VARIETAL PERFORMANCE OF TURMERIC UNDER LITCHI BASED AGROFORESTRY SYSTEMS

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A THESIS

BY

MD. MOSARAFF ALI SARKER

Student No. 1005011

Session: 2010

Thesis Semester: March-August, 2012

MASTER OF SCIENCE (M.S.)
IN
AGROFORESTRY

DEPARTMENT OF AGROFORESTRY

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR

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BISMILLA-HEER- RAHMANIR- RAHEEM

All praises are due to Almighty Allah, Who kindly enabled the Author to complete the present research work

DEDICATED TO MY

BELOVED PARENTS

DECLARATION

I declare that, the dissertation entitled **"VARIETAL PERFORMANCE OF TURMERIC UNDER LITCHI BASED AGROFORESTRY SYSTEM"** submitted to the Hajee Mohammad Danesh Science and Technology University, Dinajpur, for the degree of M S in Agroforestry is an original research outlined and carried out by me. No part of the thesis has been submitted elsewhere for any degree.

Jun, 2012 **The Author**

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ABBREVIATION AND ACRONYMS

AEZ	:	Agro-ecological zone
BARC	:	Bangladesh Agricultural Research Council
BAU	:	Bangladesh Agricultural University
BBS	:	Bangladesh Bureau of Statistics
BCR	:	Benefit Cost Ratio
BCSIR	:	Bangladesh Council of Scientific and Industrial Research
CD	:	Cowdung
cv	:	Cultivar
DAP	:	Days after planting
FAO	:	Food and Agricultural Organization
LSD	:	Least Significant Difference
m^2	:	Square metre
MOP	:	Muriate of Potash
N	:	Nitrogen
NS	:	Non Significant
RCBD	:	Randomized Complete Block Design
RH	:	Relative Humidity
TSP	:	Triple Superphosphate
t/ha	:	ton/hectare

VARIETAL PERFORMANCE OF TURMERIC UNDER LITCHI BASED AGROFORESTRY SYSTEMS

Abstract

An experiment was conducted in the farmer's litchi orchard in the village named Jorkali of Biral upazila under Dinajpur district in order to investigate the performance of different turmeric variety under 7 years old Litchi (*Litchi chinensis*) orchard. The experiment was consisted of RCBD 2 (two) factors with 3 (three) replications. Among the two factors, one factor was two production systems: T_1= Litchi + Turmeric and T_2= Turmeric (sole crop); another factor was three turmeric variety: V_1= BARI 1, V_2= BARI 2 and V_3= BARI 3.

The experimental results revealed that the main effect of variety on growth, yield contributing characters and yield of turmeric were significantly varied with each other. At 180 DAP, the highest yield (24.67 tha^{-1}) was recorded in BARI 3 whereas lowest yield of turmeric was recorded in BARI 2 (21.50 tha^{-1}). Moreover, at 240 DAP, highest yield of turmeric was recorded in BARI 1 (43.83 tha^{-1}) whereas lowest yield of turmeric was recorded in BARI 2 (39.33 tha^{-1}). Again, the yield of turmeric was also significantly influenced by the main effect of different production systems. The highest fresh yield (25.78 and 43.44 tha^{-1} at 180 and 240 DAP) was recorded under sole cropping of turmeric. Significantly, the lowest yield (20.56 and 40.00 tha^{-1} at 180 and 240 DAP) was recorded in litch+termeric based Agroforestry system.

The interaction effect of different turmeric variety and production systems on the yield of turmeric was found significantly different at different DAP. The highest fresh yield 26.67 tha^{-1} at 180 DAP was recorded in open condition with BARI 3 variety and the lowest fresh yield 17.67 tha^{-1} was found under litchi based agroforestry system with BARI 2 variety. But at 240 DAP, the highest fresh yield 46.33 tha^{-1} was recorded in open condition with BARI 1 variety and the lowest fresh yield of turmeric 37.33 t/ha was found under litchi based Agroforestry system with BARI 2 variety. Finally it can be concluded that BARI 1 is the best turmeric variety for production in the floor of 7 years old litchi orchard.

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CHAPTER 1

INTRODUCTION

Bangladesh is an agrarian country enjoying tropical to sub-tropical climate. Her population is 152.3 millions in an area of 147570 sq km with a growth rate of 1.54% (BBS, 2011). The total forest area of the nation covers about 13.36% of the land (BBS, 2010). However, according to the Forest Master Plan and surveys conducted by multinational donor agencies, only 6% or a total of 0.769 million hectares land of the territory has actual tree coverage (Anonymous, 2009). But to have benefits of the 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 over population for a limited land. The realm has neither the ability to increase command areas of agricultural crops nor to increase the forest area for ecological demands. Under these fatal situations, various agroforestry systems like forest or fruit tree based agroforestry system can address the stress of the day to considerable extents.

According to Lundgren 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 mixture or in temporal sequences. The fruit based 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 facilitates maximum utilization of space in four dimensions (length, width, height and depth) leading to maximum economic productivity of the system.

Turmeric is 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 the gastrointestinal tract (Purseglove *et al.,* 1988) and many other purposes. In addition, turmeric is a high 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 world wide also increasing.

Turmeric requires hot and humid climate. It can be cultivated in most areas of the tropics and subtropics provided that rainfall is adequate 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, 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 homestead/farm land, which is called agroforestry system, may be one of the ways. In agroforestry system, turmeric must be shaded to some extend depending on 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.

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

1. To investigate the performance of turmeric under Litchi (*Litchi chinensis*) orchard.

2. To identify the suitable variety under Litchi tree for profitable turmeric production.

CHAPTER 2

REVIEW OF LITERATURE

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 literatures pertaining to the present study have been reviewed in this chapter under the following heads:

2.1 Agroforestry: A sustainable land use technology

2.2 Benefits from agroforestry system

2.3 Effect of light intensity on turmeric production

2.4 Fruit tree based agroforestry system

2.1 Agroforestry: A sustainable land use technology

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 agroforestry 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 1evels. 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 agroforestry 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 agricultureal/horticultural crops and/or livestock.

Rang *et al.* (1990) stated agroforestry 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 agroforestry 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) cosidered agroforestry 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, improved income and ensure sustainable use of land resources.

2.2 Benefits from agroforestry system

In an experiment conducted by Bhuva *et al.* (1989) at India and they plant mango cv. Rajapuri was planted in 1979 at 6×6 m, and was interplanted 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. Consequentlyin the recent year's 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 from trials 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 from consideration of the waste of light resources while Haque *et al.* (1992) claimed that the practice of producing trees in crop fields is 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 arecanut (*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) realised 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 9 m 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 (2000) inferred that *Tagetes minuta* can be successfully grown at 50x75 cm spacing with 40 kg N/ha under eight year old Poplar, resulting in monetary gains (net profit) of about Rs. 52000/ha/year.

2.3 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 *Leucuena leucocephala*, *Eucalyptus camaldulensis*. Ghoraneem or Manilkara spp. were carried out in Madhya Pradesh, India. The hightest 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. Agroforest 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.

2.4 Fruit tree based agroforestry systems

Osei *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=0.05) than from the other treatments during 1993/94 to 1995/96. Widely spaced coconuts intercropped with cocoa spaced at 3 m $\times$ 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 multi-storeyed 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 3 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 also 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 under any other crop and averaged at 28.4 t/ha compared with 26.3 t for cassava grown in 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 pod 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 (0.41 t/ha).

In a field study in 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 1.26 cm $year^{-1}$ 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 + acidlime + arrowroot and (C) banana + betelvine + pineapple + elephant foot yam, on arecanut 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 arecanut; in crop system A (irrigated), the yield of arecanut rose by 4.1%, but arecanut yields decreased in all other plots by 10.5-24.2%. This decrease in yield 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*), jews' mallow (*Corchorus olitorius*) and *Solanum gilo*. Sweet potato and *S. gilo* caused a marked reduction in the yield of papaya. Land Equivalent Ratio (LER) values for papaya intercropped with okra, watermelon, sweet potato, bush greens, jews' 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 is 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 fuelwood 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.

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 intercropped 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 photosynthetically 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 soyabean 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 arecanut 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 tillers 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 arecanut 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 arecanut plantation was significantly higher (154.5 g) when compared to open conditions (118.8 g/plant). Individual rhizomes of ginger grown in arecanut plantation were slightly bigger (4.5 g/rhizome) than the crop grown in open (3.4 g/rhizome). Yield of arecanut was not affected due to intercropping with ginger during the two years study. However, there was slight improvement in the yield of arecanut (3.20 kg chali/palm) when compared to monocropping of arecanut (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 arecanut plant. They reported a progressive improvement of dry matter production in tops up to 210th day while in rhizome it continued up to 240th day after planting. Singh *et al.* (1986) from a survey of 190 farms of varying size on which arecanuts were intercropped with five cash crops, inferred that ginger was one among the crops which can be profitably intercropped with arecanuts. 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 x 8 m. The yield of turmeric ranged form 4.78 t h^{-1} (cv. Ventimetta) to 17.36 t ha^{-1} (cv. Amruthaparri 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 (5x5m, 5x4m and 5x3m); 5x4m was found to be the most suitable for ginger and 5x5m 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 8.61 t 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 per cent of the yield obtained from crops raised on open areas.

Satheesan and Ramadasan (1980) studied relative performance of turmeric raised as an intercrop in coconut garden and as a pure crop. The incident Photosynthetically active radiation (PAR) at any given time of the day was about 50 per cent 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.

CHAPTER 3
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 Description of the Experimental Site

3.1.1 Location

The experiment was conducted in the farmer's litchi orchard in Jorkali of Biral upazila under Dinajpur district. The geographical location of the site was between 25° 13' latitude and 88° 23' longitude, and about 37.5m above the sea level.

3.1.2 Soil characteristics

The experimental plot was situated in a medium high land belonging to the old Himalayan Piedmont Plain area (AEZ 01). Land was well-drained as drainage system was well developed. The soil texture was sandy loam in nature. The details soil properties are presented in Appendix-I.

3.1.3 Climate

The experimental site was situated under the tropical climate characterized by heavy rainfall from July to August and scanty rainfall the rest period of the year. Monthly maximum and minimum temperatures, rainfall and relative humidity recorded during the experimental period (April 2010 to January 2011) are included in the Appendix-II.

3.2 Experimental period

April 2010 to February 2012

3.3 Seed collections

Turmeric rhizome was collected from Spices Research Center, Bogra

3.4 Experimental design

Design: Factorial RCBD with 3 (three) replications

3.5 Experimental treatments

The experiment consisted of 2 (two) factors:

Factor A: (Two production systems)

T_1= Litchi + Turmeric

T_2= Turmeric (sole crop)

Factor B: (Three turmeric variety)

V_1= BARI 1

V_2= BARI 2

V_3= BARI 3

Treatment combinations:

T_1V_1 = Litchi + BARI 1

T_1V_2 = Litchi + BARI 2

T_1V_3 = Litchi + BARI 3

T_2V_1 = sole cropping of BARI 1 turmeric variety

T_2V_2 = sole cropping of BARI 2 turmeric variety

T_2V_3 = sole cropping of BARI 3 turmeric variety

3.6 Structural description of the treatments

1st layer (upper layer): Litchi tree

Scientific name: *Litchi chinensis*

Family: Sapindaceae

Spacing: 5m x 3m

Establishment: 2004

Planting direction: North-South

General description of Litchi tree

Litchi chinensis is an evergreen tree that is frequently less than 10 m (33 ft) tall, sometimes reaching more than 15 m (49 ft). The bark is grey-black, the branches a brownish-red. Leaves are 10 to 25 cm (3.9 to 9.8 in) or longer, with leaflets in 2-4 pairs. Litchee have a similar foliage to the Lauraceae family likely due to convergent evolution. They are adapted by developing leaves that repel water, similar to laurophyll or lauroide leaves which are adapted to high rainfall and humidity in laurel forest habitats. Flowers grow on a terminal inflorescence with many panicles on the current season's growth. The panicles grow in clusters of ten or more, reaching 10 to 40 cm (3.9 to 16 in) or longer, holding hundreds of small white, yellow, or green flowers that are distinctively fragrant.

Fruits mature in 80–112 days, depending on climate, location, and cultivar. Fruits reach up to 5 cm (2.0 in) long and 4 cm (1.6 in) wide, varying in shape from round, to ovoid, to heart-shaped. The thin, tough inedible skin is green when immature, ripening to red or pink-red, and is smooth or covered with small sharp protuberances. The skin turns brown and dry when left out after harvesting. The fleshy, edible portion of the fruit is an aril, surrounding one dark brown inedible seed that is 1 to 3.3 cm (0.39 to 1.3 in) long and .6 to 1.2 cm (0.24 to 0.47 in) wide. Some cultivars produce a high percentage of fruits with shriveled aborted seeds known as 'chicken tongues'. These fruit typically have a higher price, due to having more edible flesh.

3.7 Land preparation

The land was opened in the 3rd week of April 2010 and prepared thoroughly by spading to obtain a good tilth, which was necessary to get better yield of this crop (Ahmad, 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.

3.8 Experimental materials

Three variety of turmeric viz. BARI 1, BARI 2 and BARI 3 was used in the experiment as the test crop. The seed rhizome was collected from Bangladesh Spices Research Institute, Bogra.

3.9 Crop establishment

The seed rhizome of turmeric was planted maintaining a row to row distance of 50cm, a plant to plant distance of 25cm and a depth of 10cm. The weight of each seed-rhizome was of 15-20g.

3.10 Intercultural operation

Weeding is done as felt necessary. Earthing-up was done thrice; the first one after 60, the second one after 90 and the final one after 110 days of planting. Some plants were rotten by water logging condition. This condition was controlled by drainage. Some turmeric plants were affected by leaf spot and rhizome rot disease, which were controlled by spraying Rovral and Dithane M-45 @ 4.5g/L at an interval of 15 days, respectively.

3.11 Application of manure, fertilizer and Dolochoon

The doses of fertilizers and manures and their methods of application as recommended by MD. Mamum Al Ahsan Chowdhury (2006) as follows:

Recommended fertilizer/manure rates and method of application for turmeric

Manure/ fertilizers	doses per hectare
Well decomposed cow dung	10 (ton)
TSP	45 (kg)
MOP	125 (kg)
Gypsum	105 (kg)
Zinc sulphate	3 (kg)
Dolochoon	240 (kg)

Cow dung and Dolochoon were applied seven days before planting. One half of N and other fertilizers were applied before planting of rhizome. Rest of the N fertilizer were applied in 3 splits between 2 rows after planting of rhizome at 50, 80 and 110 days of planting.

3.12 Sampling and data collection

Ten plants were randomly selected from each plot to record data on the following parameters such as

Plant height: The plant height was measured from ten plants in centimeter (cm) from the ground level tip of the longest leaf of the sample plants at 120, 180, 240 days after planting (DAP). The mean was also calculated.

Number of leaves per plant: The number of leaves per plant was counted from selected ten plants at the maximum plant growth. The mean number of leaves was calculated by dividing total number of leaves observed from ten plants by ten.

Number of tillers per plant: The number of tillers per plant was recorded from the above selected ten plants at the maximum plant growth.

Length of leaf blade: Ten plants were selected from each plot and 3 leaves viz., large, medium and small per plant were used for measurement. It was measured in centimeter (cm) with the help of a meter scale.

Breath of leaf blade: Ten plants were selected from each plot and 3 leaves viz., large, medium and small per plant were used for measurement. It was measured in centimeter (cm) with the help of a meter scale.

Fresh leaf weight per plant: After harvest, leaves of 10 selected plants from each plot were collected and weight of leaves was taken by and ordinary balance in gram (g) and their mean was calculated.

Dry leaf weight per plant: After harvest, leaves of 10 selected plants were weight and dried in and oven for 24 hours at 70 ^{0}C till constant weight. After drying, the leaf samples were weight and mean weight was calculated in gram (g).

Number of finger per plant: The number of finger per selected plant was counted at harvest time and their mean was calculated.

Fresh finger weight per plant: The weight of fresh finger per selected plant was recorded with the help of a balance at the time of harvest and their average was calculated as weight of individual plant.

Dry finger weight per plant: After harvest, finger of 10 selected plants were weighed and dried in an oven for 24 hours at 70 ^{0}C till constant weight. After drying, the dry fingers were weighed and mean weight was calculated in gram (g).

Fresh rhizome weight per plant: The weight of fresh rhizome per selected plant was recorded with the help of a balance at the time of harvest and their average was calculated as weight of individual plant.

Dry rhizome weight per plant: After harvest, rhizome of 10 selected plants were weighed and dried in an oven for 24 hours at 70 ^{0}C till constant weight. After drying the dry rhizome weighed and mean weight was calculated in gram (g).

Total yield per hectare: Yield of rhizome per plot was converted into yield per hectare and expressed in tons.

3.13 Data analysis:

The collected data were statistically analyzed using the "Analysis of variance" (ANOVA) technique and the significance of the mean differences was adjudged by the Duncan's New Multiple Range Test (DMRT) with the help of computer package MSTAT-C programme (Gomez and Gomez, 1984).

Plate 1: Litchi+Turmeric based agroforestry systems

Plate 2: Sole cropping of turmeric (open condition)

Plate 3: Intercultural operation in litchi+turmeric based agroforestry systems

Plate 4: Data collection in growth phase of the crops

Plate 5: Land preparation and seed plantation

Plate 6: Harvesting and sample collection

CHAPTER 4
RESULTS AND DISCUSSION

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

4.1 Main effect of variety on growth, yield contributing characters and yield of turmeric

4.1.1 Plant height (cm)

Among the treatments different days after planting (DAP), the plant height was found significant at 120 DAP (Table.1). The tallest plant (110.05 cm) was observed in BARI 1(V_1) followed by BARI 2 (89.50 cm) where as the shortest plant (78 cm) was observed in BARI 3 (V_3). Again at 180 DAP the tallest plant (140 cm) was observed in BARI 1 (V_1) followed by BARI 2 V_2 (117.7 cm) and the shortest plant (107.3 cm) was observed in BARI 3 (V_3). This might be occurred due to their genetic character. Partially similar result also was found by Garrity *et al.* (1992).

4.1.2 Number of tiller per plant

Number of tiller per plant of turmeric varied significantly at different days after planting (DAP). At 120 DAP; the maximum number of tiller (2.68) was recorded in BARI 1 followed by 2.38 in BARI 2. On the other hand, minimum number of tiller was recorded in BARI 3 (2.10). Again, at 180 DAP, the maximum number of tiller (4.02) was recorded in BARI 1 followed by 3.62 in BARI 2. On the other hand, minimum number of tiller was recorded in BARI 3 (3.28).

4.1.3 Number of leaf per plant

Number of leaf per plant of turmeric varied significantly at different DAP. At 120 DAP, the highest number of leaf (8.58) was recorded in BARI 1 followed by BARI 2. On the other hand, lowest number of leaf was (5.68) recorded in BARI 3. Again, at 180 DAP, the highest number of leaf (17.37) was recorded in BARI 1 followed by BARI 2. On the other hand, lowest number of tiller (11.73) was recorded in BARI 3.

4.1.4 Length of leaf blade (cm)

Length of leaf blade of turmeric varied significantly at different DAP. At 120 DAP, the maximum length of leaf blade (59.67 cm) was recorded in BARI 1 followed by BARI 2. On the other hand, minimum length of leaf blade (50 cm) was recorded in BARI 3. Again, at 180 DAP, the maximum length of leaf blade (73.67 cm) was recorded in BARI 1 followed by 67.83 cm in BARI 2. On the other hand, minimum length of leaf blade (61.67 cm) was recorded in BARI 3.

4.1.5 Breadth of leaf blade (cm)

Breadth of leaf blade of turmeric diverse significantly at different DAP. At 120 DAP, the maximum breadth of leaf blade (16.25 cm) was recorded in BARI 1 followed by 13.92 cm in BARI 2. On the other hand, minimum breadth of leaf blade (11.33 cm) was recorded in BARI 3. For a second time at 180 DAP, the maximum breadth of leaf blade (22.67 cm) was recorded in BARI 1 followed by 18.97 cm in BARI 2. On the other hand, minimum breadth of leaf blade (16.25 cm) was recorded in BARI 3.

Table 1: Main effect of variety on plant height and number of tiller/plant of turmeric at different days after planting (DAP)

Treatments (Variety)	Plant height (cm)		Number of tiller/plant	
	120 DAP	180 DAP	120 DAP	180 DAP
V_1	110.50 a	140.0 a	2.68 a	4.01 a
V_2	89.50 b	117.7 b	2.38 b	3.61 b
V_3	78.00 c	107.3 c	2.10 c	3.28 b
lsd $_{(0.05)}$	2.26	3.45	0.25	0.38

Note: Means with similar letter(s) in a column do not differ significantly

Table 2: Main effect of variety on leaf characters of turmeric at different DAP

Treatments (Variety)	Number of Leaf/plant		Length of leaf blade (cm)		Breath of leaf blade (cm)	
	120 DAP	180 DAP	120 DAP	180 DAP	120 DAP	180 DAP
V_1	8.58 a	17.37 a	59.67 a	73.67 a	16.25 a	22.67 a
V_2	7.40 b	14.88 b	53.67 b	67.83 b	13.92 b	18.97 b
V_3	5.68 c	11.73 c	50.00 c	61.67 c	11.33 c	16.25 c
lsd $_{(0.05)}$	0.20	1.66	2.12	3.99	1.30	2.17

Note: Means with similar letter(s) in a column do not differ significantly

4.1.6 Number of finger per plant

Number of finger per plant of turmeric varied significantly at different DAP. At 180 DAP, the highest number of finger (23.50) was recorded in BARI 1 whereas lowest number of finger (11.73) was recorded in BARI 3 which was statistically similar with BARI 2. Moreover, at 240 DAP, highest number of finger was recorded in BARI 1 (38.17) followed by BARI 2. On the other hand, lowest number of finger (30.17) was recorded in BARI 3.

4.1.7 Fresh finger weight per plant

Fresh finger weight per plant of turmeric varied significantly at different DAP. At 180 DAP, the highest number of finger (23.50) was recorded in BARI 1 whereas lowest number of finger (11.73) was recorded in BARI 3 which was statistically similar with BARI 2 variety. Furthermore, at 240 DAP, maximum weight of fresh finger (385.3 g) was recorded in BARI 3 which was statistically similar with BARI 1. On the other hand, the minimum fresh weight of finger (322.8 g) was recorded in BARI 2 variety.

4.1.8 Dry finger weight per plant

Dry finger weight per plant of turmeric varied significantly at different DAP. At 180 DAP, the maximum dry weight of finger (54.33 g) was recorded in BARI 3 whereas minimum dry weight of finger was recorded in BARI 2 (40.83 g). Moreover, at 240 DAP, maximum weight of dry finger was recorded in BARI 3 (104.3 g), and the minimum dry weight of finger (76.17 g) was recorded in BARI 2 variety.

4.1.9 Fresh rhizome weight per plant

Fresh rhizome weight per plant of turmeric varied significantly at DAP. At 180 DAP, the maximum fresh weight of rhizome (87 g) was recorded in BARI 3 which was statistically similar with BARI 1. The minimum weight of rhizome was recorded in BARI 2 (71.50 g). Moreover, at 240 DAP, maximum weight of fresh rhizome was recorded in BARI 3 (115.7 g) whereas minimum fresh weight of rhizome was recorded in BARI 2 (99.67 g).

4.1.10 Dry rhizome weight per plant

Dry rhizome weight per plant of turmeric also varied significantly at different DAP. At 180 DAP, the maximum dry weight of rhizome (14.50 g) was recorded in BARI 1 which was statistically similar with BARI 3 whereas lowest dry weight of rhizome was recorded in BARI 2 (11.83 g). Moreover, at 240 DAP, maximum weight of dry rhizome was recorded in BARI 1 (114.8 g) whereas minimum fresh weight of rhizome was recorded in BARI 2 (16.50 g).

4.1.11 Fresh yield of turmeric (tha^{-1})

Fresh yield of turmeric varied significantly at different DAP. At 180 DAP, yield of turmeric was found not significant. The highest yield (24.67 tha^{-1}) was recorded in BARI 3 whereas lowest yield of turmeric was recorded in BARI 2 (21.50 tha^{-1}). Moreover, at 240 DAP, highest yield of turmeric was recorded in BARI 1 (43.83 tha^{-1}) whereas lowest yield of turmeric was recorded in BARI 2 (39.33 tha^{-1}).

4.1.12 Dry yield of turmeric (tha^{-1})

Dry yield of turmeric varied significantly at different DAP. At 180 DAP, highest dry yield (2.65 tha^{-1}) was recorded in both BARI 1 & BARI 3 whereas lowest dry yield of turmeric was recorded in BARI 2 (2.250 tha^{-1}). Moreover, at 240 DAP, highest dry yield of turmeric was recorded in BARI 1 (7.8 tha^{-1}) whereas lowest yield of turmeric was recorded in BARI 2 (6.82 tha^{-1}).

Table 3: Main effect of variety on number of finger and finger weight per plant of turmeric at different DAP

Treatments (Variety)	Number of finger/plant		Fresh finger wt./plant (g)		Dry finger wt./plant (g)	
	180 DAP	240 DAP	180 DAP	240 DAP	180 DAP	240 DAP
V_1	23.50 a	38.17 a	154.7 a	385.0 a	45.67 b	90.00 b
V_2	20.92 b	33.00 b	135.8 b	322.8b	40.83 b	76.17 c
V_3	18.85 b	30.17 c	146.5 b	385.3 a	54.33 a	104.3 a
lsd $_{(0.05)}$	2.25	1.93	11.38	14.83	6.41	4.08

Note: Means with similar letter(s) in a column do not differ significantly

Table 4: Main effect of variety on weight of rhizome per plant of turmeric at different DAP

Treatments (Variety)	Fresh rhizome wt./plant (g)		Dry rhizome wt/plant (g)	
	180 DAP	240 DAP	180 DAP	240 DAP
V_1	83.83 a	114.8 a	14.50 a	21.17 a
V_2	71.50b	99.67 b	11.83 b	16.50 b
V_3	87.00 a	115.7 a	14.00 a	22.00 a
lsd $_{(0.05)}$	3.25	3.77	1.75	1.75

Note: Means with similar letter(s) in a column do not differ significantly

Table 5: Main effect of variety on yield contributing characters of turmeric at different DAP

Treatments (Variety)	Fresh yield (t/ha)		Dry yield (t/ha)	
	180 DAP	240 DAP	180 DAP	240 DAP
V_1	23.33 a	43.83 a	2.65 a	7.80 a
V_2	21.50 a	39.33 b	2.250 b	6.81 b
V_3	24.67 a	42.00 a	2.65 a	7.77 a
lsd $_{(0.05)}$	3.49	2.33	0.26	0.39

Note: Means with similar letter(s) in a column do not differ significantly

4.2 Main effect of production system

4.2.1. Plant height and Number of tiller/plant

The influence of litchi based cropping system on plant height and number of tiller per plant of turmeric were significant (Table 6). Turmeric grown under agroforestry systems grew more vigorously than those grown in sole cropping i.e. in full sun light conditions. It exhibited considerably higher height under Agroforestry system. The tallest plant (96.11 and 129.11 cm at 120 and 180 DAP), respectively was obtained in litchi + turmeric based Agroforestry system during the growing seasons, the corresponding figures for sole cropping was (89.22 and 114.22 cm at 120, 180 DAP). On the other hand, number of tiller per plant was found not significant in 120 DAP. In case of 180 DAP, the highest number of tiller per plant was found in litchi + turmeric based agroforestry system (4.01). This was happened due to excessive cell division in partial shade condition. A similar result was found by Chowdhury *et al.* (2009).

Table 6: Main effect of production system on plant height and number of tiller/plant of turmeric at different DAP

Treatment	Plant height (cm)		Number of tiller/plant	
	120 DAP	180 DAP	120 DAP	180 DAP
Litchi + turmeric	96.11 a	129.11 a	2.01	4.01 a
Open	89.22 b	114.22 b	1.77	3.27 b
lsd $_{(0.05)}$	3.20	4.88	0.35	0.54

Note: Means with similar letter(s) in a column do not differ significantly

4.2.2. Leaf characters

The effects of litchi based cropping system on leaf characters of turmeric were significant except breadth of leaf blade (Table 7). Turmeric grown under agroforestry systems grew more dynamically than those grown in sole cropping i.e. in full sun light conditions. It exhibited considerably the more number of leaf per plant in agroforestry system. The highest number of leaf per plant (7.71 and 21.40 at 120 and 180 DAP, respectively) was obtained in litchi + turmeric based agroforestry system during the growing seasons, the corresponding figures for sole cropping were 6.73 and 7.92 at 120 and 180 DAP, respectively. On the other hand, length of leaf blade was found significant in 120 and 180 DAP, the long length was found in litchi based agroforestry system. This was happened due to excessive cell division in partial shade condition. Similar results were found Chowdhury *et al.* (2009).

Table 7: Main effect of production system on leaf characters of turmeric at different DAP

Treatment	Number of Leaf/plant		Length of Leaf blade (cm)		Breath of Leaf blade (cm)	
	120 DAP	180 DAP	120 DAP	180 DAP	120 DAP	180 DAP
Litchi + turmeric	7.71 a	21.40 a	58.89 a	70.78 a	14.67	20.98
Open	6.73 b	7.92 b	50.00 b	64.67 b	13.00	17.61
lsd $_{(0.05)}$	0.29	2.35	3.00	5.64	1.84	3.07

Note: Means with similar letter(s) in a column do not differ significantly

4.2.3. Number of finger and finger fresh & dry weight per plant

The plead with of litchi based cropping system on number of finger and finger fresh & dry weight per plant of turmeric were significant (Table 8). Turmeric was found under sole cropping i.e. in full sun light conditions more dynamically than those grown in agroforestry systems. Significantly the highest number of finger per plant (23.40 and 36.44 at 180 and 240 DAP) was recorded in open condition. Similar trend was focused incase of fresh & dry weight per plant. Significantly, the highest fresh & dry weight per plant was observed in open condition. Selina, 2008 was examined this type of result in her thesis.

4.2.4. Rhizome fresh & dry weight per plant

The influence of litchi based cropping system on rhizome fresh & dry weight per plant of turmeric were not significant in all the DAP except 240 DAP (Table 9). Rhizome dry weight per plant was found 24.33 g in open condition.

Table 8: Main effect of production system on number of finger and finger weight per plant of turmeric at different DAP

Treatment	Number of finger/plant		Fresh finger wt./plant (g)		Dry finger wt./plant (g)	
	180 DAP	240 DAP	180 DAP	240 DAP	180 DAP	240 DAP
Litchi + turmeric	18.78 b	31.11 b	135.56 b	345.00 b	41.44 b	84.67 b
Open	23.40 a	36.44 a	155.78 a	383.78 a	52.44 a	95.67 a
lsd $_{(0.05)}$	3.17	2.73	16.09	20.97	9.07	5.77

Note: Means with similar letter(s) in a column do not differ significantly

Table 9: Main effect of system on weight of rhizome per plant of turmeric at different DAP

Treatment	Fresh rhizome wt./plant (g)		Dry rhizome wt/plant (g)	
	180 DAP	240 DAP	180 DAP	240 DAP
Litchi + turmeric	79.78 ns	109.89 ns	12.44 ns	15.44 b
Open	81.78 ns	110.22 ns	14.44 ns	24.33 a
lsd $_{(0.05)}$	4.59	5.34	2.47	2.47

Note: Means with similar letter(s) in a column do not differ significantly

4.2.5. Rhizome yield

The yield of turmeric (t/ha) showed almost similar pattern of variations between the two different production systems as above yield contributing parameters (Table 10). The highest fresh yield (25.78 and 43.44 t/ha at 180 and 240 DAP) was recorded under sole cropping of turmeric. Significantly, the lowest yield (20.56 and 40.00 t/ha at 180 and 240 DAP) was recorded in litch+turmeric based agroforestry system. The reason of maximum yield reduction in agroforestry might be that the upper and middle layer trees canopy densely covered almost the entire ground layer plots consequently partial shading effect on turmeric was higher. Similar trend was recorded incase of dry yield except 180 DAP insignificant. The highest dry yield (2.54 and 7.82 t/ha at 180 and 240 DAP) was recorded under sole cropping of turmeric. Significantly, the lowest yield (2.49 and 7.10 t/ha at 120 and 240 DAP) was recorded in litch+turmeric based agroforestry system.

Table 10: Main effect of production system on rhizome yield of turmeric at different DAP

Treatment	Fresh yield (t/ha)		Dry yield (t/ha)	
	180 DAP	240 DAP	180 DAP	240 DAP
Litchi + turmeric	20.56 b	40.00 b	2.49 ns	7.10 b
Open	25.78 a	43.44 a	2.54 ns	7.82 a
$lsd_{(0.05)}$	4.93	3.29	0.36	0.56

Note: Means with similar letter(s) in a column do not differ significantly

4.3 Interaction effect of production systems and turmeric variety

4.3.1 Plant height and number of tiller/plant

The interaction effect of production systems and turmeric variety on the plant height of turmeric was found significantly different at different DAP (Table 11). The tallest plant of turmeric 115 cm and 153 cm was found at both the 120 and 180 DAP in T_1V_1 (litchi + BARI 1) combination. The shortest plant of turmeric 74.67 cm and 102.3 cm was recorded at 120 and 180 DAP in T_2V_3 (open + BARI 3) combination.

This might be attributing due to the stimulation of cellular expansion and cell division of leaf under shading condition (Garrity *et al.,* 1992). Number of tiller plant^{-1} of turmeric variety was also significantly affected by the interaction of litchi tree and turmeric variety at 120 and 180 DAP. The maximum number of tillers plant^{-1} was (3.476 and 4.533) at 120 and 180 DAP in T_1V_1 (litchi + BARI 1) combination followed by T_1V_2. The minimum number of tillers plant^{-1} was (1.667 and 3.033) at both 120 and 180 DAP, respectively in T_2V_2 (open + BARI 2) combination followed by T_2V_3.

Table 11: Interaction effect of of production systems and turmeric variety on plant height and number of tiller/plant of turmeric at different DAP

Treatment combination		Plant height (cm)		Number of tiller/plant	
		120 DAP	180 DAP	120 DAP	180 DAP
Litchi (T_1)	V_1	115.0 a	153.0 a	3.46 a	4.53 a
	V_2	92.00 c	122.0 c	3.10 b	4.20 a
	V_3	81.33 e	112.3 d	2.46 c	3.30 b
Open (T_2)	V_1	106.0 b	127.0 b	1.90 d	3.50 b
	V_2	87.00 d	113.3 d	1.66 d	3.03 b
	V_3	74.67 f	102.3 e	1.73 d	3.26 b
lsd $_{(0.05)}$		3.20	4.88	0.35	0.54

Note: Means with similar letter(s) in a column do not differ significantly

4.3.2 Leaf characters

The interaction effect of litchi tree and turmeric variety on leaf characters of turmeric were significant (Table 12). The highest number of leaf per plant of turmeric (9.167 and 25.73 at 120 and 180 DAP, respectively) was found in T_1V_1 (litchi + BARI 1) combination. On the other hand, the lowest plant number of leaf per plant of turmeric (5.367 and 7.267 at 120 and 180 DAP, respectively) was obtained in T_2V_3 (open + BARI 3) combination. This might be attributing due to the stimulation of cellular expansion and cell division of leaf under shading condition. Garrity *et al.* (1992) observed number of leaf per plant affected minimum due to shading condition in mixed cropping of turmeric. Length of leaf blade of turmeric was significantly affected by the interaction of litchi tree and turmeric variety at 120 and 180 DAP. The highest length of leaf blade (64.0 and 77.33 at 120 and 180 DAP, respectively) was recorded in T_1V_1 (litchi + BARI 1) combination followed by T_1V_2. The lowest length of leaf blade (45.0 and 61.0 at 120 and 180 DAP, respectively) was found in T_2V_3 (open + BARI 2) combination followed by T_2V_2. Again, breadth of leaf blade of turmeric was also significantly affected by the interaction of litchi tree and turmeric variety at both the 120 and 180 DAP. The highest breadth of leaf blade (17.50 and 23.33 at 120 and 180 DAP, respectively) was observed in T_1V_1 (litchi + BARI 1) combination followed by T_1V_2. The lowest breadth of leaf blade was (11.0 and 14.5) at both 120 and 180 DAP was found in T_2V_3 (open + BARI 2) combination followed by T_2V_2.

4.3.3. Number of finger and finger fresh & dry weight per plant

The interaction effect of litchi based cropping system on number of finger and finger fresh & dry weight per plant of turmeric were significant (Table 13). Significantly the highest number of finger per plant (25.0 and 41.0 at 180 and 240 DAP) was recorded in open condition with BARI 1 variety and the lowest was 16.67 and 28.67 recorded under litchi+BARI 3. Significantly the highest number of fresh finger weight per plant (164.3 and 403.3 at 180 and 240 DAP) was recorded in open condition with

BARI 1 variety followed by open condition with BARI 2 and the lowest was found in litchi+BARI 2, respectively. Significantly the highest number of dry finger weight per plant (61.67 and 110.0 at 180 and 240 DAP) was recorded in open condition with BARI 3 variety followed by open condition with BARI 2. On the other hand, lowest dry finger per plant was recorded under litch+BARI 2 based agroforestry system

4.3.4. Rhizome yield

The yield of turmeric (t/ha) showed almost similar pattern of variations between the two different production systems as above yield contributing parameters (Table 14). The highest fresh yield 26.67 t/ha at 180 DAP was recorded in open condition with the turmeric variety BARI 3 followed by sole cropping with BARI 1 and BARI 2. On the other hand, the lowest fresh yield 17.67 t/ha was found under Litchi + BARI 2 based Agroforestry systems. Again, at 240 DAP the highest fresh yield 46.33 t/ha was recorded in open condition with BARI 1 variety whereas the lowest fresh yield 37.33 t/ha was found under Litchi + BARI 1 variety based Agroforestry systems (AGF). The reason of maximum yield reduction in AGF might be that the upper and middle layer trees canopy densely covered almost the entire ground layer plots consequently partial shading effect on turmeric was higher. Significantly the highest dry yield (2.73 and 8.23 t/ha at 180 and 240 DAP) was recorded in open condition with BARI 1 variety followed by open condition with BARI 2 and BARI 3. The lowest turmeric dry yield (2.23 and 6.43 t/ha at 180 and 240 DAP, respectively) was recorded under Litchi + BARI 2 variety based Agroforestry systems.

Table 12: Interaction effect of production systems and turmeric variety on leaf characters of turmeric at different DAP

Treatment combination		Number of leaf/plant		Length of leaf blade (cm)		Breath of leaf blade (cm)	
		120 DAP	180 DAP	120 DAP	180 DAP	120 DAP	180 DAP
Litchi (T_1)	V_1	9.16 a	25.73 a	64.00 a	77.33 a	17.50 a	23.33 a
	V_2	7.96 b	22.27 b	57.67 b	72.67 ab	14.83 bc	21.60 a
	V_3	6.00 d	16.20 c	55.00 b	62.33 c	11.67 de	18.00 b
Open (T_2)	V_1	8.00 b	9.00 d	55.33 b	70.00 b	15.00 b	22.00 a
	V_2	6.83 c	7.50 d	49.67 c	63.00 c	13.00 cd	16.33 bc
	V_3	5.36 e	7.26 d	45.00 d	61.00 c	11.00 e	14.50 c
$lsd_{(0.05)}$		0.29	2.35	3.00	5.64	1.84	3.07

Note: Means with similar letter(s) in a column do not differ significantly

Table 13: Interaction effect of production systems and turmeric variety on number of finger and finger weight per plant of turmeric at different DAP

Treatment combination		Number of finger/plant		Fresh finger wt./plant (g)		Dry finger wt./plant (g)	
		180 DAP	240 DAP	180 DAP	240 DAP	180 DAP	240 DAP
Litchi (T_1)	V_1	22.00 ab	35.33 b	145.0 b	366.7 b	39.67 c	83.33 c
	V_2	17.67 c	29.33 cd	123.3 c	308.3 d	37.67 c	72.00 d
	V_3	16.67 c	28.67 d	138.3 bc	360.0 b	47.00 bc	98.67 b
Open (T_2)	V_1	25.00 a	41.00 a	164.3 a	403.3 a	51.67 b	96.67 b
	V_2	24.17 ab	36.67 b	148.3 ab	337.3 c	44.00 bc	80.33 c
	V_3	21.03 b	31.67 c	154.7 ab	410.7 a	61.67 a	110.0 a
$lsd_{(0.05)}$		3.17	2.73	16.09	20.97	9.07	5.77

Note: Means with similar letter(s) in a column do not differ significantly

Table 14: Interaction effect of production systems and turmeric variety on rhizome yield of turmeric at different DAP

Treatment combination		Fresh yield (t/ha)		Dry yield (t/ha)	
		180 DAP	240 DAP	180 DAP	240 DAP
Litchi (T_1)	V_1	21.33 b	41.33 b	2.57 abc	7.37 c
	V_2	17.67 c	37.33 c	2.23 c	6.43 d
	V_3	22.67 b	41.33 b	2.27 bc	7.50 bc
Open (T_2)	V_1	25.33 ab	46.33 a	2.73 a	8.23 a
	V_2	25.33 ab	41.33 b	2.63 ab	7.20 c
	V_3	26.67 a	42.67 b	2.63 ab	8.03 ab
lsd $_{(0.05)}$		2.93	3.29	0.36	0.56

Note: Means with similar letter(s) in a column do not differ significantly

CHAPTER 5

SUMMARY AND CONCLUSION

The experiment was conducted in the farmer's litchi orchard in Jorkali of Biral upazila under Dinajpur district to investigate the performance of turmeric under Litchi (*Litchi chinensis*) orchard. The geographical location of the site was between 25° 13' latitude and 88° 23' longitude, and about 37.5m above the sea level. The experiment consisted of 2 (two) factors RCBD with 3 (three) replication. Treatments were Factor A (Production systems): T_1= Litchi + Turmeric and T_2= Turmeric (sole crop); Factor B (Litchi variety): V_1= BARI 1, V_2= BARI 2 and V_3= BARI 3. The treatment combinations were T_1V_1 = Litchi + BARI 1, T_1V_2 = Litchi + BARI 2, T_1V_3 = Litchi + BARI 3, T_2V_1 = sole cropping of BARI 1 turmeric variety, T_2V_2 = sole cropping of BARI 2 turmeric variety and T_2V_3 = sole cropping of BARI 3 turmeric variety.

Main effect of variety on growth, yield contributing characters and yield of turmeric were significantly varied each other. Among the different days after planting (DAP) treatments, the plant height was found significant at 120 DAP (Table.1). In case of 120 DAP the tallest plant (110.05 cm) was observed in BARI 1(V_1) followed by BARI 2 (89.50 cm) where as the shortest plant (78 cm) was observed in BARI 3 (V_3). Again at 180 DAP the tallest plant (140 cm) was observed in BARI 1 (V_1) followed by BARI 2 (117.7 cm) where as the shortest plant (107.3 cm) was observed in BARI 3 (V_3). At 120 DAP, the maximum number of tiller (2.68) was recorded in BARI 1 followed by 2.38 in BARI 2. On the other hand, minimum number of tiller was recorded in BARI 3 (2.10). Again, at 180 DAP, the maximum number of tiller (4.02) was recorded in BARI 1 followed by 3.62 in BARI 2. On the other hand, minimum number of tiller was recorded in BARI 3 (3.28). At 120 DAP, the highest number of leaf (8.58) was recorded in BARI 1 followed by 7.40 in BARI 2. On the other hand, lowest number of leaf was recorded in BARI 3 (5.68). Again, at 180 DAP, the highest number of leaf (17.37) was recorded in BARI 1 followed by 14.88 in BARI 2. On the other hand, lowest number of tiller was recorded in BARI 3 (11.73). At 120 DAP, the maximum length of leaf blade (59.67 cm) was recorded in BARI 1 followed by 53.67 cm in BARI 2. On the other hand, minimum length of leaf blade (50 cm) was recorded in BARI 3. Again, at 180 DAP, the maximum length of leaf blade (73.67 cm) was recorded in BARI 1 followed by 67.83 cm in BARI 2. On the other hand, minimum length of leaf blade was recorded in BARI 3 (61.67 cm). At 180 DAP, the highest number of finger (23.50) was recorded in BARI 1 whereas lowest number of finger was recorded in BARI 3 (11.73) which was statistically similar with BARI 2. Moreover, at 240 DAP, highest number of finger was recorded in BARI 1 (38.17) followed by in BARI 2. On the other hand, lowest number of finger was recorded in BARI 3 (30.17). At 180 DAP, the highest number of finger (23.50) was recorded in BARI 1 whereas lowest number of finger was recorded in BARI 3 (11.73) which was statistically similar with BARI 2. Moreover, at 240 DAP, maximum weight of fresh finger was recorded in BARI 3 (385.3 g) which was statistically similar with BARI 1 (385 g). On the other hand, fresh weight of finger was recorded in BARI 2 (322.8 g). At 180 DAP, the highest fresh weight of rhizome (87 g) was recorded in BARI 3 which was statistically similar with BARI 1 whereas lowest weight of rhizome was recorded in BARI 2 (71.50 g). Moreover, at 240 DAP, maximum weight of fresh rhizome was recorded in BARI 3 (115.7 g) whereas lowest fresh weight of rhizome was recorded in BARI 2 (99.67 g). However, at 180 DAP, yield of turmeric was found not significant. The highest yield

(24.67 tha^{-1}) was recorded in BARI 3 whereas lowest yield of turmeric was recorded in BARI 2 (21.50 tha^{-1}). Moreover, at 240 DAP, highest yield of turmeric was recorded in BARI 1 (43.83 tha^{-1}) whereas lowest yield of turmeric was recorded in BARI 2 (39.33 tha^{-1}).

Different growth and yield parameters of turmeric were significantly influenced by the different of production system. Turmeric growth and yield was found under sole cropping i.e. in full sun light conditions were more vigorously than those grown in Agroforestry systems. Significantly the highest number of finger per plant (9.72, 23.40 and 36.44 at 120, 180 and 240 DAP) was recorded in open condition. Similar trend was focused incase of fresh & dry weight per plant. Significantly, the highest fresh & dry weight per plant was observed in open condition. The highest fresh yield (25.78 and 43.44 t/ha at 180 and 240 DAP) was recorded under sole cropping of turmeric. Significantly, the lowest yield (20.56 and 40.00 t/ha at 180 and 240 DAP) was recorded in litch+termeric based Agroforestry system. The reason of maximum yield reduction in AGF might be that the upper and middle layer trees canopy densely covered almost the entire ground layer plots consequently partial shading effect on turmeric was higher. Similar trend was recorded incase of dry yield except 180 DAP insignificant. The highest fresh yield (25.78 and 43.44 t/ha at 180 and 240 DAP) was recorded under sole cropping of turmeric. Significantly, the lowest yield (9.14 and 10.56 t/ha at 180 and 240 DAP) was recorded in litch+termeric based agroforestry system.

Interaction effect was highly focusing point in the experiment. Significantly the tallest plant of turmeric was (115 and 153 cm) at both the 120 and 180 DAP in T_1V_1 (litchi + BARI 1) combination. The smallest plant of turmeric was (74.67 and 102.3 cm) at 120 and 180 DAP in T_2V_3 (open + BARI 3) combination. This might be attributing due to the stimulation of cellular expansion and cell division of leaf under shading condition. Garrity *et al.* (1992) observed plant height affected minimum due to shading condition in alley cropping of turmeric. Again, number of tiller plant^{-1} of turmeric was significantly affected by the interaction of litchi tree and turmeric variety at 120 and 180 DAP. The maximum number of tillers plant^{-1} was (3.476 and 4.533) at 120 and 180 DAP in T_1V_1 (litchi + BARI 1) combination followed by T_1V_2, respectively. The minimum number of tillers plant^{-1} was (1.667 and 3.033) at both 120 and 180 DAP in T_2V_2 (open + BARI 2) combination followed by T_2V_3. Significantly the highest number of finger per plant (10.67, 25.0 and 41.0 at 120, 180 and 240 DAP) was recorded in open condition with BARI 1 variety and the lowest was 5.93, 16.67 and 28.67 recorded under litchi+BARI 3. Significantly the highest number of fresh finger weight per plant (86.67, 164.3 and 403.3 at 120, 180 and 240 DAP) was recorded in open condition with BARI 1 variety followed by open condition with BARI 2 and the lowest was found in litchi+BARI 2, respectively. Significantly the highest number of dry finger weight per plant (32.67, 61.67 and 110.0 at 120, 180 and 240 DAP) was recorded in open condition with BARI 3 variety followed by open condition with BARI 2. On the other hand, lowest dry finger per plant was recorded under litch+BARI 2 agroforestry system. The yield of turmeric (t/ha) showed almost similar pattern of variations between the two different production systems as above yield contributing parameters (Table 14). The highest fresh yield 26.67 t/ha at 180 DAP was recorded in open condition with BARI 3 and the lowest fresh yield 17.67 t/ha was found under Litchi + BARI 2 variety based agroforestry system. While at 240 DAP the highest fresh yield 46.33 t/ha was recorded in open condition with BARI 1 variety whereas the lowest fresh yield 37.33 t/ha was found under Litchi + BARI 1 variety. Significantly the highest dry yield (2.73 and 8.23 t/ha at 180 and 240 DAP, respectively) was recorded in open condition with BARI 1 variety while the lowest dry yield (2.23 and 6.43 t/ha at 180 and 240 DAP) was recorded under Litchi + BARI 2 variety based agroforestry systems.

From the above results and discussion it can be concluded that among the two turmeric production systems, sole cropping gave more rhizome yield as compare with the litchi based agroforestry systems. Again, among the three turmeric variety like BARI 1, BARI 2 and BARI 3, BARI 1 variety gave best performance and it is also the best suitable variety for cultivation in association with litchi based agroforestry system i.e. in the floor of the litchi garden of the northern part of Bangladesh.

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APPENDIX

Appendix I. Results of physical and chemical analysis of the soil samples taken from the experimental plot before planting

Characteristics	Analytical data
Textural Class	Sandy Loam
Organic matter (%)	1.1
Soil pH	6.1
Total N%	0.06
P	5.91 μg/g soil
S	21.44 ,,
B	0.39 ,,
Mn	9.4 ,,
Zn	3.0 ,,
Na	0.12 me/100 g soil
Ca	1.8 ,,
Mg	0.30 ,,
K	0.15 ,,

Source: The physical and chemical analysis of soil samples were done by SRDI, Dinajpur.

Appendix II. Distribution of monthly average temperature, relative humidity, total rainfall of the experiment site during the period from April 2010 to January 2011.

Month	Air temperature (°C)		Relative humidity %	Total Rainfall (mm)
	Max.	Min.		
April 2010	32.8	21.1	83	54.0
May 2010	13.9	21.5	77	213.0
June 2010	33.2	23.2	82	333.0
July 2010	32.0	25.8	85	369.0
August 2010	32.4	26.2	84	466.0
September 2010	32.0	25.0	89	97.0
October 2010	31.6	21.0	90	00
November 2010	27.5	15.5	72	00
December2010	26.6	11.9	85	00
January 2011	20.85	9.15	80	00

Source: Wheat Research Center, Dinajpur.