesis was the key factor of higher rice-yield.

2. Quality parameters

Daughter rhizomes were bigger when turmeric was cultivated on dark-red soil than in the red or gray soil, although the rhizomes were same in size (data not presented). Color of turmeric powder was a favorable yellow when cultivated on dark-red soil followed by gray soil.The curcumin content was the highest (0.20%) in the turmeric cultivated on dark red soil followed by gray soil (0.10%). Protein content of turmeric in dark-red was the highest (5.2%), which was 40% higher than that in other soil types. Total fat content was 3.6% in the turmeric cultivated on dark-red and gray soil, and was 2.1% in red soil Sodium content of turmeric was the highest when cultivated on red soil followed by gray soil, whereas K content was the highest when cultivated on gray soil followed by red soil. The calcium content of turmeric in gray soil was the highest, which was 2 to 3 times greater than that in other soil types. Turmeric contained 6.3 μg g-1 Mg when planted in gray soil followed by red soil, whereas Fe content was the highest when cultivated on dark-red soil.

The color of turmeric powder was the deepest yellow when cultivated on dark-red soil followed by gray soil. We could not determine the specific elements required for preferable coloring of turmeric. However, a proper combination of minerals, nutrients and soil pH is required. The curcumin, protein and total fat content of turmeric were highest when cultivated on dark-red soil, perhaps due to optimum mineral and soil pH levels. Sodium content of turmeric was the highest when cultivated on red soil though this soil did not contain the largest amount of Na. Turmeric in gray soil had the highest K, Ca and Mg contents, because this soil contained the largest amount of K, Ca and Mg. Iron (Fe) content of turmeric was the highest in dark-red soil followed by gray soil. We did not find any clear relationship between the mineral content in soil and that of turmeric powder. However, it is assumed that balanced fertilization (naturally existed in soil), soil pH and soil physiological properties were necessary for higher mineral content of turmeric.

Other studies reported that yield and quality of crops are positively and/or negatively correlated with physical, chemical and nutrient properties of soil (Oya, 1972; Miyazawa *et al*., 2004). From the results/information of this study and other studies, it is assumed that a certain ratio of minerals, a balanced fertilization, a limited soil pH and a certain soil physical properties are required to increase yield and quality of a specific plant species.

2.11 Effect of light intensity on spice production

Singh *et al.* (2001) observed the effect of these tree species namely eucalyptus (*E. tereticornis*), acacia (*A. nilotica*) and poplar (*P. deltoides*) on the performance of turmeric in Haryana, India. The mean emergence count of turmeric was the maximum when grown in association with acacia while the minimum in the control i.e. open. The mean height attained by turmeric after 90 days was the highest under eucalyptus and lowest under poplar. The yield of turmeric was in the order: eucalyptus>control> poplar>acacia.

From an investigation on the multistoried Agroforestry system at the Bangladesh Agricultural University, Mymensingh, Rahim and Haider (2002) claimed that natural resources could be used properly in this system. When trees of different heights are planted in an Agroforestry system, they absorb sunlight from different strata.

From studies conducted in Kerela, India, Jayachandra *et al.* (1998) indicated that coconut and ginger combination under rainfed conditions gave good returns as ginger performed well under shade where few other crops could do. The yield of ginger was 11-27% higher than open fields. Even the yield was better under 50% artificial shade than under open conditions.

Intercropping of turmeric with *Leucuena leucocephala*, *Eucalyptus camaldulensis*, ghoraneem or *Manilkara spp*. were carried out in Madhya Pradesh, India. The highest yield of turmeric was observed in the *L. leucocephala* treatment. The yield of turmeric decreased with increasing tree age and with increasing density of planting of trees (Mishra and Pandey, 1998).

Sathish *et al.* (1998) evaluated the performance of twelve turmeric varieties in a 20 year old coconut plantation. Plant crop cycle duration, yield and quality were assessed. The Cuddapah produced the tallest plant (57.27 cm) and BSR-1 produced the great number of tillers (4.47/clumps).

Nair (1983) stated that multi-species tree gardens characterized by a large variety of multipurpose plants in various vegetation layers provided scopes for effective utilization of environmental factors like water, nutrients and sunlight. He also stated that shade lowered ground surface temperature, which may reduce the rate of loss of soil organic matter by oxidation.

Michon and Mary (1994) said that multistoried village gardens in the vicinity of Bogor, West Java, Indonesia have long been essential multi-purpose production system for low income households. However, they were being subjected to important conversion processes to socioeconomic changes found in over crowd semi urban zones.

Michon *et al.* (1986) stated that multistoried Agroforestry system is characterized by intensive integration of forest species and commercial crops forming a forest like system. Agroforesty is a profitable production system and provides a buffer between villages and protected forest.

CHAPTER THREE

MATERIALS AND METHODS

CHAPTER THREE

MATERIALS AND METHODS

In this chapter the materials and methods have been presented which include brief description of location of the experimental site, soil, climate, materials used and methodology followed in the experiment. The details are described below:

3.1 Locations of the experimental plots

The present research work was carried out at a farmers' field (Under Mango trees and open control) adjacent to the HSTU Research Farm, Dinajpur during 24 March 2018 to 10 January 2019 the upland conditions, The site lies between 25 degree 13 latitude & 88 degree 23 longitudes at the elevation of 40m above the sea level.

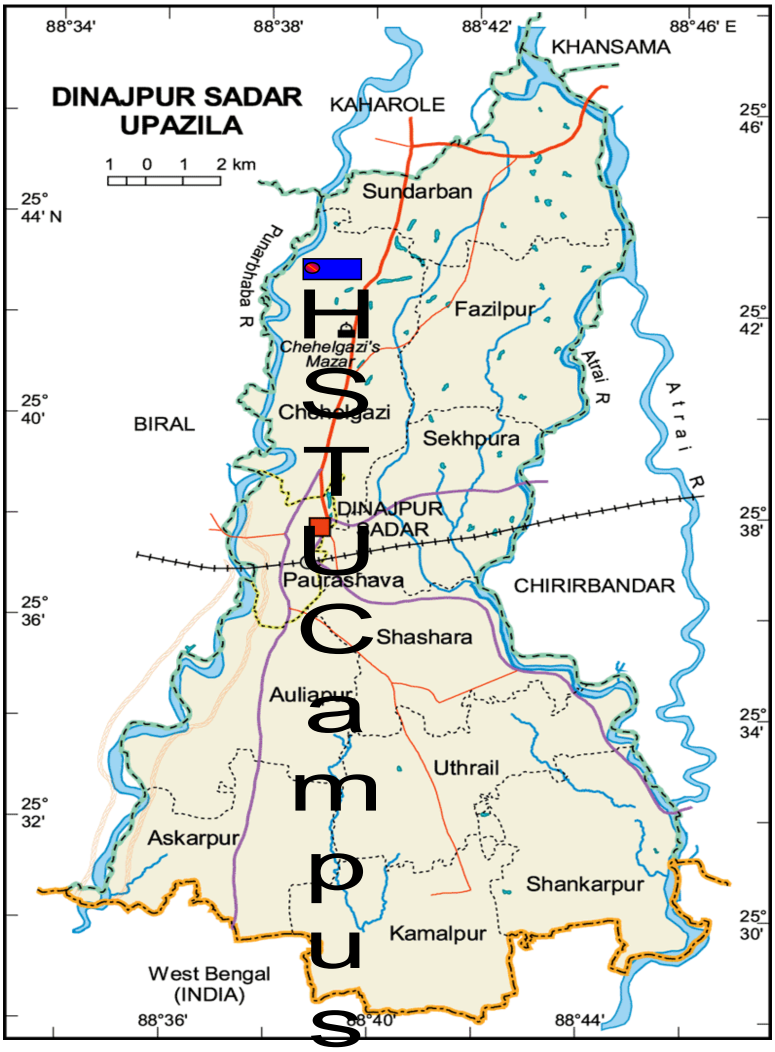

Figure 3.1: Showing the map of HSTU area in Dinajpur Sadar

3.2 Soil Characteristics

The experiments were laid out in a medium high land belonging to the AEZ of Himalayan piedmont plain area. The soil texture was sandy loam with a pH of 5.0 (very acidic).The structure of soil was fine and the organic matter, total N, P, K, S, Zn and B contents were 1.20%, 0.06%, 29.35μ/g soil, 0.21μ/100g soil, 6.13μ/g soil, 0.73μ/g soil and 0.27μ/g soil respectively. The soil characteristics were tested at the Regional Laboratory, SRDI, Dinajpur.

3.3 Status of the Mango plants

The first study was done under 11 years mango trees planted in 2008 by the HSTU Research Farm, Dinajpur. Each tree was pruned every year. The characteristics of mango trees were follows:

Characteristics	Values
Average height	7M
Average diameter at the breast height	32cm

3.4 Climate and weather

The climate of the study area is characterized by a heavy rainfall during kharif season (April to September, 2018) while a scanty rainfall during the rest period, i.e. during the rabi season (October to March, 2018). The mean maximum temperature in the in the summer (March to September, 2018) was 35℃ and the mean maximum temperature in the winter (November, 2018 to January, 2019) 11.9°C. The humidity was 87% in January and 88% in July. The mean annual rainfall was 1822mm most of which occurred in during June-September and light showers occurs during the Rabi season (October, 2018-January, 2019).

3.5 Experimental Designs

The experiments were laid out in the RCBD. There were two treatments in the experiment, first experiment was set with three varieties of turmeric under mango shade and second was set with three varieties under open space (control). There were three replications in each study. The size of plot was 3m×3m.But for data analysis, the plot size was measured as 3m×0.6m as necessary.

3.6 Experimental treatments

The experiment consisted of 2(two) factors:

Factor A: (Two production systems)

T_1=Under mango shade+ Turmeric

T_2=Open place+ Turmeric

Factor B: (Three local turmeric varieties)

V_1=Thailand

V_2=Malshira

V_3=Debipat

3.7 Treatment combinations of the study

The two treatments used with three varieties of turmeric (Thailand, Malshira and Debipat) under mango shade and open space (control) in each study were :

T_1V_1= Turmeric thailand var. under mango shade

T_1V_2= Turmeric malshira var. under mango shade

T_1V_3= Turmeric debipat var. under mango shade

T_2V_1= Turmeric thailand var. under open field

T_2V_2= Turmeric malshira var. under open field

T_2V_3= Turmeric debipat var. under open field

3.8 Structural description of the treatments

1^{st} layer (upper layer): Mango tree

Scientific name: *Mangifera indica*

Family: Anacardiaceae

Spacing: 3m×3m

Planting Direction: North-South

3.9 Land preparation

The land was opened in the last week of March 2018 and then prepared thoroughly by spading and cross spading to obtain a good tilth, which was necessary to get better yield of this crop (Ahmed, 1969). All the weeds, stubbles and crop residues were removed from the field and bigger clods were broken into smaller pieces. Finally, the land was pulverized and leveled uniformly.

3.10 Experimental materials

Three varieties of turmeric Thailand, Malshira and Debipat were used in the experiment as the test crop. The seed rhizome was collected from local market near Nilphamari District.

3.11 Manuring and fertilizers

For the Two treatments, recommended doses of fertilizers (nitrogen, phosphorus, potasium, sulphar and zinc) and method of applications were followed as per Fertilizer Recommendation Guide-2012, Bangladesh Agricultural Research Council.

3.12 Crop establishment

The seed-rhizomes/fingers of variety of turmeric were planted maintaining a line to line distance of 60 cm, plant to plant distance 20cm and a depth of 10cm under mango trees and open field/space (control). Weight of each seed/rhizome of Thailand was 20g Malshira was 18 and Debipat turmeric was 17g.

Plate 1: Turmeric (Thailand, Malshira and Debipat) varieties were planted under mango shade

Plate 2: Turmeric (Thailand, Malshira and Debipat) varieties were planted under open field (control)

3.12.1 Intercultural operation

Weeding was done regularly for better growth of turmeric. It was done gradually Nine times after germination. Cowdung were applied seven days before planting. N, P, K, S and Zn were applied before the planting of turmeric varieties .Some plants were rotten by water logging condition. This condition was controlled by drainage. Some turmeric plants were affected by leaf spot disease, which were controlled by spraying Roval and Dithane M-45 @4.5g/L at an interval of 15 days respectively.

3.12.2 Application of manures and fertilizers

For the treatments the doses of fertilizers and their methods of application as recommended by are given below:

Fertilizer	Low dose (kg/ha)	Factor	Per plot (2m×2m) (g)	Total amount(g)
N	120	2.17	238.36	2812.32
P	36	5	162	1944
K	105	2	189	2268
S	15	5.5	74.25	891
Zn	3	2.78	7.506	90.072

Cow dung (CD) were applied seven days before planting**.** N, P, K, S and Zn were applied before the planting of turmeric varieties. Those doses were for turmeric were recommended by Fertilizer Recommendation Guide 2012, Bangladesh Agricultural Research Council (BARC).

3.13 Harvesting

Turmeric varieties were harvested (on 10 January 2019) after 292 days of planting when the leaves turned yellow and started drying up.

3.14 Sampling and data collection

3.14.1 During germination period

- **Germination data:** Number of plants was counted after 10 days by turns after germination of turmeric plants within 140 days after planting (DAP). Germination speeds were calculated as followed by (Zhang and Fu, 2010). Germination speed was calculated as under (Chiapusio *et al.,* 1997):

  S= (N1*1) + (N2–N1)*1/2 + (N3- N2)*1/3 + … + (Nn- Nn-1) *1/n

  Where, N1, N2, N3,…, Nn-1, Nn refers to the proportion of germinated rhizomes on the 10 days, 20 days , 30 days,…. 140 days.

Number of plant: It was counted after 10 days by turns after germination of turmeric plants within 180days after planting (DAP).

Plant height (cm): It was measured from the ground level up to the longest leaf at 60, 90, 120 and 180 days after planting (DAP).

Length of leaf blade (cm): Three leaves per plant from the three lines in every plot of turmeric variety were used for this purpose at 60, 90, 120 and 180days after planting (DAP).

Width of leaf (cm): Three leaves per plant from the three lines in every plot of turmeric variety were used for this purpose at 60, 90,120 and 180days after planting (DAP).

3.14.2 During harvesting period

Number of plant per plot: During harvesting, number of plants of turmeric per plot was counted.

Total number of fingers per plot: It was counted after harvesting from turmeric rhizomes.

Number of finger per plant: It was counted after harvesting from total number of finger per plot of turmeric varieties.

Length of biggest rhizome (cm): It was measured from every lines of every plot of turmeric varieties.

Width of biggest rhizome (cm): It was also measured from every lines of every plot of turmeric varieties.

Number of total nodes per rhizome: Again, it was measured from biggest rhizome of every lines of every plot of turmeric varieties.

Total Length of internodes per rhizome (cm): It was also measured from biggest rhizome of every lines of every plot of turmeric varieties.

Fresh weight of rhizomes per plot: The fresh weight of fresh rhizomes from every lines of the turmeric variety plots were recorded with the help of a balance at the time of harvest.

Fresh weight of rhizomes per hectare: The fresh weight of fresh rhizomes from every lines of the turmeric variety plots were converted into fresh weight per hectare.

Dry weight of rhizomes per plot/100g: After harvest, 100g rhizomes from each plot of turmeric varieties were dried in an oven for 48 hours at 80°C til constant weight. After drying, the dry rhizomes were weighted.

Dry weight of rhizomes per hectare: Dry weight of rhizomes per plot/100g were converted into dry weight per hectare.

3.15 Light intensity

Light intensity were measured by an LUX meter (Hanna company) before the harvesting at the time of 10 am, 1pm and 4 pm.

3.16 Data analyses

The data on various growth and quality parameters of turmeric varieties under mango shade were statistically analyzed to examine the variations of the results due to the two treatments compared.

The analysis was done by Factorial design with two factors and each factor had three replications. The factors were:

Factor A: Systems i.e.

System 1: Turmeric grown under mango tree

System 2: Turmeric grown open field

Factor B: Three local varieties of turmeric i.e.

V_1= Thailand variety

V_2= Malshira variety

V_3= Debipat variety

Means of each parameter were separated by TUKEY HSD - multiple comparison method. A two way interaction were obtained by factorial analysis of anova (AOV).

All data were analyzed by the help of computer system STATISTIX 10.

CHAPTER FOUR

RESULTS AND DISCUSSION

CHAPTER FOUR

RESULTS AND DISCUSSION

The results of study are presented in the chapter under different sections comprising growth and quality contributing characteristics of three turmeric varieties. The results are discussed here citing accessible literatures.

4.1 Main effect of agroforestry Systems on the growth and quality of turmeric

4.1.1 Plant height (cm)

The plant height was significantly influenced by effect of agroforestry production systems. The tallest plant heights (26.27 cm, 66.29 cm, 89.33 cm and 116.37cm) were recorded in mango+turmeric based agroforestry system (T_1) at the 60, 90, 120 and 180days after plantings (DAPs), respectively. On the contrary, significantly the shortest plant heights (21.37 cm, 48.11 cm, 68.11 cm and 110.78 cm) were observed in open control (T_2) at 60, 90 120 and 180 DAPs, respectively. Partially similar result also was found by Meerabai *et al.* (2000), different turmaric varieties with mango based agroforestry system.

Table 4.1: Main effect of agroforestry production systems on the plant height of turmeric varieties at different DAP

Treatments	Plant height 60DAP (cm)	Plant height 90DAP (cm)	Plant height 120DAP (cm)	Plant height 180DAP (cm)
Under mango (T_1)	26.27a±1.84	66.29a±2.64	89.33a±3.33	116.37a±4.35
Open filed (T_2)	21.37b±0.58	48.11b±2.81	68.11b±3.47	110.78a±3.69
CV%	29.87	24.8	22.48	18.49

*In a column different letters are significantly different at P≤ 0.05, 0.01 and 0.001 by Tukey HSD test

4.1.2 Length of leaf (cm)

Length of leaf varied significantly by agroforestry production systems where longest leaf blades (24.88 cm, 32.66 cm,46.33 cm and 59.18 cm) were found in mango+turmeric (T_1) at the 60,90, 120 and 180 days after plantings (DAPs), respectively. And on the other hand the shortest leaf blades(23.13 cm, 20.29 cm, 31.92 cm, and 53.07 cm) were recorded with T_2 at 60, 90 120 and 180 DAPs, respectively. According to Schoch (1972), more stimulation of cellular expansion and cell divisions occurred under shaded conditions, which were also similar result.

Table 4.2: Main effect of agroforestry production systems on the length of leaf blades of turmeric varieties at different DAP

Treatments	Length of leaf 60DAP (cm)	Length of leaf 90DAP (cm)	Length of leaf 120DAP (cm)	Length of leaf 180DAP (cm)
Under mango (T_1)	24.88a±1.06	32.66a±1.19	46.33a±1.63	59.18a±2.21
Open filed (T_2)	23.13a±1.13	20.29b±0.73	31.92b±1.12	53.07b±1.70
CV%	23.81	19.48	18.69	18.26

*In a column different letters are significantly different at P≤ 0.05, 0.01 and 0.001 by Tukey HSD test

4.1.3 Width of leaf (cm)

It varied significantly influenced by agroforestry production systems at different days after planting (DAPs). Width of leaf (3.88 cm) was found in T_1 and (3.70 cm) in T_2 at 60 DAP, they were statistically similar. Again, at 90 DAP, width of leaf were found in T_1 (6.48 cm) and T_2 (6.18 cm) which were statistically similar. The maximum width of the leaf T_1 (10.74 cm) and T_2 (10.55 cm) were found at 120 DAP, and which were also similar. Again, at 180 DAP, The maximum width of leaf (16.18 cm) was observed in T_1 and the other hand the minimum width of leaf (15.37 cm) was found in T_2. Similar results were found by Chowdhury *et al.* (2009).

Table 4.3: Main effect of different agroforestry production systems on the width of leaf of turmeric varieties at different DAP

Treatments	Width of leaf 60DAP (cm)	Width of leaf 90DAP (cm)	Width of leaf 120DAP(cm)	Width of leaf 180DAP(cm)
Under mango (T_1)	3.88a±0.17	6.48a±0.24	10.74a±0.38	16.18a±0.42
Open field (T_2)	3.70a±0.10	6.18a±0.17	10.55a±0.31	15.37a±0.34
CV%	19.43	17.63	17.27	12.69

*In a column different letters are significantly different at P≤ 0.05, 0.01 and 0.001 by Tukey HSD test

4.1.4 Number of finger and size of turmeric varieties

In different quality parameters, number of finger is an important parameter. They were significantly influenced by different agroforestry production systems of turmeric varieties. The highest total number of finger per plot during harvesting time was 50.96 in T_2. The lowest total number of finger per plot was 49.66 in T_1. Again the Maximum number of finger per plant was 4.13 in T_2 and the minimum was 3.72 found in T_1, which were converted from total no. of finger per plot to total no. of finger per plant. Selina, 2008 was observed this type of result in her thesis.

Length of the biggest rhizome and width of the biggest rhizome are important quality contributing parameters. The length of biggest rhizome was found T_1 (27.1 cm) and T_2 (27.10 cm), which were statistically similar .Again, longest wide of biggest rhizome was observed in T_2 (21.14 cm), on the other hand, the lowest wide of biggest rhizome was found in T_1 (19.43 cm). Similar result found by Pushkaran *et al.* (1985).

Table 4.4: Main effect of mango shade on the number of finger and size of turmeric varieties

Treatments	Total no. of finger per plot	No of finger per plant	Length of biggest rhizome (cm)	width of biggest rhizome (cm)
Under mango (T_1)	49.66a ± 4.35	3.72a ±0.29	27.1a ± 0.75	19.43b ± 0.64
Open filed (T_2)	50.96a ± 2.55	4.13a ± 0.19	27.10a ± 0.29	21.14a ± 0.60
CV%	35.08	31.65	10.73	14.76

*In a column different letters are significantly different at $P \leq 0.05$, 0.01 and 0.001 by Tukey HSD test

4.1.5 Quality parameters of turmeric varieties

Number of plant per plot, number of node of finger per rhizome, length of internode per finger (cm) and number of shoot per plot are important quality parameters of turmeric. Those were varied significantly by different agroforestry production systems.

The highest number of plant per plot was recorded 13.14 in T_1 and lowest number of plant per plot was observed 12.29 in T_2. Again, number of node of finger per rhizome was found 19.48in T_2 was highest and the lowest was 18.70 in T_1.

And then, length of internode per finger was recorded 4.28 cm in T_2 was the highest and the lowest was found 3.87 cm in T_1.

At the number of shoot per plot, maximum number of shoot was found in T_2 (6.11) and the minimum was observed in T_1 (5.55). Similar result found by Pushkaran *et al.* (1985).

Table 4.5: Main effect of mango shade on the quality parameters of turmeric varieties

Treatments	No. of plant per plot	No. of node of finger per rhizome	Length of inter-node per finger (cm)	No. of shoot per plot
Under mango (T_1)	13.14a ± 0.24	18.70a ± 0.43	3.87a ± 0.13	5.55a ± 0.33
Open field (T_2)	12.29b ± 0.21	19.48a ± 0.29	4.28a ± 0.15	6.11a ± 0.28
CV%	7.83	9.94	18.8	28.03

*In a column different letters are significantly different at $P \leq 0.05$, 0.01 and 0.001 by Tukey HSD test

4.1.6 Fresh rhizome weight (kg) per plot and dry rhizome weight (g) per plot

Total fresh weight of rhizome of turmeric varieties was varied significantly by the effect of different agroforestry production systems. The total fresh weight of rhizome 1.27 kg was recorded in T_1 and 1.98 kg in T_2 was observed, which were statistically similar.

Again dry weight of rhizome of turmeric varieties per plot was also varied significantly by the effect of different agroforestry production systems. On the other hand, the maximum dry weight of rhizome 20.33 g was observed in T_1 and the minimum dry weight of rhizome 19.33 g was found in T_2. Similar results have been also reported by Srikrishnah and Sutharsan (2015) who reported that 50 % shade level is suitable for the cultivation of turmeric.

Table 4.6: Main effect of mango shade on fresh weight and dry weight of turmeric varieties

Treatments	Total fresh weight of rhizome kg/plot	Dry weight of rhizome 100g/plot
Under mango (T_1)	1.27b ± 0.13	20.33a ± 0.33
Open field (T_2)	1.98a ± 0.12	19.33b ± 0.36
CV%	38.30	2.23

*In a column different letters are significantly different at $P \leq 0.05$, 0.01 and 0.001 by Tukey HSD test

4.1.7 Fresh weight of rhizome (kg) per hectare and total dry weight of rhizome (kg) per hectare

Total fresh weight of rhizome of turmeric varieties was varied significantly by the effect of different agroforestry production systems. Fresh rhizome weight was converted into kilogram per hectare .So, the minimum total fresh weight of rhizome 7055 kg/ha was found in T_1 and maximum 11000 kg/ha in T_2 was recorded.

And then, dry weight of rhizome of turmeric varieties per plot was also varied significantly by the effect of different agroforestry production systems. Again, Dry rhizome weight (g) per 100g was converted into kilogram per hectare. So, the maximum dry weight of rhizome 2126kg/ha was observed in T_2 and the minimum dry weight of rhizome 1456 kg/ha was found in T_2. Similar result found in Hossain *et al*., 2005a.

Table 4.7: Main Effect of mango shade on fresh weight and dry weight per hectors of turmeric varieties

Treatments	Total fresh weight of rhizome kg/ha	Total dry weight (kg)/ha
Under mango (T_1)	7055	1456
Open field (T_2)	11000	2126
CV%	38.30	2.23

*In a column different letters are significantly different at P≤ 0.05, 0.01 and 0.001 by Tukey HSD test

4.2 Main effect of Variety on growth and quality contributing characters of turmeric

4.2.1 Plant height (cm)

Plant height was varied significant by the effect of turmeric varieties at different days after planting (DAP). The plant heights of turmeric varieties, tallest plant height 24.94 cm in V_2 at 60 DAP .On the other hand, the shortest plants heights were 23.30cm in V_1 and 23.22 cm in V_3 at 60 DAP, which were statistically similar. Again, at 90,120 and 180 DAPs, the tallest plants were observed in V_2 (65.44 cm, 87.83 cm and 121.00 cm). On the other hand, the shortest plants (45.66 cm and 62.72 cm) were recorded in V_1 at the 90,120 DAPs respectively. So the moderate plants heights (60.50 cm and 85.61 cm) were observed in V_3 at 90 and 120 DAPs. Finally, at 180 DAPs, the shortest plant height

(108.44 cm) was found in V_3 and the moderate height of the plant (111.28 cm) was recorded in V_1. Partially similar result also was found by Garrity *et al.* (1992).

Table 4.8: Main effect of variety on plant height of turmeric under agroforestry production systems at different DAP

Variety	Plant height 60 DAP (cm)	Plant height 90 DAP (cm)	Plant height 120DAP (cm)	Plant height 180 DAP (cm)
Thailand (V_1)	23.30a±2.23	45.66b±4.30	62.72b±5.30	111.28ab±4.19
Malshira (V_2)	24.94a±1.70	65.44a±2.60	87.83a±2.60	121.00a±3.39
Debipat (V_3)	23.22a±1.29	60.50a±3.31	85.61a±3.92	108.44b±6.48
CV%	31.78	25.81	22.08	18.2

*In a column different letters are significantly different at $P \leq 0.05$, 0.01 and 0.001 by Tukey HSD test

4.2.2 Length of leaf (cm)

Length of leaf of turmeric varied significantly at different days after planting (DAP).At 60 DAP, the maximum length of leaf blade 26.27 cm was observed in V_2 and 26.80 cm was found in V_3,which were almost statistically similar; and the minimum 18.94 cm was recorded in V_1.Again, at 90 DAP, The maximum length of leaf blade 30.05 cm was observed in V_3, the minimum length of leaf blade 22.44 cm was observed in V_1 and the moderate length of leaf blade 26.94 cm was found in V_2.Then, at 120 DAP, the maximum length of leaf blade 44.27 cm was recorded in V_3, the minimum length of leaf blade 32.50 cm was found in V_1, and the moderate length of leaf blade 40.61 cm was observed in V_2. Moreover, at 180 DAP, the highest length of leaf blade 59.16 cm was found in V_2, the lowest was 52.66 cm in V3 followed by V_2, and the moderate length of leaf blade 56.55 cm was found in V_1.Similar results were found in Chowdhury *et al.* (2010).

Table 4.9: Main effect of variety on length of leaf blade of turmeric under different agroforestry production systems at different DAP

Variety	Length of leaf 60DAP (cm)	Length of leaf 90DAP (cm)	Length of leaf 120DAP (cm)	Length of leaf 180DAP (cm)
Thailand (V_1)	18.94b±1.36	22.44b±1.85	32.50b±2.39	56.55a±2.19
Malshira (V_2)	26.27a±0.89	26.94a±1.85	40.61a±2.04	59.16a±2.08
Debipat (V_3)	26.80a±0.87	30.05a±1.63	44.27a±2.00	52.66a±3.00
CV%	18.87	28.58	23.4	18.64

*In a column different letters are significantly different at $P \leq 0.05$, 0.01 and 0.001 by Tukey HSD test

4.2.3 Width of leaf (cm)

Width of leaf of turmeric was varied significantly at different days after planting (DAP).The width of leaf at 60 DAP, V_1 (3.94 cm), V_2 (3.94 cm) and V_3 (3.50) were recorded, they were almost statistically similar. Then, at 90 DAP, the lowest width of leaf 5.94 cm in V_3,and the highest width of leaf were observed in V_1(6.61 cm) and V_2(6.44 cm),which were statistically similar. Again at 120 DAP, the maximum width of leaf 11.50 cm was found in V_1, the minimum width of leaf 10.77cm was observed in V_2 and the moderate width of leaf 9.66 cm was recorded in V_3. Moreover, at 180 DAP, the maximum width of leaf were recorded in V_1 (16.55 cm) and V_2 (16.05), they were statistically similar. On the other hand, the minimum width of leaf was found in V_3 (14.72 cm). Similar results were found by Chowdhury *et al.* (2010).

Table 4.10: Main effect of variety on width of leaf of turmeric under different agroforestry production systems at different DAP

Variety	Width of leaf 60DAP (cm)	Width of leaf 90DAP (cm)	Width of leaf 120 DAP (cm)	Width of leaf 180 DAP (cm)
Thailand(V_1)	3.94a±0.15	6.61a±0.23	11.50a±0.45	16.55a±0.47
Malshira(V_2)	3.94a±0.17	6.44a±0.25	10.77ab±0.39	16.05ab±0.44
Debipat (V3)	3.50a±0.18	5.94a±0.28	9.66b±0.33	14.72b±0.42
CV%	18.95	17.36	15.87	12.07

*In a column different letters are significantly different at $P \leq 0.05$, 0.01 and 0.001 by Tukey HSD test

4.2.4 Number of finger and size of turmeric varieties

Number of finger is an important quality contributing parameter. The effect of turmeric varieties on the number of finger of turmeric under different agroforestry production systems was significantly varied. The highest total number of finger per plot during harvesting time 56.27 was observed in V_2, the lowest total number of finger 39.77 was found in V_1 and the moderate total number of finger per plot was 54.88 observed in V_3 .Then the total number of finger per plot were converted into number of finger per plant , the highest number of finger per plant were recorded in V_2(4.29) and V_3(4.14) , they were almost statistically similar. On the other hand the lowest number of finger per plant was observed in V_1 (3.35).

Length of the biggest rhizome and width of the biggest rhizome are important quality contributing parameters. The highest length of biggest rhizome were found inV_1 (27.25 cm) and V_2 (27.82 cm), which were statistically similar and the lowest length of biggest rhizome was recorded in V_3 (26.23 cm). Again, longest wide of biggest rhizome was observed in V_2 (22.13 cm), the lowest width of biggest rhizome was found in V_3 (18.66 cm) and the moderate width of the biggest rhizome was observed in V_1 (20.06 cm). Similar result found by Pushkaran *et al.* (1985).

Table 4.11: Main effect of variety on the number of finger and size of rhizome under different agroforestry production systems

Variety	Total no. of finger per plot	No of finger per plant	Length of the biggest rhizome (cm)	Width of the biggest rhizome (cm)
Thailand (V_1)	39.77b ± 2.01	3.35a ± 0.16	27.25a ± 0.70	20.06ab ± 0.58
Malshira (V_2)	56.27a ± 4.36	4.29a ± 0.30	27.82a ± 0.77	22.13a ± 0.91
Debipat (V_3)	54.88a ± 5.04	4.14a ± 0.37	26.23a ± 0.58	18.66b ± 0.59
CV%	35.08	31.65	10.73	14.76

*In a column different letters are significantly different at $P \leq 0.05$, 0.01 and 0.001 by Tukey HSD test

4.2.5 Quality parameters of turmeric varieties

The Number of plant per plot, number of node of finger per rhizome, length of inter-node per finger (cm) and number of shoot per plot are important quality parameters of turmeric. Those were varied significantly by different agroforestry production systems.

The highest number of plant per plot were observed 13.00 and 13.27 in V_2 and V_3 respectively and lowest number of plant per plot was observed 11.88 in V_1.

Then, the highest number of node of finger per rhizome were recorded 19.50 in V_2 and 19.27 in V_3, they were statistically almost similar, on the other hand the lowest was found in V_1 (18.50). Again, the maximum length of internode per finger were recorded 4.24 cm in V_1 and 4.05 cm in V_3, they were statistically similar and which were followed by the lowest in V_2 (3.93). At the number of shoot per plot, The maximum number of shoot was found in V_2 (6.27) and the minimum were observed 5.66 in V_1 and 5.55 in V_3, they also were statistically similar. Similar result found by Pushkaran *et al.* (1985).

Table 4.12: Main effect of variety on the quality parameters under different agroforestry production systems

Variety	No. of plant per plot	No. of node of finger per rhizome	Length of inter-node per finger (cm)	No. of shoot per plot
Thailand(V_1)	11.88b ± 0.25	18.50a ± 0.52	4.24a ± 0.18	5.66a ± 0.33
Malshira(V_2)	13.00a ±0.26	19.50a ±0.37	3.93a ± 0.15	6.27a ± 0.39
Debipat(V_3)	13.27a ± 0.26	19.27a ± 0.44	4.05a ± 0.21	5.55a ± 0.41
CV%	7.83	9.94	18.80	28.03

*In a column different letters are significantly different at $P \leq 0.05$, 0.01 and 0.001 by Tukey HSD test

4.2.6 Fresh rhizome weight (kg) per plot and dry rhizome weight (g) per plot

Total fresh weight of rhizome of turmeric varieties was varied significantly by the effect of different agroforestry production systems. The total fresh weight of rhizome were observed in V_1 (1.66 kg), V_2 (1.76 kg) and V_3 (1.45 kg), those data were almost statistically similar.

Again dry weight of rhizome of turmeric varieties per plot was also varied significantly by the effect of different agroforestry production systems. The maximum dry weight of rhizome 21.83 g was observed in V_1, the minimum dry weight of rhizome 17.83 g was found in V_3 and the moderate dry weight of rhizome 19.83 was observed in V_2. Similar results have been also reported by Srikrishnah and Sutharsan (2015) who reported that 50 % shade level is suitable for the cultivation of turmeric.

Table 4.13: Main effect of varieties on fresh weight and dry weight under different agroforestry production systems

Variety	Total fresh weight of rhizomes kg/plot	Dry weight of rhizomes 100g/plot
Thailand (V_1)	1.66a ± 0.16	21.83a ± 0.21
Malshira (V_2)	1.76a ± 0.21	19.83b ± 0.21
Debipat (V_3)	1.45a ± 0.15	17.83c ± 0.21
CV%	38.30	2.23

*In a column different letters are significantly different at P≤ 0.05, 0.01 and 0.001 by Tukey HSD test

4.2.7 Fresh rhizome weight (kg) per hectare & dry rhizome weight (kg) per hectare

Fresh weight of rhizome of turmeric varieties was varied significantly by the effect of different agroforestry production systems. Fresh weight (kg) of rhizome was converted per plant to per hectare. So, maximum fresh rhizome weight per hectare were recorded in V_2 (9777 kg) and V_1 (9222 kg), they were almost statistically similar and minimum fresh weight of rhizome per hectare was found in V_3 (8050 kg).

Again dry weight of rhizome of turmeric varieties per plot was also varied significantly by the effect of different agroforestry production systems. The maximum dry weight of rhizome was observed in V_1 (2013 kg), the minimum dry weight of rhizome was recorded in V_3 (1436 kg) and the moderate dry weight of rhizome was found in V_2 (1939 kg). Similar result found in Hossain *et al.*, 2005a.

Table 4.14: Main effect of variety on fresh weight and dry weight of rhizome per hectors under different agroforestry production systems

Variety	Fresh weight of rhizomes kg/ha	Dry weight of rhizomes kg/ha
Thailand (V_1)	9222	2013
Malshira (V_2)	9777	1939
Debipat (V_3)	8055	1436
CV%	38.30	2.23

*In a column different letters are significantly different at P≤ 0.05, 0.01 and 0.001 by Tukey HSD test

4.3 Interaction effect of different agroforestry production systems and turmeric varieties on growth and quality contributing characters of turmeric at different DAP

4.3.1 Plant height (cm)

The interaction effect of the different agroforestry production systems and turmeric varieties on the plant height of turmeric was found significantly different at different days after planting (DAP) .The tallest plant was recorded in T_1V_2 (28.22 cm) combination at the 60 DAP and the lowest plant height was found in T_2V_3 (20.77 cm) combination. Again, at 90 DAP, the tallest plant height was observed in T_1V_3 (70.88 cm) combination, which was followed by T_2V_1 (31.55cm) combination. Then, at 120 DAP, the tallest plant height was recorded in T_1V_3 (97.00 cm) combination and the lowest plant height was found in T_2V_1 (45.44 cm) combination.

Moreover, the tallest plant height was observed in T_1V_3 (131.33 cm) combination, and the shortest plant height was recorded in T_2V_3 (85.56 cm) combination at 180 DAP. Partially similar result also was found by Meerabai *et al.* (2000), different turmaric varieties with mango based agroforestry system.

Table 4.15: Interaction effect of different agroforestry production systems and turmeric variety on plant height of turmeric at different DAP

Interaction treatments	Plant height 60 DAP (cm)	Plant height 90 DAP (cm)	Plant height 120DAP (cm)	Plant height 180 DAP (cm)
Mango x Thailand (T_1V_1)	24.94a	59.77ab	80.00ab	103.44bc
Mango x Malshira (T_1V_2)	28.22a	68.22a	91.00ab	114.33ab
Mango x Debipat (T_1V_3)	25.66a	70.88a	97.00a	131.33a
Open x Thailand (T_2V_1)	21.66a	31.55c	45.44c	119.11ab
Open x Malshira (T_2V_2)	21.66a	62.66ab	84.66ab	127.67a
Open x Debipat (T_2V_3)	20.77a	50.11b	74.22b	85.56c
CV%	30.74	18.63	15.9	13

*In a column different letters are significantly different at $P \leq 0.05$, 0.01 and 0.001 by Tukey HSD test

4.3.2 Length of leaf (cm)

The length of leaf blade of turmeric varied significantly by the interaction effect of different agroforestry production systems, and turmeric varieties at different days after planting (DAPs). The longest length of leaf blade was observed in T_1V_3 (27.66 cm) combination and the shortest was found in T_2V_1 (16.55 cm) combination at 60 DAP. Then, at 90 Dap, the longest length of leaf blade was observed in T_1V_3 (36.00 cm) combination and the shortest was recorded in T_2V_1 (16.33 cm) combination. Again the longest length of leaf blade was observed in T_1V_3 (51.00 cm) combination and the shortest was found in T_2V_1 (25.22 cm) combination at 120 DAP. Moreover, at 180 DAP, the longest length of leaf blade was found inT_1V_3 (63.88 cm) combination and the shortest was observed in T_2V_3 (41.44 cm) combination. Garrity *et al.* (1992) observed number of leaf per plant affected minimum due to shadding condition in mixed cropping of turmeric.

Table 4.16: Interaction effect of different agroforestry production systems and turmeric variety on length of leaf

Interaction treatments	**Length of leaf 60DAP (cm)**	**Length of leaf 90DAP (cm)**	**Length of leaf 120DAP (cm)**	**Length of leaf 180DAP (cm)**
Mango x Thailand (T_1V_1)	21.33bc	28.55bc	39.77b	55.00a
Mango x Malshira (T_1V_2)	25.66ab	33.44ab	48.22a	58.66a
Mango x Debipat (T_1V_3)	27.66a	36.00a	51.00a	63.88a
Open x Thailand (T_2V_1)	16.55c	16.33e	25.22c	58.11a
Open x Malshira (T_2V_2)	26.88ab	20.44de	33.00b	59.66a
Open x Debipat (T_2V_3)	25.94ab	24.11cd	37.55b	41.44b
CV%	18.27	15.92	14.12	14.7

*In a column different letters are significantly different at $P \leq 0.05$, 0.01 and 0.001 by Tukey HSD test

4.3.3 Width of leaf (cm)

Width of leaf of turmeric plants varied significantly by the interaction effect of different agroforestry production systems, and turmeric varieties at different days after planting (DAPs).The maximum width of leaf were observed in T_1V_1 (4.11 cm) and T_2V_2 (4.00 cm) combinations which were statistically similar at 60 DAP, the minimum width of leaf were recorded in T_1V_1 (3.88 cm), T_1V_3 (3.66 cm), T_2V_1 (3.77 cm) and T_2V_3 (3.33 cm) combinations which were almost statistically similar. At 90 DAP, the maximum width of leaf were found in T_1V_1 (6.88 cm), T_1V_2 (6.33 cm), T_1V_3 (6.22 cm), T_2V_1 (6.33 cm) and

T_2V_2 (6.55 cm) combinations, which were also almost statistically similar ; and the minimum width of leaf was observed in T_2V_3 (5.66 cm).Then, at 120 DAP, maximum width of leaf were found in T_1V_1 (11.88 cm), T_2V_1(11.11 cm) and T_2V_2(11.22 cm) combinations, they were almost statistically similar, the minimum was observed in T_2V_3 (9.33 cm).Moreover, the maximum weight of leaf was recorded in T_1V_1 (17.11 cm) combinations and the minimum was found in T_2V_3 (13.77 cm) combinations at 180 DAP. Similar results were found by Chowdhury *et al.* (1992).

Table 4.17: Interaction effect of different agroforestry production systems and turmeric variety on width of leaf

Interaction treatments	Width of leaf 60DAP (cm)	Width of leaf 90DAP (cm)	Width of leaf 120 DAP (cm)	Width of leaf 180 DAP (cm)
Mango x Thailand (T_1V_1)	4.11a	6.88a	11.88a	17.11a
Mango x Malshira (T_1V_2)	3.88a	6.33a	10.33ab	15.77ab
Mango x Debipat (T_1V_3)	3.66a	6.22a	10.00ab	15.66ab
Open x Thailand (T_2V_1)	3.77a	6.33a	11.11ab	16.00ab
Open x Malshira (T_2V_2)	4.00a	6.55a	11.22ab	16.33ab
Open x Debipat (T_2V_3)	3.33a	5.66a	9.33b	13.77b
CV%	19.14	17.46	15.89	11.64

*In a column different letters are significantly different at $P \leq 0.05$, 0.01 and 0.001 by Tukey HSD test

4.3.4 Number of finger and size of turmeric varieties

Number of finger is an important quality contributing parameter. The interaction effect of different agroforestry production systems and turmeric varieties on number of finger and size of turmeric varieties were significantly varied. The highest total number of finger per plot during harvesting time was observed in T_2V_2 (59.22) combination and the lowest total number of finger was found in T_2V_1 (37.55) combination. Then the total number of finger per plot were converted into number of finger per plant, the highest number of finger per plant were recorded in T_2V_2 (4.66) and T_2V_3 (4.43) combinations, they were almost statistically similar. On the other hand the lowest number of finger per plant were observed in T_1V_1 (3.39), T_1V_2 (3.92), T_1V_3 (3.86) and T_2V_1 (3.32) combinations, they were also almost statistically similar.

Length of the biggest rhizome and width of the biggest rhizome are important quality contributing parameters. The highest length of biggest rhizome was found in T_1V_2 (28.38 cm) combination and the shortest length of the biggest rhizome was observed in T_1V_3 (25.24 cm) combination. Again, longest width of biggest rhizome was observed in T_2V_2 (23.77 cm) combination, on the other hand, the lowest width of biggest rhizome was found in T_1V_3 (17.94 cm) combination. Similar result found by Pushkaran *et al.* (1985).

Table 4.18: Interaction effect of different agroforestry production systems and turmeric variety on the number of finger and size of rhizome

Interaction treatments	Total no. of finger per plot	No of finger per plant	Length of the biggest rhizome (cm)	Width of the biggest rhizome (cm)
Mango x Thailand (T_1V_1)	42.00a	3.39a	27.38a	19.84ab
Mango x Malshira (T_1V_2)	53.33a	3.92a	28.66a	20.50ab
Mango x Debipat (T_1V_3)	53.66a	3.86a	25.24a	17.94b
Open x Thailand (T_2V_1)	37.55a	3.32a	27.11a	20.27ab
Open x Malshira (T_2V_2)	59.22a	4.66a	26.97a	23.77b
Open x Debipat (T_2V_3)	56.11a	4.43a	27.22a	19.38b
CV%	35.08	31.65	10.73	14.76

*In a column different letters are significantly different at $P \leq 0.05$, 0.01 and 0.001 by Tukey HSD test

4.3.5 Quality parameters of turmeric varieties

The Number of plant per plot, number of node of finger per rhizome, length of inter-node per finger (cm) and number of shoot per plot are importantquality parameters of turmeric. Those were varied significantly by different agroforestry production systems.

The tallest number of plant per plot were observed T_1V_2 (13.22) and T_1V_3 (13.77) combinations which were statistically similar, The lowest number of plant per plot was found in T_2V_1 (11.33) combination and the moderate were recorded in T_1V_1 (12.44), T_2V_2 (12.77) and T_2V_3 (12.77) combinations which were almost statistically similar.

Then, the highest number of node of finger per rhizome were recorded in T_1V_2 (19.66), T_2V_1 (19.22), T_2V_2 (19.33) and T_2V_3 (19.88) combinations, they were statistically almost similar, on the other hand the lowest was found in T_1V_1 (17.77) and the moderate was observed in T_1V_3 (18.66) combination. Again, the maximum length of internode per finger were recorded in T_1V_1 (4.28 cm), T_2V_1 (4.20 cm), T_2V_2 (4.21 cm) and T_2V_3 (4.44 cm) combinations, they were almost statistically similar and the minimum was found in T_1V_2 (3.66 cm) and T_1V_3 (3.65 cm) combinations which were also statistically similar. At the number of shoot per plot, The maximum number of shoot were observed in T_2V_2 (6.77) and T_2V_3 (6.11) combinations which were statistically similar, The minimum were observed in T_1V_1 (5.88), T_1V_2 (5.77), T_1V_3 (5.00) and T_2V_1 (5.44) combinations, they also were almost statistically similar. Similar result found by Pushkaran *et al.* (1985).

Table 4.19: Interaction effect of different agroforestry production systems and turmeric variety on the quality parameters

Interaction	No. of plant per plot	No. of node of finger per rhizome	Length of internode per finger(cm)	No. of shoot per plot
Mango x Thailand (T_1V_1)	12.44ab	17.77a	4.28a	5.88a
Mango x Malshira (T_1V_2)	13.22a	19.66a	3.66a	5.77a
Mango x Debipat (T_1V_3)	13.77a	18.66a	3.65a	5.00a
Open x Thailand (T_2V_1)	11.33b	19.22a	4.20a	5.44a
Open x Malshira (T_2V_2)	12.77a	19.33a	4.21a	6.77a
Open x Debipat (T_2V_3)	12.77a	19.88a	4.44a	6.11a
CV%	7.83	9.94	18.8	28.03

*In a column different letters are significantly different at $P \leq 0.05$, 0.01 and 0.001 by Tukey HSD test

4.3.6 Fresh rhizome weight (kg) per plot and dry rhizome weight (g) per plot

Fresh weight of rhizome of turmeric varieties was varied significantly by the effect of different agroforestry production systems. The highest total fresh weight of rhizome were observed in T_2V_2 (2.45 kg) and T_2V_1 (2.09 kg) combinations, those data were almost statistically similar and the lowest were observed in T_1V_1 (1.24 kg), T_1V_2 (1.07 kg), T_1V_3 (1.50 kg) and T_2V_3 (1.40 kg) combinations, those data were also statistically similar.

Again dry weight of rhizome of turmeric varieties per plot was also varied significantly by the effect of different agroforestry production systems. The highest dry weight of rhizome was observed in T_1V_1 (22.33 g) combination, the lowest dry weight of rhizome was found in T_2V_3 (17.33 g) combination. Similar results have been also reported by Srikrishnah and Sutharsan (2015) who reported that 50 % shade level is suitable for the cultivation of turmeric.

Table 4.20: Interaction effect of different agroforestry production systems and turmeric variety on fresh rhizome weight and dry rhizome weight

Interaction treatments	Total fresh weight of rhizome kg/plot	Dry weight of rhizome 100g/plot
Mango x Thailand (T_1V_1)	1.24bc	22.33a
Mango x Malshira (T_1V_2)	1.07c	20.33c
Mango x Debipat (T_1V_3)	1.50bc	18.33e
Open x Thailand (T_2V_1)	2.09ab	21.33b
Open x Malshira (T_2V_2)	2.45a	19.33d
Open x Debipat (T_2V_3)	1.40bc	17.33f
CV%	38.30	2.23

*In a column different letters are significantly different at $P \leq 0.05$, 0.01 and 0.001 by Tukey HSD test

4.3.7 Fresh rhizome weight (kg) per hectare & dry rhizome weight (kg) per hectare

Fresh weight (kg) of rhizome was converted per plant to per hectare. So, maximum fresh rhizome weight per hectare was recorded in T_2V_2 (13611 kg) combination and minimum fresh weight of rhizome per hectare was found in T_1V_2 (5944 kg) combination.

Again, dry weight of rhizome of turmeric per plot was also varied significantly by the interaction effect of different agroforestry production systems and turmeric varieties. The maximum dry weight of rhizome was found in T_2V_2 (2631 kg) combination. Moreover, the minimum dry weight of rhizome was observed in T_1V_2 (1208 kg) combination. Similar result found in Hossain *et al.*, 2005a.

Table 21: Interaction effect of different agroforestry production systems and turmeric variety on fresh rhizome weight and dry rhizome weight per hectares

Interaction treatments	Fresh weight of rhizome kg/ha	Dry weight of rhizome kg/ha
Mango x Thailand (T_1V_1)	6888	1538
Mango x Malshira (T_1V_2)	5944	1208
Mango x Debipat (T_1V_3)	8333	1527
Open x Thailand (T_2V_1)	11611	2476
Open x Malshira (T_2V_2)	13611	2631
Open x Debipat (T_2V_3)	7777	1348
CV%	38.30	2.23

*In a column different letters are significantly different at P≤ 0.05, 0.01 and 0.001 by Tukey HSD test

4.4 Germination speed

4.4.1 Main effect of agroforestry systems on the germination speed of turmeric plant

Figure 4.1 shows the germination speed of turmeric plant by the effect of different agroforestry systems. Highest germination speed was observed in T_1 (under mango). And the lowest germination speed was found in T_2 (under open control). The details are presented in Appendix-IV.

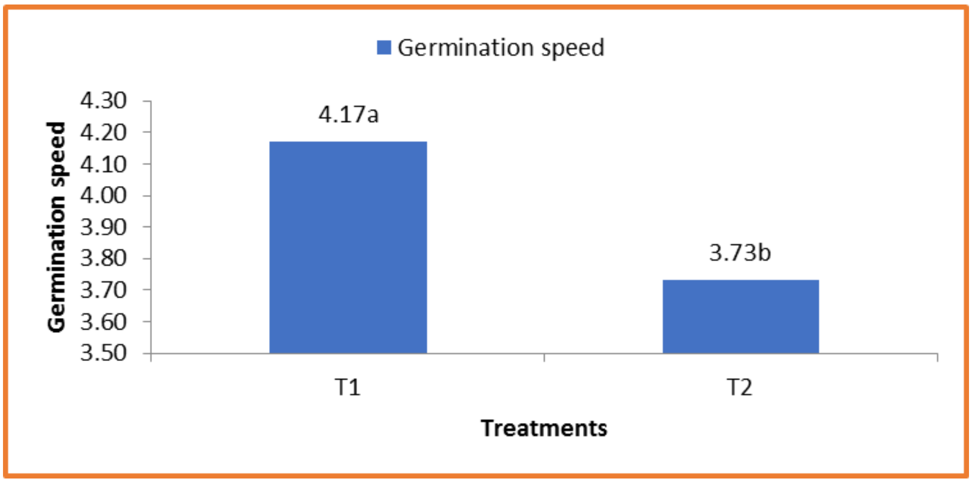

Figure 4.1: Effect of agroforestry systems on the germination speed of turmeric plant. In a bar diagram, different letter (s) show statistically significant at P≤0.05 by Tukey's Range Test. (T_1=under mango shade, T_2= under open control).

4.4.2 Main effect of turmeric varieties on the germination speed of turmeric plant

Figure 4.2 shows the germination speed of turmeric plant by the effect of turmeric varieties under different agroforestry systems. The highest germination speed were found in V_2 (Malshira variety) and V_3 (Debipat variety), they were statistically similar. The lowest germination speed was found in V_1 (Thailand variety). The details are presented in Appendix-IV.

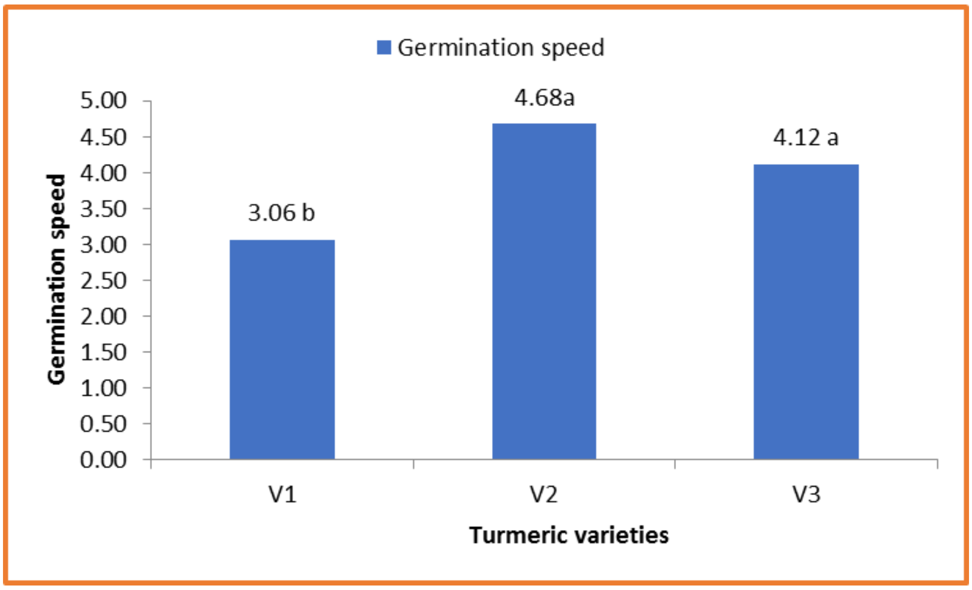

Figure 4.2: Effect of turmeric varieties on the germination speed of turmeric plant. In a bar diagram, different letter (s) show statistiscally significant at $P \leq 0.05$ by Tukey's Range Test. (V_1= Thailand variety, V_2= Malshira variety) and V_3 (Debipat variety).

4.4.3 Main effect of interaction on the germination speed of turmeric

Figure 4.3 shows the germination speed of turmeric plant by the effect of interaction of different agroforestry production systems and turmeric varieties. Highest germination speed were recorded in T_1V_3 (under mango and debipat variety) and T_2V_2 (under open control and malshira variety). The lowest germination speeds were observed in T_1V_1 (under mango and thailand variety) and T_2V_2 (under open control and debipat variety). The details are presented in Appendix-IV.

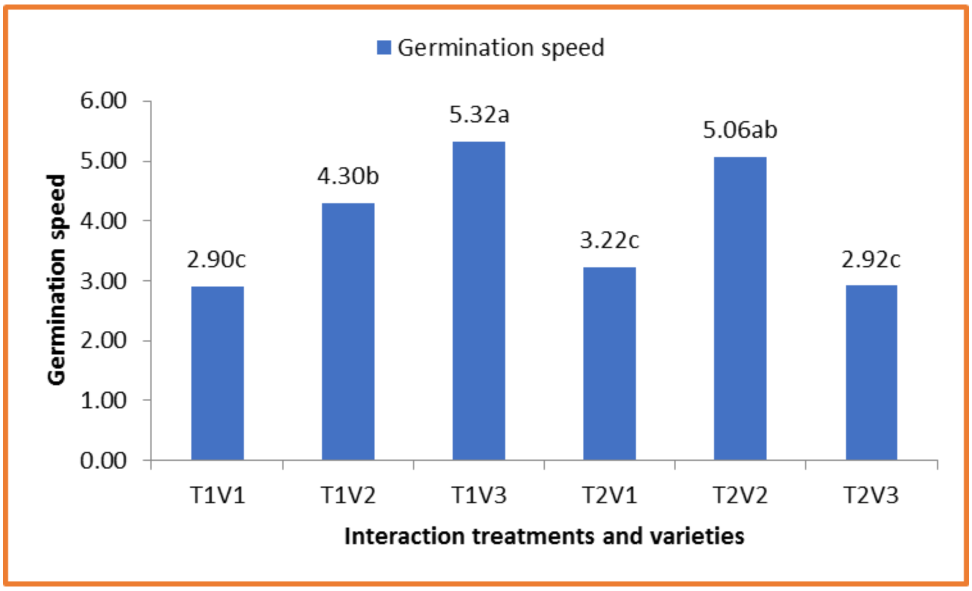

Figure 4.3: Effect of interaction on the germination speed of turmeric plant. In a bar diagram, different letter (s) show statistically significant at P≤0.05 by Tukey's Range Test. (T_1V_1= under mango and thailand variety, T_1V_2= under mango and malshira variety, T_1V_3= under mango and debipat variety, T_2V_1= under open control and thailand variety, T_2V_2= under open control and malshira variety, T_2V_3= under open control and debipat variety.

4.5 Light intensity (LUX)

4.5.1 Effect of light intensity on different Agroforestry systems of turmeric production

Light intensity at different time of the day was varied significantly in different Agroforestry systems of turmeric production. Statistically, highest light intensity was recorded under open control (T_2) (74.33 LUX) and lowest was found under mango (T_1) (32.93 LUX) at the time of 10.00am (Table 4.21). Again, highest light intensity was recorded in T_2 (178.85 LUX) and lowest was found in T_2 (55.41 LUX) at the time of 1pm. Moreover, highest light intensity was observed in T_2 (51.11 LUX) at the time of 4pm. The lowest light intensity were found in T_1 (18.41 LUX) at the time of 4pm. Overall, the total light intensity was recorded highest in T_2 (304.30 LUX) and lowest was observed in T_1 (106.74 LUX). Similar result found by Singh *et al.* (2001).

Table 4.22: Effect of light intensity on different Agroforestry production systems of turmeric

Treatment	Light intensity (LUX)			Total light intensity (LUX)
	10am	1pm	4pm	
Under mango (T_1)	32.93b±0.30	55.41b±0.30	18.41b±0.20	106.74b±0.57
open control (T_2)	74.33a±0.66	178.85a±0.47	51.11a±0.18	304.30a±0.86
CV %	4.99	1.77	2.85	1.85

* In a column different letters are significantly different at P≤0.05, 0.01 and 0.001 by Tukey HSD test.

4.5.2 Relationship between light intensity (LUX) and fresh turmeric rhizome yield (kg/ha)

Figure 4.4 shows that the fresh turmeric rhizome yields were increased by the increasing rate of total light intensity. Here, fresh turmeric rhizome weight (kg/ha) (table 4.7) was considered as fresh turmeric rhizome yield (kg/ha). The highest turmeric yield was 11000 kg/ha when the total light intensity was 106.74 LUX in T_2 (open field). On the other hand, the lowest turmeric yield was 7055 kg/ha when the total light intensity was 304.30 LUX in T_1 (under mango). So, highest light intensity was increased with the increasing of the fresh turmeric rhizome yield. Similar result found by Singh *et al.* (2001). The details are presented in Appendix- III.

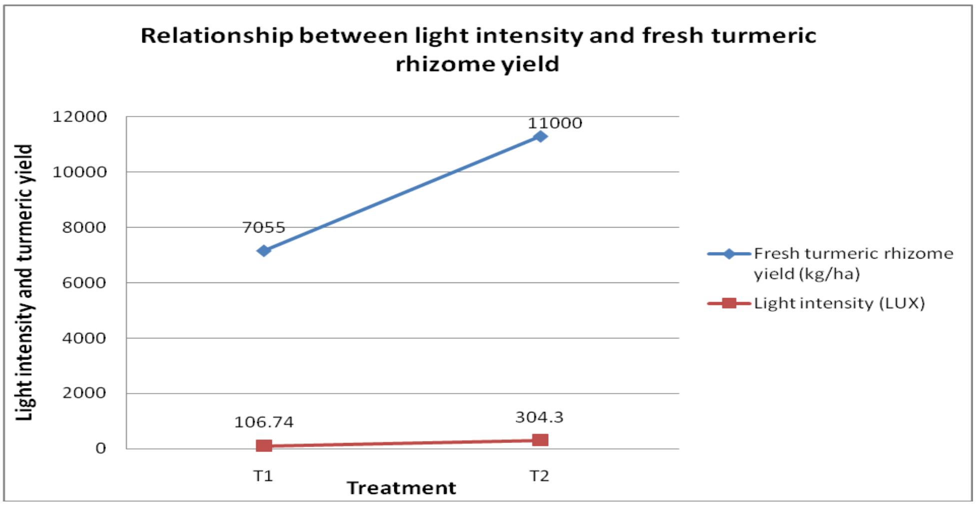

Figure 4.4: Relationship between total light intensity (LUX) and fresh turmeric rhizome yield (kg/ha). In a line diagram, different letter (s) show statistically significant at P≤0.05 by Tukey's Range Test. (T_1=under mango tree, T_2= open control).

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

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SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

The experiment was conducted at the departmental research field of Agroforestry and Environment, Hajee Mohammad Danesh Science and Technology University, Dinajpur during 24 March 2018 to10 January 2019 to find out growth and quality of three turmeric (*Curcuma longa L.*) varieties under different agroforestry systems such as under mango and open control. The geographical location of the site lies between 25 degree 13 latitude & 88 degree 23 longitudes at the elevation of 40m above the sea level. The experiment consisted of two (2) factors RCBD (Randomized Complete Block Design) with three (3) replications. Treatments were Factor A (production systems): T_1= Under mango shade + Turmeric and T_2= Open space + Turmeric; Factor B: (Three Turmeric variety): Local varieties, V_1=Thailand, V_2=Malshira and V_3=Debipat. The treatment combinations were T_1V_1= Under mango + Thailand, T_1V_2= Under mango+Malshira, T_1V_3=Under mango +Debipat, T_2V_1=Open +Thailand, T_2V_2=Open+Malshira and T_2V_3=Open+ Debipat.

All data were calculated with Statistics 10 software and MS Excel 2007. The growth and quality of turmeric were significantly varied by the main effect of different agroforestry production systems, varieties and interactions with systems and varieties. The tallest plant heights, length of leaf blade and width of leaf were recorded in under mango and lowest found open control. The maximum number of finger, length of the biggest rhizome and width of the biggest rhizome were recorded open control, and minimum were found under mango. The highest fresh weight of rhizome was obtained open control and lowest under mango. And the highest dry weight of rhizome was found open control and lowest was observed under mango. The tallest plant heights with malshira variety and maximum plants height, length of leaf, width of leaf, Number of finger, length and width of the biggest rhizome with malshira variety were recorded. The highest fresh weight of rhizome was found with malshira variety and lowest with debipat variety, the highest dry weight of rhizome was found in thailand variety. Again, The longest plant height was recorded under mango with debipat variety but maximum biggest rhizomes lengths were under mango with thailand variety and maximum biggest rhizome width was found open control with malshira variety. The highest fresh rhizome weight and dry rhizome were recorded with open control with malshira variety and, on the other hand the lowest were found under mango with malshira variety.

5.2 Conclusion

From the above results and discussion it can be concluded that among the two production systems, the growth and quality of turmeric with it is germination speed was better under mango shade than open condition. On the other hand the highest yield was found better in open control than mango shade. Between turmeric varieties, malshira did better performance than thailand and debipat varieties. Surprisingly that fresh rhizome turmeric yield was increased with the increasing rate of light intensity.

5.3 Recommendations

The recommendations that can be put forward from the present study are as follows:

- The experiment should be standardized through trials and errors using similar trees at different locations before using commercial basis.
- Soil quality and intercultural operation should be maintained.
- Orchard age and tree plantation time should be also considered.

REFERENCES

REFERENCES

Abedin, M.Z. and Quddus, M.A. (1990). Household fuel situation, homegardens and Agroforestry practices at six agro-ecologically different locations of Bangladesh In: Homestead Plantation and Agroforestry. Proceeding of a National workshop held 17-19 July 1998 in Joydebpur. Bangladesh. BARI/WINROCK. pp. 19-53.

Afzalur, R. and Islam, S. S. (1997). Financial viability of agroforestryunder participatory approach in Bangladesh: The case of ForestDepartment's first logged over plots of Dinajpur. Bangladesh J. For., Sci. 26(1): 47-55.

Ahmed, K. (1969). Phul Phul O Shak-Shabji (in Bangla).2nd Ed, Alhaj Kamisuddin Ahmed, Bangla No. 2, Sher-E-Bangla Nagar, Dhaka-15. pp. 438-439.

Aiyelaagbe, I.O.O and Jolaoso, M.A. (1992). Growth and yield responseof papaya to intercropping with vegetable crops in southwesternNigeria. Agroforestry Systems, 19(1): 1-14.

Akter, M.S., Abedin, M.Z. and Quddus, M.A. (1989). Why farmers growtrees in agricultural fields: some thoughts, some results. In: Research Report, 1988-89. On Fam Research Division, Joydebpur.

Akter, M.S., Abedin, M.Z. and Quddus, M.A. (1990). Why farmer grow treesin agricultural fields; some results Proc. Regional Symposium on Tree Plantation in the Humid/Sub-humid Tropics in Asia; held on May 5-9 1988 in University Partanian, Malaysia

Alam, M.S., Haque, M.F., Abedin, M.Z. and Akter, S. (1990). Homestead trees and household fuel uses in and around the FSR site, Jessore. In: Homestead plantation and Agroforestry in Bangladesh. By M. Z. Abedin,C. K. Lai and M. O. Ali (eds.). BARI Joydebpur Bangladesh. Pp. 106-119.

Ali, M.A. (1999). Performance of Red amaranth and Lady's finger growth at different orientations and distances under Guava and Drumstick trees. MS diss., BSMRAU, Gazipur, Bangladesh.

Allen PC, Danforth HD, Augustine PC. Dietary modulation of avian coccidiosis. Int J Parasitol. 1998;28:1131-40.

Angami, T., Kalita, H., Touthang, L., Chandra, A., Devi, H. L., Baruah, S., ... & Khatoon, A. (2017). Assessing the suitability of turmeric seed rhizome sizes on biometric and qualitative traits under mid hill conditions. Journal of Experimental Biology, 5, 5.

Anonymous (2009). Fruit Production Manual, HRDP/DAE/BADC, Dhaka. 252p.

Atta-Krah, A.N. (1990). Alley Cropping with Leucarna effect follows on Soil fertility and crop yields. Agric., Comb, 26(1): 1-10.

Baghel, B.S., Sharma, D.P., Pandey, S.K., Tiwari, R. and Gupta, N. (2004a). Productivity and profitability of fruit based inter crop of turmeric under Agro-climatic conditions of Madhya Pradesh. National seminar on Opportunities and potentials of spices for crop diversification, help during Jan 19-21, 2004 at Jawaharlal Nehru Vishwa Vidyalaya, Jabalpur, (M.P.), pp.15-16.

Baghel, B.S., Sharma, D.P., Tiwari, R. and Gupta, N. (2004b). Performance of turmeric cultivars as mango based inter crop under Jabalpur agro-climatic condition of Madhya Pradesh. National seminar on opportunities and potential of spices for crop diversification, held during Jan. 19-21, 2004 at Jawaharlal Nehru Krishi Vishwa Vidyalaya, (M.P.), pp. 18-19.

Barrios E., Sileshi G. W., Shepherd, K. and Sinclair, F.L. (2012). Agroforestry and soil health: linking trees, soil biota and ecosystem services. Soil Ecol. Ecosyst. Serv. pp. 315–330.

Basavaraju, T.B. and Gururaja, R.M.R. (2000). Tree-crop interactions in Agroforestry systems: a brief review: Indian Forest, 126(11): 1155-1164.

Bayala J., Heng, L.K., van Noordwijk, M. and Ouedraogo, S.J. (2008). Hydraulic redistribution study in two native tree species of Agroforestry parklands of West African dry savanna. Acta Oecol. 34(3): 370–378.

Bayala, J., Sanou J., Teklehaimanot, Z., Kalinganire, A. and Ouedraogo S. (2014). Parklands for buffering climate risk and sustaining agricultural production in the Sahel of West Africa. Curr. Opin. Environ. Sustain. 6: 28–34.

Bayala, J., Sanou J., Z. Teklehaimanot, S. Ouedraogo, A. Kalinganire, R. Coe, M. van Noordwijk. (2015). Advances in knowledge of processes in soil–tree–crop interactions in parkland systems in the West African Sahel: A review. Agric. Ecosyst. Environ. 205: 25–35.

Bayala, J., Sileshi, G.W., Coe, R., Kalinganire, A., Z. Tchoundjeu, Sinclair, F. and Garrity D. (2012). Cereal yield response to conservation agriculture practices in drylands of West Africa: A quantitative synthesis. J. Arid Environ.78: 13–25.

BBS. (2011). Statistical Pocket Book of Bangladesh. Bangladesh Bureau of Statistics, Ministry of Planning, Govt of Peoples' Republic of Bangladesh

BBS. (2017). Statistical Pocket Book of Bangladesh. Bangladesh Bureau of Statistics, Ministry of Planning, Govt of Peoples' Republic of Bangladesh

Beer, J. (1988). Litter production and nutrient cycling in coffee (Coffea arabica) or Cacao (*Theobroma cacao*) plantations with shade trees. Agroforestry systems, 7: 103-114.

Behera, D., Munsi, P.S. and Ray, D. (2014). Studies on the performance of intercrops on the nutrient uptake and yield attributes of mango cv. Amrapali. Advance research journal of crop improvement. (5): 2.

Bertomeu M. (2006). Financial evaluation of smallholder timber-based Agroforestry systems in Claveria, Northern Mindanao, the Philippines. Small Scale For. Econ. Manag. Policy, 5(1): 57–81.

Bhuva, H.P., Katrodia, J.S., Patel, G.L. and Chundawat, B.S. (1989). Response of intercropping on economies and effects on main crop of mango under south Gujarat conditions. ActaHocticulue, 231: 316-320.

Braconnier, S. (1998). Maize-coconut intercropping effects of shade and root competition on maize growth and yield. Agronomic. 18(5-6): 373-382

Chauhan, D.P. (2002). Chemotherapeutic potential of curcumin for colorectal cancer. Current Pharmaceutical Design, **8**, 1695-1706.

Chiapusio, G., Sanchez, A.M., Reigosa, M.J., Gonzalez, L. and Pellissier, F. (1997). Do germination indices adequately reflect allelochemical effects on the germination process? Journal of Chemical Ecology. 23(11): 2445-2453.

Chowdhury, M.K. and Satter, M.A. (1992). Agroforestry practice in traditional farming system of Bangladesh. A report prepared for BARC/Winrock Intl., Dhaka, Bangladesh.

Chowdhury, M.K. and Satter, M.A. (1993). Homestead and crop land agroforestry practices in the high Ganges river Floodplain. pp. 23-56. In: Agroforestry Farming System Linkage in Bangladesh. BARC Winrock International. Dhaka, Bangladesh

Chowdhury, M.M.A.A., Miah, M.M.U., Amin, M.HA., Akter, M.M. and Hanif, M.A. (2010). Effect of fertilizer and lime on the performance of turmeric-ghora neem based agroforestry system. Jour. of Agrof. and Ent. 3(2): 69-72.

Corlett, J.E., Ong, C.K. and Black, C.R. (1989). Microclimatic modification in intercropping and alley - cropping systems. In: Meteorology and Agroforestry (Reifsynder, W.S. and Damhofer, T.O. eds.). ICRAF, Nairobi, Kenya. pp. 419-430.

Corlett, J.E., Ong, C.K. and Black, C.R. (1989). Microclimatic modification in intercropping and alley - cropping systems. In: Meteorology and Agroforestry (Reifsynder, W.S. and Damhofer, T.O. eds.). ICRAF, Nairobi, Kenya. pp. 419-430.

Dhondge, A. J., Kale, A. N., Mohod, S. B., & Kalbande, S. R. (2019). Investigation on drying kinetics and techno-economics of solar-biomass hybrid drying system. Plant Archives, 19(2), 59-62.

Dupraz, C., Newman, S.M. and Gordon, A.M. (1997). Temperate Agroforestry: the European way. Temperate Agroforestry systems, CAB International, Wallingford, U.K. pp. 181–236.

Emebiri, L.C. and Nwufo, M.L. (1994). Performance of the West African vegetable crop Telfairia occidentals as a function of distance from a row of mango trees. Agroforestry Systems, 27 (2): 183-186.

Franzel, S. (2004). Financial analysis of Agroforestry practices, in J.R.R. Alavalapati and D.E. Mercer (eds), Valuing Agroforestry Systems, Kluwer Academic Press, Dordrecht, the Netherlands, pp. 9−37.

Garrity D.P., Akinnifesi F.K., Ajayi O.C., Weldesemayat, S.G., Mowo, J.G., Kalinganire, A., Larwanou, M. and Bayala, J. (2010). Evergreen agriculture: a robust approach to sustainable food security in Africa. Food Secur. 2(3): 197–214.

Garrity D.P., Akinnifesi F.K., Ajayi O.C., Weldesemayat, S.G., Mowo, J.G., Kalinganire, A., Larwanou, M. and Bayala, J. (2010). Evergreen agriculture: a robust approach to sustainable food security in Africa. Food Secur. 2(3): 197–214.

Ghosh, C.R. and Sengar, S.S. (1989). Effect of varying level of nitrogen and potassium fertilization on growth and yield of turmeric (*Curcuma domestica* Linn) under rain fed conditions. Water and nutrient management for sustainable production and quality of spices: Proceeding of the National Seminar, Madikeri, Kamatats, India, 5-6 October: 47-51

Ghosh, S.P. (1987). Growth, productivity and nutrient uptake by cassava in association with four perennial species. Tropical-Agriculture, 64 (3): 233-236

Gill, A.S., Roy, R.D. and Baipai, C.K. (1992). Growth of Leucama leucocephala in a mango based, intercropped agroforestry system Leuscaena Research Reports, 13(2): 22-23.

Gill, B.S., Singh, A., Singh, D., Gandhi, N. and Kaur, J. (2008). Growth and yield of turmeric (*Curcuma longa* L.) intercropped in poplar (Populus deltoids Bartram ex Marshall) plantation at Punjab. J. Spices & Aromatic Crops. 18(1) : 40-42.

Glover, J.D., Reganold, J.P. and Cox, C.M. (2012). Agriculture: plant perennials to save Africa's soils. Nature. 489(7416): 359–361.

Grado, S.C. and Husak, A.L. (2004). ‘Economic analyses of sustainable Agroforestry systems in the Southeastern United States’, in J.R.R. Alavalapati and D.E. Mercer (eds), Valuing Agroforestry Systems, Kluwer Academic Press, Dordrecht, the Netherlands, pp. 39−57.

Gupta, C.R. and Awasthi, O.P. (1999). Analysis of yield variation in coffee under different canopy shades. Hort. 1. 12 (1): 61-65

Haque, M.A. (1996). Agroforestry in Bangladesh: Production of treesand crops. Seminar presented at the 26th National Agroforestry Working Meeting held on 25 November 1996. BARC, Dhaka, Bangladesh

Haque, M.A., Hossain, M.A., Hocking, D. and Islam, M.K. (1992). Production of trees in the crop field. Proc. Bangladesh Agril. Univ. Res. Prog. 6:212-218.

Harou, A. (1983). Economic principles of appraise agroforestry project. Agricultural Administration. 12:127-139

Hegde, N.K., Sulikere, G.S. and Rethmun, B.P. (2000). Distribution of Photo Synthetically Active Radiation (PAR) and performance of ginger under arecanut shade. Spices and aromatic plants challenges and opportunities in the new century, Contributorypapers of the Centennial conference on spices and aromatic plants, 20-23 September, 2000 held at Calicut, India. pp. 107-112

Hocking, D. and Islam, K. (1998). Trees on farms in Bangladesh; 5, Growth of top and root peuned trees in wetland rice fields and yields of under story crops, Agroforestry System, 40(1); 98-109.

Hossain, M. A., Ishimine, Y., Akamine, H. and Motomura, K. 2005a. Effects of Seed Rhizome Size on Growth and Yield of Turmeric (*Curcuma longa* L.). Plant Prod. Sci 8 : 86-94.

Hossain, M.K. (1999). Shade effect on the yield and quality of pineapple in a jackfruit-pineapple agroforestry system. Unpublished [MS Thesis], Department of Agroforestry and Environment, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur.

Imo, M. and Timmer, V. R. (2000). Vector competition analysis of a Leucaena-maize alley cropping system in western Kenya. For Ecol Manage. 126: 255–268.

Iqbal, N. (2018). "A Food Forest Grows in Atlanta". USDA.gov blog. Retrieved 17 June 2018.

Jackson, I.E. (1987). Tree and crop selection and management to optimize overall system productivity, especially light utilization in agroforcstry. Meteorology and Agroforestry. 1CRAF, WMO and UNEP.

Jayachandran, B.K. and Nair, G.S. (1998). Performance of mango-ginger (Curcuma amadaRoxb.) under different levels of shade, J. Spices and Aromatic Crops, 7(2); 145-146.

Jayachandran, B.K., Ancy, J., Babu, P., Nizam, S.A. and Mridula, K.R. (1998). Under the coconut tree: in India, ginder has it made in shade Kerala agricultural university, Kerala, India. Agroforestry Today, 10(3): 16-17.

Kass, D.I., Jose, F.A.S., Jaime, S.O. and Fereira, P. (1992). Ten years experienced with alley farmimg in Central America, Paper present at the international conference on alley farming in IITA, Ibadan, Nigeria, 14-18, September, 1992.

Kellman, M. (1979). Soil enrichment by neotropical savanna trees. J. Ecol. 67: 565-577.

Khattak S, Saeed ur R, Ullah Shah H, Ahmad W, Ahmad M. Biological effects of indigenous medicinal plants *Curcuma longa* and Alpinia galanga. Fitoterapia. 2005;76(2):254-7.

Khattak, S. U., Iqbal, Z., Lutfullah, G., Bacha, N., Khan, A. A., Saeed, M., & Ali, M. (2014). Phytotoxic and herbicidal activities of Aspergillus and Penicillium species isolated from rhizosphere and soil. Pakistan Journal of Weed Science Research, 20(3).

Kohli, R.K., Batis, D. and Singh, H.P. (1998). Allelopathy and its implications in agroecosystem. Journal of Crops Production. 1(1): 169-202.

Korikanthimath, V.S., Kiresur, V., Hiremath, G.M., Rajendra, H., Ravindra, M., Hosmani, M.M., Hegde, R. and Mulge, R. (1997). Economics of mixed cropping of cardamom (Elecuaria cardamom Maton) in arccanut (*Areca catechu* L.) gardens, J Spices Aromatic Crops, 6; 107-113.

Korikanthimath, V.S., Rajendra, H., Ravindra, M., Hosmani, M.M., Hegde, R. and Mulge, R. (2000). Coconut based cardamom multistoried cropping system compatibility and yield pattern, Crop Res. Hisar, 20(2); 343-349.

Kumar, B. and Gill, B.S. (2010). Growth, yield and quality of Turmeric (*Curcuma longa* L.) as influenced by planting method, plant density and planting material. J. Spices & Aromatic Crops. 19(1&2) : 42-49.

Kundu S, Biswas TK, Das P, Kumar S, De DK. Turmeric (*Curcuma longa*) rhizome paste and honey show similar wound healing potential: a preclinical study in rabbits. Int J Low Extrem Wounds. 2005;4(4):205-13.

Kuyah, J., Dietz, C., Muthuri, M., van Noordwijk and Neufeldt, H. (2013). Allometry and partitioning of above-and below-ground biomass in farmed Eucalyptus species dominant in Western Kenyan agricultural landscapes. Biomass Bioenergy. 55: 276–284.

Kuyah, S., Öborn, I., Jonsson, M., Dahlin, A.S., Barrios, E., Muthuri, C. and Nyberg, Y. (2016). Trees in agricultural landscapes enhance provision of ecosystem services in Sub-Saharan Africa. International Journal of Biodiversity Science, Ecosystem Services & Management, 12(4): 255-273.

Lai, R. (1989). Agroforestry systems and soil surface management of tropical alfisol. Parts I-VI. Agrofor. Syst. 8(1-3): 1-29.

Lassoie, J.P. and Buck, L.E. (2000). Development of Agroforestry as Integrated Land Use Management strategy. American Society of Agronomy, Inc. 677 south Segoe, Madison, Wisconsin, 53711 USA.

Leakey, R. (1996). Definition of agroforestry revisited. Agroforestry today, 8, 5-5.

Leonardi, C. (1996). Effects of shading on peppers. Cortures-Protette (Italy): 25(7): 61-65.

Leve, M.K. (2008). Effect of methods of planting and time of earthing on the growth and yield of turmeric under guava based Agrihorticultural practice. M.Sc. (Ag) Agronomy Thesis submitted to JNKVV, Jabalpur.

Lopez-Serrano, F., Martinez-Garcia, E., Dadi, T., Rubio, E., Garcia-Morote, F., LucasBorja, M. and Andres-Abellan, M. (2015). Biomass growth simulations in a natural mixed forest stand under different thinning intensities by 3-PG processbased model. Eur. J. For. Res. 134(1): 167–185.

Ludgren, B.O. and Raintree, J.B. (1992). Sustained Agroforestry, In: Agric. Re. for Dev, Potentials and challenges in Asia, (Nestel B. ed.) ISNAR, pp. 37-49.

Luedeling, E. and Buerkert, A. (2008). Effects of land use changes on the hydrological sustainability of mountain oases in northern Oman. Plant Soil. 304(1–2): 1–20.

Luedeling, E., Huth, N. I., Kindt, R. and Konig, K. (2014). Agroforestry systems in a changing climate challenges in projecting future performance. Curr. Opin. Environ. Sustain. 6: 1–7.

Luedeling, E., Sileshi, G., Beedy, T. and Dietz, J. (2011). Carbon sequestration potential of Agroforestry systems in Africa, in: B.K. Kumar, P.K.R. Nair (Eds.), Carbon Sequestration Potential of Agroforestry Systems: Opportunities and Challenges, Advances in Agroforestry. 8: 61–83.

Luedeling, E., Smethurst, P.J., Baudron, F., Bayala, J., Huth, I. N., Vannoordwijk, M. Ong, K.C., Mula, R., Lusiana, E., Muthun, C. and Sinclair, F.L. (2016). Field-scale modeling of tree-crop interactions: challenges and development needs. Agricultural Systems. 142: 51-69.

Lundgren, B.O. and Raintree, J.B. (1982). Sustained Agroforestry. In: Nestel. B. (ed.) Agricultural research for development, potentials and challenges in Asia. 1SNAR, The Netherlands, pp. 37-49.

MacDicken, K.G. and Vergara, N. (1990). Agroforestry: Classification and Management. John Wiley and Sons, New York, USA. pp. 321-319.

Mannan, M.A. (2000). Plant biodiversity in the homestead of Bangladesh and its utilization in Crop improvement. Ph. D thesis, Bangabandhu Shekh Muzibur Rahman Agricultural University, Gazipur, Bangladesh

Mannan, M.A., Mian, M.A.K., Aziz, M.A. and Haque, H. (2004). Evaluation of some stone originated Mango Accession. Bangladesh JPL Breeding and genetics, 17(1): 25-29.

Marz, U. (1992). The economic potential of an agroforestry system with neem for small farms in Sudano-Sahelian zone of Burkina Faso. Tropenlandwirt, 93; 23-38.

Meerabai, M., Jayachandran, B.K. and Asha, K.R. (2000). Boosting spice production under coconut gardens of Kerala maximizing yield of turmeric with balanced fertilization. Better Crops Inter., 14(2): 10-12.

Miah, M.G. (1993). Performance of selected multipurpose tree species and field crops grown in associated as affected by tree branches pruning. A Ph.D. dissertation, CLSU, Philippines.

Miah, M.G., Garriry, D.P. and Agron, M.L. (1995). Light availability to the understorey annual crops in an Agroforestry system. In: Sinoquet, H. and P. Cruz (ed). Ecophysiology of tropical inter cropping. IRNA Editions, Paris, France. pp. 265-274.

Michon, G. and Mary, F. (1994). Conversion of traditional village gardens and new economic strategies of rural households in the area of Bogor, Indonesia. Agroforestry systems, 25(1): 31-54.

Michon, G. and Mary, F. (1994). Conversion of traditional village gardens and new economic strategies of rural households in the area of Bogor Indonesia. Agroforestry systems, 25(1): 31-54

Michon, G., Mary, F. and Bomaprd, J.M. (1986). Multistoried agroforestry garden systems in west Sumara, Indonesia. Agroforestry System, 4(4); 315-339.

Michon, G., Mary, F. and Bompard J. M. (1986). Multistoried Agroforestry garden systems in West Sumatra, Indonesia. Agrofor. System. 4(4): 315-338.

Mishra, R.K. and Pandey, V.K. (1998). Intercropping of turmeric under different tree species and their planting patter in Agroforestry system. Zonal Agricultural Research Station, Ambikapur, M. P., India. Range Management and Agroforestry, 19(2): 199-202.

Mishra, R.K. and Pandey, V.K. (1998). Intercropping of turmeric under different tree species and their planning patter in agroforestry system, Zonal Agricultural Research Station, Ambikapur, M. P., India Range Management and Agroforestry, 19(2): 199-202.

Mithofer, D. and Waibel, H. (2003). Income and labour productivity of collection and use of indigenous fruit tree products in Zimbabwe. Agrofor. Syst. 59(3): 295–305.

Musvoto, C., Campbell, B.M. and Kirchmann, H. (2000). Decomposition and nutrient release from mango and miombo woodland litter in Zimbabwe. *Soil Biology and Biochemistry*. 32: 1111–1119

Muthuri, C., Bayala, J., Iiyama, M. and Ong, C. (2014). Trees and micro-climate. J. De Leeuw, M. Njenga, B. Wagner, M. Iiyama (Eds.), Treesilience: An Assessment of the Resilience Provided by Trees in the Drylands of Eastern Africa, World Agroforestry Centre, Nairobi, Kenya. pp: 81–85.

Nair, P.K.R. (1983). An Introduction to Agroforestry. Kluwer academic Publishers. ICRAF. pp: 121 & 273.

Nair, P.K.R. (1984). Soil productivity aspects of Agroforestry. ICRAF, Nairobi, Kenya

Nair, P.K.R. (1990). An Introduction to Agroforestry. Kluwer Academy Publishers, ICRAF. pp: 37-54.

Nair, P.K.R. (1993). Agroforestry systems in the Tropics. Kluwer Academic Publishers, ICRAF.

Nishiyama T, Mae T, Kishida H, Tsukagawa M, Mimaki Y, Kuroda M *et al*. Curcuminoids and sesquiterpenoids in turmeric (*Curcuma longa* L.) suppress an increase in blood glucose level in type 2 diabetic KKAy bmice. J Agric Food Chem. 2005;53(4):959-63.

Nizam, S.A. and Jayachandran, B.K. 1997. Effect of seed rhizome size and varities on the quality of ginger (*Zingiber officinale* R.) under open and shade, South Indian Hort., 45 (1-2): 50-52.

Ong, C.K., Wilson, J., Black, M. and Van Noordwijk (2015). Synthesis: key Agroforestry challenges in the future Tree–Crop Interactions: Agroforestry in a Changing Climate, CABI. pp. 326–334.

Ong, C.K., Wilson, J., Black, M. and Van Noordwijk (2015). Synthesis: key Agroforestry challenges in the future Tree–Crop Interactions: Agroforestry in a Changing Climate, CABI. pp. 326–334.

Osei-Bonsu, K., Opoku-Ameyaw, K., Amoah, F.M. and Oppong, F.K. (2002). Cacao-coconut intercropping in Ghana: agronomic and economic perspectives. Agroforestry Systems. 55(1): 1-8.

Pagella, T.F. and Sinclair, F.L. (2014). Development and use of a typology of mapping tools to assess their fitness for supporting management of ecosystem service provision. Landsc. Ecol. 29(3): 383–399.

Palma J., Graves A., Burgess, P. Vander, W. and Herzog, F. (2007). Integrating environmental and economic performance to assess modern silvoarable Agroforestry in Europe. Ecol. Econ. 63(4): 759–767.

Parthasarthy, V.A., Johny, A.K., Jayarajan, K. and Utpala, P. (2006). Site suitability for turmeric production in India , GIS interpretation green page : Research Article. 6(2):142-147.

PCARRD. (1983). Technology for Agroforestry Symposium Workshop, December 19-20, 1979, PCARRD, Los Banos.

Perseglove, J.W. (1972). Tropical Crops: Monocotyledons. Halsted Press Division, Wiley. London.chnique, 23: 807-819.

Porte, A. and Bartelink, H. (2002). Modelling mixed forest growth: a review of models for forest management. Ecol. Model. 150(1): 141–188.

Purseglove, J.W.G., Brown, C.L. and Robbins, S.R.J. (1981). Spices. Longman scientific & Technical Co-published in the united states with John weley & sons, Inc., New York. Vol., 2:457.

Pushkharan, K., Babylatha, A.K. and George, K.M. (1985). Comparative performance of turmeric varieties in coconut gardens. South Indian Hort. 33: 269-270.

Rahim, M.A. and Haider, M.A. (2002). Multiple cropping systems for home gardens. APA News. The Asia-Pacific Agrofor. Newsletter, No. 2011p.

Raintree, J.B. (1997). Agroforestry concepts, In; Alam, M.K. F.U. Ahmed and A.M. Ruhul Amin (des.), Agroforestry; Bangladesh Perspectives, BARC, pp. 1-17

Rajwswari, A. and Kamalam, N. (1999). Genetic study of yield and yield components in greengram (*Vigna radias* (L.) Wilczek) under partially shaded coconut orchard. Legume Res, 22(4): 237-240.

Randhawa, K.S. and Mishra, K.A. (1974). Effect of sowing dates, seed-size and spacing on the growth and yield of turmeric. Punjab horticultural journal.

Rang, A., Bhat, M.L., Makaya, A.S., Masoodi, N.A. and Sharma, D.P. (1990). Agroforestry Research in India. Indian J. Agric. Sci. 68: 559-566.

Rao, M.R., Nair, PK.R. and Ong, C.K. (1998). Biophysical interactions in tropical Agroforestry systems. Agrofor. Syst. 38(1–3): 3–50.

Rasmussen, H.B., Christensen, S.B., Kvist, L.P. and Karazami, A.A. (2000). Simple and efficient separation of the curcumins, the antiprotozoal constituents of *Curcuma longa*. Planta Med. 66:396-8.

Revishankar, C. and Muthuswamy, A. (1986). Dry mater production and recovery of dry ginger in relation to light intensity, Ind, cocoa Arccanut, Spices J, 10: 4-6.

Rosenstock, T., Tully, K., Arias-Navarro, C., Neufeldt, H., Butterbach-Bahl, K. and Verchot, L. (2014). Agroforestry with N2-fixing trees: sustainable development's friend or foe? Curr. Opin. Environ. Sustain. 6: 15–21.

Santos-Martin, F. and Van Noordwijk, M. (2009). Trade-offs analysis for possible timber-based Agroforestry scenarios using native trees in the Philippines. Agrofor. Syst. 76(3): 555–567.

Srikrishnah, S. and Sutharsan, S. (2015). Effect of different shade level on growth and tuber yield of turmeric (*Curcuma longa* L.) in the Batticaloa district of Sri Lanka. American-Eurasian J Agric. & Environ. Sci. 15:813-816.

Sarkar, band Saha A. (1997). Note on Effect of light intensity on growth and yield on radish (*Raphanus sativas* L) Indian Agric. 41(4): 295-298.

Sarker, F.I.M.G.W., Biswas, J.C. and Maniruzzaman, M. (2014). Climate Change Adaptation and Economic Profitability: Crop Land Shifting to Mango Orchard in Rajshahi Region. Bangladesh Rice J. 18(1&2): 8-17.

Satheesan, K.V. and Ramadasan, A. (1980). Growth and productivity of turmeric grown as a pure and as air intercrop is coconut garden. In: Proceed, of the Nati, Sem. On Ginger and Turmeric. CPCRI, Calicut: 69-75.

Sathish, H., Venkatesha, J., Chandrappa, H.S., Hegde, N. and Mathew, M. (1998). Performance of promising turmeric cultivars under coconut cropping systems. Division of Hort., Univ, of Agril, Sci., Bangalore, India, Development in plantation crops research. Proc. Of the 12th symposium on plantation crops. India 27-29 November 1996, 220-222.

Sathish, Venkatesha, H. Chandrappa, J.H. Hedge, S. and Mathew, N.M. (1998). Performance of promissing turmeric cultivars under coconut cropping systems. Division of Hort., Univ. of Agril. Sci., Bangalore, India. Development in plantation crops research. Proc. of the 12th symposium on plantation crops. India. 27-29 November 1996, pp. 220-222.

Saxena, M.B.L. (1984). Improved crop variety in agroforestry. Agroforestry in Arid and semi-Arid Zones. Central Arid Zone Research Institue, Jodhpur India.

Schoch, P.G. (1972). Effects of shading on structural characteristics of the leaf and yield fruit in Capsicum annual L. J. Amer. Soc. Hoxt. Sci. 97(4): 461-464.

Schoeneberger, M.M., Bentrup, G. and Patel-Weynand, T. (2017). Agroforestry: enhancing resiliency in US agricultural landscapes under changing conditions. Gen. Tech. Report WO-96. Washington, DC: US Department of Agriculture, Forest Service, 96.

Sellathurai, P. (1997). Homegarden Agroforestry and sustainability in Kandy district, Srilanka. M. Sc. Thesis. Agricultural University of Norway.

Siddique, A.B. (1995). Importance of vegetables and spices production Horticulture Research and Development project, Dhaka.

Sileshi, G., Akinnifesi, F. K., Ajayi, O. C. and Place, F. (2008). Meta-analysis of maize yield response to woody and herbaceous legumes in sub-Saharan Africa. Plant Soil. 307(1–2): 1–19.

Singh, H., Gurbachan, S., Sing, H. and Sing, G. (2001). Performance of numeric in association with multipurpose tree species. Central Soil Salinity Res, Insitut, Krnal, Haryana, India, Applied Biol, Res, 3(1-2): 57-60.

Singh, H., Gurbachan, S., Singh, H., Singh, G. (2001). Performance of turmeric in association with multipurpose tree species. Central Soil Salinity Res. Institute, Karnal, Haryana, India, Applied Biol. Res. 3(1-2): 57-60.

Singh, R.K. and Baranwal, V.K. (1993). Arecanut based high density multiple species cropping system for Northern region of West Bengal, Indian CocoamArecanut and Spices J, Agrie. Sci, 68(8): 559-66.

Singh, R.P., Ong, C.K. and Saharan, N. (1989). Above and below ground interactions in alley cropping in semi-arid India. Agrofor. Syst. 9: 259-274.

Singh, S.R., Banik, B.C. and Hasan, M.A. (2013). Effect of different intercrops on yield, quality and shelf-life in mango cv. Himsagar (*Mangifera indica* L). Intl. J. Agric. Env. Biotech. 6(1): 121-126.

Solanki, K.R. (1998). Agroforestry research in Indian Journal of Agricultural Science. 68(8): 559-566.

Soriano, H.M. (1991). Soil fertility and productivity aspects of alley cropping schemes using legumes tree as hedgerows and coms as an alley crop, A, Ph, D, dissertation, UPLB, Laguna.

Sreekurnari, M.T., Abraham, K. and Ramanujism, T. (1998). The performance of cassava under shade. J. Root Crops, 14(1): 43-52.

Sritham, R. and Lenz. R. (1992). Effect of light regime on growth, carbohydrates and nitrate concentration in kohlrabi Angewandte Botanik. 66(3-4): 130-134.

Stocking, M., Bojo, J. and Abel, N, (1990). Financial and economic analysis of agroforestry: key issues. In prinskey, R.T. (cd), Agroforestry for sustainable production economic implications. Commonwealth Science council, London, pp 13-119.

Sundararaj, D.D. and Thulasidas, G. (1976). Botany of field crops. Botany of field crops.

Swain, S.C. (2014). Performance and profitability study of different mango based intercropping systems in Easternghat high land zone of Odisha. Journal of Crop and Weed, 10(2): 170-178.

Tiwari, T., Virk, D. and Sinclair, F. (2009). Rapid gains in yield and adoption of new maize varieties for complex hillside environments through farmer participation: I. Improving options through participatory varietal selection (PVS). Field Crop Res. 111(1): 137–143.

Van Noordwijk, M., Martikainen, P., Bottner, P., Cuevas, E., Rouland, C. and Dhillion, S.S. (1998). Global change and root function. Glob. Chang. Biol. 4(7): 759–772.

Van Oijen, M., Dauzat, J., Harmand, J.M., Lawson, G. and Vaast, P. (2010). Coffee Agroforestry systems in Central America: II. Development of a simple processbased model and preliminary results. Agrofor. Syst. 80(3): 361–378.

Vegara, N.T. (1982). New directions in agroforestry: the potentials of tropical legume tree. EAPI, East-west Center Honolulu Hawaii.

Wainwright, J. (1995). Towards a ciupled light partitioning and transpiration model for use in intercrops and agroforestry. In: Eciphysiology of tropical intercropping. Sinoquel, H. and Cruz, P. (ed), IRNA, Paris, France. pp. 73-89.

Wannawong, S., Belt, G.H. and McKetta, C.W. (1991). Benefit-cost analysis of selected agroforestry systems in northcastern Thailand Agroforestry Syst., 16(1): 83-94.

Wickenberg J, Ingemansson SL, Hlebowicz J. Effects of *Curcuma longa* (turmeric) on postprandial plasma glucose and insulin in healthy subjects. Nutr J. 2010;9:43.

Wickenberg, J., Ingemansson, S. L., & Hlebowicz, J. (2010). Effects of *Curcuma longa* (turmeric) on postprandial plasma glucose and insulin in healthy subjects. Nutrition journal, 9(1), 43.

Yamoah, C.F., Agboola, A.A. and Mulogoy, K. (1986). Decompositon, nitrogen release and weed control by prunings of selected alley cropping shrubs. Agrofor. Syst. 4: 247-254.

York, E.T. (1991). The importance of Agroforestry education and training Agrofor. Syst, 12: 7-12.

Zhang, W., Ahanbieke, P., Wang, B.J., Xu, W.L., Li, L.H., Christie, P. and Li, L. (2013). Root distribution and interactions in jujube tree/wheat Agroforestry system. Agroforest Syst. 87: 929–939.

APPENDICES

APPENDICES

Appendix-I: The physical and chemical properties of soil in Agroforestry and Environment farm HSTU, Dinajpur

Soil characters	Physical and chemical properties
Texture	
Sand (%)	65
Silt (%)	30
Clay (%)	5
Textural class	Sandy loam
CEC (meq/ 100g)	8.07
pH	5.35
Organic matter (%)	1.06
Total nitrogen (%)	0.10
Sodium (meq/ 100g)	0.06
Calcium (meq/ 100g)	1.30
Magnesium (meq/ 100g)	0.40
Potassium (meq/ 100g)	0.26
Phosphorus (µg/g)	24.0
Sulphur (µg/g)	3.2
Boron (µg/g)	0.27
Iron (µg/g)	5.30
Zinc (µg/g)	0.90

Source: Soil Resources Development Institute, Dinajpur (2018)

Appendix-II: Monthly records of different weather data at the period from March 2018 to January 2019

Month	** Air Temperature (°C)			**Relative humidity (%)	*Rainfall (mm)
	Maximum	Minimum	Average		
March	34.1	17.3	25.7	69	30.0
April	34.1	20.7	27.4	66	128.8
May	35.1	23.0	29.5	78	176.0
June	37.0	25.3	31.2	70	211.4
July	36.0	26.3	31.2	82	142.0
August	36.3	25.4	31.3	84	254.6
September	36.9	26.3	31.2	80	98.2
October	35.4	20.6	28.0	62	06.0
November	33.8	15.0	24.4	70	00.0
December	28.9	10.6	19.8	66	01.0
January	26.7	9.6	18.15	77	00.0

* Monthly Total

** Monthly average

Source: Wheat Research Centre (WRC), Nashipur, Dinajpur

Appendix-III: Light intensity during October before harvesting time at different time

Treatment	Variety	Replication	Line	Light intensity at 10.00 am (LUX)	Light intensity at 1.00 am (LUX)	Light intensity at 4.00 am (LUX)	Total light intensity in a day (LUX)
T_1	V_1	R_1	L_1	30	52	17	99
T_1	V_1	R_1	L_2	30	55	18	103
T_1	V_1	R_1	L_3	32	55	17	104
T_1	V_2	R_1	L_1	30	55	17	102
T_1	V_2	R_1	L_2	33	54	18	105
T_1	V_2	R_1	L_3	32	54	18	104
T_1	V_3	R_1	L_1	33	56	19	108
T_1	V_3	R_1	L_2	33	53	19	105
T_1	V_3	R_1	L_3	35	56	18	109
T_1	V_1	R_2	L_1	35	59	18	112
T_1	V_1	R_2	L_2	32	55	17	104
T_1	V_1	R_2	L_3	33	55	19	107
T_1	V_2	R_2	L_1	34	55	20	109
T_1	V_2	R_2	L_2	34	56	20	110
T_1	V_2	R_2	L_3	34	56	18	108
T_1	V_3	R_2	L_1	33	59	19	111
T_1	V_3	R_2	L_2	33	56	19	108
T_1	V_3	R_2	L_3	35	55	18	108
T_1	V_1	R_3	L_1	35	53	18	106
T_1	V_1	R_3	L_2	34	55	17	106
T_1	V_1	R_3	L_3	33	55	19	107
T_1	V_2	R_3	L_1	35	56	20	111

Appendix-III: Contd.

Treatment	Variety	Replication	Line	Light intensity at 10.00 am (LUX)	Light intensity at 1.00 am (LUX)	Light intensity at 4.00 am (LUX)	Total Light intensity in a day (LUX)
T_1	V_2	R_3	L_2	33	55	20	108
T_1	V_2	R_3	L_3	32	57	18	107
T_1	V_3	R_3	L_1	33	55	17	105
T_1	V_3	R_3	L_2	33	56	19	108
T_1	V_3	R_3	L_3	30	58	20	108
T_2	V_1	R_1	L_1	78	178	50	306
T_2	V_1	R_1	L_2	79	178	50	307
T_2	V_1	R_1	L_3	72	178	51	301
T_2	V_2	R_1	L_1	76	180	51	307
T_2	V_2	R_1	L_2	76	179	52	307
T_2	V_2	R_1	L_3	73	177	52	302
T_2	V_3	R_1	L_1	76	178	53	307
T_2	V_3	R_1	L_2	77	178	52	307
T_2	V_3	R_1	L_3	76	180	51	307
T_2	V_1	R_2	L_1	77	179	50	306
T_2	V_1	R_2	L_2	70	177	50	297
T_2	V_1	R_2	L_3	65	176	51	292
T_2	V_2	R_2	L_1	75	178	51	304
T_2	V_2	R_2	L_2	71	185	52	308
T_2	V_2	R_2	L_3	76	179	52	307
T_2	V_3	R_2	L_1	76	177	53	306
T_2	V_3	R_2	L_2	75	178	52	305
T_2	V_3	R_2	L_3	69	178	51	298
T_2	V_1	R_3	L_1	75	180	50	305
T_2	V_1	R_3	L_2	71	179	50	300
T_2	V_1	R_3	L_3	70	177	51	298
T_2	V_2	R_3	L_1	71	179	51	301
T_2	V_2	R_3	L_2	79	177	52	308
T_2	V_2	R_3	L_3	76	176	50	302
T_2	V_3	R_3	L_1	78	178	50	306
T_2	V_3	R_3	L_2	73	185	51	309
T_2	V_3	R_3	L_3	77	185	51	313

Source: Department of Agroforestry, records of light intensity observation, HSTU

Appendix-IV: Germination speed (Chiapusio *et al.,* 1997) of ginger varieties under different agroforestry systems

Treatment	Variety	Replication	Line	Germination speed
T_1	V_1	R_1	L_1	2.73
T_1	V_1	R_1	L_2	2.63
T_1	V_1	R_1	L_3	2.64
T_1	V_2	R_1	L_1	2.62
T_1	V_2	R_1	L_2	2.67
T_1	V_2	R_1	L_3	3.68
T_1	V_3	R_1	L_1	3.74
T_1	V_3	R_1	L_2	4.33
T_1	V_3	R_1	L_3	4.80
T_1	V_1	R_2	L_1	2.60
T_1	V_1	R_2	L_2	3.01
T_1	V_1	R_2	L_3	3.28
T_1	V_2	R_2	L_1	3.92
T_1	V_2	R_2	L_2	4.05
T_1	V_2	R_2	L_3	5.02
T_1	V_3	R_2	L_1	4.48
T_1	V_3	R_2	L_2	4.23
T_1	V_3	R_2	L_3	4.97
T_1	V_1	R_3	L_1	2.85
T_1	V_1	R_3	L_2	3.27
T_1	V_1	R_3	L_3	3.10
T_1	V_2	R_3	L_1	4.14
T_1	V_2	R_3	L_2	5.71
T_1	V_2	R_3	L_3	6.86
T_1	V_3	R_3	L_1	7.46
T_1	V_3	R_3	L_2	6.61
T_1	V_3	R_3	L_3	7.26
T_2	V_1	R_1	L_1	3.05
T_2	V_1	R_1	L_2	3.15

Appendix-IV: Contd.

Treatment	Variety	Replication	Line	Germination speed
T_2	V_1	R_1	L_3	3.28
T_2	V_2	R_1	L_1	4.64
T_2	V_2	R_1	L_2	4.84
T_2	V_2	R_1	L_3	5.05
T_2	V_3	R_1	L_1	2.79
T_2	V_3	R_1	L_2	2.90
T_2	V_3	R_1	L_3	2.97
T_2	V_1	R_2	L_1	3.20
T_2	V_1	R_2	L_2	3.20
T_2	V_1	R_2	L_3	3.55
T_2	V_2	R_2	L_1	5.24
T_2	V_2	R_2	L_2	5.12
T_2	V_2	R_2	L_3	5.15
T_2	V_3	R_2	L_1	2.99
T_2	V_3	R_2	L_2	2.89
T_2	V_3	R_2	L_3	2.99
T_2	V_1	R_3	L_1	3.08
T_2	V_1	R_3	L_2	3.19
T_2	V_1	R_3	L_3	3.29
T_2	V_2	R_3	L_1	5.12
T_2	V_2	R_3	L_2	5.16
T_2	V_2	R_3	L_3	5.24
T_2	V_3	R_3	L_1	2.94
T_2	V_3	R_3	L_2	2.83
T_2	V_3	R_3	L_3	2.96

Source: Department of Agroforestry, records of light intensity observation, HSTU

Appendix-V: Some plates on my research experiment

Plate 3: Sowing of turmeric rhizome

Plate 4: Field preparation for sowing

Plate 5: In front of my turmeric plot with my Supervisor

Plate 6: Counting number of turmeric plants

Plate 10: Preparing tag for recognizing plots

Plate 8: Measuring length and wide of leaf

Plate 9: Taking instructions from my supervisor sir

Plate 10: Measuring width of leaf

Plate 11: Measuring plant height

Plate 12: Measuring light intensity by LUX meter

Plate 13: In front of my turmeric plot

Plate 14: Vegetative stage of under mango (T_1) and open control with thailand (V_1), malshira (V_2) and debipat (V_3) varieties

Plate 15: Fresh rhizomes from different lines of under mango (T_1), and open field (T_2) with thailand (V_1), malshira (V_2) and debipat (V_3) variety after harvesting were collected

Plate 16: Harvesting of turmeric varieties from the field

Plate 17: Preparing rhizome for necessary data

Plate 18: Preparing rhizomes for drying

Plate 19: Taking weight of rhizomes

Plate 20: Dry rhizomes were ready

Plate 21: Drying of turmeric rhizome